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GEOGRAPHIC INFORMATION SYSTEMS AND COASTAL PLANNING IN AUSTRALIA

ABSTRACT. The objective of this paper is to demonstrate the ability of visualization and simulation techniques to aid and simulate current and future directions in coastal planning. The process of visualization will interrogate the coastal cities of Portland, Apollo Bay, Anglesea and Hobsons Bay in south-eastern Australian coastal seaboard through a progression of projections and simulated forecasts from 2014 to 2050 to see if a process(s) or methodology could help in planning the future growth of coastal settlements. The analysis uses Geographic Information Systems (GIS) associated with planning application software.

KEY WORDS: simulation techniques, visualization techniques, coastal planning, sustainable growth, coastal settlements

INTRODUCTION

Over the past few decades coastal cities around the world have grown at an incredible rate. With this growth have come major challenges relating to land use planning, social relationships, economic development, bio-diversity and the degradation of the ecological footprint. Three forces are working to influence the growth rate of coastal cities. They include: population growth (i.e. the type and quantity of human demand for land); the existing and future properties of the land (i.e. current land status or changes due to nature and human activities); and, finally technical changes of a land system (i.e. zoning or the influence of other external factors).

Coastal cities have long been susceptible to processes of change. Different cities have taken very different approaches to these developments, with some realizing the unprecedented opportunity for revitalization of depressed yet extremely valuable land/property. Others, through necessity or short sightedness, have chosen to remove funding from these areas further exacerbating the problem.

Sassen [2001] has observed that "Since the 1980s the weight of economic activity in coastal cities has shifted from production to finance and highly specialized services". Similarly, Van der Knapp & Pinder [1992] have also concluded that "historically the relationship between cities their coasts and ports has been interwoven, both physically and economically. However, this long-established symbiosis was broken during the 20th century with cities becoming more multifunctional and subsequently reducing their dependence on the ports, where traditional relationships between cities their coasts and ports were further weakened by structural economic changes". Thus, "the evolution of maritime technology, movement of coastal activities and coastal closures were also associated with the decline of traditional industry, especially in relation to docklands" [Hoyle 1988], and thus "waterfront regeneration was seen, to some extent, as an urban panacea, a cure-all for ailing cities searching for a new self-image or way to compete for capital development or tourism" [Marshall 2001].

The 20th century shows drivers for coastal city regeneration as being

- the reduction in many industrial activities and subsequent need to adapt to a changing use of the area;
- a need to use derelict buildings as high quality residential zones; and
- the reintegration of industrial zones back into the city.

Accordingly, how can we undertake modelling of future growth scenarios that adequately and accurately incorporates climate change and population growth scenarios to better aid our land use strategies and planning policies. While normative thinking historically involved estimate-informed scenarios, and more recent GIS modelling has offered some scope for appreciating the scenarios and impacts, both are limited by the complexity and volume of information, and the accuracy of the information at hand. Complexity and volume, while ideal for GIS modelling, is only as good as the number of variables incorporated and the quality and accuracy of the data imputed.

Therefore, this paper addresses: To efficiently plan for future urban growth you must undertake a two-step process. Step one is to disaggregate demographic and social economic information. Step two is to combine this with environmental, infrastructure and forecast data within land use models. And, as a consequence, can visualization techniques portray information so that it is legible, easy to understand and thus more likely to be used by practitioners?

This paper offers a model for a more detailed investigation of the research question, drawing upon 4 south-eastern Australian coastal cities that are already experiencing climate change and population growth impacts, that additionally incorporates the tool of urban design as a frame to better consider growth and its consequences upon the physical, environmental and infrastructure landscape of each city.

SUSTAINABILITY

What constitutes sustainability and sustainable development? For the purpose of this discussion sustainability can be defined as "a multidimensional and multi-level approach to creating future oriented way of living that balances human activity and wildlife processes over long term time frames. The New South Wales government has defined sustainability as "living within the limits of what the environment can provide, the equal distribution of resources and opportunities". [New South Wales 2014].

The concept of sustainability development is based on three pillars: economic, social and environmental sustainability. The effects of urban patterns on the ecosystem using the concepts of the three pillars has been examined by several researchers including, Alberti [2005], Amir & Gidalizon [1990], Brunckhorst [2005], Buhmann [2003], Byrd [2011], Curtis [2010], Farr [2007] and Girardet [1999]. Our research mirrors the three pillars concepts as it examines the impact of development at the personal, economic and environmental level. The concept of sustainable development is now commonplace in the planning process

The topic of sustainable development, its evaluation and their respective tools are the centre piece of this research. A number of researchers [Amir & Gidalizon, 1990; Rees & Wackernagel, 1996; Satterthwaite, 1997; Morse, McNamara *et al.*, 2001; Becker, 2004; Alberti, 2005; Brunckhorst, 2005; Robinson, Carmichael *et al.*, 2006; Wallis 2006; Ness, Urbel-Piirsalu *et al.*, 2007; Wallis, Richards *et al.*, 2007; Graymore, Sipe *et al*., 2009; Arciniegas, 2012; Garschagen & Romero-Lanko, 2013] have looked at the effect urban patterns have had on the concept of sustainability and sustainable development.

Planning has been defined as "a conceptual system" [Chadwick 1971]. Today's land systems are complex natural economic systems consisting of environmental, economic and social factors.

The traditional approach to the Land Use Planning Process is expressed in Fig. 1 that involves:

- The establishment of goal;
- The formulation of what needs to be resolved (i.e. the problem);
- A selection of courses of action (i.e. scenarios);
- Evaluation of the scenarios;
- Selection of a course of action;
- Implementation of an action plan to resolve the problem;
- Review of the implementation of the action plan; and

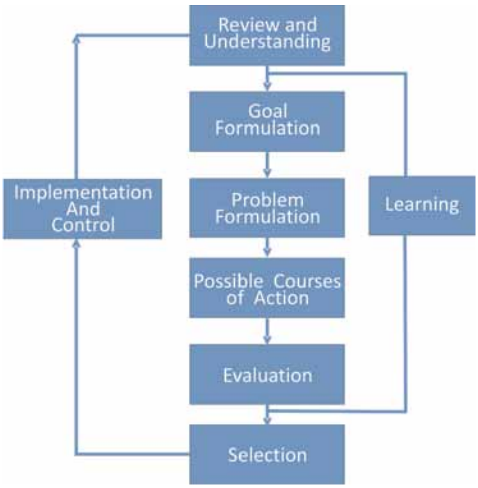

Fig. 1. The Planning Process.
Source: [Reif, 2013].

- Modification of the plan if required to meet the goals of the project.

This type of framework represents a traditional normative model where the planner sets up a set of goals and from these develops measurable objectives.

The use of scenarios in land use planning is well documented [Wollenberg, Edumnds et al., 2000; Tress & Tress, 2003; Dockerty, Appleton et al., 2006; Verburg, Schulp et al., 2006; Shaw, Sheppard et al., 2009; Varum & Melo, 2010: and Schroth, 2014]. The question facing today's town planner is how to better understand the complexities and variables that comprise the land use planning discipline. Modelling provides one method to better understand the complexities and variables to gain a greater insight into how the various factors are interrelated. There are many forms of land use planning models including: GIS based models; Econometric type integrated models; Simulation integrated models; Dynamic simulation models; Integrated land use/transportation models; and Global level simulation models.

Models can be classified according to three basic purposes:

1. Descriptive models that categorize and relate much about the inner workings of the urban environment that affect its structure;

2. Projection models involving relationships between variables; and

Normative models where the planner sets up a series of goals and from these goals develop a series of measurable objectives

Land use models (see Fig. 2) can represent a range of topics including: Land classification; Land structure and analysis; Land evaluation; Land potential productivity; Land carrying capacity; and Demand forecasting.

The development of Geographic Information Systems (GIS) has added to the development

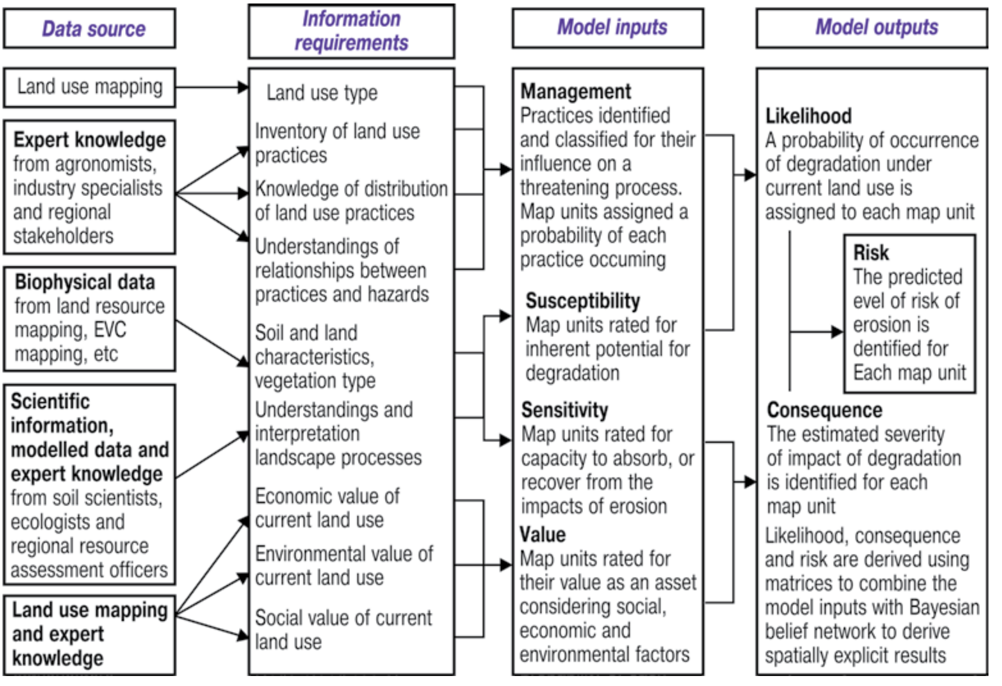

Fig. 2. A theoretical model highlighting the components in a land use planning model

Source: [Victoria, Department of Primary Industry, 2007].

of land use models and opened new horizons for the management and manipulation of spatial data sets. There are four types of GIS analytical approaches to spatial analysis and modelling. They include:

- Rules Based Spatial Analysis;
- Knowledge Based Spatial Analysis;
- Interactive Spatial Analysis Method; and
- Geographic Spatial Analysis

McHarg [1969] has explained that "of the four approaches, rule-based modelling is perhaps the most widely used GIS-based approach in the form of map overlay analysis which has many applications in planning contexts. Data pertaining to several attributes of a study area (elevation, slope, climate, hydrology, land uses) are stored in layers in a GIS. Different layers are overlain to generate maps showing "unique conditions"". Unwin [1996] has also observed that "overlay analysis is used also to predict a new map as a function of the distribution of observed attributes". The four approaches were collectively used in this research providing the ability for the data to be visualized in either 2D or 3D which aided in its interpretation.

Data visualization is not a new phenomenon (Fig. 3). Few [2007] has concluded that "data visualization dates back to the 2nd century AD. The earliest table that has been preserved was created in the 2nd century in Egypt to organize astronomical information as a tool for navigation. A table is primarily a textual representation of data, but it uses the visual attributes of alignment, white space, and at times rules (vertical or horizontal lines) to arrange data into columns and rows. Tables, along with graphs and diagrams, all fall into the class of data representations called charts".

In the 17th century Rene Descartes, the French philosopher and mathematician, invented the visual representation of quantitative data in relation to two-dimensional co-ordinate scales. Two individuals in the 1970s and 1980s wrote ground breaking works relating

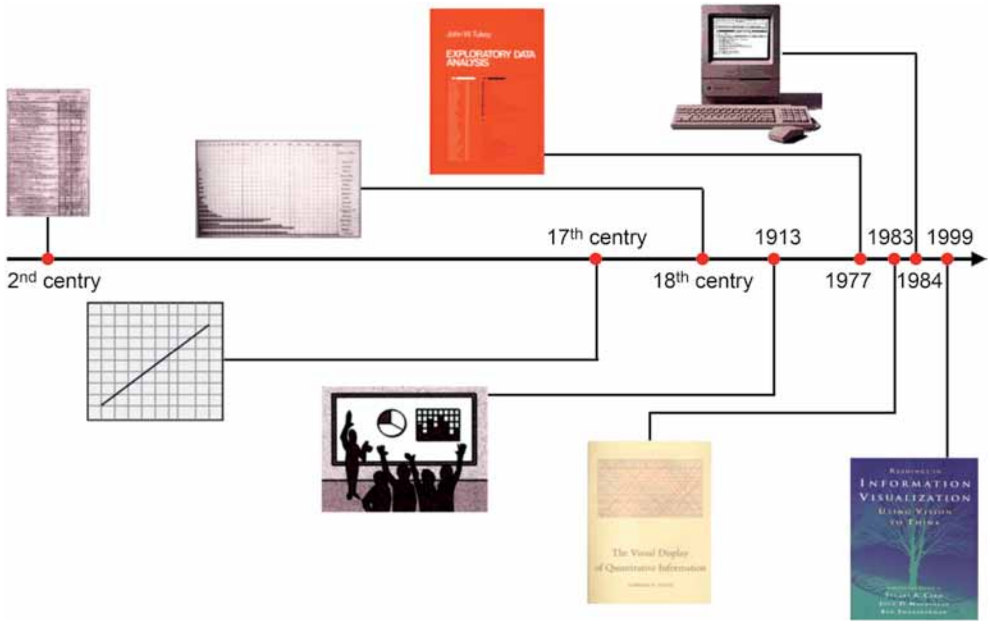

Fig. 3. History of data visualization timeline.
Source: [Few, 2007].

to data visualization as a means of exploring and understanding the complexities of data issues. One was Tukey of Princeton, who in 1977 developed a predominantly visual approach to exploring and analysing data called *exploratory data analysis*. The second was Tufte who published a ground-breaking book *The Visual Display of Quantitative Information* [1983] "which showed that there were effective ways of displaying data visually and then there were the ways that most of us were doing it, which were sadly lacking in effectiveness" [Few 2007].

Friedman [2008] has explained that the "main goal of data visualization is to communicate information clearly and effectively through graphical means". Visualizing large amounts of information interactively is one of the most attractive and useful capabilities of GIS. "Visualization of geographical information has been termed "geo-visualization"" [Thurston 2001].

The role landscape visualisation and its impact on land use planning [Zube, Simcox et al., 1987; Bishop, 1994, 2013; Davis & Keller, 1997; Al-Kodmany, 2001; Appleton & Lovett, 2003, 2005; Dockerty, Lovett et al., 2005; Andreinko, Andrienko et al., 2007; Salter, Campbell et al., 2009; Pettit, Raymond et al., 2011; Berry, Higgs et al., 2012; Bishop, Pettit et al., 2012; Aurambout, Sheth et al., 2013; Berry, Higgs et al., 2012; Lovett, 2014] has been applied in Australia and various other parts of the world. For GIS to be an effective visualization tool a GIS has to perform several functions including putting complex images into the minds of the viewers. Visualization of data assists in understanding the urban design process which is a crucial element in the geodesign/urban development process.

To define "urban design", the Urban Design Alliance defines it as: "Urban Design is the art of making places for people. It includes the way places work and matters such as community safety, as well as how they look. It concerns the connections between people and places, movement and urban form, nature and the built fabric, and the processes for ensuring successful villages, towns and cities".

Urban Design has eight Objectives:

1. Developing and insuring character – A place with its own identity;

2. Establishing continuity and enclosure – A place where public and private spaces are clearly distinguished;

3. Establishing the quality of the public realm – A place with attractive and successful outdoor areas;

4. Solidification of the ease of movement – A placed that is easy to get to and move through;

5. Strategic legibility – A place that has a clear image and is easy to understand;

6. Supporting adaptability – A placed that can change easily;

7. Ensuring diversity – A place with variety and choice; and

8. Encouraging sustainability – A placed that meets the needs of today without compromising the future.

The structural components of an Urban Design Framework are shown in Fig. 4.

Cities throughout the world have used GIS and its visualization and urban design capabilities for determining the capability to accommodate additional growth. A list of recent applications includes the cities of Auckland (New Zealand), Charleston (South Carolina, USA); Madrid (Spain), Adelaide (Australia), North Vancouver (Canada), and Reykjavik (Iceland).

CASE STUDY LOCATIONS

To test and validate the study research statement a case study approach was used to analyze and visualize for the future growth of Portland, Apollo Bay, Anglesea and Hobsons Bay. The four communities represent a rural industrial/agricultural/service community (Portland; population 10,000); a regional agricultural/retirement/tourism centre (Apollo Bay; population 2,500); a peri-urban center that is a commuter suburb to the regional city of Geelong (Anglesea; population 2,500) and a coastal city (Hobsons Bay; population 90,000) in metropolitan Melbourne, all in the state of Victoria in Australia. The location of the four communities is shown in Fig. 5.

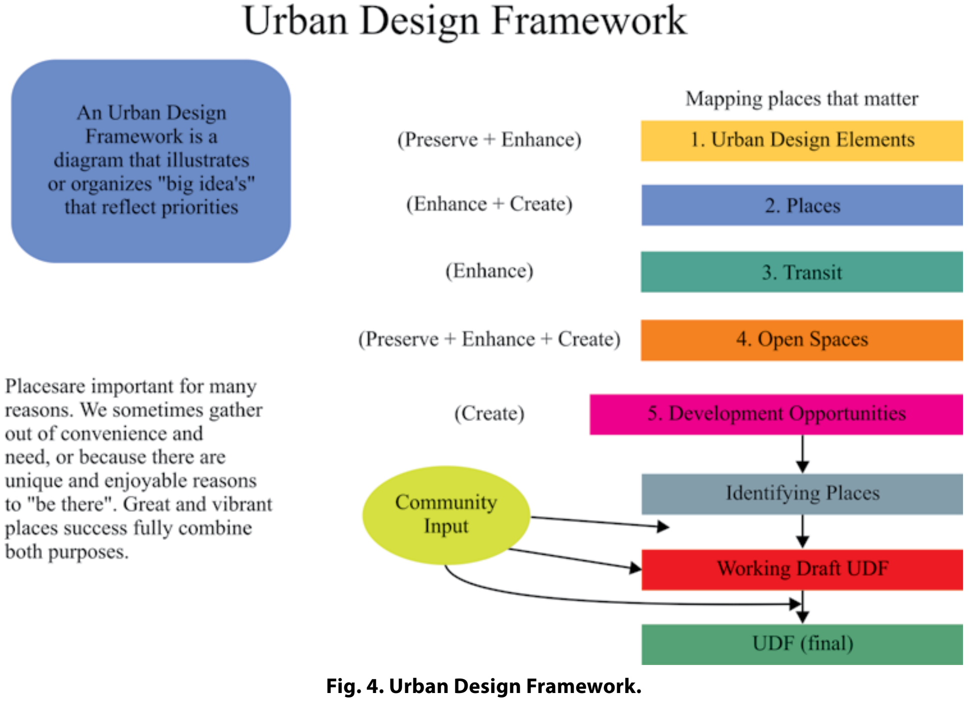

Fig. 4. Urban Design Framework.

Source: [Herron, 2012].

Fig. 5. Location of the Four Test Sites.

Source: [Herron, 2014].

RESEARCH METHODOLOGY, SOFTWARE AND DATA

The study methodology used for the research is based on the concept of scenario planning, that focuses on the use of scenarios; Landscape visualization; Sustainable development evaluations; Multi-criteria analysis; Categorization of tools for sustainability analysis; and, Spatial models through the use of Geographical Information Systems (GIS) (see Fig. 6).

Walker [2011] observes that "for the purpose of this discussion the term scenario is defined as an alternative plan that is being considered". Therefore, three scenarios have been developed for this research a low scenario equating to 90% of the Victorian government predicted population and housing growth forecast to 2050, a base scenario that is the actual Victorian government forecast, and a high scenario which is 110% of the of the Victorian government population and housing forecast to 2050. The key element is the growth in the number of houses per five-year period. The growth is what generates all of the sustainable indicators.

The use of indicators is crucial because they represent a measure of comparable success of each scenario that is developed. The primary goal of scenario planning is to correctly rank scenarios by each indicator score. The methodology for this research

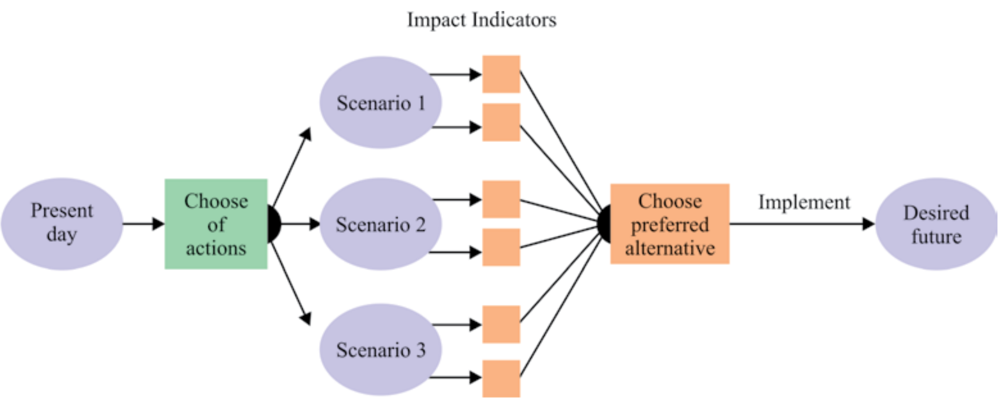

Fig. 6. Scenario planning in the decision making process.

Source: [Walker, 2011].

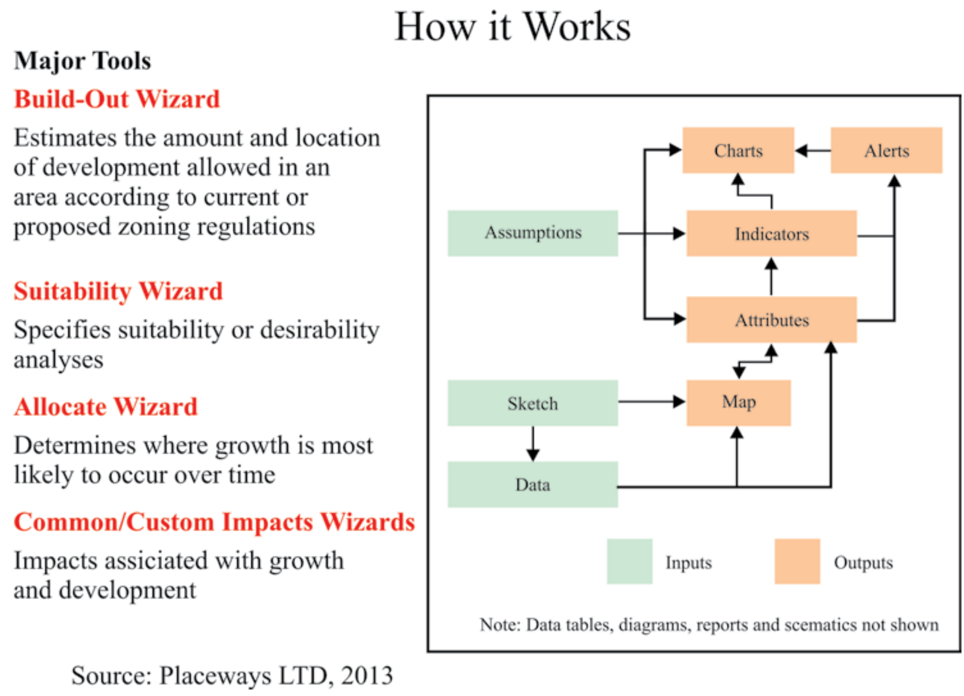

Fig. 7. Community Viz: how it works.

consisted of four procedures as highlighted in Fig. 7. A build-out analysis was performed on the four communities (Portland, Apollo Bay, Anglesea and Hobsons Bay). The build-out analysis depicts the residential, industrial and commercial potential from 2016 through 2050.

Community Viz is a planning and simulation software package. To develop economic, demographic and planning scenarios the software performs four functions including: the estimation, amount and location of new development allowed in an area according to current or proposed zoning regulations; the suitability of the new development to an area; the allocation of where growth is most likely to occur over a specific time span and finally the development of a series of environmental indicators showing the impact of the new development on the landscape.

The suitability analysis was performed on the respective build out results for each city with criteria used in the suitability analysis including:

- Proximity to the city centre;
- Sewer access;
- Proximity to hazardous areas; and
- Shoreline access

The next analysis stage was the allocate procedure which takes the results from the build out and suitability analysis and allocates the demand for buildings across the available supply of potential building locations.

Through the impact function in Community Viz over 50 indicators were developed showing the impact of development over time on the urban landscape (Table 1). The indicators included:

- Distance functions from new developments, i.e. to amenities, parks, schools, etc.;
- Environmental impacts from new development, i.e. CO^2 emissions,

Table 1. Indicators showing the Impact of Climate Change/Global Warming and Population Growth on Anglesea 2016–20

Indicator	units	Indicator	units
Common Impacts – Annual CO Auto Emissions	lbs	Common Impacts – Commercial Jobs to Housing Ratio	commercial jobs/dwelling unit
Common Impacts – Annual CO^2 Auto Emissions	tons	Common Impacts – Labour Force	workers
Common Impacts – Annual Hydrocarbon Auto Emissions	lbs	Common Impacts – Population	persons
Common Impacts – Annual NOx Auto Emissions	lbs	Common Impacts – Residential Dwelling Units	dwelling units
Common Impacts – Commercial Energy Use	million BTU/year	Common Impacts – Residential Energy Use	million BTU/year
Common Impacts – Commercial Floor Area	sq metres	Common Impacts – Residential Water Use	gallons/year
Common Impacts – Commercial Jobs	commercial jobs	Common Impacts – School Children	school children
Common Impacts – Vehicle Trips per Day			

Source: [Walker, 2011].

floodplain percentage, hydrocarbon emissions, residential water and energy usage, waste water generation, etc.;

- Land use characteristics including agricultural, commercial, industrial, open space percent, type of residential density, etc.;
- Transportation characteristics including; jobs, new transport, street density, bicycle coverage, etc.; and
- Recreation characteristics including park and recreation percentage, housing near schools, etc.

The indicators generated in the Community Viz software are based on international sources including:

- Commercial energy usage: the US Commercial Building, Energy Consumption Survey 2003; Energy Information Administration, Office of Energy Markets & End Use;
- Annual Household Energy Use: US Energy Information Administration; Auto Emissions, US EPA 2008;
- Daily Water Usage: residential water use trends in North America journal *AWWA* 1003: 2 Feb. 2011.

Australia has yet to provide a complete list of input data which could be used as information resources relating to the default assumption values in the common impact analysis. The common impacts decision tool uses formulas and default settings that are intended to serve only as a starting point for further analysis. The impact displayed may not pertain to or describe local conditions.

CASE CITIES: PORTLAND

The City of Portland (Fig. 8) is located in the south-western region of the Australian state of Victoria approximately 360 kilometres west from Melbourne. Portland is the major residential and commercial centre for Glenelg Shire, hosts approximately 10,000 people, and is the oldest place of European settlement in Victoria being founded in 1815.

Facing economic and natural sustainability deterioration, Portland is one of the most vulnerable communities in Victoria. Portland's

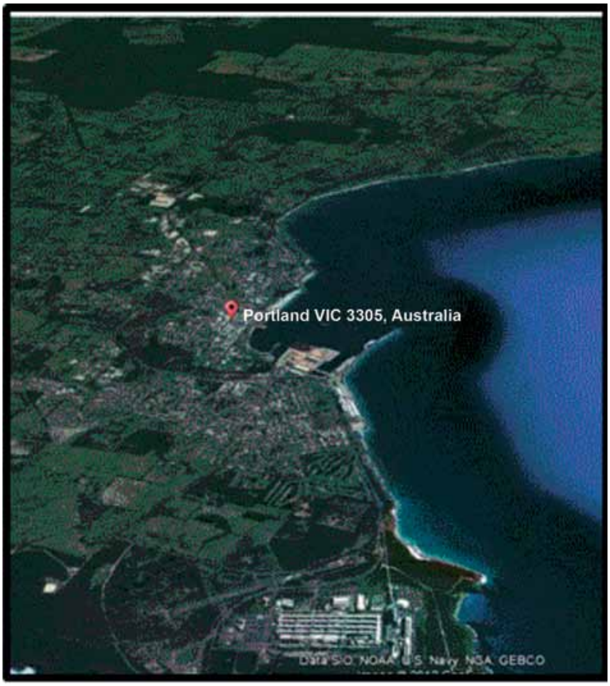

Fig. 8. Aerial Photo of Portland, Victoria.
Source: [Google Earth, 2014].

number one employer is the Alcoa smelter employing 700 staff and contributing 15% of the export GDP for the state Victoria. The smelter has electricity contracts with the Victorian government until 2025. Portland is a large producer of CO^2 emissions that are the result of the Alcoa smelter that consumes 25% of all electricity generated in Victoria all of which is generated through the burning of brown coal. Portland is also home

Table 2. Portland Simulation Data
Low/Base/High Scenarios

	2016	2021	2026	2031	2036	2041	2046	2050
Scenario 1 Low Population	10,702	11,104	11,489	11,852	13,037	14,341	15,775	17,353
Total Dwelling	4,909	5,094	5,270	5,437	5,980	6,578	7,236	7,960
New Dwelling Units	13	198	374	541	1,084	1,682	2,340	3,064
Scenario 2 Average Population	11,891	12,338	12,766	13,169	14,486	15,934	17,528	19,281
Total Dwelling	5,455	5,600	5,856	6,041	6,645	7,309	8,040	8,844
New Dwelling Units	559	764	960	1,145	1,749	2,413	3,144	3,948
Scenario 3 High Population	13,080	13,572	14,043	14,486	15,934	17,528	19,281	21,209
Total Dwelling	6,000	6,226	6,442	6,645	7,309	8,040	8,844	9,729
New Dwelling Units	1,104	1,330	1,546	1,749	2,413	3,144	3,948	4,833

Source: [Herron, 2012].

to the "green triangle" or the second largest sustainable forestry plantation in Australia, and this industry was severely impacted economically by the recent Japanese earthquakes and corresponding nuclear events of 2010–2011. The entire forestry harvest was destined for the Japanese pulp and paper industry over a 20 year period. This "green triangle" processing industry is wholly based in the area most affected by the tsunami and subsequent nuclear power plant disaster, and the industry has no immediate short or medium term date for the recommencement of pulp and paper production.

Demography

With a population of 10,000 people, Portland has a current population density of 290 km^2. The city has an area of 34.48 km^2 in size comprising 7,029 parcels or lots (i.e. residential, commercial and industrial) that host 7,029 buildings of which 4,053 are private dwellings. The amount of land dedicated to open space in Portland (i.e. parkland municipal and state parks, gardens and reserves and sporting reserves) is only 229.78 ha or 0.0229 ha per resident. Portland has a transportation system that includes a local and interstate bus network, and a regional air service to Melbourne.

The 2010 Census stated that Portland had 4,443 full time employed residents working in 20 employment categories. The top 4 industry sectors are manufacturing with 925 respondents (20.8%) followed by health care and social assistance with 563 respondents (12.6%), retail with 486 respondents (10.8%), and accommodation and food services with 372 respondents (8.36%). The top 4 categories represent 52% of the total employment in Portland. The remaining 16 employment categories by level of employment are: construction; education and training; transport and warehousing; agriculture forestry and fishing; wholesale trade; public administration and safety; professional, scientific and technical services; administrative and support services; financial and insurance services; rental, hiring and real estate services; arts and recreational services; electricity, gas, water and waste services; information media and telecommunications and mining.

Scenarios for Modelling

The population and housing scenarios are shown in Table 2. The scenarios were

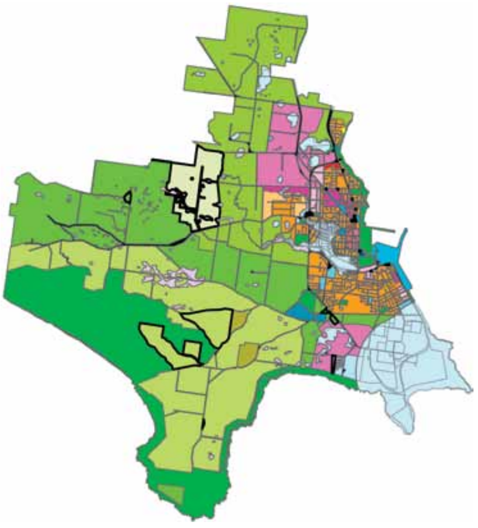

Fig. 9. Portland Development in 2016.
Source: [Herron, 2015].

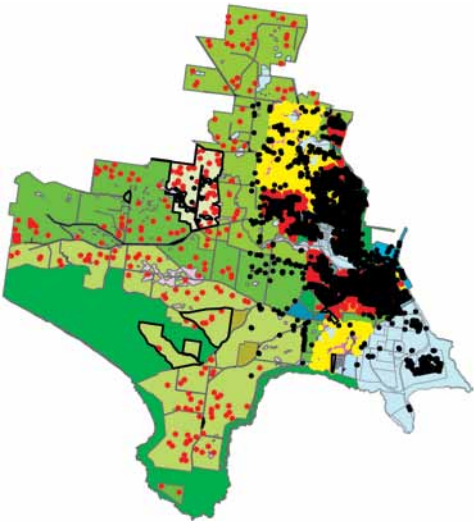

Fig. 10. Portland Residential, Commercial and Industrial Development in 2050
Source: [Herron, 2015].

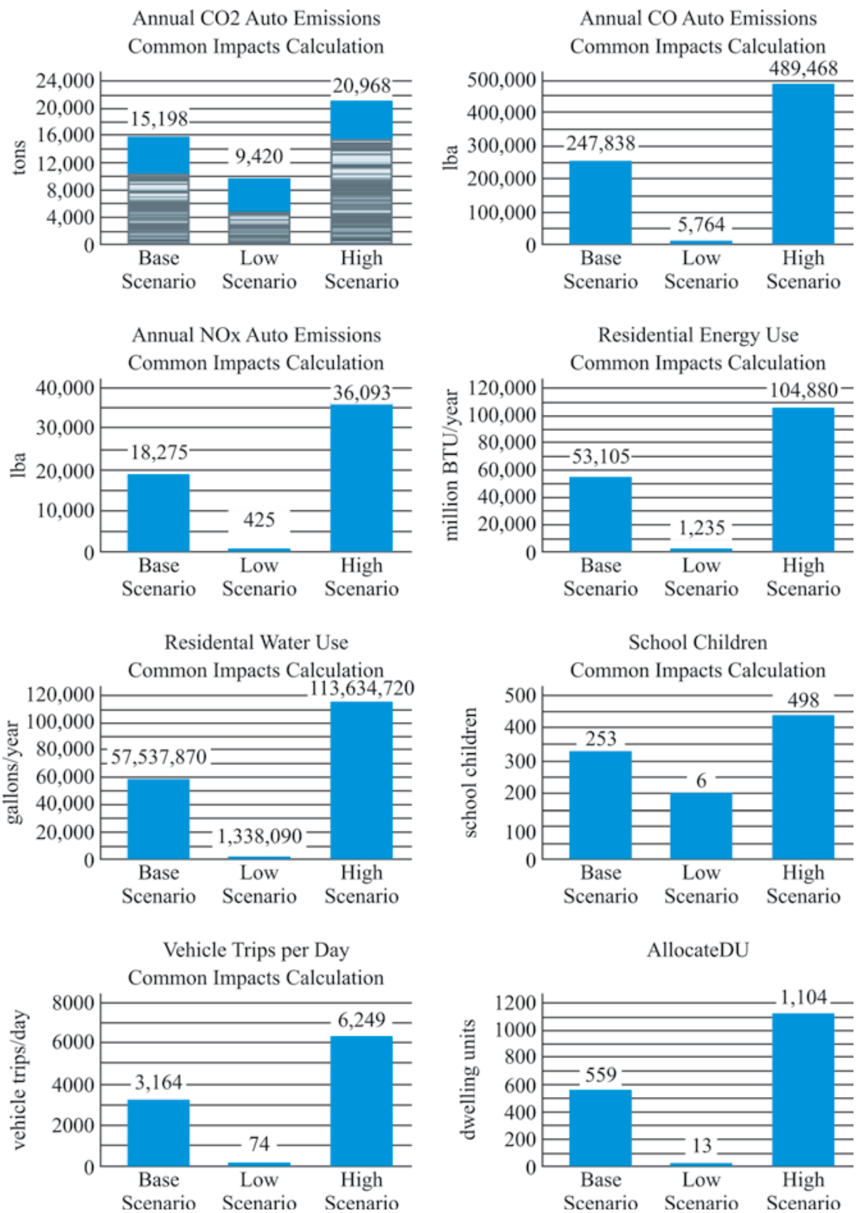

Fig. 11. Portland indicators for 2016

input to Community Viz software where the software performed three analyses namely:

- A **Build-Out analysis** that showed the residential, commercial and industrial potential for Portland from 2016 through 2050;
- A **Suitability Analysis** was done on the build out results. The suitability analysis used 8 criteria:

CBD proximity	Heritage locations
Sewer access	Proximity to Zone 2 industrial areas
Proximity to the smelter	Projected coastal movement from 2016 through to 2050
Shoreline access	Fertilizer plant

- **An Allocate analysis**. The allocate function takes the results from the build out and sustainable analysis and allocates the demand for buildings across the available supply of potential building locations

The result was a build out of potential residential locations up to the 2050. These locations were constrained by the eight suitability factors (CBD proximity, sewer access, proximity to the Smelter, shoreline access, fertilizer plant, heritage locations, proximity to Zone 2 and projected coastal movement from 2016 and 2050). The 4833 proposed dwellings were overlaid on the 3D model of Portland that showed all existing buildings and dwellings which highlighted the current and future growth corridors. The yellow dots top right corner of Portland in Fig. 9 represent residential dwellings and red dot s commercial/industrial developments for 2015.

Fig. 10 represents the combined development in Portland in 2050. Residential development is again represented by yellow dots while commercial/industrial development is represented by red dots. The pattern of residential development is similar with residential development located in north and south Portland.

With the proposed development a series indicators were developed including:

Residential Water Use	Annual CO Auto Emissions
Annual CO_2 Auto Emissions	Annual NOx Auto Emissions
Residential Energy Use	Vehicle Trips Per Day
Dwellings	School children

The 2016 results are shown in Fig. 11.

CASE CITIES: APOLLO BAY

Apollo Bay, situated on the Victorian coastline 187 km south of Melbourne. Apollo Bay is a small settlement with a population of 2,500. The major commercial activity is tourism. Fig. 12 depicts Apollo Bay's location, and Fig. 13 provides a demographic overview of Apollo Bay.

Apollo Bay's current issues include: increasing population, residential density issues, public transport issues, water quality concern, and a shifting economic climate. These issues led to Graymore [2008] posing the question of how useful current tools are for sustainability assessment at the regional scale. Additionally Apollo Bay is physically constrained in its growth by reserved forestry and conservation lands, and the steep to heavy undulating topography that envelopes its surrounds. Its growth can therefore only build upon and within the existing subdivided land in the town.

Methodology

The simulation exercise entailed the development of three scenarios (Low, Average and High) for the period of 2016 through 2050 (Table 3).

In addition to the projected population and dwelling numbers, physical and infrastructure constraints (i.e. water and sewer networks; electrical networks; transport networks flooding patterns; storm surge sea level rise and acid sulphate soils) were developed to further restrict and control the development.

The analysis took into consideration the physical and natural impediments and two other criteria:

- Areas which had shoreline access and
- Areas which had a close proximity to the central business district of Apollo Bay

The four combined criteria were used to rank areas in order of preference for new development areas shown in Figs 14 and 15.

Figure 14 and 15 shows where development will occur in 2016 and 2050. The light blue (sea level rise) and dark blue (storm surge) outlines on the Apollo Bay coastline shows the impact that the two factors will have on the Apollo Bay landscape. Development along the coastline is restricted over the time period because of the encroaching sea level rise with future development as indicated by Fig. 14 being focused or driven inland. Fig. 15 highlights the increased density pattern of future development. The modelling done for this research kept the same density parameters i.e. (dwellings per ha; minimum separation distance between buildings; layout pattern and setback distances).

Table 3. Growth Scenarios for Apollo Bay 2016 to 2050
Low/Base/High Scenarios

Scenario 1	**2011**	**2016**	**2021**	**2026**	**2031**	**2036**	**2041**	**2046**	**2051**
Low Population	2577	2602	2784	2939	3082	3113	3145	3176	3208
Houses	3064	3092	3285	3440	3554	3589	3678	3790	3903
difference		28	221	376	490	525	614	726	839
Scenario 2	**2011**	**2016**	**2021**	**2026**	**2031**	**2036**	**2041**	**2046**	**2051**
Medium Population	2577	2739	2931	3094	3245	3277	3310	3343	3377
Houses	3064	3255	3458	3621	3741	3778	3872	3989	4108
difference		191	394	557	677	714	808	925	1044
Scenario 3	**2011**	**2016**	**2021**	**2026**	**2031**	**2036**	**2041**	**2046**	**2051**
High Population	2577	2766	2960	3125	3277	3310	3343	3376	3411
Houses	3064	3271	3475	3639	3760	3797	3891	4009	4129
difference		207	411	575	696	733	827	945	1065

Source: [Herron, 2012].

Results

Several indicators (Annual CO_2 Auto Emissions, Annual CO Auto Emissions; Annual NOx Auto Emissions; residential water and energy use, etc.) were generated to demonstrate the effect an increase in the population will have on the environment and landscape. Each indicator showed substantial increases the result of increased population or development pressures as shown by Fig. 16.

Fig. 12. Aerial Photo of Apollo Bay, Victoria.
Source: [Google Earth, 2014].

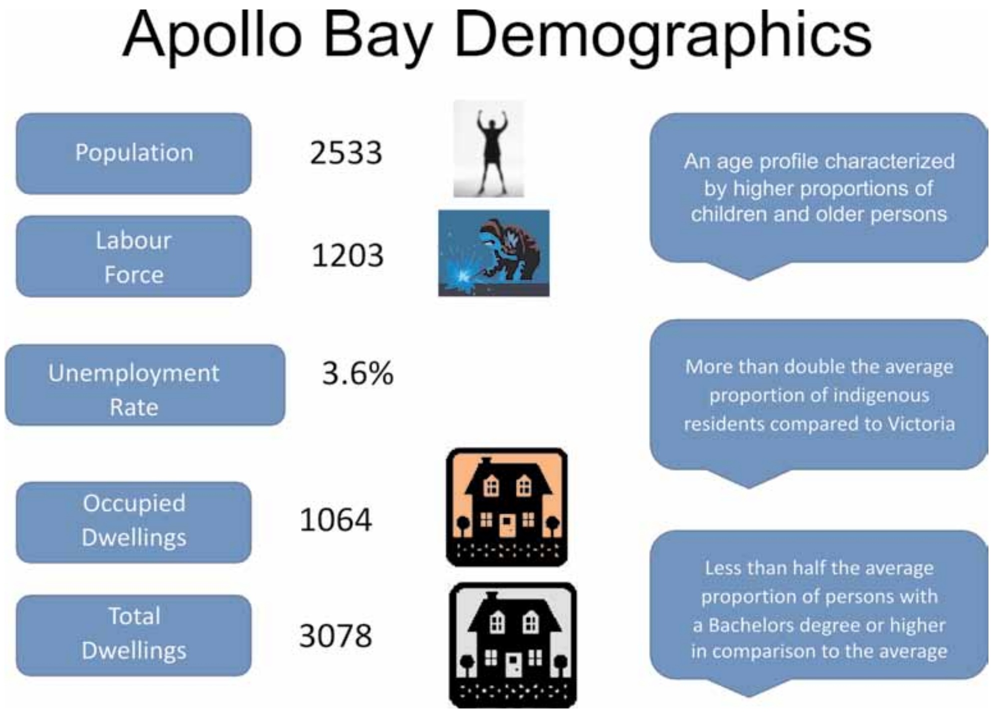

Fig. 13. Apollo Bay Demography.
Source: [iD Consulting, 2014].

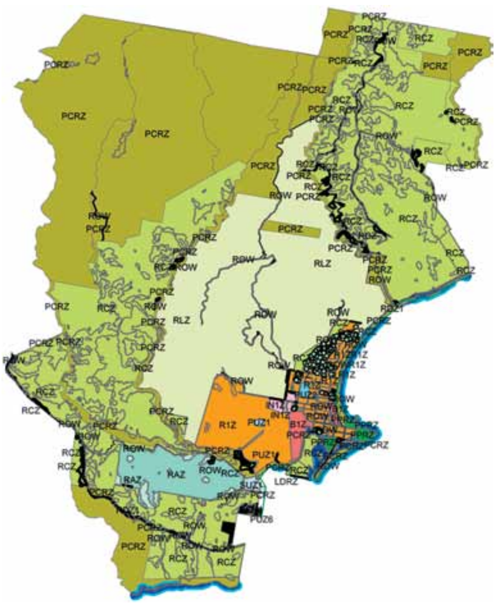

Fig. 14. Apollo Bay Development 2016.
Source: [Herron, 2015].

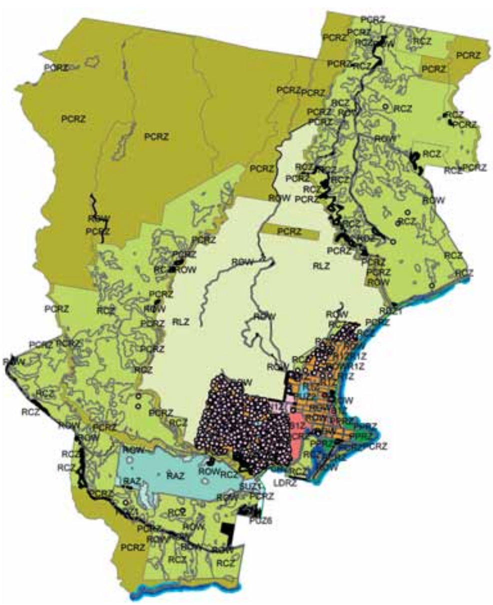

Fig. 15. Apollo Bay Development 2050.
Source: [Herron, 2015].

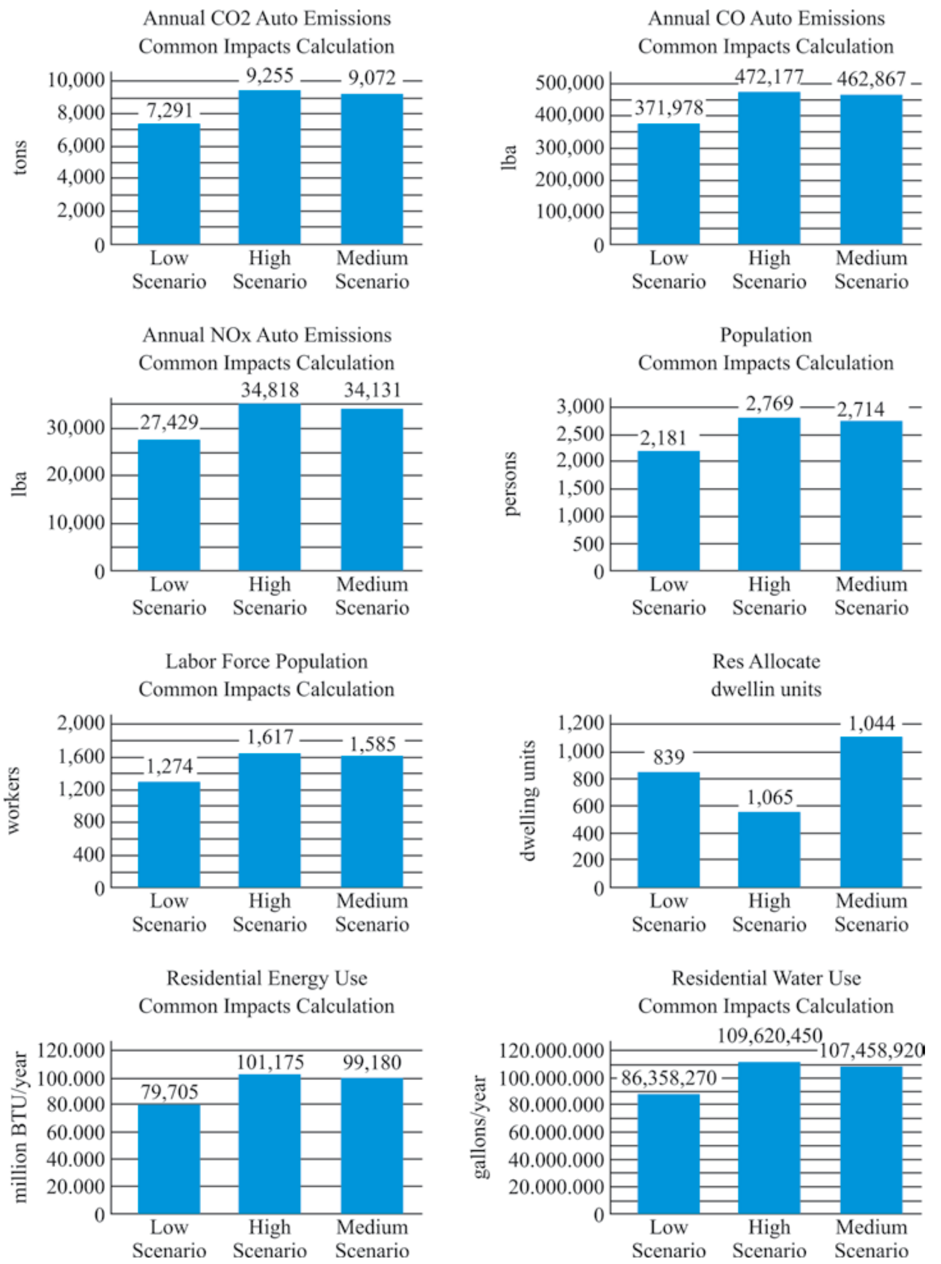

Fig. 16. Apollo Bay Indicators

CASE CITIES: ANGLESEA

The town of Anglesea (Fig. 17) is within the Surf Coast Shire, which is located in Victoria to the south of Melbourne and Geelong. Early development in the Shire dates from the 1850s due to its beaches and holiday lifestyle. Access to communities such as Anglesea was difficult until the opening of the Great Ocean Road in the 1920s. The Great Ocean Road enabled towns such as Anglesea to become tourist centres particularly with the advent of private vehicle transport. The Surf Coast Shire, experienced significant growth from the 1980s onward with key environmental and sustainability issues relating to this growth, specifically urban sprawl and increased degradation of the

Fig. 17. Aerial Image of Anglesea Victoria.

Source: Google Earth, 2014.

Table 4. Three Growth Scenarios for Anglesea 2016–2050
Low/Base/High Scenarios

Scenario 1	**2011**	**2016**	**2021**	**2026**	**2031**	**2036**	**2041**	**2046**	**2051**
Low Population	2538	2543.3	2565	2571	2623	2808	2996	3196	3365
Houses	2887	2967	3048	3088	3127	3349	3573	3812	4013
difference		28	161	201	240	462	686	925	1126
Scenario 2	**2011**	**2016**	**2021**	**2026**	**2031**	**2036**	**2041**	**2046**	**2051**
Medium Population	2538	2569	2591	2597	2649	2836	3026	3228	3399
Houses	2887	2997	3079	3119	3159	3383	3609	3850	4054
difference		110	192	232	272	496	722	963	1167
Scenario 3	**2011**	**2016**	**2021**	**2026**	**2031**	**2036**	**2041**	**2046**	**2051**
High Population	2538	2826	2850	2857	2913	3120	3328	3550	3438
Houses	2887	3297	3431	3475	3721	3970	4234	4459	
difference		410	500	544	588	834	1083	1347	1572

Source: [Victoria, Department of Planning and Community Development, 2014].

environment. Additionally Anglesea is physically constrained in its growth by reserved conservation lands, a brown coal mining tenement, and the steep to heavy undulating topography that envelopes its surrounds. Its growth can therefore only build upon and within the existing subdivided land in the town.

The Anglesea population and housing are shown in Table 4.

Scenario Modelling Results and Discussion

Fig. 18 shows the following information on new development (i.e. new houses) in 2016.

Yellow dots represent residential dwellings and the red dots represent commercial/ industrial buildings. Fig. 19 shows residential development in 2050. The development is centred in the north and western portion of Anglesea.

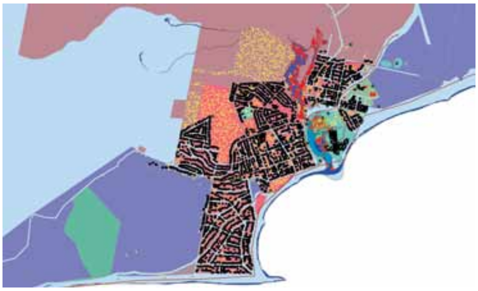

Fig. 18. Anglesea in 2016.
Source: [Herron, 2015].

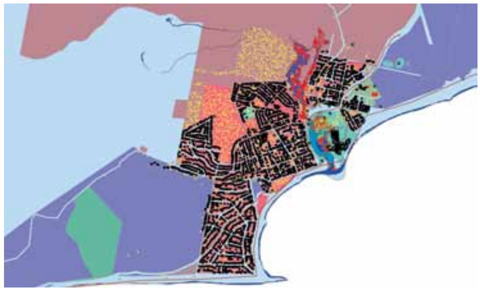

Fig. 19. Residential Development in Anglesea 2050.
Source: [Herron, 2015].

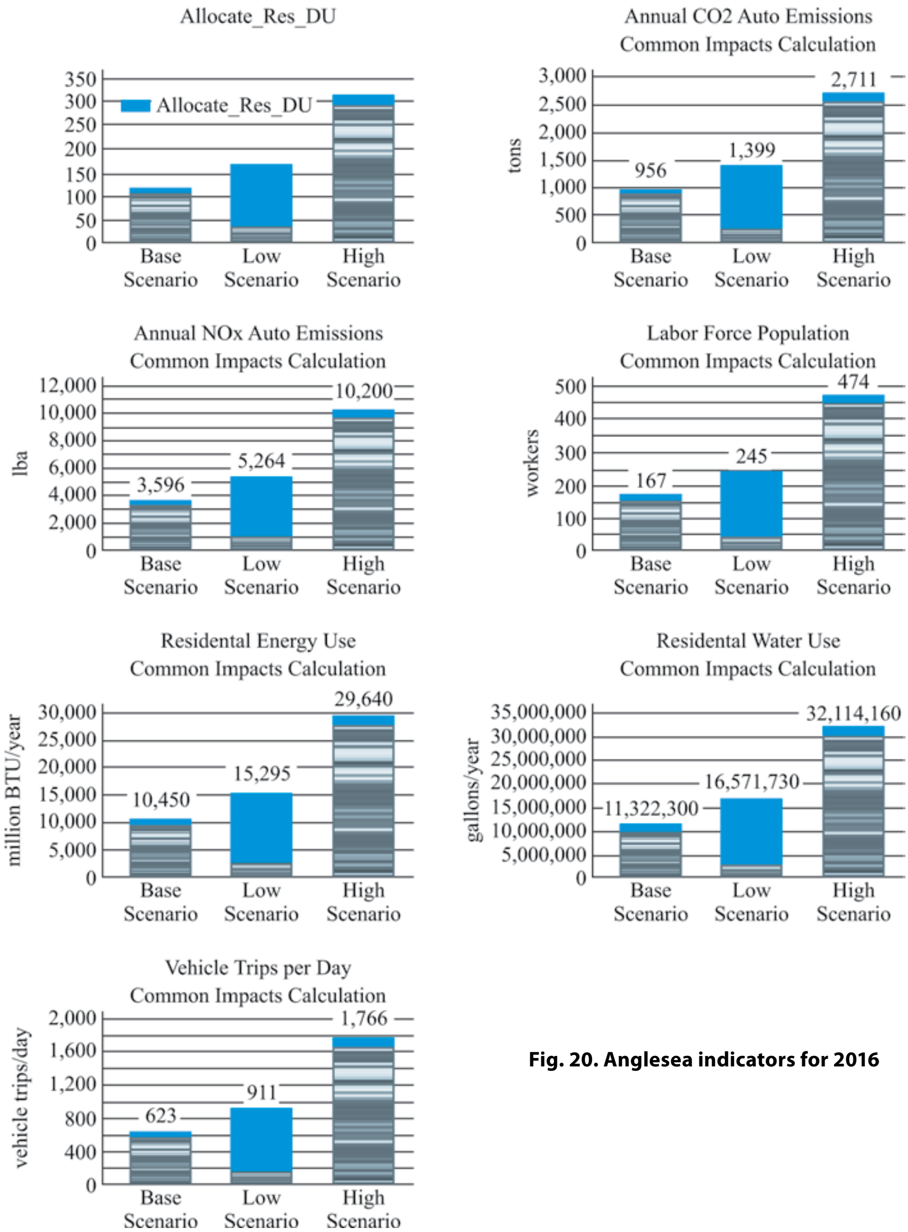

Fig. 20. Anglesea indicators for 2016

The growth in population and development to 2050 has the following impacts on the landscape of Anglesea. Fig. 20 shows the results of 2016 simulation and is indicative of the impacts, which will occur in Anglesea.

CASE CITIES: HOBSONS BAY

Hobsons Bay was created on 22nd June 1994 following the amalgamation of the former cities of Williamstown and Altona and includes parts of the suburbs of Laverton and South Kingsville. Hobsons Bay is situated on the north-western flank of Port Phillip Bay around 10 km west of central Melbourne. The City covers an area of approximately 66 km^2 (Fig. 21).

Hobsons Bay has over 20 km of bay frontage, quality residential areas, and a huge expanse of environmentally significant open space, and a range of major industrial complexes, that contribute significantly to the economy of Victoria. Hobsons Bay needs to address both current and projected issues of increased population growth; open space requirements; coastal flooding and storm surges; residential density issues; and, industrial land use issues.

Demography

The demography for Hobsons Bay is shown in Fig. 22.

With a population of 89,111 people, Hobsons Bay has a current population density of 1388.22 km^2. The City has an area of 64 km^2 in size comprising 41,686 parcels or lots of which 35,386 are occupied by private dwellings. Hobsons Bay has 10 dedicated parks and a 23 km of coast. It has a transportation system that includes a local and interstate bus network, and a metropolitan and regional train service. Hobsons Bay has recently completed an Urban Design Frameworks study for all the major settlement areas with the City. The dominant employment sectors are manufacturing which represent 11.3% of the workforce, healthcare at 9.4% and retail which represents 9.1% of the workforce.

Scenarios for Modelling

The scenarios used in this research are based on an integrated model of: population land use, transportation, and environmental projections from the City of Hobsons Bay and the Victorian and Commonwealth levels of government. Three scenarios (Table 5) were developed from the Victorian population and housing forecast to 2050. A low scenario equating to 90% of the of the Victorian government predicted population and housing growth forecast to 2050, a base scenario which is the actual Victorian government forecast and a high scenario

Fig. 21. Aerial Image of Hobsons Bay.

Source: [Google Earth, 2014].

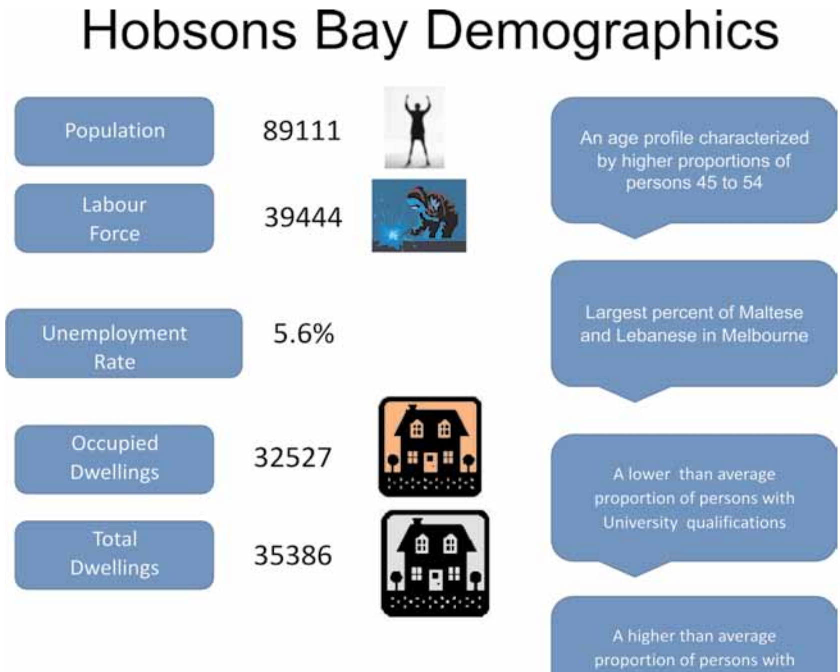

Fig. 22. Hobsons Bay Demography.
Source: [iD Consulting 2014]

which is 110% of the Victorian government forecast.

The Build-out, Suitability and Allocate analyses were performed on the Hobson Bay data. The suitability analysis performed on the Hobsons Bay build-out analysis result used 12 criteria including coast flooding projections from 2040 through 2100; proximity to oil refineries, chemical plants and oil tank farms; and trees and native vegetation.

Results

For the period 2016 through to 2050 the number of new dwellings constructed

Table 5. Three Growth Scenarios for Hobsons Bay 2016–2050
Low/Base/High Scenarios

	2016	2021	2026	2031	2036	2041	2046	2050
Scenario 1 Low Population	81996	84848	87602	90119	93,002	95,977	99,047	102,215
Total Dwelling	33370	34902	36359	37739	39,319	40,965	42,680	44,467
New Dwelling Units	1376	1432	1489	1549	1,611	1,675	1,742	1,812
Scenario 2 Average Population	91,107	94,275	97,336	100,132	103,335	106,641	110,052	113,572
Total Dwelling	37,078	38,780	40,399	41,932	43,688	45,517	47,422	49,408
New Dwelling Units	2111	2577	2224	2,342	2,184	2,419	2,407	2,528
Scenario 3 High Population	100,218	103,703	107,070	110,145	113,669	117,305	121,057	124,930
Total Dwelling	40,786	42,658	44,439	46,125	48,056	50,068	52,164	54,348
New Dwelling Units	2,753	2,974	3,211	3,468	3,746	4,046	4,369	4,179

Source: [Victoria, Department of Planning and Community Development, 2014]

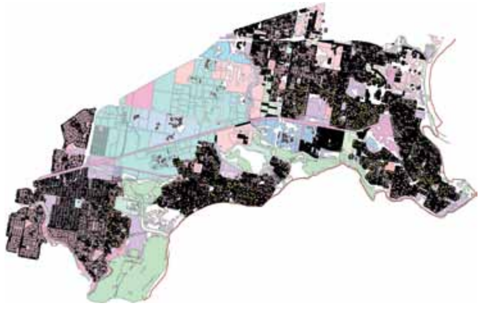

Fig. 23. Hobsons Bay Development 2016.

Source: [Herron, 2015].

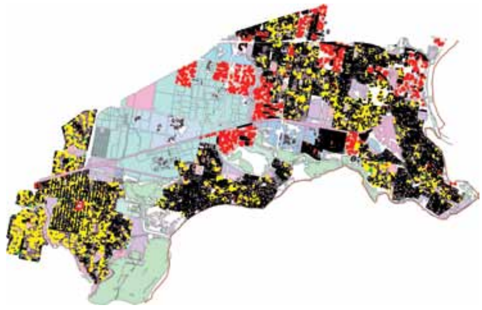

Fig. 24. Hobsons Bay Development 2050.

Source: [Herron, 2015].

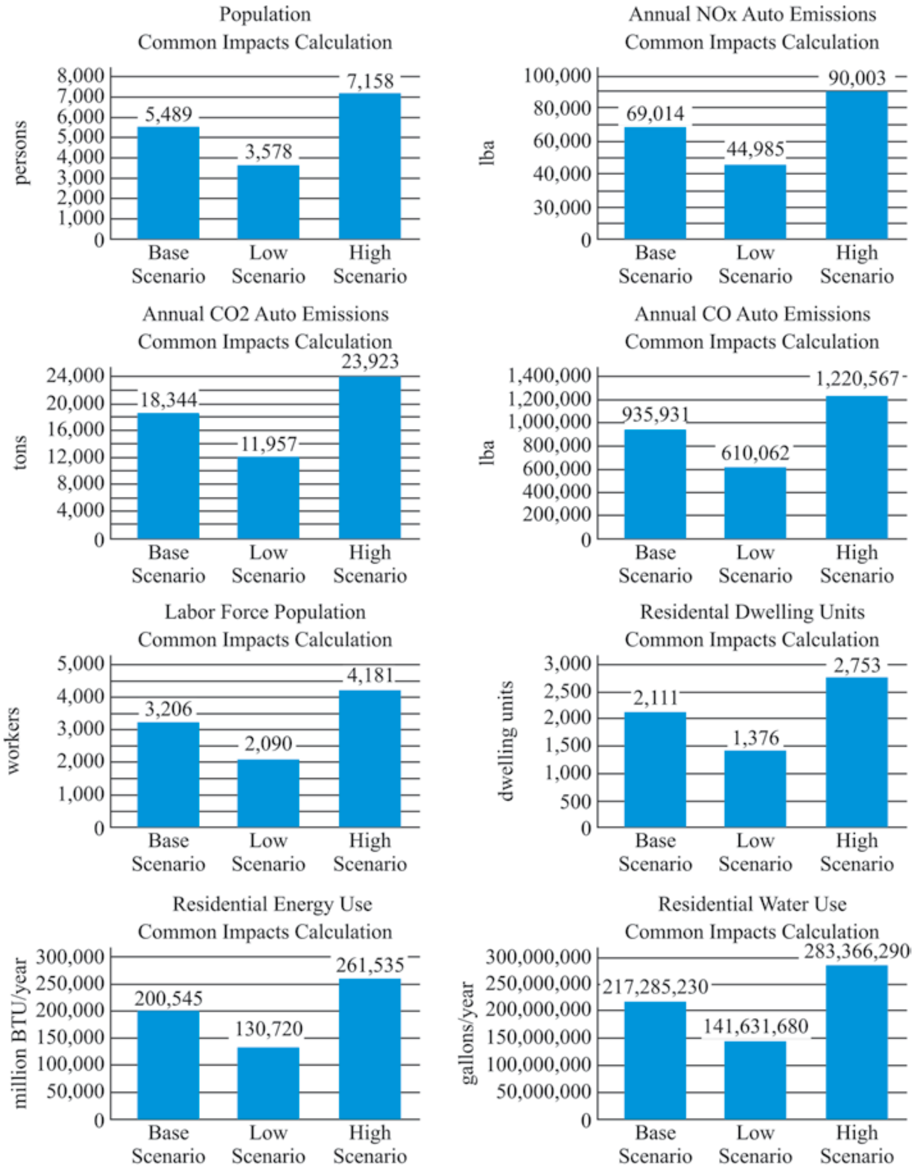

Fig. 25. Hobsons Bay indicators for 2016

could range from 12,686 to 28,746 dwelling units (Table 5). Fig. 23 shows residential development in 2016 and Fig. 24 shows development in 2050. Residential development is represented by yellow dots and commercial development by red dots.

Other issues that impact the future land use include: coastal inundation, increased temperatures, reduction in rainfall, sea level rise, soil degradation, long term employment outlook in the manufacturing sector. All of these factors impact the land use allocation and planning.

Every calculated indicator showed substantial increase being the result of increased population or development pressures as shown by Fig. 25.

DISCUSSION

The research undertaken for this paper relating to the four test sites has generated ten discussion points which are listed below

1. Population increases generating more emissions and greater impacts of climate change;

2. Increased consumption of energy and water resources;

3. Open space allowances decrease for new developments and General overall open space decreases per head of population;

4. Urban density increases;

5. For metropolitan areas (i.e. Hobsons Bay the scale of development) will increase;

6. For regional and rural locations (i.e. Portland, Apollo Bay and Anglesea) urban sprawl will increase as these locations have available land which will for new development;

7. New residential and or commercial development will add greater stress on existing physical and or natural infrastructure;

8. The exodus of more jobs (i.e. commercial and industrial jobs to peripheral areas and being replaced service industry jobs); and,

9. More mixed commercial/residential developments in the metropolitan and regional centres.

As indicated above, Portland, Apollo Bay, Anglesea and Hobsons Bay face the impacts of climate change and sea level rise, as well as various other impacts due to population growth and human activities. It is now accepted and reflected in various literature, as well as in government policies internationally, and in Australia that concern is warranted to address the potential impacts of climate change in regional coastal areas [Macintosh, 2012].

The results of the Community Viz simulation model as indicated in the various city sections, provided scenarios of future growth, issues relating to that growth and the corresponding risks. The decision making process regarding climate change is complex. The development of adoption processes to mitigate climate change by many governments involves using a risk management approach [AGO 2006].

To be able to deal with the many complex factors for adaptation, this paper proposes the use of an adaptation framework that includes the precautionary approach and the visualisation scenario modelling of Community Viz, considering a scenario-modelling framework.

Using the scenario-modelling process as above, the integration of Adaptation Planning will help Portland, Apollo Bay, Anglesea and Hobsons Bay respectively to plan for a possible sustainable future. However, this is a complex process and it is recommended to use the principles of the Design Based Adaptation Model (DBAM), adapted from Roös [2012] (Fig. 26) to suit the four community's growth scenario, as indicated in Tables 2 through to 5.

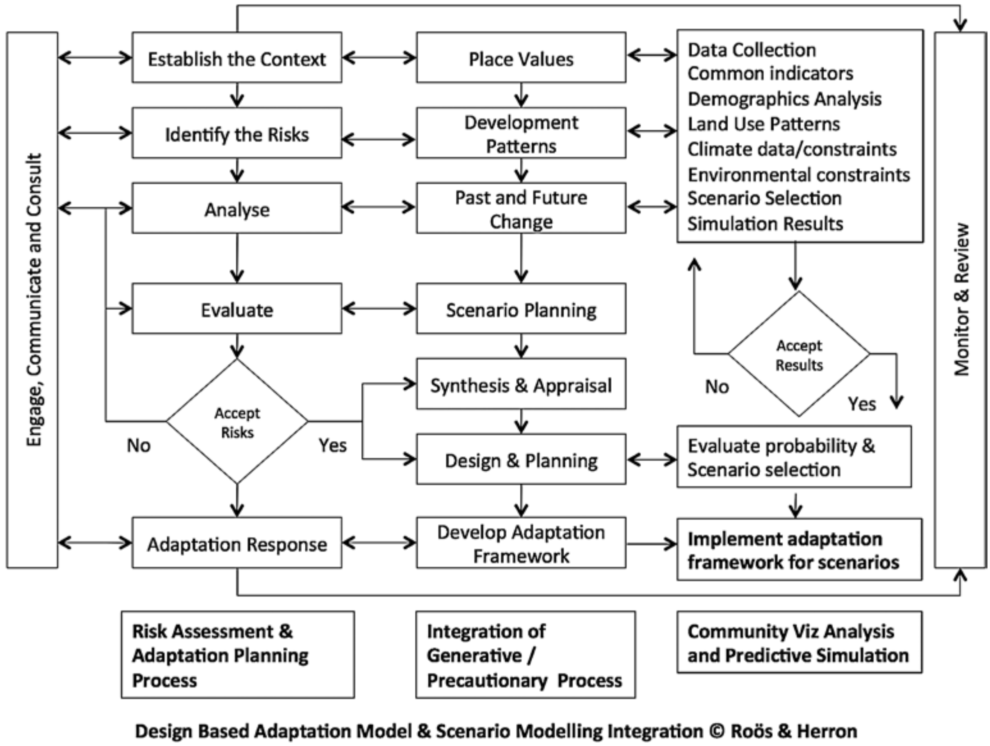

Fig. 26. Design Based Adaptation Model [Roös 2012]

The following 9 conclusions can be drawn:

Point 1 Population increases generating more emissions and greater Climate Change impacts. For each of the four research sites (Portland, Apollo Bay, Anglesea and Hobsons Bay) as the project population increases the environmental indicators used to highlight environmental degradation increased (i.e. CO, CO^2, Auto Emissions, residential water and energy consumption, etc.) The level of increase is predicated on the number of cars and individuals per household. The more individuals or cars per household the greater level of emission or consumption of water and energy per household. For the regional/rural sites (i.e. Apollo Bay, Anglesea and Portland) the opportunity of reducing the number of vehicles is remote as public transport has not developed into a reliable alternative to owning a motor vehicle. In the metropolitan areas (i.e. Hobson Bay) there is the possibility to reduce car numbers per household. This reduction is the results of mass public transport which is located in the metropolitan region.

Point 2 Increased consumption of energy and water resources as indicated by Figures 9–45 occurred for each of the study locations throughout the 40 year simulation period. Water and energy consumption will increase as the result of population growth. The level of increase can be reduced through water sensitive design and energy efficient equipment and appliances. The other point on increased energy consumption is the substitution of coal based generated electricity with electricity generated by renewable sources will reduce the impacts of climate change on the landscape.

Point 3 Open space ratio will decrease as a result new developments. The analysis show for communities that had prescribed city or township boundaries new development or increased development will reduce the allotted opens space per head of population. For Hobsons Bay the advent of high rise developments has reduced and will further reduce the open space ratio for residents as well developments come on line. In the regional and rural study locations (i.e. Portland, Apollo Bay and Anglesea this was not a major issue as the reduction in open space was minimal).

Point 4 Urban density increases. The current population for Hobsons Bay is 90,000 with an urban density of 1,385 persons per ha by 2050 the population will be 125,000 with an estimated 1,922 per ha.

Point 5 For metropolitan areas (i.e. Hobsons Bay the scale of development will increase). Hobsons Bay has only a limited area to incorporate the additional 25,000 to 30,000 residents by 2050 density and the scale of development will need to expand. Hobsons Bay has just passed new building regulations and zoning regulations in 2014 that allow for the construction of taller residential buildings (i.e. up 30 storeys). Future regulations will increase the story limit to 50 stories.

Point 6 For regional and rural locations (i.e. Portland, Apollo Bay and Anglesea) urban sprawl will increase as these locations have available land which will be available for new development? Regional and rural communities in Victoria have not had their building regulations altered to allow for higher storied residential buildings in 2015. The 2015 height level is four stories. The three regional/rural study sites have a limited supply of residential land suitable for development. This shortage will become an issue before 2050 requiring additional new residential land to be made available for development purposes. The new residential land will add to the urban sprawl characteristics of the landscape.

Point 7 New residential and/or commercial development will add greater stress on existing physical and or natural infrastructure. Each of the four research sites will experience growth. The residential growth levels for the period 2016 through 2050 range from 35 to 50%. This growth will put stress on the natural infrastructure such as beaches, marshes and coast lines all of which are contained in the four study sites. The future residential development will require additional reticulated water and sewer systems. In the regional and rural study sites are serviced by a combination of septic sewer systems and reticulated

Point 8 The exodus of commercial and industrial jobs to peripheral greenfield sites away from the city centre. In Hobsons Bay and Portland industrial jobs are now being located in peripheral areas surrounding the respective locations as industrial land which is close to the city centres is being rezoned for residential purposes. The demand for residential land is such that current land uses are transformed into current and future residential areas.

Point 9 More mixed commercial/residential developments in the metropolitan and regional centers. The addition of the mixed use zone into the Victorian planning system allows for greater flexibility for mixed developments that contain both residential and commercial components. The four research locations each have had their planning legislation augmented to incorporate the new planning zone. Developers can obtain greater return through the use of mixed residential and commercial development.

CONCLUSION

The topic of land use planning is both complex and multifaceted. It is comprised of significant numbers of data sets, interdependencies, analyses, scenarios and outcomes. The research question specifically asked could visualization techniques portray the information so that it is easily understood and thus more likely to be used. Over 150 datasets, 100 assumptions, 100 attributes and 100 indicators were used in the spatial analysis of the four research locations. Through the process of visualization we saw what type of development would occur, where it would occur, when it would occur and the impact that development would have on the landscape and the environment.

The end product was a series of maps and charts that simply explained the proposed residential and commercial development of Portland, Apollo Bay, Anglesea and Hobsons Bay and it associated impacts till 2050.

A clear conclusion evident, when you compare all 4 coastal cities is that the impact of climate change will largely be as a result of coast line change and erosion arising from storm surges and water level increases. Subtle and least recognized co-impacts will be increases in the water tables within the cities resulting in changes to bore water supplies, increased flooding and ponding, artificial constant flooding of creek exits, wetlands and estuaries as a result of increases of water tables and sea water levels, major erosion impacts upon coastal edge road and bridge infrastructure thereby impacting upon the security of transportation, and increase risk of bushfire hazard. Bushfire, water table, estuarine flooding, and transport infrastructure impacts (compounded more so because the cities are totally dependent upon 2 exit roads in a time of bushfire event) are more concentrated in Apollo Bay and Anglesea due to their "at the edge" locations, whereas low-lying flooding and transport infrastructure impacts (and to a much lesser extent bushfire) will be more prevalent in Portland and Hobsons Bay. Thus, in all four instances long-established transport infrastructure historically erected to enable access to the aesthetic attributes of the beach and coast is at a corresponding risk to the coastal edge itself that has been the subject to the majority of climate change investigations, and the full-consequence of increase bushfire risk in Apollo Bay and Anglesea continue to be little comprehended and planned for. The research, while accordingly with conventional conclusions about prospective changes to the coastal edge as a consequence of climate change, has identified additional variables that are being little comprehended and incorporated in strategic planning; such variables may in fact have greater consequences upon human life and safety than previously understood. Thus research in need to be understand the complexity of climate change upon these cities and not be blinkered by the excessive literature rhetoric about coastal edge change but approach the topic holistically using a greater raft of technologies, scenario-making and perspectives. ■

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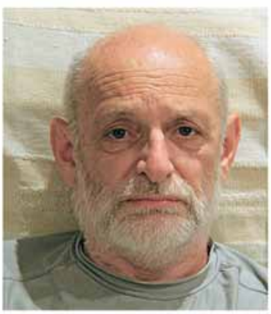

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