

A GIS based planning support system for assessing financial feasibility of urban redevelopment

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Abstract Urban densification trends combined with redevelopment increasingly moving away from large former industrial and transport sites toward existing town centres and corridors indicate redevelopment is becoming increasingly complex, difficult to plan for and undertake. The interplay between land and property markets and planning frameworks suggest city planners and urban researchers need new tools and methodologies to gain insights into ways to deliver effective responses. Despite the need, there is a limited availability of comprehensive models to fulfil the task. This paper describes a GIS-based tool to assess parcel-level financial feasibility and housing supply associated with urban redevelopment within a precinct. The tool incorporates existing and potential built form and

parameters associated with the planning framework and land and property markets. Using a real case study in a workshop, tool performance was evaluated by professional urban planners in terms of its capacity to produce metrics and visualisations of potential scenarios of redevelopment. Results indicate the usefulness of the tool for emulating land market conditions and testing scenarios of planning regulation and market changes for strategic planning purposes.

Keywords Modelling · Visualisation · Scenario · Urban consolidation

If the manuscript is published, the “Financial Feasibility of Urban Redevelopment GIS Toolbox” and a “sample data” will be available to any interested user for download at the “CityData” <https://citydata.be.unsw.edu.au/> link at the website of the City Futures Research Centre/University of New South Wales, Sydney, Australia, under a Creative Commons Attribution-Non-Commercial 4.0 International License (CC BY-NC 4.0).

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Introduction and background

Australian cities are rapidly moving toward a higher density future as governments plan to meet population growth targets. In Australia, higher density residential development has recently reached record levels with new apartments estimated to account for 48% of national housing commencements in 2015–2016 (HIA 2017). Current population forecasts for the next 25 years predict an additional 1.6 million households are expected to reside within the existing urban envelopes of the five largest Australian cities, making a substantial process of urban redevelopment and land use intensification a likely outcome. While these are not new processes in Australia (Cardew 1980; Randolph 2006; Butler-Bowden and Pickett 2007), the

scale and speed at which redevelopment is being delivered are unprecedented and have proven to be contentious (Ruming 2014).

Contemporary planning theory and practice both see the pursuit of compact city policies implemented through mixed-use higher density urban redevelopment and infill development as the principal mechanism for reshaping our cities (Forster 2006; OECD 2012; UN Habitat 2013). Higher-density residential development, often focused on transport hubs and ‘magnet’ infrastructure, has become a dominant feature in location decisions about new housing supply. Major claims about the social, economic and environmental benefits of urban compactness, as seen in improved urban amenity, affordability, accessibility, liveability, productivity, sustainability and efficiency, now dominate the rhetoric of planning and development discussion both in Australia and internationally (ASBEC 2010; Major Cities Unit 2012; UN Habitat 2013).

There has been significant discussion in the literature about the effect of land use and planning regulations and issues with their restriction internationally, such as in India (Brueckner and Sridhar 2012), in the UK (Cheshire and Sheppard 2002), and the USA (Ihlanfeldt 2007; Geshkov and DeSalvo 2012). Geshkov and DeSalvo (2012), for example, investigated the impacts of varied land-use controls on the spatial size of cities. In the context of USA cities, they found that maximum lot size requirements, urban growth boundaries, minimum square footage limits, maximum building permit restriction, minimum person per room controls, result in less spatially expansive urban areas. Brueckner and Sridhar (2012) identified benefits from the relaxation of building height restrictions in Indian cities, including a reduction in sprawl and as a result annual saving in commuting costs for the city’s edge households. Ihlanfeldt (2007) examined the economic impacts of building controls. Looking at more than 100 cities in Florida, he found that a more restrictive regulatory environment increases house prices, decreases land prices, and increases the sizes of newly constructed homes. Cheshire and Sheppard (2002) presented an empirical evaluation of the benefits and costs of land-use planning regulations across income groups in the UK. They found that planning produces benefits of considerable value, but at high costs, and that welfare would be improved by permitting more development.

Cities periodically need to undertake reinvestment and redevelopment of the built environment to ensure their continued functionality and to reflect modern standards of living. With the exception of a few geographically focused mega-projects, in most Australian cities redevelopment has largely operated in a piecemeal fashion—block by block. This approach has resulted in the production of substantially less new housing stock than through urban expansion. Over the past three decades, however, there has been a greater emphasis on urban consolidation and densification of existing urban areas, and building activity has increasingly looked towards urban infill areas for opportunities for housing development (Tajani and Morano 2015).

This policy shift has occurred during a period of substantial reconfiguration of urban economies. Manufacturing and industrial activities have been relocated to the fringes of urban areas or offshore into cheaper labour markets. In their wake, large parcels of often centrally located land became available for conversion into housing. As these spaces start to become scarce, and as governments become more concerned with the additional infrastructure and service costs associated with fringe dwelling construction (Lieske et al. 2015), there is increasing attention directed towards areas of existing housing, both detached and multi-unit, to provide additional dwellings for a growing population. Previous research has documented the ‘knock-down-rebuild’ phenomenon and its large and often unacknowledged contribution to the progressive redevelopment and revitalisation of urban areas (Pinnegar et al. 2015). As highlighted by van den Nouwelant et al. (2015), development costs in urban redevelopment contexts are often higher than in other locations. This is due to a range of factors. Fragmented landownership makes parcel aggregation and associated holding costs more expensive, and existing properties need to be purchased at market value. Also, former higher density built form leads to costlier construction methods and financing options. Additionally, existing local communities with expectations of scale and design add risk to the development process. Consequently, to be successful, market-driven urban redevelopment requires a buoyant property market, or the potential for significant value uplift, capitalising on locational advantages and low initial entry cost for developers.

Financial feasibility is a consolidated field of development appraisal. As described by Harvard (2014), methods and systems are available to assist developers determine the best price to bid for a piece of land. These methods require very detailed information on cost components, taxes, fees, interest rates, expected sales proceeds, as well as general and site level planning and building restrictions. Such a level of detail is not typically available to urban planners, and indeed not necessary for the level of assessment they perform for planning purposes in precincts, neighbourhoods or wider regions. Therefore, these methods, while useful for developers for specific projects and proposals, are not typically used in the planning assessment of potential developments or to explore the impacts of hypothetical planning control scenarios.

Two methods for financial feasibility assessment of redevelopment designed for planners have recently been reported in the literature, Tajani and Morano (2015) and Troy et al. (2015a, b). Tajani and Morano (2015) developed an evaluation model of the financial feasibility of social housing in urban redevelopment in Italy. They argue that policy targets for the proportion of social housing to be included in new developments at the developer's cost across Europe have been defined without assessment of financial feasibility, and that indeed tools to undertake such evaluation are missing. Based on general constructions costs and sales revenues, their model produces a compromise solution between the objectives of private sector profit and collective demands for social housing. Using a case study in Italy, only 7 out of 20 project proposals were financially feasible including social housing, and only 3 of the 7 proposals achieved 30% social housing units as stated in the policy target.

Troy et al. (2015a, b) developed a model to evaluate the financial feasibility of urban redevelopment in the form of multi-unit housing. This model was part of broad research on the new high density urban development trends in consolidated urban areas of Sydney, and the potential economic barriers imposed by Strata laws on redevelopment. In Australia, a 'strata title' allows individual ownership of part of a property (generally apartments and townhouses), combined with shared ownership of the remainder (common areas of the property, such as driveways, foyer, gardens, lifts, etc.) through a legal entity called the owners corporation; it offers a legal mechanism for

space to be vertically subdivided and traded, allowing individualised property rights to be applied to multi-unit housing (Troy et al. 2017). Terms such as 'condo', 'multi-family' or 'mid-rise residential' properties are found in the literature with similar meaning. According to the current New South Wales (NSW) Strata regulations, at least 75% of units, through their owners' votes, are required to approve the sale a whole strata building for redevelopment (<http://stratalaws.nsw.gov.au/>). Results from Troy's model indicate that left to the market, strata redevelopment is only likely to occur in locations where land values are sufficiently high enough to drive redevelopment or when densities are significantly increased above existing permitted levels. These findings had an important impact on recent policy and practice in Sydney; the project report (Troy et al. 2015b) was used by NSW Fair Trading to inform the new Strata Schemes Development Act, with 7 of the final 27 recommendations included in the new legislation which came into effect in in 2016.

Despite the narrow scope of these financial feasibility models, one focused on social housing and the other on multi-unit housing, they provide a data driven evidence basis to support urban planning. The first indicated the failure of a social housing renewal policy, and the second provided guidelines for a new policy to reduce barriers for redevelopment of multi-unit housing, in their respective study areas. One significant limitation of the two models for planning purposes, however, is their format; they were not designed and built in a way to be easily accessed and used by planners. Nor do they include functionality supporting visual analysis and communication. Thus, they would not fall under the category of planning support systems (PSS), which can be defined simply as computer based-tools which can assist planners to more effectively undertake their day to day jobs (Geertman et al. 2017).

In order to overcome this limitation, this research incorporates the approach of Troy et al. (2015b) within a geographic information system (GIS). The analytical tools and visualisation capabilities of the GIS enable the creation of a financial feasibility PSS. The PSS extends the scope of the former model, including strata and non-strata properties, and provides additional outputs, including maximum developer profit available at current planning controls, as well as the supply of housing and commercial floor space at minimum

profit and maximum height. Using a real case study within a workshop setting, urban planners explored and tested the new tool through a set of questions: (1) is urban redevelopment in the study area financially feasible under current planning controls? (2) If so, can urban redevelopment provide enough supply to meet future housing demand projections? (3) To what extent would changing planning controls affect financial feasibility and housing supply? (4) How resilient is the study area given increasing development costs with fixed revenue potential? (5) and, How useful is the tool for planning purposes?

After discussing the context, precedents, and aim of this research (“[Introduction and background](#)” section), the paper describes the methods applied and data requirements (“[Methodology](#)” section), and the context of the case study (“[Case study](#)” section). Then, using a workshop with urban planners, the financial feasibility analysis is developed within the context of a number of scenarios, and results are discussed (“[Analysis and result](#)” section). “[Conclusion](#)” section concludes the paper.

Methodology

The rationale of the financial feasibility model

A common approach to understanding the financial feasibility of a given urban development scenario is to establish present land market conditions and test whether a development would be realised under current or modified planning arrangements; where the realisation depends on the developer reaching a minimum required profit margin. The method utilised in Troy et al.’s model takes a different approach by seeking to estimate the number of units that would need to be built for any given situation to make a redevelopment financially feasible (Troy et al. 2015b). In reality, there are going to be specific planning constraints which will impact the possibility of delivering a particular scenario. However, rather than feed this in as an upfront constraint on feasibility modelling, this approach enables planners to uncover the type of planning environment needed to establish a financial case for redevelopment.

According to Troy et al. (2015b) model, there are three principal components to estimating the financial feasibility of redevelopment of existing housing stock:

- *Buyout cost* The cost of purchasing land and existing property that will be redeveloped. An estimation of the likely current market buyout cost of existing properties was estimated using the NSW Valuer-General’s sales data for properties at the scale of Australian Statistical Geography Standard Statistical Area Level 2 (SA2) and the estimated stamp duty payable by a prospective developer.
- *Redevelopment cost* The cost of replacing existing stock with a new construction. For selected combinations of building quality and type, redevelopment cost is estimated using the Rawlinsons Construction Cost Guide (Rawlinsons 2016). The case study presented here assumes 2-bedroom units with 90 m² floor area and medium standard quality of construction to produce a cost per dwelling (including a 50% on-cost overhead and 20% builders profit component). Assumptions are based on the design guidelines proposed by the “NSW State Environmental Planning Policy No. 65: Design Quality of Residential Apartment Development” (SEPP 65).
- *Sale proceeds* The revenue from selling the new property after redevelopment. An estimate of the likely sale proceeds for new dwellings is based on the current sale values of similar new built development in the SA2 area, discounting the 10% Goods and Service Tax (GST) payable by the developer upon sale.

A redevelopment is only deemed financially feasible when the potential sale proceeds exceed the costs (buyout plus redevelopment) and the model generates the number of units of the selected typology that would be required to trigger this event. The model then estimates the building form outcome for each land parcel in terms of Floor Space Ratio (FSR) and building height. Once this has been achieved, a comparison can be made of the output building form and the existing planning framework to determine its compliance and the likelihood of a redevelopment scenario being approved.

It is important to note here what the model does, what the model does not do, and the intended audience. The broad goal was to develop a GIS-based PSS to help planners to understand likely redevelopment potential. The tool uses a financial feasibility assessment (revenues minus costs) and not an

econometric model (e.g. hedonic price model). The model was designed to assess the probable decisions of developers on the redevelopment of each parcel within a region of interest within an existing planning framework and set of land market conditions. The outcomes of this assessment provide an assessment of the overall capacity of a region for redevelopment (i.e. housing stock that can be built in the next few years), the potential spatial distribution of redevelopment capacity, and insights into how redevelopment capacity and the spatial distribution of redevelopment could vary if land market conditions and/or planning regulations were changed. Urban planners are the intended audience. The model is static and uses general parameters to characterise the land market, which are appropriate for the scope and scale of local government urban planning.

The model is not designed to replace detailed financial appraisal models, which provide developers with accurate estimations of redevelopment costs and revenues for specific projects and sites. The tool is not used to estimate land market values, but to check the impact of known land/property values in an area, together with planning controls, on the potential capacity of redevelopment of this area.

The model is also not designed to project the dynamics of the land market and urban redevelopment into the future. While this would certainly be a useful planning tool, it is beyond the scope of the model presented here.

Model development and interface

The model was developed as a GIS-based PSS using the ESRI's ArcGIS toolbox. The advantages of this format include the easy way the tool can be shared with users, and the ability to create a user-friendly interface for urban planners. The model was constructed using ModelBuilder, which ESRI describes as “a visual programming language for building workflows” (ESRI 2017). The GIS PSS tool, called ‘Urban Redevelopment Financial Feasibility’ (URFF), is a suite of six interconnected sub-models (Fig. 1). In this tool, the output of one model may be needed as input for another model. Table 1 describes the goal of each of the sub-models, the outputs produced, and the interdependencies among the sub-models (output of some sub-models are required as input for other sub-

models in the toolbox). Throughout the text, we will refer to the tool as the ‘URFF PSS’.

Each model is presented within a user-friendly interface where planners can input geographic data and parameter values required for the calculations performed by the model. Changing the parameters of one or more models enables scenarios to be built and compared. Supporting text is added to the model window, including a general description of the model goal and specific information about the data requirements for each field. When the OK button is pressed on the model window, the tool runs the entire sequence of operations included in the model and generates outputs in the form of new attributes to the geographic data inputs. It is recommended users run the models from 1 to 6 in order to obtain the full financial feasibility assessment for an area of interest.

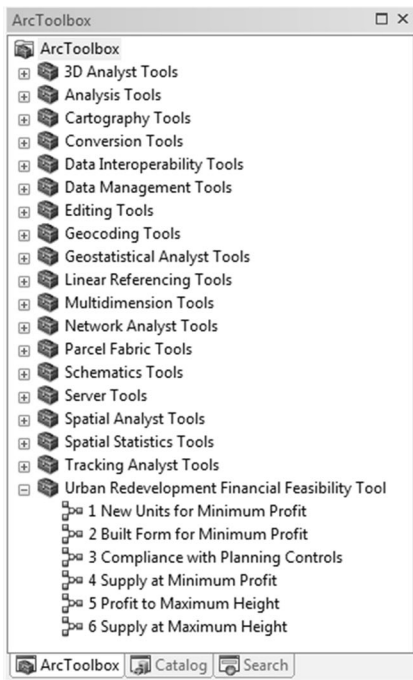
Figure 2 illustrates the tool interface, showing the window for Model 1 with parameters entered by the user, and the geographic data input layer with additional attributes generated by the run of Model 1 (number of new units required for a redevelopment to be financially feasible at or above the minimum profit rate selected). It also presents the tool's help showing supporting information for one of the model's parameters (sale price for new unit).

By changing parameters the URFF PSS tool can be used to create different scenarios of planning controls and test the impacts of hypothetical decisions on the financial feasibility of redevelopments, availability of housing, and their spatial distribution in an area. After running the 6 models, further ex-post analysis may be conducted within the GIS environment including comparing and visualising different scenarios.

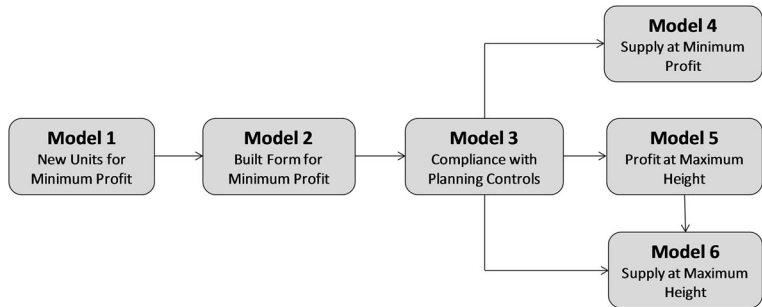
Data requirements

As a GIS-based PSS the initial input data for the URFF PSS is a polygon layer of study area parcel boundaries. Five attributes are required for each parcel: area of the parcel; number of existing units; whether the property is part of a strata scheme; maximum height permitted; and the maximum FSR permitted by the planning framework.

The model also requires a number of single value parameters to be defined by the user. Accurate input of these parameters requires an understanding of the present and near future land market conditions in the study area. First, the user should observe the study area



a



b

Fig. 1 Structure of the urban redevelopment financial feasibility tool (URFF PSS). **a** The URFF PSS toolbox. **b** Model interdependency

Table 1 Description of the models underpinning the URFF PSS: goal, outputs and interdependencies

Model	Goal	Model dependency	Output
1	Calculates the number of new units required for a redevelopment to achieve a minimum profit margin		Number of new units by parcel for minimum profit
2	Calculates the floor space ratio (FSR) and number of floors of a new building to accommodate the required number of new units financially feasible	Model 1	FSR and number of floors for a new building to accommodate the number of new units for minimum profit
3	Checks if FSR and number of floors of a new financially feasible building comply with planning controls	Model 2	Compliance of FSR and Height of new building to the max FSR and max Height permitted (1 for compliant, and 0 for not compliant)
4	Calculates the supply of residential units (with or without commercial floors) in a new building financially feasible at minimum profit and compliant to planning controls	Model 1 Model 2 Model 3	For each new building, financially feasible at minimum profit and compliant to planning controls: Minimum supply (number of units), and Minimum commercial floor space (area unit)
5	Calculates the profit for each new building compliant to planning controls to be built to the maximum height permitted	Model 1 Model 2 Model 3	For each new building, compliant to planning controls: Maximum number of units, and Profit to redevelopment at maximum height permitted
6	Calculates the supply of residential units (with or without commercial floors) in a new building compliant to planning controls at maximum height permitted	Model 2 Model 3 Model 5	For each new building, financially feasible at maximum height permitted by planning controls: Maximum supply (number of units), and Maximum commercial floor space (area unit)

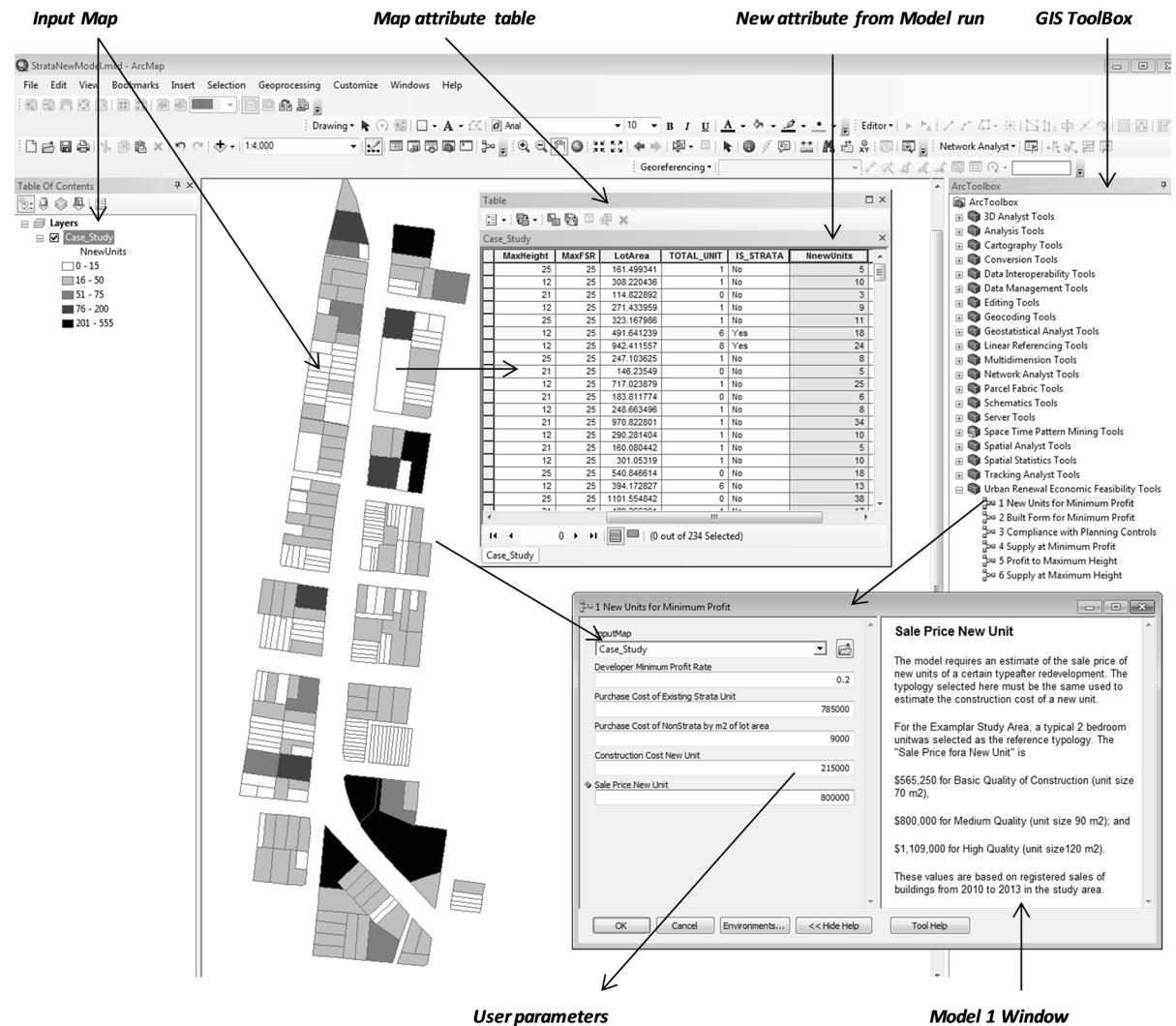


Fig. 2 URFF PSS: model interface within a GIS environment

and identify existing predominant building typologies, and based on recent sales data, estimate the potential cost a developer would incur to purchase existing stock before redevelopment. It is recommended that the cost of properties with strata units be estimated based on the number of units by parcel and the median cost of each unit; while non-strata properties, which are generally more varied in their typologies, be based on the size of the parcel and a median cost for each land areal unit. Second, the model requires the user to define a predominant typology for new developments, including size of the unit, and their standard of construction quality. Estimated costs for construction and the median sale price of new units must be related

to the size and quality of new units. Scenarios can be built testing redevelopment under varied typologies for new units. Construction costs can be based on standard construction guides, and sales prices can be assessed through records of sales of new properties of similar typology in the study area, or in areas with similar characteristics. Third, urban shape parameters, such as site coverage (proportion of the parcel covered by the building footprint) and private area rate (proportion of the building for private use only, excluding common areas such as stairs, lifts, corridors, and entrance halls), need to be entered for the model to calculate the new building form. As expected in urban areas undergoing densification, more services may be

required for an increased residential population. Therefore, the last parameter required in the URFF PSS tool is the number of commercial floors that should be included in new buildings with 5 or more floors. If commercial use is selected, the model will calculate both the supply of new residential units, as well as the supply of commercial floor space resulting from redevelopment.

Case study

The Kensington Town Centre, including 234 parcels along Anzac Parade within Sydney's South-East region, has been selected as the case study for testing the performance and usefulness of the URFF PSS. The case study enables assessment of the impact of potential changes to the capacity of the town centre to support growth in housing and commercial use, and to identify potential changes to the local planning framework applicable to the area.

Sydney's South-East region is expected to have significant population growth and redevelopment due to its amenity value, connectivity, and high levels of services. This region contains both large urban parks (Centennial and Moore Parks exceeding more than 300 ha), and internationally renowned beaches (Bondi, Coogee and Maroubra). An educational and health hub in the area includes one of the major universities in Sydney (UNSW), a technical college and a hospital complex (Prince of Wales Hospital, Royal Hospital for Women, Sydney Children's Hospital, and Prince of Wales Private Hospital). The education and health hub generates employment and attracts large number of service users. In terms of connectivity, the region is only 7 km from the Sydney central business district, 5 km from the main international airport, and is receiving upgraded public transport infrastructure in the form of a new light rail, expected to be operational from 2019. Town centres in the study area are zoned as medium to high density residential and mixed-use. Town centre building heights in general range from 4 to 8 floors. In the vicinities of town centres, parcels are generally zoned as medium density, consisting mostly of 2–4 floor multi-unit buildings or 1–2 floor townhouses. The remaining area is low density housing with detached single dwellings.

The Kensington and Kingsford Town Centres continue to be of interest to developers. Multiple scattered and uncoordinated new construction projects have been undertaken in the last decade where single dwellings and small buildings are replaced with 6–8 floor new multi-unit buildings. These two town centres form a corridor along a major road in South-East Sydney, called Anzac Parade. Figure 3 locates Kensington–Kingsford Town Centres in relation to Sydney CBD and other local amenities (Fig. 3a). Figure 3 also illustrates an example of an urban redevelopment undertaken in Anzac Parade in 2013, in which two parcels with single floor commercial units (Fig. 3b) were amalgamated and a seven floor high rise building was built with a commercial ground floor and 42 new residential units (Fig. 3c).

Like many areas where urban densification is occurring, the local Council has been approached by a number of developers with requests for construction at building heights above the existing planning controls, particularly in the Kensington and Kingsford Town Centres. Developers justify their request based on increasing land and property values in the region, and outdated planning regulations. The Council, in turn, trying to avoid the continuation of a piecemeal redevelopment, took two recent initiatives. First, it launched an urban design competition for the corridor; and second, engaged in a research exercise to develop and evaluate a GIS-based PSS to assist in the assessment of likely redevelopment in light of existing planning controls. The URFF PSS would enable the Council to explore a number of What if? redevelopment scenarios and evaluate their current regulation parameters, the topic of this paper.

Table 2 presents the model parameters calibrated as default values for the study area as used to assess the financial feasibility of urban redevelopment in 2016. Any of these parameters can be changed by users. Acquisition costs and sale proceeds are contingent on a number of variables, including location, and profile of existing buildings. To establish a profile of the existing land and building stock, land title records from NSW Land and Property Information were obtained for all properties in the study area. The lots of each strata scheme were aggregated enabling both the number of lots in a scheme (building) and the registration date (age) to be established. This information was attached to the cadastre for NSW which allowed location and land size attributes to be

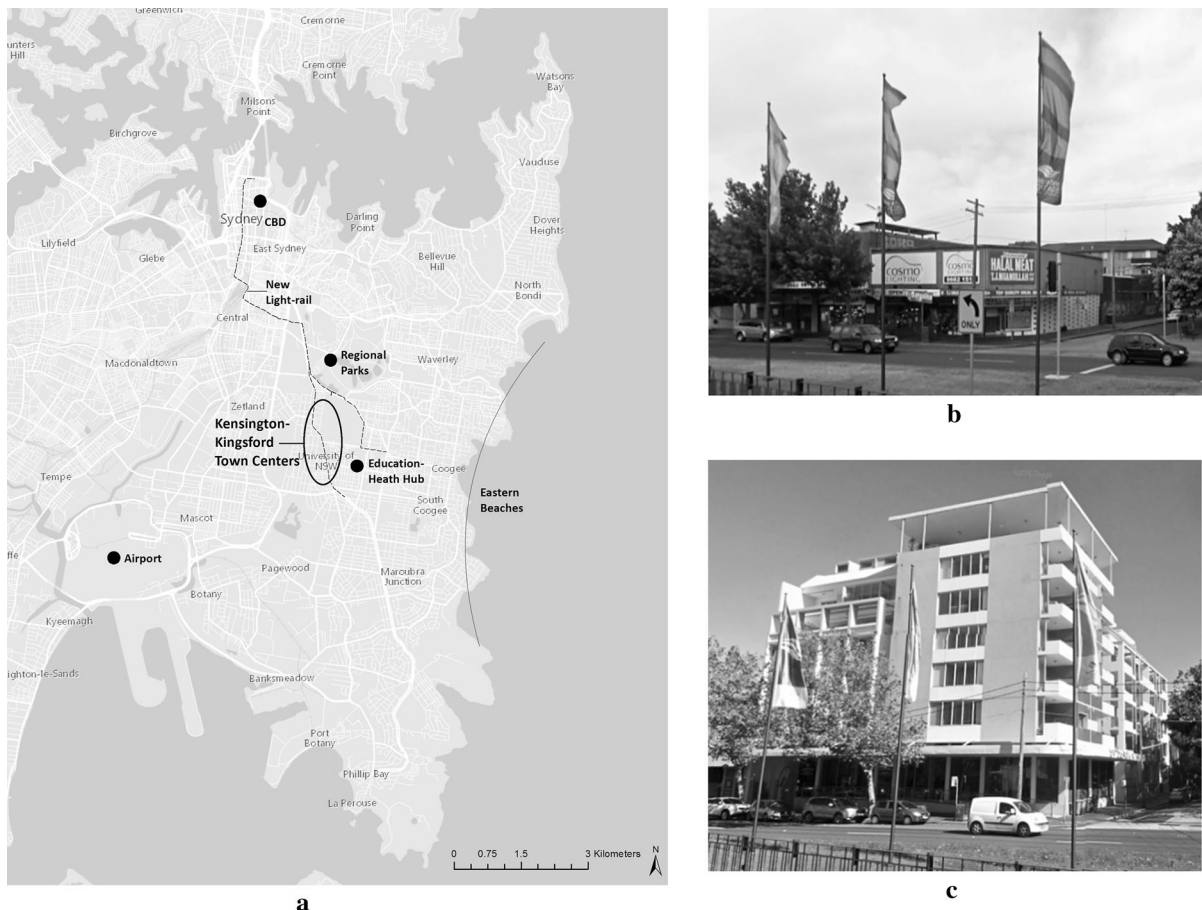


Fig. 3 Study area and exemplar urban redevelopment. **a** Kensington Town Centre in South–East Sydney. **b** Before: 2 parcels with a single floor unit each used as commerce until 2011.

c After: amalgamated parcel with a 7 floor building (commercial ground floor and 42 dwellings), built from 2011 to 2013

incorporated. Moreover, all property sales during 2015 in the SA2 where the study area is located were collected from the NSW Valuer-General’s sales data, then divided by type and size. These data were used to identify the median sale price of existing units (for strata properties of predominant typology) and the average price per square meter of land for non-strata properties (land buyout cost).

There are number of assumptions that underpin this analysis which may alter the outcome. These assumptions may be broadly split into technical or practical limitations, and conceptual limitations. This analysis is based on median sale values for both old and redeveloped units, which makes no allowance for the particular configuration of dwelling sizes in each block of flats or variation in actual building quality. Many older blocks have more lots registered on a

strata plan than there are actual dwellings, for example where a garage is a lot separate from the dwelling lot. In these cases, as the buyout cost is based on the total number of units multiplied by the median sale value, the model is likely to overestimate costs.

There is likely substantial price heterogeneity within a given SA2 based on parcel location and other geographic features, for example accessibility to public transport. Median values disguise the premium associated with geographic attributes which vary spatially and are likely to affect buyout costs. However, this effect will also apply to potential sale values, which again will underestimate the notional sale price of a new unit in that location and therefore underestimate the notional viability of a redevelopment. The net effect of spatial heterogeneity will to some extent be cancelled out. Nonetheless, given there can be

Table 2 Model parameters for the study area

Parameters	Description	Default value
Financial		
Land buyout cost	Cost to purchase existing property for non-strata schemes by area	AU\$9000/m ²
Sale price of existing units	Median cost to purchase existing strata properties (predominant typology)	AU\$785,000/unit
Cost of construction of new units	Cost to construct a new 2-bedroom unit (90 m ²) with medium quality	AU\$214,548/unit
Sale price of new units	Median sale price of a new 2-bedroom unit (90 m ²) with medium quality	AU\$799,000/unit
Urban shape		
Size of new units	Size of units with medium quality	90 m ² /unit
Site coverage	Proportion of the parcel occupied by the building footprint	0.60
Private area rate	Proportion of the total built up area for private use, excluding common areas (stairs, lifts, corridors, etc.)	0.8
Land use		
Number of commercial floors	Number of commercial floors for new building with 5 or more floors	1 floor

substantial uplift in values between old and new apartments in these locations, the model will likely underestimate the feasibility of redevelopment.

The URFF PSS tool is underpinned by modelling which is necessarily retrospective. All model assumptions are based on previous market conditions and as recent experience tells us, these can change quickly and dramatically. The analysis was based on the calendar year 2015, which was the last full year of data available at the time of this work. The dynamics of the local market would have likely changed since then. However, a strength of the tool is that new data can be easily entered, allowing planners to quickly rerun redevelopment scenarios and consider any changes in likely feasibility given changed market conditions.

Finally, the model makes no assessment of the likelihood of being able to sell the new dwellings should they be built. Using current sale values does imply that similar dwellings have been sold in a given area at that price point and one could assume that others would also sell if available. If dwellings were constructed at any scale, this may have implications for price and sale potential, and is not considered in this analysis.

Analysis and results

In order to test the performance and usability of the URFF PSS tool in a real-world context, a workshop

was run in May 2016 with five urban planners responsible for strategic planning in the study area. The tool was installed on a MapTable, which provided a large screen for visualisation, and also touch screen interactivity (Fig. 4). MapTables have been founded to be an effective platform for enabling planners and experts to collaboratively explore decision spaces (Arciniegas and Janssen 2012; Boulange et al. 2017). The workshop had the following sequence of activities:

- Participants filled in a pre-workshop questionnaire characterising their skills in GIS, duration of their career in urban planning, and previous experience with planning support systems
- Participants were introduced to the URFF PSS tool rationale, goals, parameters, interface and forms of interactivity. This step was also used to check the validity of the calculations, rationale and values estimated for the model parameters against the knowledge and experience of local planners
- Participants were then asked to answer some questions using the URFF PSS tool: Is urban redevelopment in the study area financially feasible under current planning and property market conditions? Can financially feasible urban redevelopment under the current planning context provide enough supply to attend future housing



Fig. 4 Participatory and interactive workshop with urban planners using the URFF PSS tool

demand projections? To what extent would changing planning controls affect financial feasibility and housing supply? How resilient is the study area given the context of urban redevelopment with increasing development costs and fixed revenue potential? The participants manipulated the tool themselves, selecting and changing parameters, running the models, analysing results, and comparing scenarios. When necessary, a technical expert provided support. The analysis developed by the participants is described in “[Is urban redevelopment in the study area financially feasible under current planning and property market conditions?](#)” to “[How resilient is the study area in a context of urban redevelopment with increasing development costs and fixed revenue potential?](#)” sections.

- d. Finally, participants filled in a post-workshop questionnaire describing their assessment of the tool’s performance and usability for the tasks proposed, and suggesting recommendations for its improvement. This is described in “[How useful is the tool for planning purposes?](#)” section.

The responses of the pre-workshop questionnaires indicated that: (a) All participants were well experienced in strategic planning (varying from 6 to 30 years

of professional experience); (b) participants’ understanding of how GIS can be used for strategic planning was rated as 4 (moderate, on a scale between 1/no understanding to 5/advanced); (c) their practical skills using GIS for strategic planning were rated as 3.75 (slightly below moderate, again on a scale between 1/no understanding to 5/advanced); (d) young planners had more practical skills than senior planners, although all shared the same level of understanding of the benefits of technology; (e) none of the participants had used a MapTable before; and (f) most of the young planners had some previous experience with one or more computer supported planning systems (E-view econometric/statistic package, sketch-up, and EarthMine viewer were mentioned).

This section presents the analysis and results obtained in the workshop by the urban planners. Each subsection addresses one of the four questions posed to the workshop participants (“[Is urban redevelopment in the study area financially feasible under current planning and property market conditions?](#)” to “[How resilient is the study area in a context of urban redevelopment with increasing development costs and fixed revenue potential?](#)”). The final sub-section describes their assessment of the experience based on the post-workshop questionnaire (“[How useful is the tool for planning purposes?](#)”).

Is urban redevelopment in the study area financially feasible under current planning and property market conditions?

Models 1, 2 and 3 of the URFF PSS Tool were used to answer this question. Model 1 calculated the number of new units required to achieve minimum profitability, Model 2 estimated the building form required to accommodate these new units, and Model 3 checked which new buildings complied with current planning controls. The input data included the parameters described in Table 2, and a parcel layer with current attributes of existing built units, land area, and planning controls (maximum height only, since this area had no set limit for FSR).

The models indicated that 44% of the parcels in the study area (102 out of 234 parcels) can potentially be redeveloped at current planning and market conditions. Although this represents less than half of the parcels in the area, redevelopment identified as feasible could replace 161 existing units with 1374 new residential units (not considering any commercial use). The majority of the parcels which are financially feasible to redevelop would lead to significant building height rise: up to 6 floors for 75% of the new buildings, and 5 floors for 21% of the new buildings. This implies significant potential densification in the study area.

Figure 5 illustrates the current heights in the study area (Fig. 5a) and the maximum heights permitted by the current planning framework (Fig. 5b). Figure 5c presents the result of Models 1, 2 and 3: the building heights required to turn urban redevelopment profitable at a margin of at least 20%, and an indication of which buildings comply with the current maximum threshold (dark grey parcels are compliant; while light grey parcels would need to exceed current height limits to be feasible).

Can urban redevelopment which is financially feasible under the current planning context provide enough supply to attend future housing demand projections?

Models 4, 5 and 6 of the URFF PSS tool were used to answer this question. Model 4 calculates the supply of new residential units in buildings that reach minimum financial feasibility and are compliant with current planning controls. This is called ‘minimum supply’.

Since some buildings are financially feasible below the maximum height permitted, the actual potential supply for urban redevelopment can be further extended. In this situation, Model 5 calculates the supply of new residential units to the maximum height permitted by current planning controls, called the ‘maximum supply’, and the increased profitability achieved. Model 4 and 6 also allow the user to include commercial floor space in new buildings which have 5 or more floors. In this case, the number of residential units is reduced in order to provide space for commercial use. The input data used in these models consists of parameters described in Table 2, and the map of parcels with original attributes, and new attributes produced by models 1, 2 and 3.

Future demand for residential units used in this study is based on projections of population and dwellings growth in the South–East Sydney Region by the NSW Department of Planning and Environment (DPE 2015, 2016), disaggregated to the Kensington Town Centre area through a synthetic population database developed by Leao et al. (2017). According to these projections, the demand for new dwellings in the study area by 2031 will be just over 2000 units for the low growth scenario, 3000 units for the medium growth scenario, and almost 5000 units for the high growth scenario (Fig. 6a). The URFF PSS tool indicated that the supply of housing under current land market and planning conditions varies from 2500 to 3000 units for the minimum and maximum supply, respectively (Fig. 6b). These totals include the new units from urban redevelopment minus the number of units that have been replaced, plus the number of existing units in the other parcels not renewed. These results indicate that the maximum supply at current planning and land market conditions would be able to satisfy the demand projected to 2031 in the region for the low and medium population growth scenarios; but only 60% of the demand for the high growth scenario. The minimum supply meets only the demand of the low growth scenario. These comparisons potentially overestimate supply, since in practice not all financially feasible parcels may be renewed. It is likely that planning controls in the study area will need to be revised in order to accommodate an increasing population.

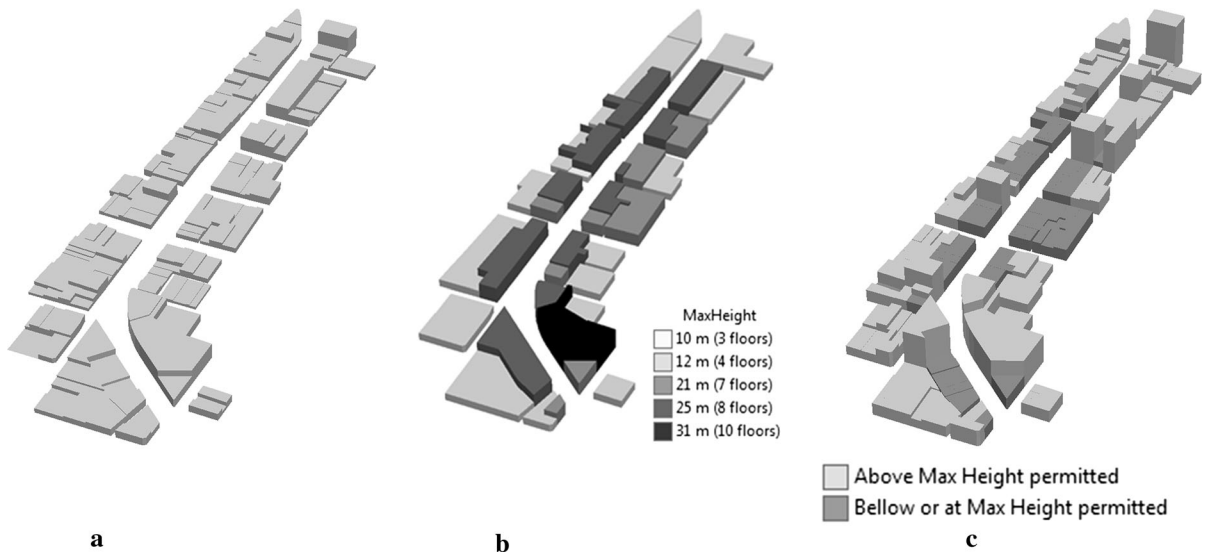


Fig. 5 Financial feasibility under current planning and property market conditions. **a** Current heights. **b** Current maximum heights (planning control). **c** Heights required for financial feasibility and compliance with planning control

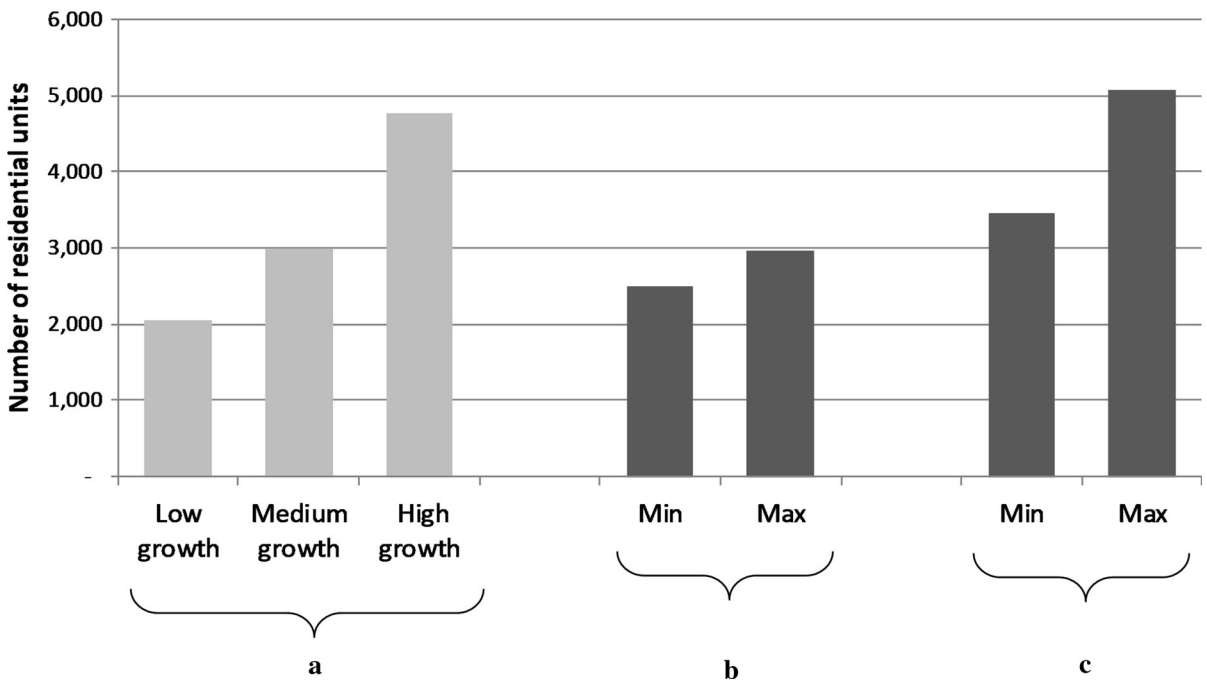


Fig. 6 Comparison between 2031 housing demand and housing supply under current and increased planning controls. **a** Demand in 2031. **b** Supply at current context. **c** Supply with increased max height (+ 3 floors)

To what extent changing planning controls would affect the financial feasibility of redevelopment and housing supply?

To answer the posed question, this section tested the effect that increased maximum heights would have on the number of parcels and new residential units that would become financially feasible to be developed, compared with current conditions. Figure 5b showed the current planning regulations in the study area, in which the maximum heights vary from 10 m (3 floors) to 31 m (10 floors). This information is available as an attribute of each parcel in the input layer. Therefore, in order to test different maximum heights, the input map needs to be edited. In this analysis, the maximum height has been increased, adding one extra floor to each parcel at a time, from 1 to 5 floors on top of the existing regulation (considering 3 m per floor). Then Models 1–6 were run for each scenario in order to obtain the full assessment of financial feasibility or redevelopment for these new conditions.

This flexibility in the planning controls would certainly increase housing supply in the area, but before running the models, the extent of the impact of such change is unknown. The number of floors required for a redevelopment to be financially feasible is the same for all scenarios, since costs, revenues and building form parameters have not been changed. The difference in each scenario is the number of parcels that can accommodate new buildings which now comply with the new and higher maximum height. Figure 7 shows the growth of the number of residential units (Fig. 7a) and commercial floor space (Fig. 7b) in the study area as more land parcels become financially feasible for redevelopment from increasing the maximum building height allowance. The addition of 3 floors to current maximum height at each parcel had the largest impact. A new maximum height 3 floors higher than the current threshold increased the supply of residential units by 120–160% and the supply of commercial floorspace by 115%, when compared to current conditions. This was due to the larger number of feasible parcels, and also the higher density allowed by the new height, particularly where the full extent of permitted development, up to max height, is used. Increasing the maximum height by 1 or 2 floors, however, had a very modest impact, due to both dwindling number of additional feasible parcels and lower levels of density achievable. Figure 7c identifies

in dark grey the parcels in the study area which were already financially feasible for redevelopment at current planning controls; it identifies in black the additional parcels that become compliant with the new planning control of increased maximum height of + 3 floors; and in light grey it indicates the parcels which are not financially feasible to redevelop, even under the more flexible planning regulation (current heights remain unchanged for the parcels which are not renewed).

These results demonstrate that changing planning controls do not have a linear impact on increasing the potential for redevelopment, residential unit and commercial floor space growth. Indeed, local conditions in terms of the type and size of existing development and property market conditions play an important role. The new PSS tool can therefore enable planners to better understand how a given precinct will likely respond to changing planning controls, and based on that, make decisions on the most appropriate new standards according to desired outcomes.

How resilient is the study area in a context of urban redevelopment with increasing development costs and fixed revenue potential?

This section assesses the effect of hypothetical land and property market variations on the redevelopment process in the study area. Scenarios were built considering a context in which existing stock which is suitable for redevelopment is increasing in value, as a result of transport improvements. The construction cost and sale price of new units are considered unchanged, due to stable financial and labour conditions.

The scenarios reflect different buyout values for land and property, starting from the current default value, and then increasing it from 1 to 20%. For each scenario, the model indicates the number of parcels which are financially feasible and compliant with planning controls, and the total number of new residential units that can be built considering the minimum required profit.

The results of this analysis, presented in Fig. 8, indicate the likely outputs in terms of new units that could be expected to be redeveloped under land market variations. Increasing number of residential units could be produced through redevelopment within the prevailing planning context with up to 5%

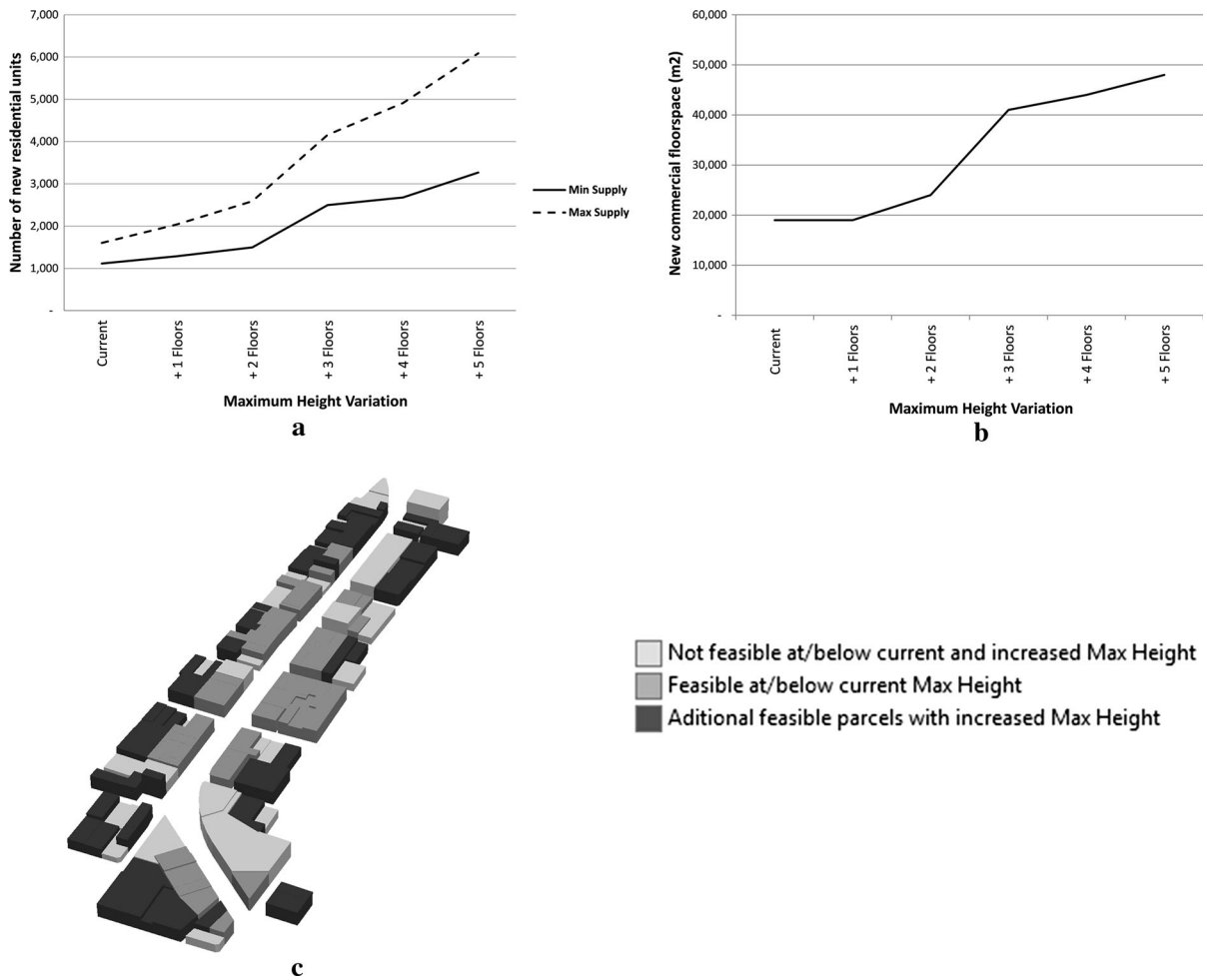


Fig. 7 Effect of increasing maximum height on the supply or residential units and commercial floorspace. **a** Number of new residential units by increased Max Height. **b** Commercial floor

space by increased Max Height. **c** Financial feasibility of parcels with Max Height increased by 3 floors

additional buyout cost (from 1.400 to 1500—see Fig. 8a), assuming all other financial parameters remain unchanged. This is due to the fact that some land parcels are financially feasible to be redeveloped below the maximum height permitted, and therefore, the increased buyout cost can be compensated by building more floors and selling additional residential units. However, when the buyout cost increases by 6%, some parcels are not financially feasible for redevelopment at or under the maximum height threshold, and potential housing supply drops significantly. The modelling shows that across the case study area around 100 parcels could be redeveloped within current planning controls and land market conditions. These 100 parcels are still feasible up to a 5% increase in buyout costs (Fig. 8b, c). The number

of feasible parcels declines rapidly as buyout costs escalate to 8% when only an additional 60 parcels (yielding around 1100 units) might be feasible for redevelopment and down to around 50 feasible parcels (less than 1000 units) with a 20% increase in buyout costs (Fig. 8b, d). This result demonstrates firstly, the relation between land costs and site yields and secondly, that land and property marked variations have a non-linear response on the potential for redevelopment and housing supply growth.

How useful is the tool for planning purposes?

“Is urban redevelopment in the study area financially feasible under current planning and property market conditions?” to “How resilient is the study area in a

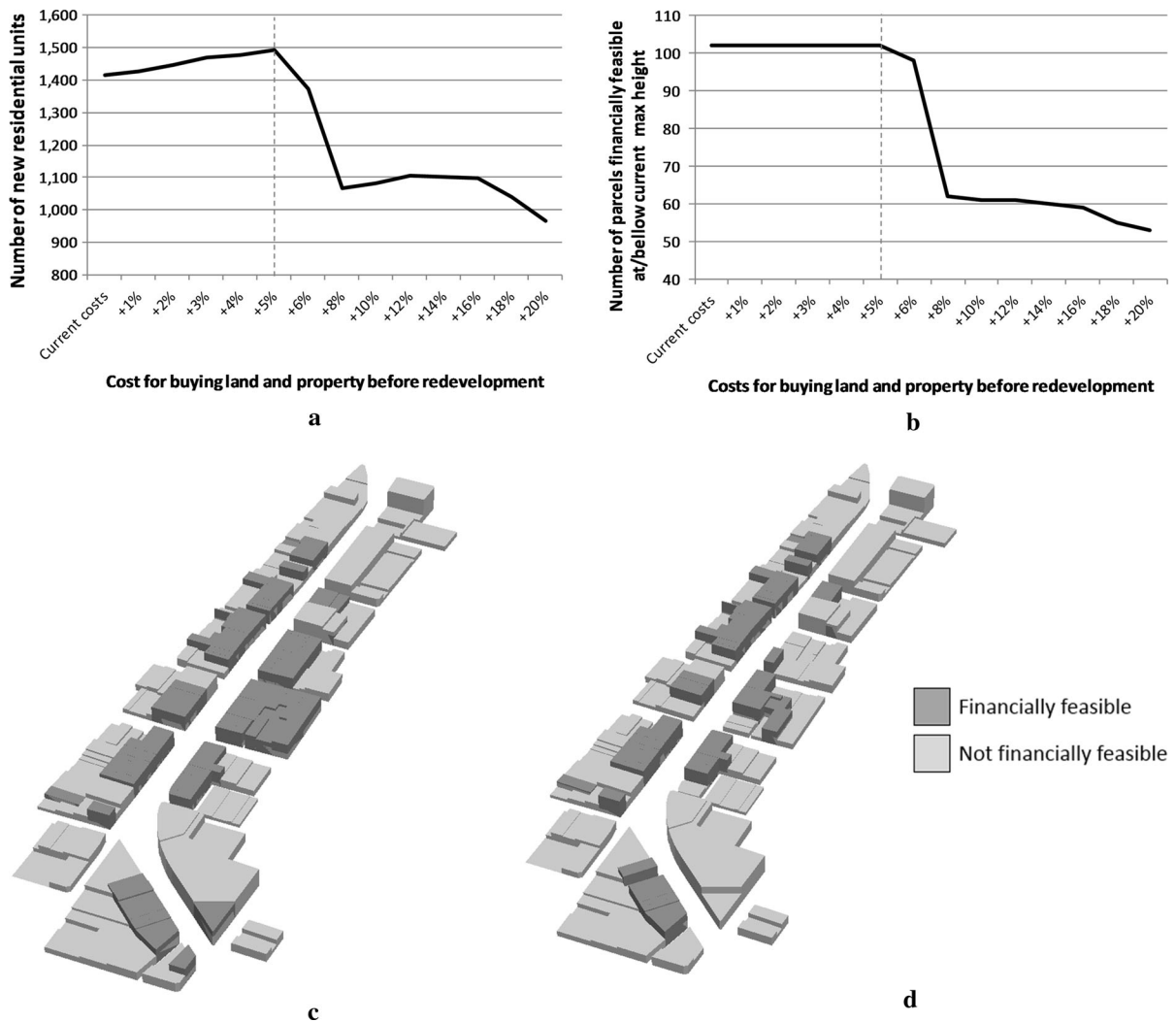


Fig. 8 Effect of increasing buyout cost from current default value to 20% on redevelopment capacity. **a** Number of new residential units from redevelopment under increasing buyout

context of urban redevelopment with increasing development costs and fixed revenue potential?” sections reported the results of the use of the URFF PSS tool in a workshop of professional urban planners who work for the local government where the study area is located. “How useful is the tool for planning purposes?” section describes the urban planners’ assessment of the performance and usability of the tool for planning purposes, based on their responses to the post-workshop questionnaire.

Given a 5-point scale (from 1/no use, to 5/very useful), the participants rated the usefulness of the tool to assist in better understanding the current context as

cost. **b** Number of parcels from redevelopment under increasing buyout cost. **c** Parcels financially feasible with + 5% buyout cost. **d** Parcels financially feasible with + 20% buyout cost

4.5, in which the youngest planners tended to 5 (very useful), and the most senior planners tended to 4 (moderate useful). All participants rated the tool as 5 (very useful) for exploring new scenarios.

Table 3 summarises the main strengths and weaknesses of the tool as identified by the urban planners based on their experience in the workshop, as documented in their evaluation responses in the post-workshop questionnaire.

When asked if they would consider using the URFF PSS tool for strategic planning, all participants responded in the positive. They indicated the following planning applications as suitable tasks to be

Table 3 Strengths and weaknesses of the URFF PSS tool for urban planning purposes

	Strengths	Weaknesses
Model concept	<p>The tool is based on a comprehensive model with relevant variables</p> <p>The tool assists in understanding the interactions between variables</p> <p>The tool assists in estimating redevelopment capacity</p> <p>The tool assists in assessing planning control's revision</p>	<p>The inclusion of additional variables, such as more diverse housing typologies, could improve model estimations</p>
Modelling structure	<p>The tool interface facilitates the entry of data to the models</p> <p>The combination of models in the tool facilitates the understanding of the role of different variables on the financial feasibility or urban redevelopment</p>	
Visualisation capability	<p>The mapping environment is useful for visualisation of results</p> <p>3D visualisation facilitates understanding of building volumes</p>	
Ease of use	<p>The tool is easy to use, even for professionals with limited GIS skills</p> <p>Data required by the tool to run is reasonably easy to obtain</p> <p>It is easy to change parameters, build different scenarios and compare them</p>	<p>Changing parameters should be more flexible, coping with range of values, and not only median parameters</p> <p>Some issues were found with the sensitivity of the MapTable touch screen</p>

assisted by the tool: assessment of planning proposals; Local Environmental Plan (LEP) reviews; assessing rezoning applications; revising/preparing controls for sites/precincts; understanding changes in feasibility as parameters are modified; exploring scenarios; testing options; and briefing management and officials. They indicated that the simplified suit of models in the URFF PSS tool, with one major typology and median values for land market parameters, is appropriate for analysis of small and reasonably homogeneous precincts, such as the study area used in the workshop, but maybe not suitable for larger areas with significant internal variations. They also suggested the extension of the tool to incorporate additional variables, for example relating construction costs to building sustainability levels, or housing supply to demographics.

Conclusions

Higher density development in the form of apartment markets evolved gradually in Australia following the introduction of strata title legislation in the early 1960s (Randolph 2006) and more recently with the

incorporation of explicit policies to encourage urban consolidation and redevelopment within urban areas as a main driver of strategic metropolitan planning (Forster 2006). While these planning policies are now in place, the implementation of urban redevelopment in built-up areas has proved challenging (Troy et al. 2015b).

As urban development moves increasingly away from redundant industrial and transport sites and into existing town centres and development corridors, the renewal process is getting more complex, difficult to plan for and undertake. Fragmented land ownership patterns, multiple land parcel sizes and a wide range of existing uses, both commercial and residential, present a complex renewal problem. For example, earlier rounds of redevelopment have created areas in Sydney where walk-up flats pose problems for amalgamation and buy out, despite legislation to ease this. At the same time, some low density commercial developments, still common in many town centres and transport corridors, are increasingly subject to high land value and speculation due to their advantageous location and potential for densification. Increasingly, planners are looking to better understand the likely

potential for such areas as they bring forward plans for redevelopment that are both economically viable as well as socially and economically appropriate.

In this paper, we have presented a GIS-based PSS which provides a platform for data integration, modelling and visualisation to assist urban planners in assessing the feasibility of likely urban redevelopment scenarios. The URFF PSS tool is based on the model developed by Troy et al. (2015b). The PSS tool has been developed and tested in the context of Sydney, which is experiencing rapid urbanization and densification. With a focus on town centres and transport corridors, and encompassing strata and non-strata properties, this PSS tool aimed at providing a platform to support the testing of current conditions and selected scenarios on the financial feasibility of redevelopment and housing supply. This tool fills an important gap in the application and development of PSS for specifically emulating land market conditions and the likely urban growth scenarios determined by land redevelopment. It is important to note that the financial feasibility tool proposed here does not attempt to replace detailed financial development appraisal methods as adopted by the property industry. The URFF PSS tool focuses on a data-driven modelling approach to support strategic land-use planning in urban areas expected to experience land redevelopment.

Previous work reported in the literature provides some insights about the impact of building height restrictions on urban form (reduction of sprawl when higher heights are permitted; Geshkov and DeSalvo 2012; Brueckner and Sridhar 2012; Cheshire and Sheppard 2002), on property sizes (larger site coverage when building heights are more restricted; Ihlanfeldt 2007), on property and land values (greater regulation restrictiveness increases building/dwelling prices and decreases land prices; Ihlanfeldt 2007), and also on commuting costs (savings from a more compact city when building heights are increased; Brueckner and Sridhar 2012). The URFF PSS tool adds a contribution to the body of work on building height restrictions. The results of scenarios of increasing land costs (from 1 to 20%) and maintaining current building height restrictions have demonstrated that land and property market variations have a non-linear impact on the potential for redevelopment and housing supply growth. Moreover, scenarios with building height restriction variations (from 1 to 5 additional

floors at each parcel) and the maintenance of land market conditions have also indicated non-linear behaviour in the number of parcels which are economically feasible for redevelopment and derived housing yield. These non-linear responses are caused by the heterogeneity of the built environment including varied housing typologies with different ages, sizes, standard of construction/maintenance, and uses, and also varied land subdivision types in terms of parcel size, location and whether they are a strata title. Therefore, the results are highly dependent on contextual factors. For the Kensington Town Centre, for example, a land cost increase of up to 5% could be compensated by the number of units built up to the maximum height permitted, but a quick decline in the number of parcels where development is feasible occurred when the land cost increased from 6 to 8%, as many parcels became economically unfeasible for redevelopment within the existing planning controls. Also, in this specific case study, it was only when three additional floors were added to each parcel as the new maximum height restriction, that the number of parcels economically feasible to be redeveloped had a significant increase, along with a commensurate increase in the number of residential units. The proposed tool has the flexibility to adapt to contextual factors of different case studies, if data is available; and it is through its modelling capacity and visual outputs that behaviour can be assessed and outcomes of land market and planning controls variations be quantified.

The testing of the URFF PSS tool by professional urban planners with a real case study resulted in the following conclusions. Firstly, the tool can assist urban planning professionals to better understand the relationships between land markets and planning controls, particularly by allowing users to manipulate parameters and instantly visualise the consequences (e.g. increasing maximum height in “[To what extent changing planning controls would affect the financial feasibility of redevelopment and housing supply?](#)” section, and increasing buyout cost in “[How resilient is the study area in a context of urban redevelopment with increasing development costs and fixed revenue potential?](#)” section). Secondly, it can be used to identify potential opportunities and barriers for urban redevelopment in areas of interest, and provide a priori testing of potential revisions of planning guidelines. Thirdly, it can estimate potential residential and

commercial supply in selected areas under different scenarios, and these can be then compared to projections of housing demand. These findings are a significant contribution achieved by this research.

It is recommended that future research should extend the functionalities of the URFF PSS tool including additional combinations of dwelling typologies (different unit sizes in terms of number of bedrooms and bathrooms). This would enable the tool to better represent housing supply diversity, as well as varied standards of construction quality (from basic to high-end standard, and considerations of sustainable building construction). Together, diverse typologies and quality standards can better portray the built form created by urban redevelopment. An important consequence is that a demographic sub-model could then be developed to estimate the characteristics of new households that would potentially be attracted to the supplied housing. Planning density without understanding what is being produced and for whom risks embedding potentially inappropriate forms of development in urban areas, and this could have significant ramifications on future urban processes and structure. In conclusion, it is important the data-driven modelling tools such as the URFF PSS developed and tested in this research be further adopted in practice to enable urban planners to better plan for more sustainable and liveable communities.

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