Integrating GIS-based Land-use Suitability Analysis in the Teaching of Planning Studios

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Abstract: GIS-based land-use suitability analyses are significantly useful in urban growth planning and management. Becoming a responsible and capable urban and regional planner involves learning to reflect on the rationale of decision-making in planning, particularly in the physical planning field. For any planning programme, therefore, integrating landscape-use suitability analysis into planning education is both an essential aspect of the curriculum and central to learning in terms of developing professional skills. Unfortunately, GIS-based land-use suitability analysis and evidence-based decision making in planning remains a challenging in both education and practice. Using the urban growth management in Bendigo as an example, this paper presents a case of teaching GIS and planning studios to masters of urban planning and landscape architecture students in the University of Melbourne. The paper presents two student projects as examples and points out students' common learning experiences that repeat despite very similar planning objectives. Other observed recurring issues from these examples include difficulties in addressing system thinking across scales, and challenges to deal with complexity by synthesis and simplification of large volumes of data and information available. Reflecting these challenges, the strengths and weaknesses of the traditional spatial overlay for land-use suitability analysis, and the recent advancement in spatial information technology, the paper then discusses the emergence of geodesign as a new method for urban growth management. The paper concludes by outlining changes need to be undertaken in our educational processes aiming at mentoring a generation of urban and regional planners who are better equipped to think scientifically while shaping our built and natural environment responsibly and creatively.

Keywords: Land-use suitability analysis, Spatial overlay, Geographic Information Systems (GIS), Geodesign

1. Introduction

The GIS-based approaches to land-use suitability analysis have their roots in the applications of hand-drawn overlay techniques used by a few pioneer landscape architects in the late nineteenth and early twentieth century (Steinitz et al, 1976). McHarg (1969) advanced the overlay techniques by proposing a manual overlay cartographic procedure. The method is widely recognized as a precursor to the classical overlay procedures in GIS (Malczewski, 2004). Land-use suitability mapping and analysis since then has been perceived as the most useful applications for planning and management (Hopkins, 1977; Collins et al., 2001; (Malczewski, 2004). As a significantly useful tool for urban and regional planning, land-use suitability analysis aims at identifying the most appropriate spatial pattern for future land uses according to specify requirements, preferences, or predictors of some activity (Hopkins, 1977; Collins et al., 2001). Since the invention of the modern geographic information systems (GIS) technology, the spatial overlay procedures play a central role in many GIS applications (O'Sullivan and Unwin, 2003) including techniques that are in the forefront of the advances in the land-use suitability analysis such as multivariate approach (Taillefumier and Piégay, 2003), multi criteria assessment (MCA) (Strager and Rosenberger, 2006; Chen *et al.*, 2011; Zerger *et al.*, 2011), and multi-criteria decision analysis (MCDA) (Graymore *et al.*, 2009; Bottero *et al.*, 2013). Over the last forty years or so GIS-based spatial suitability modeling has been increasingly used as a technique for landscape evaluation and planning (Girvetz et al., 2008) , regional planning and environmental impact assessment (Marull et al., 2007; Rojas et al., 2013) and identification of potential locations for renewable energy generation (Angelis-Dimakis et al., 2011; Ramachandra and Shruthi, 2007). Of all spatial explicit spatial modeling approaches, overlay mapping is easy to undertake and has been applied in land-use suitability analysis for urban development from before the GIS technology was invented (McHarg, 1969) to today highly complicated GIS applications across time and space are proposed to inform urban and regional planning strategies (Miller et al., 1998; Steinitz, 2012; Chen, 2014; Chen and Lee, 2015).

Australia has been experiencing a severe shortage of GIS specialists who possess appropriate tertiary education qualifications and this shortage of personnel is causing difficulties not only for agencies trying to establish GIS but also for the private and academic sectors of the industry (Williamson and Hunter, 1990). While GIS has evolved from a close-expert-oriented to an open-user-oriented technology in parallel with changing perspectives of planning which has been associated with increased involvement of non-experts (public, communities, stakeholders, etc.) into planning and decision making processes (Malczewski, 2004), there has been increasing demand for GIS training in Australia's tertiary education sector associated with the planning and design professions (Garner and Zhou, 1993). This paper aims to promote GIS training in Australian design and planning schools through the discussion of the challenges in teaching of GIS-based land-use suitability in a planning studio aimed at systematically and objectively fulfilling the goals of strategic plans for future development. The paper reflects the strengths and weaknesses of the traditional spatial overlay for land-use suitability analysis and the emerging geodesign discourse and outlines the changes need to be undertaken in our educational processes aiming at mentoring a generation of planners and designers who are better equipped to think scientifically and acting responsibly and creatively when intervening with our towns, cities, and landscapes.

2. The planning studio

The most common spatial models used in GIS-based suitability studies fall into two fundamental classes of multi-criteria evaluation (MCE): Boolean overlay or weighted overlay (Malczewski, 2004). In Boolean overlay models, each criterion is classified into two subsets delineating whether or not a particular area is suitable. Criterion maps are then layered using logical connectives (i.e. AND, OR). One primary shortcoming of Boolean analysis is that criteria can only be TRUE or FALSE, which creates discrete boundaries between variables. This imposes artificial precision on mapped results and fails to model more nuanced degrees of suitability. In contrast, models that use weighted overlay bin each criterion into categories; these categories are then weighted based on their importance as decided by professionals in the field, so when combined, one criterion with relative low suitability can be recompensed by the high score of another (Lewis et al., 2014).

The planning studio requires students to use the weighted overlay approach to assess the land-use suitability for urban growth in Bendigo considering key planning goals such as *Connected and Compact City* (transport and connectivity), *City of Equality* (education, health services), *Ecological City* (environmental conservation), *Safe City* (risk of natural disasters such as flood and bushfire) which are detrimental to urban sustainability and liveability. A suitability map is then generated by overlaying all the key factors. Reflecting the current urban development in Bendigo, students are required to conclude with several recommendations aimed at improving the long-term urban development plans for the Greater Bendigo area. The studio is divided into 3 phases (Table 1). Only the second phase involves land-use suitability analysis so only this phase is discussed in this paper.

Table 1. The three phases of the planning studio

Phase 1: Weeks 1-6 *Development of GIS Skills*	– Introduction to Landscape Planning and planning process; – Introduction to GIS; GIS-based landscape suitability analysis; – Data collection (map/digital map collection, including natural, cultural, economic, and political factors); – Overlay analysis.
Phase 2 Weeks 6-8: *Where to grow in Bendigo [Regional Scale]*	– Identification of suburban/periphery issues related to urban planning at the regional level; regional landscape analysis; – GIS-based spatial analysis as applied to the Greater Bendigo region to integrate environmental, socio-economic, cultural issues to identify suitable area for future urban growth; – scale thinking in planning; – Production of an urban growth plan
Phase 3 (Weeks 8-14) *How to grow Bendigo [Local Scale]*	– Identification processes/problems related to community planning at the local level – Conceptual and detailed plan for new communities at the local scale – Development and refinement of planning strategies through mapping, drawing, diagram, modelling, narratives, etc. – Finalising design, selection and development of communication package including diagrams, maps, drawings and narratives for final presentation

3. The studio project

3.1 The project site: City of Greater Bendigo

Located 150km northwest of Melbourne (Figure 1), Bendigo's initial rapid expansion, both economically and socially, was fuelled by the discovery of gold deposits in the 1850s. The wealth generated from the mining of gold was considerable, resulting in an architectural legacy that is reflected in the number of historic buildings that characterise the inner area. With an existing population of 110,579 and an expected growth of 41.21% between 2015 and 2036 (Forecast.id 2015), Bendigo is considered one of the key regional centres to accommodate future population growth and progress within the state of Victoria (DPCD, 2010b). However, history reveals that growth in Bendigo has not been constant. The first European settlements in Bendigo were mainly induced by the Gold Rush era in the 1850s which contributed to the country´s development and influenced migration from countries such as China and Germany (Carthew and Allan 2005). This fact also stimulated the emergence of industries and alternative economic activities (City of Greater Bendigo, 2005). On the other hand, from the 1960s to 1980s Bendigo experienced a slow growth satisfying the requirements of a rural area (Carthew and Allan 2005). In the twentieth century the manufacturing sector developed as the gold deposits were depleted, but in more recent years the service sector, particularly retail, health, education and tourism, has become more prominent (DPCD, 2010b).

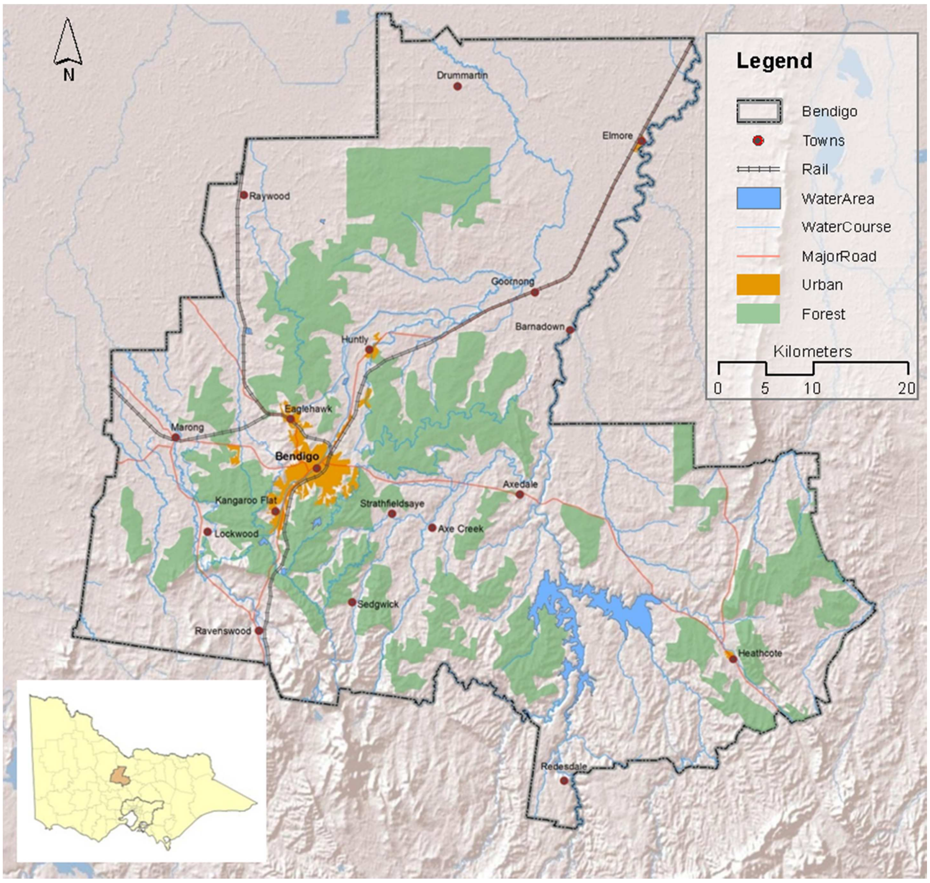

Figure 1. Location, context, and geophysical condition of City of Greater Bendigo

The city of Greater Bendigo is a major regional municipality of Victoria, including Bendigo city and surrounding rural hinterland, with six smaller townships scattered across the region. Greater Bendigo boasts large areas of national parks, reserves and bushland, as well as agriculture land, which is the major land use of the area. This region has been earmarked by the Victorian Government's Initiative Urban Development Plan for future development as one of Victoria's regional centres for increased development and new homes. Increased demand for housing, infrastructure, services driven by population growth is a crucial part of the plan for this region. From 2011 to 2016, Victoria in Future 2008 projections indicate that the average annual dwelling demand across the municipal area of Greater Bendigo will be 999; from 2016 to 2021, increasing to 1,009 per annum. Victoria in Future 2008 based demand projections over the next 5 years for Greater Bendigo indicate that the current levels of dwelling construction activity are insufficient to meet potential demand. These demand projections are 29% greater than recent building approval activity (average 775 dwellings per annum between 2005/06 to 2008/09) and 92% greater than recent residential lot construction (average 518 lots constructed per annum between 2005/06 to 2008/09). In total (excluding existing vacant residential lots) there is a residential lot supply of approximately 18,500 (Department of Planning and Community Development (DPCD), 2010a).

The City of Greater Bendigo has recently adopted the Greater Bendigo Residential Strategy as a key strategy for managing urban growth from 2014 to 2034. This strategy has been drafted in response to projected urban growth and on-going diversification of Bendigo's economy (City of Greater Bendigo, 2015). Importantly, there is increasing community support and desire for planning goals and strategies towards diverse healthy communities and transit-oriented development alongside increased demand for smaller lots and infill development in established areas (DPCD, 2010b; City of Greater Bendigo, 2015). The GBRS contains a number of key policy directions mirroring these goals, of several which are significant, such as the strengthening of the Bendigo Urban Growth Boundary (UGB) - underlining its mandate within the community of Greater Bendigo. On a practical statutory level, the Greater Bendigo Residential Strategy will be implemented through the Greater Bendigo Planning Scheme Amendment C215 (City of Greater Bendigo, 2015). Importantly, no comprehensive urban development land suitability analysis has previously been undertaken for the whole of Greater Bendigo area other than some brief restrictive zone analyses presented in the literature (DPCD, 2010a; DPCD; 2010b; City of Greater Bendigo, 2015). Using a weighted overlay analysis, this study generates a complete land-use plan for urban growth covering the whole of Greater Bendigo area. Recommendation and guidance are then offered to inform long-term urban development planning in Bendigo.

3.2 The project involving land-use suitability analysis project

The estimated increment of 45,572 persons by 2030 in Greater Bendigo (Forecast.id, 2015) has encouraged Planning Authorities to initiate a series of plans that help to determine an adequate provision of housing, services and infrastructure in the area. According to the Department of Transport, Planning, and Local Infrastructure 18,900 new dwellings are required in Bendigo to satisfy the upcoming population growth (Department of Transport, Planning and Local Infrastructure (DTPLI), 2015). In order to identify the most suitable areas to allocate this amount of dwellings social, economic and environmental factors should be considered. Bendigo has experienced a notable development during the past decades; education, health, commerce and professional services represent a significant contribution for the community as well as important sources of employment (City of Greater Bendigo, 2005). The presence of roads and rail facilities contributes to the connectivity between regional cities providing opportunities for growth in Victoria (DTPLI, 2014). Transport infrastructure, education and health, represent significant facilities and are used as anchors for growth. Through complementing and enhancing what has been already built, the benefits from the investment that has been made in the past will increase. Moreover, it will locate people in proximity to one another, and influence the generation of jobs. Additionally, natural resources and geographical characteristics provide the city an extra value.

Five objectives are established as priorities for the selection of suitable areas as follows.

1) *A connected city.* The first planning goal is to consider the benefits and opportunities that the existing infrastructure offers to the city and the community. The first objective is focused on sustainable transport and connectivity between Bendigo and the regional cities and activity centres, encouraging growth along transport corridors.
2) *A city of equality*. The second planning goal is to locate areas for future growth in proximity to education institutions and health services which are two basic requirements in every person´s life. This goal is of particular significance for a city like Bendigo which has been renowned for its health care facilities and services.
3) *An ecological city*. The third objective supports the protection of forest and natural areas acknowledging the importance for flora and fauna considering biodiversity is one of the most goals for sustainable development.
4) *A safe city*. The fourth objective recognises that the area can be affected by natural threats and disasters; therefore future developments should avoid being located in certain areas which are vulnerable to flood or bushfire risks or any other risks.
5) *A compact city*. The last goal emphasises the importance of proximity between urban developments in order to take advantage of existing resources, infrastructure, and facilities in the urbanised city core of the city.

Students are required to collect and compile GIS data corresponding to each of the five planning objectives and integrate all data in a GIS using the methodological framework as follows (Figure 2).

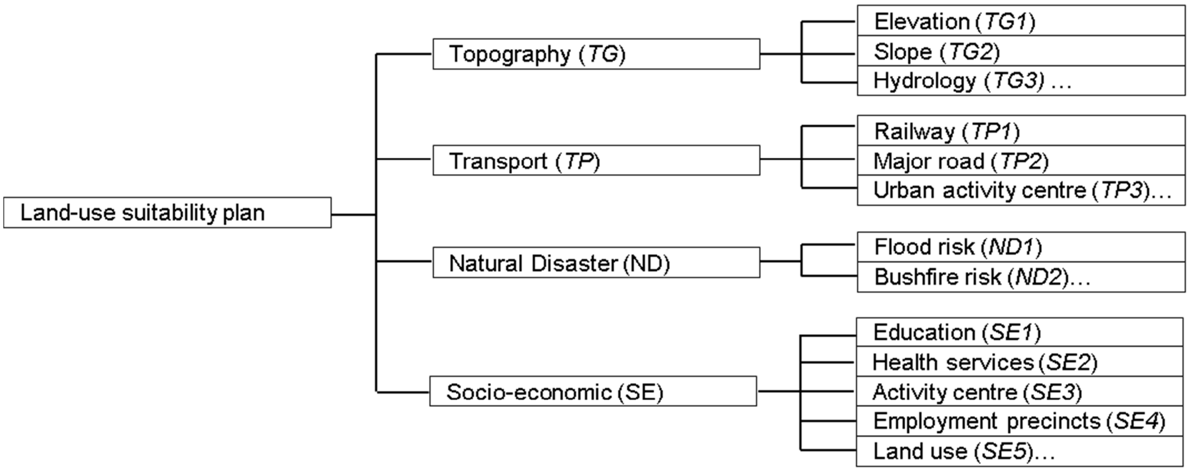

Figure 2. Geophysical and socio-economic factors considered in this study

4. The two comparative student projects

4.1 Summary of Students Project 1

The first student project (Andrea Sosa Castro, class of 2015) uses the following suitability criteria for the planning analysis.

- *Connected city - accessibility to existing infrastructure.* Bendigo is served by high capacity urban transport and roads and train facilities which represent an opportunity for growth and densification and act as attractors of investment; whereas the presences of roads increment the possibilities of public transport provision. The layer is then classified into 10 classes: class code 1 means highest development potential and 10 lowest development potential.
- *City of equality - accessibility to education and health services and jobs.* Future development is considered to be located in proximity to education and health precincts which additionally represent a significant source of employment within Bendigo. St. John of God, Bendigo Base Public Hospital, Regional Institute of Tafe, La Trobe University and Bendigo Senior Secondary College are part of the infrastructure that supports the presence of professional and skilled labour contributing to the enhancement of the area. This layer is then classified into 10 classes: class code 1 means highest development potential and 10 lowest development potential.
- *Ecological city - conservation of ecosystem and natural resources.* The uniqueness of Greater Bendigo can be its complex urban system integrating with 'green' ecosystems'. This requires more strategic, innovative, and forward-looking approaches to create a liveable, resilient, ecological and sustainable city with retaining its valuable ecology and unique culture. The surrounding linear and continuous natural systems (Environmental Significance Overlay: ESO) are key reasons that people choose to live in Bendigo and tourists choose to travel there. This layer is created and classified into 10 classes: class code 1 means lowest development potential and 10 highest development potential.
- *Safe city - natural disaster considerations.* The presence of forest, water areas and water courses enhance Bendigo's environment and biodiversity. However, possible inundations and bushfires represent a natural threat for the community. Future developments must avoid being located in areas that respond to the Land Subject to Inundation Overlay (LSIO) and the Bushfire Management Overlay (WMO). The combination of LSIO and the zones obtained from the buffer analysis represents flooding areas in Bendigo. Flood-prone layer is overlaid with the bushfire-prone layer to identify areas prone to natural disasters. This layer is created and classified into 10 classes: class code 1 means lowest development potential (highest natural disaster risks) and 10 highest development potential (lowest disaster risks).
- *Compact city – proximity to established neighbourhoods.* Due to abundant land available and a relatively small population in Australia, many Australian cities, especially regional cities, are suffered from the adverse effect from urban sprawl such as increased traffic and demand for mobility and increased investment on infrastructure, traffic congestion, landscape fragmentation and loss of biodiversity, reduced landscape attractivity and attachment to places, and

alterations of the hydrological cycle and flooding regimes. Bendigo's urban area offers a wide range of services and activities including retail, education health, and business. This layer is then classified into 10 classes: class code 1 means highest development potential and 10 lowest development potential.

The result of land-use suitability analysis for Student Project 1 is shown in Figure 3.

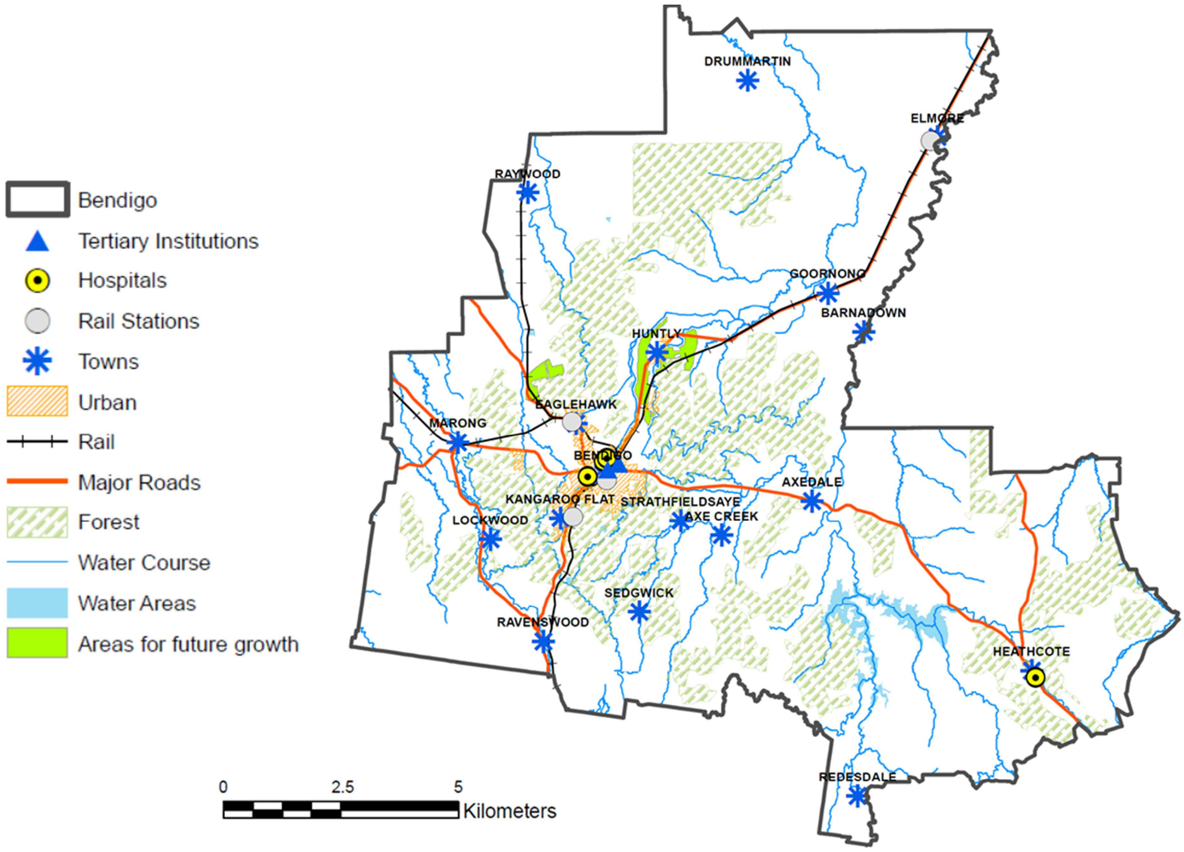

Figure 3. Three areas for urban development are identified in Student Project 1 using the land-use suitability analysis

4.2 Summary of Students Project 2

The second student project (by Nicky Megens, class of 2013) uses the following suitability criteria for the planning analysis.

- *Distance to establish neighbourhoods.* The distance to established neighbourhoods is determined by creating a Euclidean Distance layer based on the established neighbourhood data. The Euclidean distance layer is then classified into 10 classes: class code 1 means highest development potential and 10 lowest development potential (compact city).
- *Minimize risk of being affect by natural disasters.* This process uses the watercourse, water area and flood overlay as input layers. This criterion is aimed at minimising the risk of being effected by a natural disaster such as bushfire and flooding. An overlay of the three input layer is created and classified into 10 classes: class code 1 means lowest development potential (highest natural disaster risks) and 10 highest development potential (lowest disaster risks) (safe city).
- *Close to public transport*. Rail stations and rail lines are used to create a layer which is to determine land close to public transport. The layer is then classified into 10 classes: class code 1 means highest development potential and 10 lowest development potential (connected city).
- *Balance construction cost and view quality.* Mid elevations are preferred considering construction coast and housing affordability. Areas with mid-ranged elevations also have better view quality of the landscape. This layer is created by reclassifying the elevation raster into classes: class code 4-6 means mid elevation and refers to land with highest potential for development (city of equality)

- *Reduce disturbance to the natural environment.* The purpose of this criterion is to make sure the new development proposal was not on land which had forest or was within an Environmental Significance Overlay (ESO) or Vegetation Protection Overlay (VPO) are protected). This layer is classified into 10 classes: class code 1 means lowest development potential and 10 highest development potential (ecological city).

The Result of land-use suitability analysis for Project 1 is shown in Figure 4.

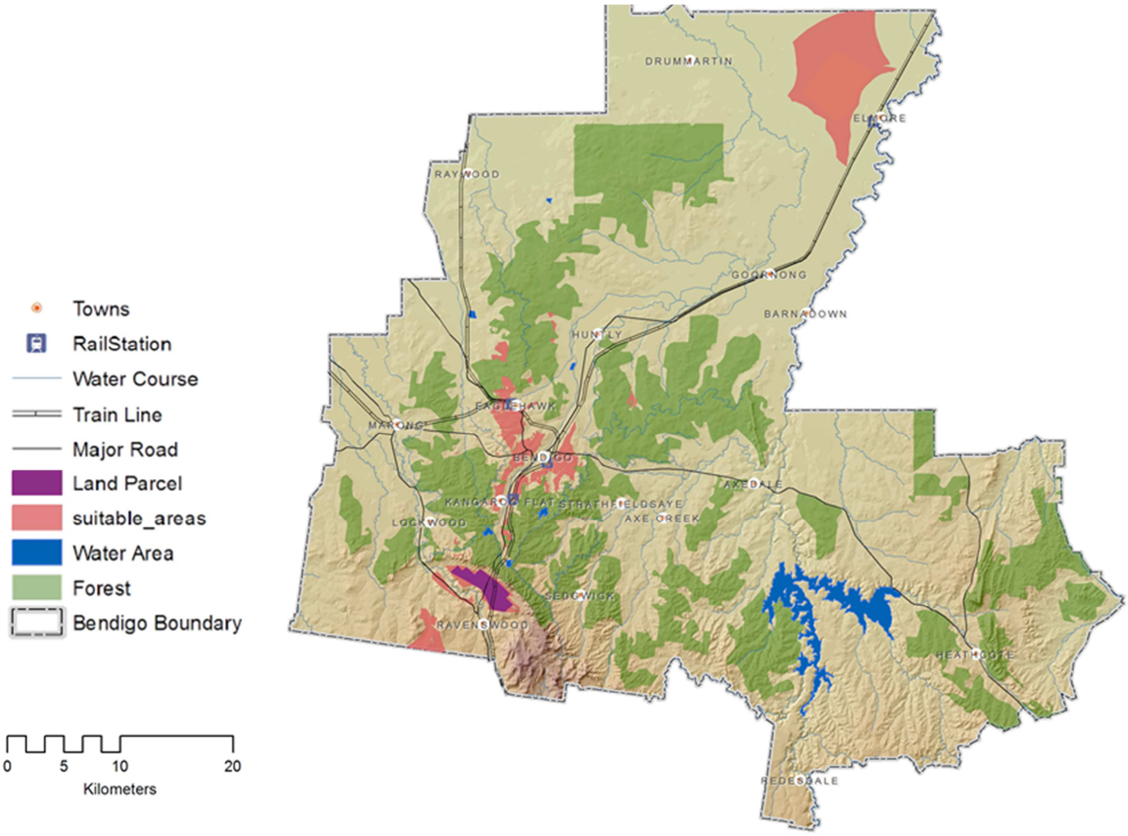

Figure 4. Areas for urban development are identified in Student Project 2 using the land-use suitability analysis. Only one suitable area is selected for as the final urban growth area.

5. Discussion

5.1 Comparison of weighted overlay for land-sue suitability analysis in the two projects

Both projects considered the five planning objective to various depth. Some of the criteria involves overlay of different input data to create a final layer reprinting one planning goal as input for the final weighted overlay analysis. The Euclidean distance analysis indicates the areas located in proximity to roads infrastructure and train stations are also better connected with key regional cities in Victoria thus have higher development potential. The reclassification determines potential areas of growth along transit corridors as well as the zones that can be served by an efficient road and public transport network. Education and health facilities represent an important source of employment and services within Bendigo. The reclassification of Euclidean distance indicates the areas that are benefited from the mentioned amenities. On the other hand these districts are considered core development areas, reinforcing the accommodation of diverse housing types and mixed use developments. Forests represent a valuable natural resource within Bendigo which accommodates a wide range of recreational activities that benefit locals and visitors. The present objective aims to protect and conserve the ecosystem and natural resources. Consequently, future developments must not be located in the conserved areas. Future growth areas will be located in proximity to consolidated urban zones in order to increment the provision of accessible facilities and employment, and reduce the negative impact from urban sprawl. The reclassification of land prone to natural disasters provides information of areas that must be avoided by future developments in order to minimize natural risks.

The first project takes a more comprehensive perspective and the area of suitable land identified following the suitability analysis is significantly smaller than that of the second project which uses less

input information (i.e. fewer restrictions in selecting suitable land). However the final suitable land proposed for future urban growth in the second project is re-selected based on the location of all suitable land identified using the suitability analysis, or other information which is not considered during the land-use suitability analysis.
The other difference of the two projects is the weighted assigned to each planning criteria in the weighted overlay analysis where the preferred criteria are processed and input with different weighting (%) applied to each criterion (Table 2). After the application of the Weighted Overlay, several levels of suitability for future growth were identified in greater Bendigo. The obtained land-use suitability map is reclassified using the levels 9 and 10 as “primary suitability” and levels 0 to 8 as “secondary or restricted”. In order to calculate an adequate site(s) that satisfy the requirements to accommodate 18,500 dwellings, the reclassified raster is converted polygon. The obtained layer allowed calculating the geometry (in hectares) of the potential sites. The different weight assigned to each planning goals reflect the priority of the planner’s (the student’s) concern, which can be subjective at times, indicating the necessity of involving public in the planning processes in the wake of the changing nature of planning which has been associated with increased involvement of non-experts into planning and decision making processes (Malczewski, 2004),

Table 2. Contribution (%) of different input layers in Weighted overlay analysis

Planning Criteria	**Raster Layers**	**Influence (%) in Overlay**	
		Project 1	**Project 2**
Connected City	Proximity to rail line / train stations	10%	25%
	Proximity to major roads	10%	-
City of Equality	Health services	15%	-
	Educational institutions	15%	-
	Construction costs and view quality	-	15%
Ecological City	Forest, ESO	15%	25%
Safe City	LSIO, WWO , watercourse, water area	20%	25%
Compact City	Proximity to established neighbours	15%	10%

5.2 Summary of and reflections on the planning studio

Half of the studio time is devoted to the hands-on teaching GIS techniques as students have no prior GIS knowledge. As far as the land-use suitability analysis for Bendigo is concerned, the selected areas are located in areas not prone to natural disasters and in proximity to established neighbourhoods, jobs, education and health services, and major roads and train facilities, which matches the current plans such as Greater Bendigo Planning Scheme (DTPLI, 2014) and the Bendigo Residential Development Strategy (City of Greater Bendigo, 2015). Although this studio’s focus is the identification of land on a municipal-wide scale, this represents only the first stage of the strategic planning process. In order that the identified areas of land can successfully contribute to Greater Bendigo’s sustainability attainment goal, it is important that the key principles of the “Compact City” model also resonate into the detailed urban design phase of the planning process. In this regard, GIS will continue to play an important role in the creation of communities that contribute to the City’s overarching sustainability and liveability objectives - particularly in relation to their walkability (including the provision of connecting footpaths), diversity (including the provision of varying lot sizes and affordable housing options), resilience (ensuring the appropriate development and ongoing management of flood prone areas), and accessibility (including the provision of local services and facilities to complement those already provided within nearby towns). However, these areas remain unexplored and challenges as there is no time for students to engage master planning at the finer scale in the studio in a single semester.

This cross-scale thinking is to examine interactions in the land system at the site level, local level, regional level, national level, and even global level. Scale thinking is essential to gain a holistic understanding of the site and its broader context. In landscape studio, design students can normally engage system thinking at a particular spatial scale. Students can understand the interacting ecological, geophysical, and socioeconomic forces that shape the production of landscape at a certain scale, however, they generally fail to recognise how these very forces are simultaneously functioning at other scales, let along to relate these cross-scale functions to gain a holistic understanding of boarder interrelated landscape processes and their potential influences on the design solution (Chen and Lee, 2015). To address all these challenges, it is necessary to reflect the redesign of the planning curriculum. For example, a series of planning studios focusing on critical components such as GIS technology, land-use suitability analysis, complexity, system thinking, and scale thinking could be planned in a sequential order in the planning curriculum.

5.3 Geodesign as an interdisciplinary approach for land use assessment and planning

GIS is a crucial tool used in urban planning studies to gain deeper understanding of the existing spatial composition of the City of Greater Bendigo (and of course any other cities facing the growth pressure). In this regard, the maps generated as part of this study, not only provide a visual representation of the Municipality's existing features, but also provide additional knowledge regarding the way in which these features interact, thereby influencing the City's future urban growth prospects. The generation of such additional knowledge is an invaluable characteristic of GIS, exploited by all levels of government in Victoria to effectively manage the State's existing assets, as well as to prepare future planning initiatives at the State, regional, and local levels. The study demonstrate that the application of spatial overlay is efficient in land-sue suitability analysis for urban development.

However, the spatial overlay-based land-use suitability analysis has been criticized due to its mythological focus on optimisation and 'best fit' (Walliss and Wall, 2015). Indeed, the old style of land use assessment and planning methodologies have been heavily influenced by processes that privilege optimisation through a highly linear process. Today in an era of advanced spatial information technology, the process is becoming more fluid, versatile, systematic, collaborative, and adaptive, emphasizing on optimization through an iterative process. Parallel to this process has been a movement to combine the sketching approach, common in landscape architecture and urban planning, with numerical analysis available in GIS (Bishop, 2013). This combination has recently been labelled "Geodesign" and is defined as follows:

> Geodesign is a design and planning method which tightly couples the creation of design proposals with impact simulations informed by geographic contexts, systems thinking and digital technology (Steinitz, 2012, p.12).

Steinitz (2012) poses six questions (each should be interpreted as a model) to facilitate the implementation of his geodesign framework: 1) How should the study area be described in content, space and time? (Representation Models); 2) How does the study area operate? (Process Models – understanding functional and structural relations in the landscape); 3) Is the current study area working well? (Evaluation Models – verify if stakeholders' expectations and needs, environmental balance conditions and cultural values are being attended to); 4) How might the study area be altered? (Change Models – verify how changing the study would be possible); 5) What differences might the changes cause? (Impact Models – analyze different possible results and choices for the land use); (6) How should the study area be changed? (Decision Models – choose among alternatives considering collective expectations and values). Geodesign clarifies land management questions to stakeholders and allows urban planners to act according to the collective will; in case of disagreement among stakeholders, project (design) alternatives should be developed and evaluated (Moura, 2015). However the systematic framework with six sub-systems appears complicated and challenging to implement in practice. The geodesign framework could be simplified and combined with the way of quantitative decision support techniques such as multi-criteria analysis and optimisation.

6. Conclusions

Planning and design thinking methods are the most essential component in planning studios teaching; what methods we would teach our students remains a question. While we recognize that the challenges to design with complexity is overwhelming, the scaled system thinking approach (Chen and Lee, 2015) and tools such as scaling ladders (Wu et al, 1999) can help simplify complexity of systems (and system of systems) under study, enhance ecological, geophysical, and cultural understanding, and, at the same time, minimize the danger of intolerable error propagation in translating information across multiple scales. Therefore, planning studio teaching should encourage students to reach the geodesign aspiration by taking a holistic perspective of all relevant design issues; but not just focus on isolated problems within the larger system. This paper present a case of planning studio teaching based on land-use suitability analysis. Two students projects selected among many produced during 4 years when the course has been offered. The students experience survey (SES) reveals students high satisfaction of the delivery of the course which heavily relies on project-based learning where GIS knowledge and planning principles are integrated as well as practical skills and principles are applied to a real project. The studio model has been proved an efficient way of teaching the two sets of knowledge and skills.

While traditional spatial overlay based on GIS remains fundamental in planning education, there is a demand for integrated geodesign approach aiming at expanding the GIS driven planning methodologies and offering new opportunity for creating strategic planning solutions amidst complex and intriguing issues surrounding a real world project. Considering that we are challenged in the middle of any number of crisis, such as climate change, global warming, water shortage, loss of biodiversity, land degradation as desertification, and so on; and that the recent advancement in big data, data mining, and computing technology are critical in realising the aspirations of geodesign in dealing with these crisis integrating system thinking and scale thinking, particular the aspirations in cross-scale dynamic simulations and quick or real-time evaluating impacts of design intervention; it is time for planning and design educators to reflect the technical component in the current planning curricula, and to formulate a robust model of effective delivery both the very basic of overlay skills such as land-use suitability analysis and the state-of-the-art spatial information technologies such as geodesign. These are changes need to be undertaken in our educational processes aiming at educating the next generation of urban and regional planners who are capable of both thinking scientifically and acting responsibly and creatively.

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