European Real Estate Society
Annual Conference
Milan, 23-26 June 2010

Modelling the Relationship between Development Design and Financial Viability

John Henneberry[1]*, Eckart Lange[2], Sarah Moore[3], Ed Morgan[2] & Ning Zhao[1]

Departments of Town and Regional Planning[1], Landscape[2] and Civil & Structural Engineering[3], University of Sheffield, Western Bank, Sheffield, S10 2TN, UK
*Corresponding author: j.henneberry@sheffield.ac.uk; +44 (0)114 222 6911

Abstract. The paper describes the development and application of physical-financial modelling techniques to the analysis of relations between development design – covering the broad characteristics of a scheme, such as land use mix, development density and built form – and financial viability. It is divided into two parts.

The first part covers the development of the model. Existing work on development and design processes gives limited attention to the engagement of the two. This circumstance is mirrored in design and development appraisal techniques and software. We use a real time 3D visualisation system to represent a proposed development. It allows the user to control the viewing position to explore all aspects of built form for a given site and to categorise and experiment with land and building use. This 'live' visualization is linked through a plug-in to a financial appraisal in a way that enables the financial structure (viability) of the scheme to be estimated instantaneously. The resultant model permits multiple alternative development strategies – incorporating a wide range of changes in uses and building designs – to be explored quickly and in detail.

The second part presents examples of the application of the model to demonstrate its potential. The tools available to developers to explore development strategies on particular sites are limited. Time and cost constraints often result in a combination of sketch schemes and outline (or even 'back of the envelope') appraisals being used to explore the relation between design and viability. Consequently, relatively few alternatives are considered in relatively little detail. The model addresses this problem and offers the potential substantially to increase developers' capacity to consider alternative approaches to site development. This is illustrated with reference to a case study site. The model also allows analytical generalisation. Using this approach, the relations between built form and financial structure are explored.

Introduction: the Development and Design Processes

The paper explores the relationship between development viability and design quality. As a first step, the development and design processes – and the ways in which they engage with one another – need to be considered. However, there is very little literature on this point, other than that relating to master planning/design coding (for example, Carmona et al, 2006) which is a second order design process (George, 1998). Recourse must instead be had to practice texts. All those reviewed by Crosby et al (2008) treat the development process, whether implicitly or explicitly, as a sequence of events - as stages in the process of producing a completed, occupied scheme (see Figure 1). Events-sequence models may vary in their levels of detail and complexity but they are essentially task and project focused (Healy 1991; Gore and Nicholson 1991). Little is said about the motivations and resources of the various actors involved in property development (who are assumed to be rational utility-maximises) or about the wider environment within which they operate (which is assumed to approximate an imperfect market with some state regulation).

Figure 1: The Development and Design Processes

The Development Process (Syms, 2002)	The Design Process (Tunstall, 2006)
0. Market appraisal	
1. Project inception	1. Inception (receiving client's brief)
	2. Feasibility (formulating design brief)
2. Site acquisition and assembly	
3. Site assessment	3. Outline proposals
4. Risk analysis	
5. Detailed design	4. Scheme design (for approvals)
6. Feasibility study	
7. Planning approval	
8. Land and development finance	5. Detailed design
	6. Construction information
	7. Measurement (bills of quantity)
9. Tendering	8. Tendering arrangements
	9. Pre-contract planning
10. Construction	10. Construction on site
	11. Completion
	12. Feed-back
11. Sales and marketing	

The design process is portrayed in a similar way (see Figure 1). Being one aspect of the wider development process, it is nested within the latter. The development project and its design are conceived and then continuously developed and refined as more information becomes available. The developer faces a fundamental dilemma in this regard. In the early stages of the development process the room for manoeuvre is considerable because the developer has made limited financial or legal commitments to the project. However, the quantity and quality of information is also limited, severely restricting the reliability and accuracy of any assessments of financial viability or marketability. As the project proceeds better information becomes available but this is at the price of increased ‘lock-in’. The developer knows more about the scheme but has less scope to react to that knowledge by withdrawing from or altering it without incurring substantial costs.

For the developer, the key design-related part of the development process is the transition from principles and possibilities to the position where the main physical parameters (development density, site morphology and use) are fixed. That is, the move from project inception, where "a few simple sketches [are compared with] ‘back of an envelope’ calculations" (Syms, 2006, page 6, square brackets added), to the detailed scheme design and feasibility study. The latter stage will include drawings of sufficient detail to obtain planning permission and a full financial appraisal, incorporating sensitivity and cash flow analyses. However, it is not clear how one progresses from the one position to the other. Most texts refer to a process of constant review so that "each time the design is refined, viability is reassessed" (Adams, 1994, page 50). Computer packages are used: by developers to assess the financial implications of change (Byrne, 1996; Syms, 2002; Havard, 2008); and by architects to develop designs and to discuss changes with the client (Tunstall, 2006). However, there is no significant integration of financial appraisal and CAD software.

All the development texts reviewed by Crosby et al (2008) take a single, fixed design as the starting point of the development appraisal. Sensitivity analysis - the assessment of the impact of specified changes upon project viability - considers market variables (such as rents, yields, prices, interest rates and building costs) but not design change. This is reflected in the structure of development appraisal software. Havard (2008) illustrates the application of industry-leading software to development appraisal. Complex, sophisticated financial analyses are supported. However, the user must enter all the physical and financial details of each part of the subject scheme (Ibid., pages 238-239). These include the use, gross floor space, net/gross ratio, construction costs and rents/yields or selling prices for each building type. Consequently, if the design is changed, most of these input variables - especially those relating to floor space, use and number of floors - have to be altered manually. While this may offer a time-consuming and awkward link between design and finance, no such link is made within CAD software. Tunstall (2006) lists 14 advantages of CAD but none relate to using it to explore the relation between design form and financial structure.

Techniques that provide a more effective link between design and finance therefore address an important shortcoming in the current set of analytical tools available to developers, designers and others with an interest in promoting schemes with higher design quality. It is to the development of such techniques that we now turn.

Visualization and Financial Appraisal

Visualization Techniques

The physical form of the built and natural environment has long been represented in visualizations. Before the digital era traditional analogue techniques such as plans, sections, sketches, perspective drawings, photomontages and physical models were used to portray existing environments and proposed changes to them. A key figure in the development of visualization techniques was the English landscape architect Humphry Repton (1752–1818). In his famous Red Books, produced for most projects he worked on (stately homes and large estates), he pioneered perspective techniques, by showing the existing situation as well as the proposed changes in the landscape by using a movable flap to unveil the underlying proposal.

Later developments in visualization include the immensely popular panoramas of the early 19th century, the equivalent of today's IMAX cinemas. In the 20th century physical models (for example, of new housing schemes) became popular in planning and design. They were also used to simulate virtual journeys through urban landscapes (Markelin and Fahle, 1979) using microscopic cameras to record on video tape. While scaled models are normally used in practice, on occasion even a 1:1 representation – that is, a real world model - is produced. The degree of abstraction or realism of the latter can range from, for example, a simple pole structure, required in Switzerland to show the volume of a proposed building, to a deceiving realism that can be achieved by full colour printing on plastic sheets to simulate a whole building with its facades (to depict, for example, the proposed reconstruction of a palace in Berlin that was destroyed during World War II).

Advances in computer technology have supported the development of visualization techniques for use in the design and planning process. Whilst computing power was limited, approaches such as electronic artistic impressions (Al-Kodmany, 1999) and photomontage (Lange, 1994) were used. Another common visualization technique is the production of three-dimensional models that can be rendered as still images or as pre-recorded 'fly-through' or 'walk-through' animations. This technique has no real time dependence. Images and videos can be rendered in a photo-realistic style, although this may take many hours to achieve. With speed increases in computers, more sophisticated techniques have been developed which allow for interactive visualization of three dimensional models within the design and planning process for landscape (Lange, 2001; Bishop, 2005); for example, to plan the position of wind turbines (Lange and Hehl-Lange, 2005). Advances in dedicated 3D processing hardware have made real-time visualization possible, especially through the use of computer game engines to provide interactive eye-level walkthroughs for 3D visualizations (Herwig and Paar, 2002).

However there are still challenges to overcome to create real-time visualization tools (Bishop, 2005). One is to provide a sufficient level of detail in the visualization to convince the viewer to accept the visualization as representative of the modelled area (Lange, 2001; Appleton and Lovett, 2003). Another is the production cost of creating such visualizations that are tied to the complexity of the model (An, 2005; Lange, 2001). Geographic Information System (GIS) data sets can be used to help in the production of 3D models (Hoinkes and Lange, 1995) and the use of these data can speed up the model development time considerably. These challenges were addressed in part of a research project examining sustainable development in urban river corridors.[1]

[1] URSULA, funded by EPSRC (see Acknowledgement for details).

Developing Visualization Techniques and Links to Financial Appraisals

In this research, 3D models of areas of the River Don corridor (and selected tributaries) in and around Sheffield are being developed so that, inter alia, proposed physical changes or 'interventions' may be visualized and then used as part of a sustainability assessment process. These models need to be viewable in real-time either as eye-level walkthroughs or as 'birds-eye' overviews and to be sufficiently representative of the actual areas and the interventions to allow stakeholders to assess the latter. The visualization system uses Simmetry3d software, a design and visualization solution based on the technologies used in the computer game industry. Simmetry3d is PC based and can also be connected to the Rave studio, a University of Sheffield virtual reality facility that supports stereoscopic three-dimensional viewing.

Models of the existing areas of Sheffield's river corridors were constructed from various data sets and the steps in which they were combined were as follows:

- A baseline terrain model was created, combining a Digital Elevation Model, (OS Land-form profile) and aerial photography, (Cities Revealed); then
- Existing landform features were created from GIS vector data (OS Mastermap) by importing these data into Simmetry3d and applying its tools to them; then
- Existing buildings were created from the GIS data (OS Mastermap) and photographic survey data were used to add facade textures; and finally
- Interventions were introduced into the existing model either by editing the GIS vector data or by creating new models and importing these into the correct location in the existing model.

The models were linked to a financial appraisal system so that the financial implications of interventions could be assessed. The financial appraisal system already had a clearly defined data interface which required the areas of different land/building use categories to be assigned to it in order for it to compute its results (discussed in more detail in the subsequent section). In order to implement the link it was necessary to identify the requirements of the whole system and the workflow proposed for its use. Investigation revealed that such a system should be able to:

- Design a new site layout to the correct size and scale;
- Categorize design elements for financial appraisal;
- View the design in 3D and in real time;
- Analyse the design in terms of the areas of its constituent parts and communicate these on to a spreadsheet for financial appraisal;
- Easily allow alterations to site layout, building heights and floor space uses so that the financial implications of such design changes may be calculated; and
- Be compatible with the real time visualization system.

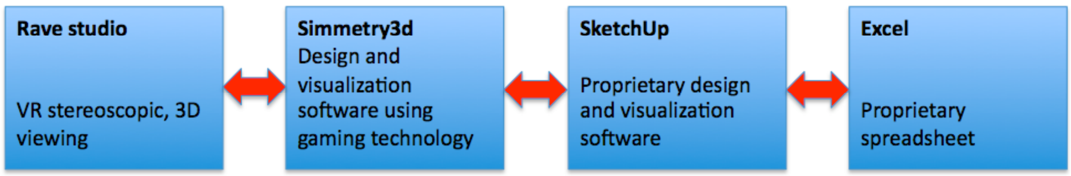
Analysis showed that these requirements could be met through the use of a generic 3D CAD system, with the addition of a bespoke 'plug-in' to transfer the data produced by the analysis to the financial appraisal spreadsheet. Plug-ins are small sub-routines of software that may be written to control a larger software application and, as such, can provide tailored functionality to more generic software applications. By adopting this approach, modelling of a site could be done in isolation as a pre-process to the more detailed and labour intensive visualization work, providing a useful resource for the creation of more detailed real time models of the new site within the larger scale visualization model.

There are many 3D CAD systems available that could be used in the ways described in this chapter. However, any such system had to be compatible with Simmetry3d, the system used for the real-time visualizations, in terms of the format of models that could be imported. This restricted the choice of CAD system. SketchUp was identified as the most suitable because it could achieve the requirements already outlined, was perceived to be easy to learn and to use, and was compatible with the visualization system.

The categorisation of the design elements was achieved through SketchUp's 'layering' system. Layers were added that corresponded to the categories required by the financial appraisal spreadsheet. These categories were: site, hard landscaping, soft landscaping, roads and footpaths, car parking, building floor and use (for example, retail, offices and so on). Practically, this means that each design element, for example, a part of a site or a floor of a building, is assigned to the layer that best describes its use, such as soft landscaping or apartments.

The link between SketchUp and the spreadsheet package required a plug-in to be written that analysed the 3D model based on layer categorisation. This analysis computed the land use area (square metres) of the design according to the pre-defined categories. These layer categories correlated to categories in the targeted spreadsheet that computed the financial implications of the design. The user may run the plug-in whenever a financial appraisal is required. For example, when a design has been successfully input and categorised, or when changes to the design or categorisations are made. The overall structure of the modelling system is described in Figure 2.

Figure 2: The Physical-financial Modelling System



Preparation of a design in SketchUp typically involves the following steps:

1. The creation of a 2D site plan.
2. The categorisation of areas within the site plan.
3. The extrusion of 2D building areas into massing models (that require each floor of the building to be included too).
4. The categorisation of the floor space within the extruded buildings.

Creation of the site plan was most easily and accurately achieved by using (importing) GIS land-use data (OS MasterMap dataset) that covered the whole site and accurately defined the site area. Existing detail within the site could easily be removed and re-modelled using the tools available within SketchUp. As already indicated, models constructed in this way could be imported into a larger scale, more detailed visualization model for real time visualization. This step involved fitting the site model to its actual location within the larger model, and then, if required, increasing the level of detail of the site model; for example, by adding vegetation or through the application of more realistic surface textures. An example of this is shown in Figure 3[2].

Figure 3: Visualization of the 'Streets' Redevelopment Option in Simmetry3d

Urban form designed by Laurence Pattacini

The approach adopted for linking the visualization model and the financial appraisal system has several advantages. Firstly, linking to site design models produced early in the overall visualization process (in SketchUp), means that experimentation with site layout and land and building use can be undertaken without the need for the more time consuming detailed visualization steps. Secondly, by creating models that are compatible with the real-time visualization software, site designs can be incorporated easily into the more detailed visualization model to allow for real-time walkthrough visualization. On-going research is looking at how the modelling and categorisation can be achieved within the visualization system. This should provide a faster step between experimentation with site layout and categorisation and real-time walkthrough within the more detailed model. Finally, financial appraisal of the initial designs (produced in SketchUp) is almost instantaneous and informs the selection of those options to be subject to more detailed visualization. With the development of the faster linkage between Simmetry3d, SketchUp and the appraisal spreadsheet, similarly speedy analysis of the financial implications of detailed design changes will be possible.

[2] In order to allow easier interpretation of the transition from SketchUp to Simmetry3d, the basic representation of the proposed development is presented here.

The Financial Analysis of Design Changes

The financial analysis of a development proposal and of changes in its design is undertaken on a spreadsheet. The residual valuation technique is adopted and both profit and land value residuals may be estimated. The developer's profit is derived by assessing the end value of the scheme and then deducting the costs of producing it, including land costs, construction and finance costs and professional fees. The land value is derived by substituting a minimum developer's profit for the land cost and then subtracting the costs associated with land acquisition, such as legal fees.

The structure of the spreadsheet mirrors that of the residual valuation method. There are separate sheets for land costs (based both on development value and on existing use value); construction costs (for site works and buildings); and the value of the scheme (covering both space for sale and rent, using unit price and rent/yield comparables, respectively, and applying specified net/gross ratios). The gross development value and the land and construction costs are then incorporated into an appraisal sheet that estimates the various finance costs and fees before calculating the developer's profit (absolute and proportionate [percentage of total costs])

The traditional residual approach thus described has many shortcomings. The final result is dependent on the estimation of many variables that, because of site idiosyncrasies, requires the extensive exercise of expert judgement. Because of gearing, minor adjustments to key input variables can result in large changes to the residual. In order to mitigate these issues, data must be gathered and treated with caution. In addition, the traditional residual is, essentially, a cross-sectional approach. It does not deal with time. This causes some significant problems: finance costs can only be approximated; no indication can be given of the financial position during the development period; the method cannot deal with phased developments or with changes in variables during development (Isaac, 1996; Havard, 2008). Finally, the treatment of interest charges as development costs raises the question of how the developer's profit should be interpreted (Crosby et al, 2008).

For these reasons, the spreadsheet incorporates a cash flow residual. This allows selection of the unit period and the definition of cash flow patterns for the costs and/or incomes associated with each element of the scheme (site works, [parts of] buildings and fees). Period-by-period, net terminal value and discounted cash flow calculations are performed. The internal rate of return (IRR) and the net present value (NPV) are the measures of return that are generated. There is also a facility for undertaking sensitivity analysis of the input scheme.

However, the novel aspect of the appraisal spreadsheet is its linkage to SketchUp – and, therefore, to Simmetry3d and the Rave studio - that allows the relation between design quality and development viability to be analysed[3]. The physical dimensions of the design are transferred from SketchUp into the first sheet of the spreadsheet. The

[3] At the time of writing (June 2010), we were aware of only one other attempt to explore this link: the StrateGis Urban Developer software package (for information, see <http://www.strategis.nl>). This is based on SketchUp and provides financial and other analyses of project performance, although it is not linked to more sophisticated visualization systems. However, we have not yet been able to undertake a detailed technical comparison of the two approaches.

gross floor space is calculated for: each building or part building by use and each type of site treatment. From these data are generated various summary measures, such as site area (using the definition specified in PPS3 Housing), site coverage (%), development density (m^2/ha) and floor area ratio (FAR) or plot ratio. Automated manipulation of these data allows them to be input into the land cost, construction cost and valuation sheets, as appropriate.

Cost and value information is automatically generated through the creation of a vba script that cross-references the SketchUp assigned site treatments and buildings/floors/uses to underlying databases. The latter's contents are determined by data availability and cost and by the research or application context. Currently, for example, unit building costs are derived from the BCIS cost database (Q4, 2009, adjusted for Yorkshire and the Humber) and landscaping costs from SPON, while secondary data on residential and commercial prices, rents and yields have been obtained from the Nationwide Building Society, CB Richard Ellis and IPD. These data have been augmented by analyses of local comparables and consultations with Sheffield City Council, local quantity surveyors and a panel of Sheffield property agents. There is also the potential to use probabilistic modelling to generate ranges of costs and values.

The financial analysis of the design is undertaken in three stages. First, a basic representation of the scheme is developed in SketchUp. This covers built form: building use, massing and positioning and amounts and treatment of open space. Next, SketchUp calculates the areas of the various elements (as described above) and transfers them to the spreadsheet via the plug-in. Then the spreadsheet undertakes the financial appraisal and provides an analysis of the financial structure of the development, including three measures of return (developers profit as a % of cost, IRR and NPV) or the development value of the site.

Once set up in this way, the financial implications of significant changes to the design can be assessed quickly and easily. Using facilities in SketchUp, building footprints, heights and positions, and open space areas and treatments may be altered. New financial appraisals are generated almost instantaneously. The extent of the design changes that may be analysed is inversely related to the level of detail to which the scheme is rendered in SketchUp. When changes become too substantial to model with the required accuracy, a new representation that incorporates such changes must be developed for financial analysis.

The next section of the paper considers the ways in which physical-financial modelling may be used to explore the relationship between development design and financial viability.

The Application of Physical-financial Modelling

Theory, Analysis and Policy

> "Urban design objectives […] can only have any impact if they are translated into fact through the development process." (Syms, 2002, page 235)

There is a substantial literature on the development process that considers it from various methodological and theoretical standpoints (see, for example, the reviews of Healey, 1991; Gore and Nicholson, 1991; Ball, 1998; Guy and Henneberry, 2002). The developer is "the key coordinator and catalyst for development" (Healey, 1991, page 224). Yet, despite their important influence on development, developers have received limited attention. Other actors, such as investors (Coakley, 1994; Pryke and Lee, 1995) or landowners (Goodchild and Munton, 1985; Adams et al, 1994), have been the subjects of special study. In contrast, in a survey of the field, Parris (2010) could only identify two UK studies (by Guy at al, 2002 and Ball, 2002) and two overseas studies (by Coiacetto, 2006 and Charney, 2007) that have explored developers' character and actions in any detail.

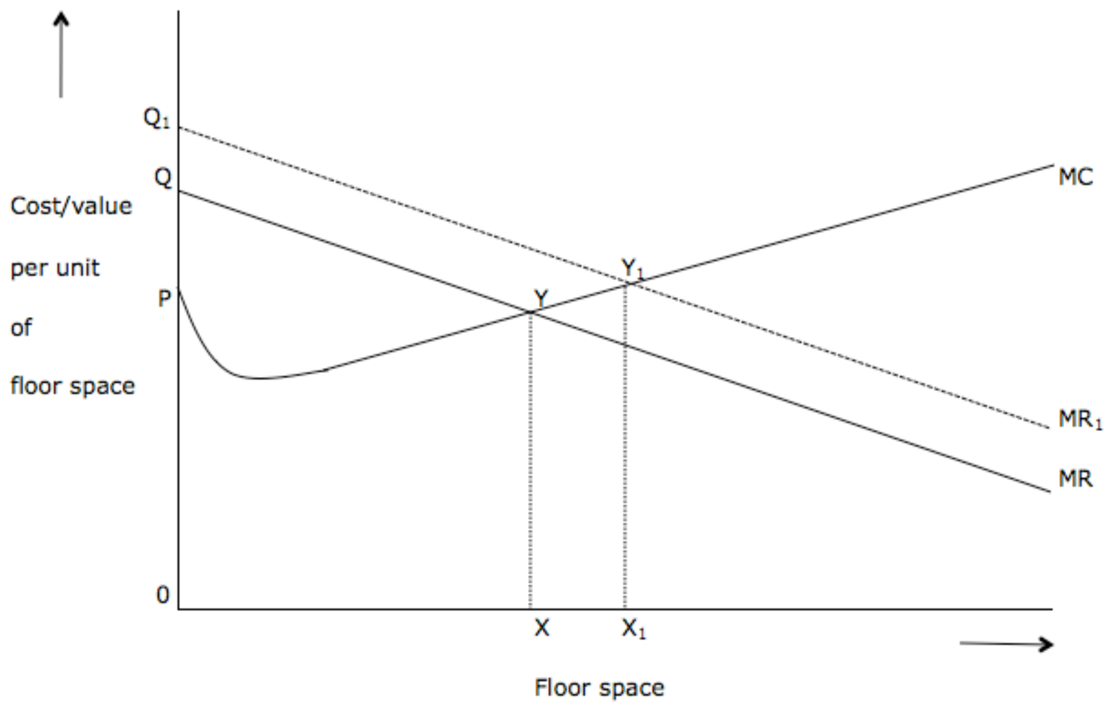
Otherwise, the way that developers behave must be imputed from normative texts on property development (for a recent review, see Crosby et al, 2008). Such texts are set within the mainstream economics paradigm. They assume that developers aim to take utility-maximising decisions that are as informed and rational as possible. Utility is invariably expressed in terms of financial return, relative to risk. Consequently, development decisions turn on financial appraisals and the latter technique and its application is at the centre of all texts. In these circumstances, it is not surprising that one of the main arguments made by policy-makers and other protagonists seeking to promote better design is that "good urban design adds value by increasing the economic viability of development" (Carmona et al, 2001, page 8). However, this position is easier to maintain at the general than at the specific level. What matters is whether the quality of a scheme's design will enhance its financial viability to the developer, not whether it will make the wider balance of economic costs and benefits more positive. It is from this more precisely defined perspective that the evidence for a link between design quality and development viability must be assessed.

This evidence falls into two broad levels and types. Taking aggregate, quantitative analyses first. Hedonic analyses of the determinants of property prices are legion. Many include measures of urban design quality and their price effects. For example, Eppli and Tu (1999) demonstrate that, for the US, New Urbanist design principles increase the price of single family houses by 10-15%; Vandell and Lane (1989) found that offices rated highly for design achieved rents 22% higher than those of poor design quality; views of and/or proximity to parks and stretches of water increase house prices by 6-11% (Luttik, 2000); hotel rooms that offer attractive views generate considerably higher income (Lange and Schaeffer, 2001); and good landscaping aesthetics have a strong, positive effect on office rents (Laverne and Winson-Geideman, 2003).

Such studies are frequently cited in support of the case for higher standards of design (cf. CABE publications). However, as Savills (2003) point out, hedonic analyses are based predominantly on existing rather than newly developed properties. In addition, their main strength - the substantial, general evidence base - is also, with regard to their applicability to the development context, a significant weakness. The variables in hedonic analyses are applied consistently across many varied cases. They must therefore be clearly defined and describe basic, measurable characteristics. Consequently, the results of hedonic analyses are simply not refined enough to be related meaningfully to the idiosyncrasies of particular development proposals on individual sites.

It is for these reasons that much attention has been paid to more qualitative, case study research. But this methodology achieves empirical richness at the cost of a restricted evidence base. For example, some of the most quoted studies in the UK are Carmona et al (2001; three pairs of case studies (6)), Savills (2003; four pairs of case studies (8)), Savills (2007; three trinities of case studies (9)) and Amion et al (2007; seven single, outline case studies). In addition, the definition of the value arising from good design is drawn very widely. It includes economic, social and environmental value accruing to a wide range of actors - such as developers, investors, occupiers and the local resident and business communities - over the short, medium and longer term. However, for reasons of market structure, most of these various streams of value are not captured by the developer (Savills, 2003). The developer is primarily interested in exchange value - that is, prices or rents/yields achieved on disposal (Macmillan, 2006; Amion, 2007) - and, secondarily, in the reputational value arising from corporate association with well-designed schemes.

Figure 4: The Optimum Development Density of a Site



Source: Fraser (1993) reproduced in Wyatt (2007), Figure 6.2, page 309

If the relation between design and value arising from a particular aspect of the development is examined in more detail, the picture is even less clear. One of the main ways that "good urban design can add value to development [is] through using land highly efficiently" (Roger Evans Associates, 2007, page 110, square brackets added); that is, by increasing the density of development. Figure 4 describes the argument (Fraser, 1993; Evans, 2004; Wyatt, 2007; Ball et al, 2008). For a site of a fixed size, development density is represented by the amount of floor space built on it. At low densities, the marginal cost (MC) of an extra unit of floor space falls. Consider building two stories instead of one: the cost of the foundations varies little, but the roof covers (almost) twice as much (usable) floor space. However, after a certain point, marginal costs begin and continue to rise because of the need for stronger foundations, more services such as lifts and so on.

Conversely, marginal revenue (MR) declines as development density increases. Occupiers derive less utility from property on the site as local environmental quality dwindles – because of less open space, more noise and pollution and so on - and the accessibility of the upper floors in higher buildings decreases. The optimum development density is X, where MR equals MC, giving a site value of PQY. However, by "creating value through the appropriate densities (sic), public space, uses and distribution of buildings" (Roger Evans Associates, 2007, page 110) good urban design can shift the marginal revenue curve upwards (to MR_1), allowing higher density development (to X_1) that is financially viable and increasing the site value to PQ_1Y_1.

Every element of this argument is open to question. Little is known of the positions or slopes of the MC and MR curves, or of the point of inflection of the former. Flanagan and Norman (1978) suggest that the marginal cost starts to increase at six stories, whereas Picken and Ilozor (2003) suggest that the turning point is at 35 stories. Chau et al (2007) found that for flats with views, marginal revenue *increased* exponentially with an increase in floor level and that the optimal building height was higher for a site with a 'better' external environment. Eppli and Tu (1999) found that house prices were higher in higher density, New Urbanist schemes than in conventional suburban developments; although this was in a very low-density environment. In contrast, Song and Knaap (2003) and Waasmer and Bass (2006) show that residents pay less for houses in denser, more central neighbourhoods.

What such studies indicate is "… that the curves …[in Figure 4]… merely represent general trends in marginal revenue and cost. In any individual development, the shapes of the curves would vary …" (Fraser, 1993, page 233). These circumstances provide a strong justification for undertaking more research on the relation between development design and viability at two levels. The first is the site level. The modelling system may be used to capture the particularities and varieties of physical form and financial structure. Development density "is a product of design, not a determinant of it" (Llewelyn-Davies, 2000, page 46). Building type and height, block size, the positions of buildings relative to one another and the distribution and quality of open space will all affect perceptions of density. Such perceptions, in turn, affect the demand for and value of development. The second is the level of analytical generalisation. Modelling techniques allow the wider implications of the replication of various sets of site-specific relations to be explored from the bottom up. Methodological choice is not limited to the breadth-depth trade-off between aggregate quantitative and qualitative case study approaches. Different types of development project display different links between design and value. There is not one but a series of optimum development densities, the determination of which depend on sites' characteristics and contexts.

Examples of the use of the modelling system for site level analysis and for generic modelling are presented in the following sections of the paper.

The Wicker Riverside, Sheffield, UK

To illustrate the application of physical-financial modelling to the analysis of design quality and development viability, the case of The Wicker Riverside in Sheffield is considered. The area lies immediately to the north of the River Don which here defines the northern edge of the city centre. It was badly affected by the floods of June 2007. Two alternative approaches to redevelopment have been designed as part of a research project[4]. 'Streets' is a relatively conservative development that proposes building alignments and massing that replicate the existing street pattern and maximise the ameliorative effect of the River Don on the scheme's microclimate (see Figure 5, which may be compared with its more detailed representation in Simmetry3d in Figure 3). The financial structure of 'Streets' is presented in Figure 7. The height of the column is the gross development value. From this are subtracted the various development costs: construction costs, professional fees, finance costs and land costs. Where, as here, total costs exceed development value, the column extends below the X-axis (which crosses the Y-axis at 0) and a negative developer's profit results[5]. Given the current economic climate, it is not surprising that the scheme is not viable.

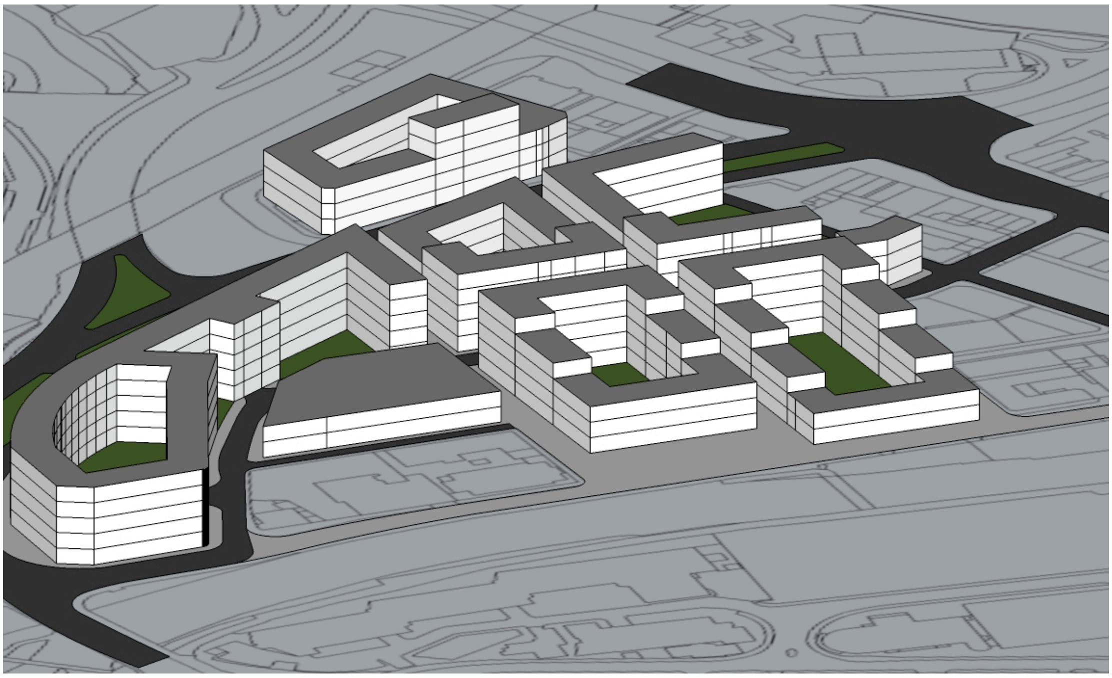
Park' is a more radical scheme that differs substantially from 'Streets' and for which a separate representation was prepared (see Figure 6). A significant area of open space is incorporated into the scheme to mitigate the impact of flooding. This involves the demolition of an additional block of existing properties (at the upper-middle-right of the site; see Figures 5 and 6) as well as a large reduction in site coverage (see, for example, the area covered by the lower-right-hand block in Figure 5). Consequently, more new floor space is built at much higher densities on some of the developed parts of the site. The financial structure of 'Park' differs markedly from that of 'Streets' for these reasons (see Figure 7) and the former is much less viable than the latter.

Once the representation of a scheme has been produced, it is relatively easy to assess the financial implications of design changes. Alterations in building heights, floor-plates and uses undertaken in SketchUp are immediately read off into the spreadsheet to produce a new appraisal. For example, changing the use of one of the tower blocks in 'Park' from offices to apartments increases viability (in the sense that it reduces the loss, see Figure 7).

[4] URSULA, funded by EPSRC (see Acknowledgement for details).

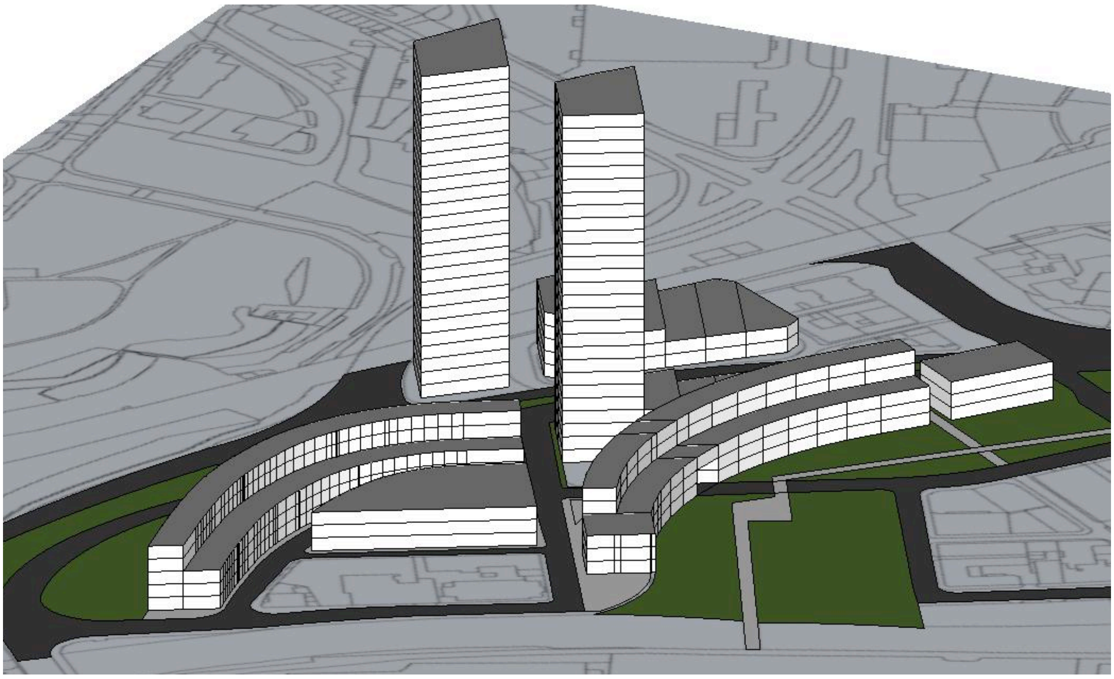
[5] Obviously, if development costs are less than development value, then a positive developer's profit would result and that part of the column would sit immediately above the X-axis.

Figure 5: Visualization of 'Streets' in SketchUp



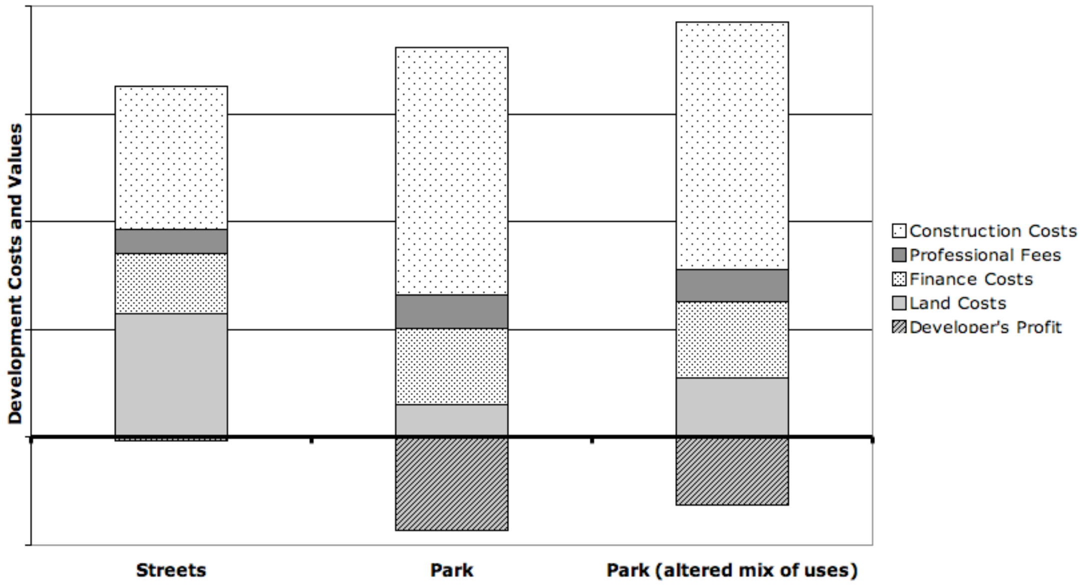
Urban form designed by Laurence Pattacini

Figure 6: Visualization of 'Park' in SketchUp



Urban form designed by Laurence Pattacini

Figure 7: Financial Structure of Redevelopment Options



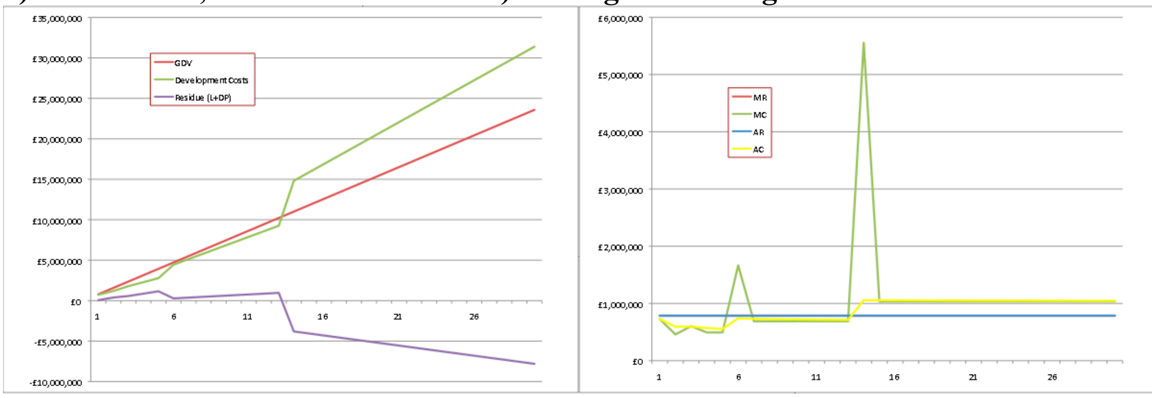
Bottom-up Generic Modelling

The results of specific site level analyses may be adapted to support bottom-up generic modelling. Take the apartment block in the revised 'Park' design option for The Wicker Riverside, as an example. Here, the selling price for apartments, the construction and other costs (fees, finance and so on) for such accommodation form the starting-point for analysis. They are then elaborated, so that the relevant costs and values for an apartment building with eight one-bedroom units on each floor are identified. Construction costs increase with height, because of growing structural and service requirements. However, the increase is not gradual and even, but sporadic and marked; and is determined by a combination of physical performance thresholds and legal regulations. Two assumptions are made. The first is that the area of the site of the apartment block remains constant. The second is that – in the first instance – the sale price of apartments also remains constant, whatever the height.

The results are described in Figure 8a. The total value of the building increases at a constant rate, as each storey is added. However, there are major increases in construction costs at 6 and 14 storeys. In the case of the latter, this produces a unit construction cost that exceeds the unit value of the apartments, causing the total value and cost curves to diverge. The marginal cost (MC) curve in Figure 8b emphasises the impact of the stepped increases in construction costs and shows that average cost (AC) is higher than average revenue (AR) for buildings of 14 storeys or more (note that marginal and average revenue are the same, given constant prices). In these circumstances, the optimum height of the apartment block (that is, the development density) is five storeys, with a secondary 'peak' at 13 storeys. These are the points of the highest residual (the difference between development value and development cost, from which the developer's profit and the land value are derived).

Figure 8: The Relation between Building Height and Financial Viability (constant apartment prices)

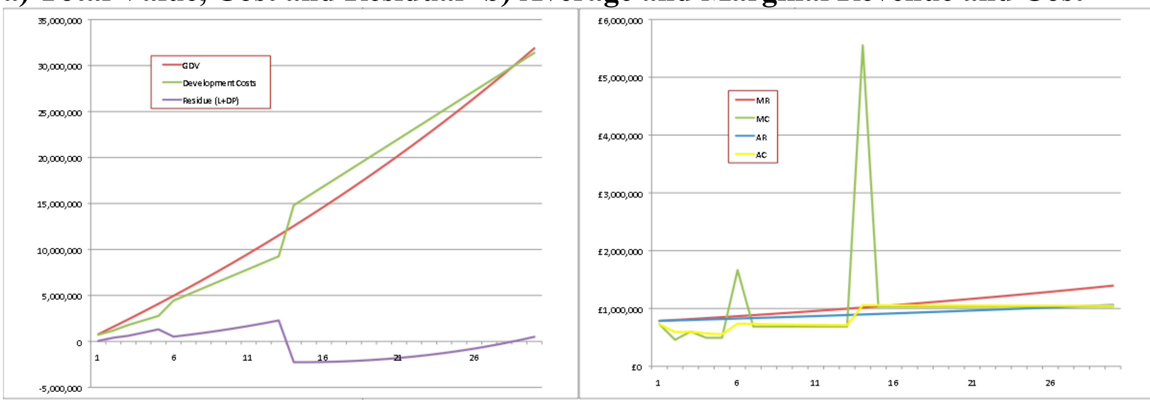
a) Total Value, Cost and Residual b) Average and Marginal Revenue and Cost



If the assumption regarding the relation between the price of an apartment and its height is altered, then the optimum height/development density will change. Were price to increase by +2% per floor (following Chau et al (2007) in principle, rather than empirically), then the results would be as in Figures 9a and 9b. Construction cost no longer diverges from development value and the highest residual occurs at 13 storeys.

Figure 9: The Relation between Building Height and Financial Viability (apartment prices increase at +2% per floor)

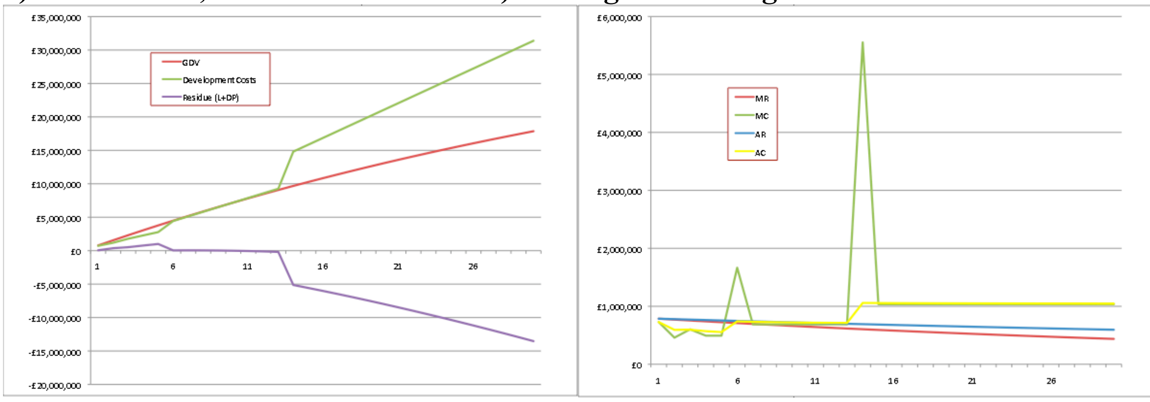
a) Total Value, Cost and Residual b) Average and Marginal Revenue and Cost



In circumstances where price decreases by -2% per floor (following the assumptions of mainstream economics), then the results would be as in Figures 10a and 10b. There is a sharper divergence between value and cost; and positive residuals only occur for buildings of less than six storeys. A feature of Figures 8-10 is their marked difference from the smooth curves of general theory depicted in Figure 4.

Figure 10: The Relation between Building Height and Financial Viability (apartment prices decrease at -2% per floor)

a) Total Value, Cost and Residual b) Average and Marginal Revenue and Cost



Conclusions

One of the key decisions that must be made by a developer relates to the strategic approach to the development of a site. This involves the identification of the broad characteristics of the scheme to be pursued, such as land use mix, development density and built form. These characteristics have a fundamental influence on the project's financial viability, its environmental performance and the chance of it obtaining planning permission. The tools available to developers to explore development strategies are limited. Time and cost constraints often result in a combination of sketch schemes and outline (or even 'back of the envelope') appraisals being used to explore the relation between design and viability. Consequently, relatively few alternatives are considered in relatively little detail. The paper describes the development and application of physical-financial modelling techniques that address this problem and offer the potential substantially to increase developers' capacity to consider alternative approaches to site development.

Clearly, the rapid representation of alternative designs and their corresponding financial structures requires simplification. Design sensitivity and financial specificity suffer as a result. The detailed distribution of land uses – such as retail units – to create active frontages around key spaces and routes may simultaneously enhance social interaction, liveliness and movement, and property values. Similarly, design decisions may enhance or exploit positive externalities (for example, by increasing the number of dwellings with a waterfront view) or reduce negative externalities (for example, by reducing the number of dwellings facing onto busy roads), thereby altering property values. The modelling system can take such factors into account through a combination of detailed revisions to the basic imported designs in Simmetry3d, followed by their return to SketchUp and their appraisal using a spreadsheet edited to incorporate the different values and costs. Currently, this is a time-consuming process but we are working both on faster exchanges between Simmetry3d and SketchUp and on further developments of the spreadsheet to include more varied, detailed cost and value data in the appraisal.

Acknowledgements

This paper is based on work undertaken as part of the URSULA project (see www.ursula.ac.uk) funded by the Engineering and Physical Sciences Research Council (grant number EP/F007388/1). The authors are grateful for EPSRC's support. The views presented in the paper are those of the authors, and cannot be taken as indicative in any way of the position of URSULA colleagues or partners or of EPSRC. All errors are those of the authors alone.

References

Adams C D (1994) *Urban Planning and the Development Process*, London: UCL Press.

Adams, D., Russell, L. & Taylor, C. (1994) *Land for industrial development*, E & F Spon, London.

Al-Kodmany, K. (1999) Using visualization techniques for enhancing public participation in planning and design: process, implementation, and evaluation, *Landscape and Urban Planning*, 45(1), 37-45.

Amion Consulting, Taylor Young, Donaldsons and Shaw, D. (2007) *Economic Value of Urban Design*, Final Report to NWDA/RENEW Northwest, Amion Consulting, Liverpool.

An, K. (2005) *Implementation of Real-Time Landscape Visualisation for planning process*, Trends in Real-Time Landscape Visualisation and Participation Proceedings, Anhalt University of Applied Sciences, 184-194.

Appleton, K. and Lovett, A. (2003) GIS-based visualisation of rural landscapes: defining 'sufficient' realism for environmental decision-making, *Landscape and Urban Planning*, 65, 117-131.

Ball, M. Lizieri, C. and MacGregor, B., (2008) *The Economics of Commercial Property Markets*, Routledge, London (2nd Edition).

Ball, R. (2002) Re-use potential and vacant industrial premises: revisiting the regeneration issue in Stoke-on-Trent, *Journal of Property Research,* 19(2), 93-110.

Bishop, I. (2005) *Visualization for participation: the advantages of real time*, Trends in Real-Time Landscape Visualization and Participation, Wichmann, Berlin, 2–15.

Byrne, P (1996) *Risk, Uncertainty and Decision Making in Property Development*, (2nd Edition) E. & F.N. Spon, London

Carmona, M., de Magalhaes, C., Edwards, M., Awuor, B. and Aminossehe, S. (2001) *The Value of Urban Design,* CABE and DETR, Thomas Telford, Tonbridge.

Carmona, M., Blum, R., Hammond, L., Stevens, Q., Dann, J., Karski, A., Pittock, C., Rowlands, S. and Stille, K. (2006) *Design Coding in Practice: an Evaluation*, DCLG Publications, Wetherby.

Cadman D & Topping R (1995) *Property Development*, London: Taylor & Francis Books Ltd, Spon Press.

Charney, I. (2007) Intra-metropolitan preferences of property developers in greater Toronto's office market, *Geoforum,* 38, 1179-1189.

Chau, K-W., Wong, S.K., Yau, Y. and Yeung, A.K.C. (2007) Determining Optimal Building Height, *Urban Studies*, 44 (3), 591-608.

Coakley, J. (1994) The Integration of Property and Financial Markets. *Environment and Planning A*, 26, 697-713.

Coiacetto, E. (2006) Real Estate Development Industry Structure: Consequences for Urban Planning and Development, *Planning Practice & Research,* 21(4), 423-441

Crosby, N., Henneberry, J. and McAllister, P (2008) *Unconventional Conventional Wisdom: Rethinking Development Appraisal*. Paper presented at the ERES Annual Conference, Krakow, June.

Darlow C (ed.) (1988) *Valuation and Development Appraisal*, London, Estates Gazette, 2nd Edition.

Eppli, M. and Tu, C. (1999) Valuing new urbanism; the case of Kentlands, *Real Estate Economics*, 27 (3).

Evans, A. (2004) *Economics and Land Use Planning*, Blackwell, Oxford.

Flanagan, R. and Norman, G. (1978) The relationship between construction price and height, *Chartered Surveyor*, 5(4), 68-71.

Fraser, W. (1993) *Principles of Property Investment and Pricing*, Macmillan, London.

George, R.V. (1997) A Procedural Explanation for Contemporary Urban Design, *Journal of Urban Design*, 2(2), 143-161.

Goodchild, R.N. & Munton, R. (1985) *Development and the Landowner*, Allen Unwin, London.

Gore, T. and Nicholson, D. (1991) "Models of the Land Development Process: a Critical Review", *Environment and Planning A*, 23, 705-730.

Guy, S. and Henneberry, J. (2002) *Approaching Development*. In Guy, S. and Henneberry, J.(eds) Development and Developers: Perspectives on Property, Blackwell, Oxford, 1-18.

Guy, S., Henneberry, J. and Rowley, S. (2002) Development Cultures and Urban Regeneration, *Urban Studies,* 39(7), 1181-1196.

Havard, T. (2008) *Contemporary Property Development*, RIBA Publishing, London (2nd Edition).

Healey, P. (1991) "Models of the Development Process: A Review", *Journal of Property Research*, 8, 219-238.

Herwig, A. and Paar, P. (2002) *Game engines: tools for landscape visualization and planning*, Trends in GIS and Virtualization in Environmental Planning and Design, 161-172.

Hoinkes, R. and Lange, E. (1995) 3D for free. Toolkit expands visual dimensions in GIS, *GIS World*, 8(7), 54-56.

Isaac, D. (1996) *Property Development: Appraisal and Finance*, London, Macmillan.

Lange, E. (1994) Integration of computerized visual simulation and visual assessment in environmental planning, *Landscape and Urban Planning*, 30(1-2), 99-112.

Lange, E. (2001) The limits of realism: perceptions of virtual landscapes, *Landscape and Urban Planning*, 54(1-4), 163-182.

Lange, E. and Hehl-Lange, S. (2005) Combining a participatory planning approach with a virtual landscape model for the siting of wind turbines, *Journal of Environmental Planning and Management*, 48(6), 833-852.

Lange, E. and Schaeffer, P.V. (2001) A Comment on the Market Value of a Room with a View, *Landscape and Urban Planning,* 55, 113-120.

Laverne, R. and Winson-Geideman, K. (2003) The Influence of Trees and Landscaping on Rental Rates at Office Buildings, *Journal of Arboriculture*, 29(5), 281-290.

Llewelyn-Davies (2000 [re-issued 2007]), *Urban Design Compendium*, English Partnerships and the Housing Corporation, London.

Luttik, J. (2000) The value of trees, water and open spaces as reflected by house prices in the Netherlands, *Landscape and Urban Planning*, 48, 161-167.

Macmillan, S. (2006) Added value of good design, *Building Research and Information*, 34 (3).

Markelin, A. and Fahle, B. (1979) *Umweltsimulation. Sensorische Simulation im Städtebau*, Schriftenr. 11, Städtebaul. Inst. Universität Stuttgart. Krämer, Stuttgart.

Parris, S. (2010) *Institutional Ecologies of Commercial Property Development,* Unpublished PhD Thesis, Department of Town and Regional Planning, University of Sheffield.

Picken, D.H. and Ilozor, B.D. (2003) Height and Construction Cost of Buildings in Hong Kong, *Construction Management and Economics*, 21, 107-111

Pryke, M. and Lee, R. (1995) Place Your Bets: Towards an Understanding of Globalisation, Socio-financial Engineering and Competition within a Financial Centre, *Urban Studies*, 32(2), 329-344.

Roger Evans Associates (2007) *Urban Design Compendium 2: Delivering Quality Places*, English Partnerships and the Housing Corporation, London.

Savills (2003) *The Value of Housing Design and Layout*, CABE and ODPM with Design for Homes, Thomas Telford, Tonbridge

Savills (2007) *Valuing Sustainable Urbanism*, The Princes Foundation and English Partnerships, London.

Song, Y., and Knaap, G.J. (2003) New urbanism and housing values: a disaggregate assessment, *Journal of Urban Economics*, 54, 218-238.

Syms, P (2002) *Land, Development and Design*, Oxford, Blackwell Publishing

Tunstall, G. (2006) *Managing the Building Design Process*, Elsevier, Oxford, 2nd Edition.

Vandell, K. and Lane, J. (1989) The economics of architecture and urban design: Some preliminary findings, *Real Estate Economics*, 17(2), 235-260.

Wassmer, R.W. and Bass, M. (2006) Does a More Centralized Urban Form Raise Housing Prices? *Journal of Policy Analysis and Management,* 25 (2), 439 - 462.

Wyatt, P (2007) *Property Valuation in an Economic Context*, Oxford: Blackwell.