The Fusion of BIM and Quadruple Net Value Analysis for Real Estate Development Feasibility Assessment

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Real estate development may benefit from a decision-support software system that is implemented with Building Information Modelling to perform Quadruple Net Value Analysis. Schemes may be created rapidly using BIM and parametric modeling. They may be assessed for economic, social, and environmental factors using spreadsheets and simulation software. They may be assessed for sensory value by using an immersive visualization system. The idea has been tested as a proof of concept in undergraduate and graduate design studios. It appears to be easy to use for students and effective in directing attention to the four factors and obtaining objective measurements.

Keywords: *real estate development, Building Information Modelling, immersive visualization*

IMPROVING THE DESIGN OF REAL ESTATE DEVELOPMENTS

The fusion of design support software and Quadruple Net Value Analysis enables real estate developers and designers to assess alternative proposals for enduring value and address not only the triple bottom line, but also the emotional appeal of the development. The framework of Quadruple Net Value Analysis combines the triple bottom line of sustainable development (economic, socio-cultural, and environmental assessment) with an additional factor of sensory value (Jerke, Porter, and Lasser 2008). This comprehensive assessment offers the potential to significantly reduce risk, maximize return on investment, and improve quality of real estate development by better accounting for all significant factors. Our hypothesis is that, through the adaptation of Building Information Modelling (BIM) and immersive visualization tools to include the metrics of quadruple net value analysis, it is possible to both thoroughly and expeditiously elucidate the enduring value of proposed real estate development assets.

The hallmarks of modern city development have been suburban tract housing estates, strip malls, and cost-effective building solutions largely lacking in architectural and aesthetic value. The primary drivers of these land and property development projects have been their financial return on investment. Proven development solutions and lending practices that seek to mitigate risk have worked against improved alignment of real estate development design and execution to the broader needs of the public. Nevertheless, innovative design conceptualization that aligns a more comprehensive list of user needs with the real estate product may enhance rental return, minimize property lease-up time and on-going vacancies, and minimize the life-cycle costs of operating the real asset. This potential is in the majority of real estate developments, but is not currently being realized. Many projects miss an opportunity to maximise the net operating income of the real estate asset and also enhance its capitalized value. The fusion of BIM and Quadruple Net Analysis will significantly reduce the costs and time currently required for an innovative design conceptualization process and will more accurately identify the comparative costs and benefits of a range of design solutions and development sensitivities.

BACKGROUND

Our basic question is how to determine the value of a real estate development scheme at the early conceptualization and feasibility analysis stage of a project. Typical valuation of individual real estate assets applies predominantly financial metrics. The appraiser has regard to such matters as comparable asset sales in the locality, net income stream of the asset, age, contingent liability, design, quality, supply and covenant strength to ascertain market value (Shapiro, Mackmin, and Sams 2013). The value accrues to the owner at the time the real estate asset is sold. Analysis of real estate development projects for feasibility is well understood to include market analysis, site acquisition issues, regulatory issues, and financial issues (Peiser and Frej 2003). However, this view of the value of real estate is arguably too limited to address imperatives for sustainability that have become widely accepted since their promulgation by the Brundtland Commission [1].

The Triple Bottom Line and Enduring Value

In one widespread criticism of the purely financial model of valuation, for real estate development to be sustainable, it must be not only economically attractive, but also socially and ecologically responsible, the formulation termed the "triple bottom line" (Elkington 1998). Analysis of energy consumption of buildings and carbon footprint has received much attention as important to establishing ecological responsibility. Social responsibility is also commonly addressed by various strategies, such as regulatory imperatives of building codes, zoning, utilities provision, mass transit, mixed use development, and incorporation of affordable housing.

However what distinguishes real estate from other investment asset classes is that it involves human habitation and therefore has value not just to its owner, but also to those that use it, visit it, and experience it. As was observed by Sir Winston Churchill, "We shape our buildings and afterwards our buildings shape us" [2]. Whilst financial analysts and valuers can identify comparative rents and capitalization rates, the current real estate feasibility and valuation approach struggles to acknowledge and incorporate less quantifiable and obvious qualities that nevertheless determine premium life-cycle performance. When a project achieves high design quality, and alignment with user needs (and anyone who visits the property is a user) the project may achieve what we term, 'Enduring Value". This enduring value is a function of the intrinsic quality of development conceptualization of individual real estate asset. Even if a real estate development satisfies the triple bottom line factors, it must still be appealing to the people who will be responsible for maintaining and preserving it. Sensory value is equally important in creation of successful real estate asset (Jerke, Porter, and Lasser 2008). Our view is that enduring value arises from the combination of the triple bottom line and an emotional attraction that arises from sensory response.

Sensory Assessment of Place

All human beings live their lives in places, that is, real estate. The comparative value of each of these places or real estate assets is in large measure determined by patterns and concentrations of repeat visitation. We tend to reward places that we find meet our needs with repeat visits and those that we do not with avoidance. We use all five senses, often in syncopation to determine the places that we reward with repeat visitation. The more time we spend in a particular place the more money we are likely to spend there, the more social connection and activity we ascribe to that place, and the more protective of its environmental value we are likely to become. This phenomenology of place is therefore fundamental to real estate income and capital value (Relph 1976; Booth 2001). Yet the current method of real estate financial feasibility and valuation is insensitive to such practical considerations.

The ability to read and navigate human settlements also underpins our appreciation of a real estate asset (Lynch 1960). However, this appreciation of the asset is all too often not made explicit so that these valuation and financial performance assumptions can be checked (Booth 2001). Furthermore, the regulatory plans, land-use zoning controls and building codes mandate prescribed and circumscribed forms of development that impact user satisfaction and alignment with need in a way that is currently very difficult to visualize and assess (Delafons 1969; Booth, 2004).

Much literature has pointed out the impact of sensory aspects on the appeal and success of urban design and urban form. The vividness and coherence of paths, nodes, edges, landmarks, and districts has been suggested as crucial to achieving urban environment with sensuous form that is "poetic and symbolic" (Lynch 1960, 119). The formal elements and behavioral patterns that lead to significant and compelling streetscapes have been catalogued (Jacobs 1994). Some streets engender a pleasant, walkable environment, while others do not. In addition to the well-established values of improved health of residents and improve air quality due to reduced vehicular use, walkable neighbourhoods have been linked to increased real estate value by Pivo and Fisher [2]. One guide to achieving walkability suggests the provision of a center to support gatherings, mixed income and mixed use development, parks and public spaces, pedestrian-oriented design, nearby schools and workplaces, and accommodation of pedestrians, bicyclists, and transit [4]. These factors point toward a tacit cultural assumption that a truly sustainable environment is one that people enjoy due to heightened pleasurable sensory experience.

Computational Advances

As computational systems advance, it may now be feasible to measure the performance of a real estate development scheme along these four dimensions in an interactive, decision-support system that combines BIM with immersive visualization. BIM provides designers with tools for creating rich representations of buildings that include not only the geometric and visual qualities, but virtually any non-graphic data as well. Parametric modelling enables designers to explore rapidly alternative schemes by varying parameter values and propagating the effects throughout a scheme. Interoperability capabilities enable designers to filter and extract information from the BIM and feed it into specialty simulation and analysis programs to obtain evaluations of the performance of a scheme. It may be possible to use immersive visualization to assess the sensory values of a scheme. The idea of simulating our experience of reality through immersive visualization, auditory simulation and other sensory actuation has been explored in many projects since the origination of the "CAVE" (Cruz-Neira et al. 1992).

The integration of development feasibility tools into an integrated computational decision-support platform can allow the relative value of alternative development concepts to be tested using Quadruple Net Value Analysis in a cost-effective and even iterative manner. In contrast to the traditional risk-prone development process relying upon tacit knowledge and assessments, we anticipate that this integrated platform will provide rapid yet thorough exploration of explicit development outcomes.

VISION

Our strategy is to integrate BIM, parametric modelling, simulation, development feasibility analysis, and immersive visualization in a comprehensive computer-based decision-support tool for land developers that achieves interactive fluidity to encourage "what if" studies (Booth, Clayton and Kim 2013; Clayton, Booth, Kim and Zarrinmehr 2013). We suggest that this integrated tool can fluently address all four aspects of Quadruple Net Value Analysis in a fashion that is usable to both land developers and designers. The fusion of these advanced information technologies promises to increase the ability of designers to address the fundamental purpose of city planning and development-the provision of an improved standard of desirable and cost effective space that meets societal needs. By making explicit what was previously overlooked or at best considered in tacit trade-offs, this tool may also increase the ability of developers, planners, and society in general to achieve sustainable development. Incorporation of land development concerns into BIM is a step toward a truly integrated platform to conceptualize, design, deliver, activate, and then manage land and property development.

Using this tool, the developer can establish financial objectives while the architect produces conceptual, but visually realistic, schemes. Working together, they can arrive at schemes that achieve economic, social, ecological, and sensory excellence. It may even be possible to bring personnel from regulatory authorities and representatives of the public into the process to see the implications of various constraints and decisions upon the sensory appeal of the development.

Speed of modelling and analysis is necessary to enable exploration of many schemes and facilitate collaboration among experts and the public. We believe that this innovative process can lead to optimized designs with enduring value.

By integrating the architect's tools and representations into the project conceptualization, two further benefits ensue. First, the developer is better able to visualize the project and make decisions about the level of quality needed in the project. Parametric modelling enables rapid generation of schemes and a more thorough exploration of solution spaces. The second benefit is integration to downstream processes. The use of BIM models at the conceptualization stage aids in all subsequent work by promoting interoperability. These benefits have been discussed in depth as general and typical benefits of the use of BIM (Smith and Tardiff 2009).

IMPLEMENTATION

The testing of this proposition has begun using a prototyping process aided by customized BIM software. We have named this proof of concept software-QNV-IV for Quadruple Net Value Immersive Visualization. We use BIM as the platform for modelling a real estate development and managing the information needed to support decision-making. We use various algorithms and computational tools to analyse the economic, socio-cultural, and environmental value of a proposal. We use immersive visualization to support the assessment of the sensory aspects of a real estate development project using qualitative methods to engage tacit knowledge. We use parametric modelling to generate urban form rapidly to enable exploration of multiple alternatives for land development.

The object-orientation and rich data models within BIM provide the foundation for fusing these multiple forms of modelling and analysis. Our development environment consists of Microsoft Visual Studio C#, Autodesk Revit and its Application Programming Interface (API), Microsoft Excel and various other tools. The use of BIM and its API enables us to

- model urban spaces rapidly using parametric modelling techniques,
- embed appropriate parameters into objects to store and retrieve information
- extract information subsets and execute analyses with either custom C# applications or spreadsheet models

- employ other interoperable tools such as energy analysis and cost estimating, and

- create models for immersive visualization.

Rapid Modelling of Schemes

Our technique for parametric urban modelling makes use of the parametric change engine and constraint modelling inherent to Revit. The parcel under consideration for development is broken into lots and streets, each represented as massing objects controlled by reference planes. These are linked parametrically to allow exploration of issues such as building height, street width, and setbacks and sidewalk widths. C# applications compute the parking required for the buildings and adjust the masses representing parking blocks automatically to have appropriate forms. A set of C# applications elaborate the masses into realistic, but schematic, facades, urban landscape and architectural features. These enable exploration of facade materials, fenestration and articulation of floors, on-street parking, placement of trees and other landscape amenities, and other factors. Figure 1 depicts a streetscape that may be parametrically varied with the software.

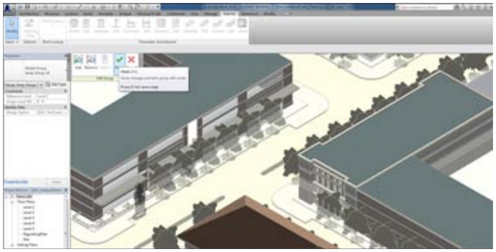

Figure 1
Parametric variation of an urban streetscape.

The massing objects and architectural objects are constructed with custom parameters to maintain information necessary for analysis. Floor areas, building footprints, lot areas, heights, area of facades and roofs, occupancy type, sidewalk widths, parking space counts, cost factors for materials and assemblies, compass orientation, location coordinates, and other relevant items are all maintained in the BIM.

Pro Forma Financial Analysis

Additional C# applications are used to extract subsets of information and control execution of analysis programs. Our strategy for development of analysis modules is incremental and emphasizes breadth: at each stage of development we will add analysis of one factor in each of the four components of quadruple net value analysis. Our first stage employs a financial pro forma analysis based on the mass model, solar shadow studies and energy analysis to gain a crude estimate of operations costs, a simple walkability audit as a social factor, and immersive visualization to assess visual sensory qualities. Other experiments have applied wind analysis and even pedestrian dynamics and crowd simulation.

The financial pro forma analysis is an example implementation. A C# program extracts data from the massing model of a mixed-use urban development to specify the total floor area for each use, the provisions for parking, the provisions for parks and other amenities, and building envelope area. These data are passed to an Excel spreadsheet that applies land acquisition cost, rental cost rates and occupancy rates, discount rates, and other factors to compute a capitalized value and project profit. figures 2 and 3 depict the spreadsheet.

An additional module varies the building heights, setbacks from the street, parking ratios, and occupancy mix through ranges and calls the pro forma spreadsheet repeatedly to search for optimum project parameters. Each set of parameters is applied to the BIM to generate a 3D model of the alternative as well as the financial analysis.

Immersive Visualization

Our intention is to use an immersive visualization setting to enable developers to explore a scheme from a sensory, emotional, tacit perspective as the fourth point of the quadruple net value analysis. To support the land development process, we must move models from the BIM environment rapidly into an immersive visualization setting, to enable interactive experimentation and collaboration. We achieve this us-

Project Information

1	Site Area	From BIM	2,963,560 sqft				
4	Use type		Apartment	Mercantile	Business	Garage	Hotel
5	Gross Floor Area per use	From BIM	400,000 sqft	500,000 sqft	400,000 sqft	200,000 sqft	250,000 sqft
	Total Gross Floor Area		1,750,000 sqft				
	Floor Area Ratio (5/1)		0.59				
18	Efficiency Rate (Lettable area/Gross area)	From BIM	80.00%	80.00%	75.00%	80.00%	80.00%
	Net Rentable Floor Area per use		320,000 sqft	400,000 sqft	300,000 sqft	160,000 sqft	200,000 sqft
	Total Net Rentable Floor Area		1,380,000 sqft				

Total Acquisition Cost

2	Site Unit Cost, including improvements ($ per sf)		$6.00				
3	Total Site Cost	1 x 2	$17,781,360				
7	Construction rate ($ per sf, from Means)		$100	$120	$150	$120	$220
	Simple construction cost per use (rate x area per use)		$40,000,000	$60,000,000	$60,000,000	$24,000,000	$55,000,000
9	Taxes/ Insurance / Permits /Fees (1 to 4% of constru	2%	$800,000	$1,200,000	$1,200,000	$480,000	$1,100,000
13	General and Administrative (G&A) (1 to 2% of const	3%	$1,200,000	$1,800,000	$1,800,000	$720,000	$1,650,000
14	Contingency (5 to 15% of construction)	5%	$2,000,000	$3,000,000	$3,000,000	$1,200,000	$2,750,000
6	Architect, Engineer, & Consultant fees (5 to 10% of c	7%	$2,800,000	$4,200,000	$4,200,000	$1,680,000	$3,850,000
10	Financing (1 to 8% of construction)	6%	$2,200,000	$3,300,000	$3,300,000	$1,320,000	$3,025,000
	Overhead cost per use		$9,000,000	$13,500,000	$13,500,000	$5,400,000	$12,375,000
17	Total Acquisition Cost per Use	3 + Sum 16	$49,000,000	$73,500,000	$73,500,000	$29,400,000	$67,375,000
	Gross Total Acquisition Cost		$310,556,360				

Figure 2
Pro forma financial analysis input values driven from the BIM.

ing a "BIM CAVE" (Kang, Ganapathi and Nseir 2012). This facility provides twelve high-definition screens arranged in a semi-circular array driven by three computers to provide a basic immersive environment for one to three viewers. The users can navigate through the setting in real time with a 170 degree field of vision. A distinctive aspect of the facility is that it uses custom software to coordinate projection of the images using commercially available Autodesk Navisworks software running under Microsoft Windows operating system. As Navisworks can read Revit files, the interoperability between the BIM and the immersive visualization generally requires only a few minutes.

An "enduring value" scorecard will be used to assess quadruple net value of each scheme. Although this has not yet been implemented, we plan to explore various methods to combine both quantitative and qualitative assessments. One approach is to use a weighting algorithm. It could be "tuned" to determine weighting factors by assessing existing places. We anticipate that development teams will want to tweak the weighting factors based on their own objectives and experience.

USE SCENARIO

A use scenario can clarify our vision and help prove the concept. In the first step, the real estate developer and designer prepare a schematic 3D design using parametric modelling. Energy modelling and wind analysis are performed using commercial BIM analysis tools. Assessment of socio-cultural objec-

Recurring Costs

8	Tenant Improvements per sqft. of Leasable Space ($ per sf)		$20	$20	$20	$20	$20
11	Leasing/ Sales per sqft. of Leasable Space		$2	$2	$2	$2	$2
12	Public Relations/ Marketing per sqft. of Leasable Space		$2	$2	$2	$2	$2
23	Operating Expenses per sqft. of Leasable Space		$ 6 per sqft	$ 6 per sqft	$ 6 per sqft	$ 6 per sqft	$ 6 per sqft
	Total Operating Cost Rate		$ 30 per sqft	$ 30 per sqft	$ 30 per sqft	$ 30 per sqft	$ 30 per sqft
26	Operating Expenses per use	5 x 23	$12,000,000	$15,000,000	$12,000,000	$6,000,000	$7,500,000
	Gross Total Operating Cost		$52,500,000				

Revenue

20	Gross Rental Rate per sqft. of Lettable Space		$ 65 per sqft	$ 80 per sqft	$ 75 per sqft	$ 20 per sqft	$ 90 per sqft
21	Occupancy Rate		80.00%	80.00%	80.00%	80.00%	80.00%
22	Gross Revenue per use	19 x 20 x 21	$16,640,000	$25,600,000	$18,000,000	$2,560,000	$14,400,000
25	Gross Revenue	Sum 22	$77,200,000				
28	Net Operating Income (NOI) per use	25 - 27	$4,640,000	$10,600,000	$6,000,000	-$3,440,000	$6,900,000
	Total Net Operating Income		$24,700,000				

Capitalized Value and Development Profit

29	Capitalization Rate (Ratio of capital investment to value)		7.90%				
30	Sale Price	28 / 29	$312,658,228				
31	Gross Project Cost	17	$310,556,360				
32	Development Profit	30-31	$2,101,868				

Figure 3
Pro forma financial output.

tives is carried out using a checklist. The scheme is then loaded into a BIM CAVE immersive visualization system so that people can assess the sensory value through a virtual walk-through. Integration of non-graphic information is then used to generate pro forma estimates of relative profitability.

The cycle of designing and testing alternative designs is both enabled and accelerated through rapid generation of schemes made possible by parametric modelling. The relative risk and return is thereby made explicit and affords a more comprehensive assessment of project viability and how it might best be improved. The progressive incorporation of the Quadruple Net Value Analysis metrics provides for the calculation of a Sustainability Dividend that can accrue through the cost-effective incorporation of sustainable design solutions to the real estate development project (Booth 2008). We see this as an estimation of a project's enduring value.

TESTING AND VALIDATION

In a first exploration, our research team constructed test applications as addins to Autodesk Revit. The applications explore economic, socio-cultural, and environmental factors. We also confirmed the process of loading the BIM of the schemes into the BIM CAVE. This step demonstrated that all four categories of factors in Quadruple Net Value Analysis can be analyzed within integrated tools built on a BIM platform.

In a subsequent step, an actual 60 acre land and property development project adjacent to a university campus was used as the scenario for testing. The project has been modelled using Autodesk Revit. This has involved the creation of a massing model capable of parametric variation to reflect changes in building heights, setbacks, occupancy type, open space and parking provision. Nine students in a post-graduate architecture design studio designed schemes for the site, analyzed them for economic feasibility through a pro forma, analysed them for socio-cultural factors through a checklist, determined the environmental impact using energy simulation, and examined sensory value by presenting their work in the BIM CAVE. This test demonstrated that students can be taught the process with the various tools and can derive insights about their designs from the process. Figure 4 depicts students using the BIM CAVE for a design review.

Figure 4
Students using the BIM CAVE for a design review.

While the economic analysis and the energy simulation are relatively well understood, and the socio-cultural analysis is currently very rudimentary, interesting observations resulted from the use of the BIM CAVE. Immersive visualization revealed in several schemes a difficulty in anticipating the effects of the outdoor space. The urban settings seemed empty and barren. The distances across the streets or between buildings seemed too large and inattention to landscaping crippled the aesthetic impact. In other schemes, attention to these two factors resulted in urban settings that were much more appealing. Students, instructors, and observers commented that the immersive visualization improved their ability to assess the experiential appeal of the various schemes.

In a second test, 17 sophomore students used the BIM CAVE to examine houses that they had designed. Students successfully explained their house designs by providing a virtual tour of the house in the immersive visualization environment.

In both tests, all students experienced no difficulties in producing the Navisworks files from Revit files for loading into the BIM CAVE, nor did they experience any significant difficulties in navigating the space. Although the level of rendering accuracy in the BIM CAVE is relatively crude, students were able to assess spatial qualities. The BIM CAVE appears to be adequate for performing basic sensory assessment in support of quadruple net value analysis, at least in a research and exploratory setting.

Additional validation tests are in progress to study other sites and involve additional students as well as practitioners.

IMPLICATIONS AND FUTURE WORK

Our study demonstrates the concept of the QNV-IV system. It confirms that implementation is feasible and has no major obstacles. Users can grasp the concept of the system and how to use it very readily. The tool appears to have an influence upon the designers and developers who use it.

The proof of concept QNV-IV software developed to date suggests that it could have wide application and utility to future real estate asset designers, developers, and financiers. It demonstrates the potential to enhance real estate asset quality and performance through improved development conceptualization, design, delivery, activation, and management. Of particular significance is this fused model's ability to allow many real estate asset users to experience proposed real estate projects and begin to discover which parametric values trigger broad and sustainable user appeal that is central to creation of enduring value from real estate. The QNV-IV is a research tool that can help to reveal tacit knowledge and hidden relationships that determine whether the public will embrace a project or reject it.

We are progressively linking Quadruple Net Value Analysis metrics to the data fields in BIM to assess the economic, socio-cultural, environmental, and sensory value of alternative real estate development solutions. We plan to incorporate audio cues into the immersive visualization environment. The syncopation of both audio and visual responses will provide for the evocation of additional senses in ways similar to those used in cinema. This will not only provide for improved alignment with user needs, preferences, and perceptions but also reveal projected real estate income and expense. The QNV-IV system has significant potential to involve all professions and stakeholders involved in the creation, performance, assessment, and, enjoyment of all forms of real estate development. The fusion of BIM and Quadruple Net Value Analysis in real estate development feasibility assessment holds significant potential to enhance the enduring value, quality, and attraction of real estate assets in human settlements.

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