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Energy, Transport, Waste and Water Demand Forecasting and Scenario Planning for Precincts:

Workshop 3 - Model specification, development and
integration.



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Executive Summary

The following report presents the outcomes of the third workshop associated with this project, held at the University of South Australia's Mawson Lakes Campus on Thursday the 15th of May 2014. The focus of this workshop is model specification, development and integration for integrated ETWW demand forecasting. Project workshop topics follow on from the second ETWW project workshop (Holyoak, 2014) and continued research with connections to other CRC projects as they progress. It has delivered an integrated framework for forecasting the demands and associated carbon impacts for energy, transport, waste and water within precincts. Forecasting based on the household unit will provide spatial unit descriptors with the temporal scale predominantly detailing carbon impacts over a typical day. Common scenarios are required for the forecasting task with necessary integration of the domains. During the workshop a number of presentations and discussions occurred on the content of previous research work, forecasting issues for the individual domains and specific forecasting issues.

The resulting framework recognises research activities associated with:

- Scenario development,
- Environmental inclusions such as the climate, infrastructure (built and green) and residential/commercial structures,
- Population profiling,
- Forecast modelling,
- Domain interactions,
- Resulting carbon impacts (with costing) and
- Behavioural inclusions.

Discussions also identified the need to utilise living laboratories as a source of information, in particular data related to behaviour and domain demands on a daily basis. Monitoring and survey exercises are recommended. The household will be the principal base modelling unit, described in terms of both the residential and physical attributes with residential typologies suggested to be based on the Mosaic data structures. Households have different activities and therefore different carbon impacts through energy, transport waste and water. Surveys and other sources of information may be possible along with existing databases such as those that reside with project partners. There is a need to clearly define the precinct with internal and external interactions and influences, in particular mixed land uses internally. Scenario definitions will initially take the form of four base conditions, identified as infill, greenfield, fringe metro and regional types with inclusions for commercial and household mixed land uses.

Introduction

The development of a shared platform for integrated ETWW (energy, transport, waste and water) demand forecasting and scenario planning will allow for the assessment of the carbon impacts and beyond under policy scenarios such as low carbon futures. This CRC for Low Carbon living project will focus on gaps, synergies, alternative approaches and required research directions to achieve its goals. It will include a series of facilitated national workshops on demand forecasting for ETWW utilities and services and on scenario generation and appraisal. The aim is to seek the development of integrated tools for demand forecasting and scenario evaluation covering ETWW with identified commonalities in data requirements and model formulation. It will first (Phase 1) develop an integrated framework for demand forecasting that will then be fully developed and implemented in Phase 2. A method for including the impacts of household behaviour change in demand forecasting will be a major component of the framework. In this way overall carbon impacts of urban developments or redevelopments can be assessed effectively and efficiently.

The following report presents the outcomes of the third workshop associated with this project, held at the University of South Australia's Mawson Lakes Campus, University Boulevard, Mawson Lakes, South Australia on Thursday the 15th of May 2014 at Room X1-03 at from 10:00am until 4:00pm. The focus of this workshop is to follow on from the second ETWW project workshop (Holyoak, 2014), focusing on model specification, development and integration for integrated ETWW demand forecasting. This report presents the key outcomes of the workshop, summarising discussions during workshop sessions with conclusions and a synthesis of these outcomes presented for the next stages of the research progress.

Present State of the CRC - A presentation by M.A.P. Taylor

The Cooperative Research Centre for Low Carbon Living has 3 programs focussed on integrated building systems and low carbon precincts. The ETWW project (RP2002) exists within program 2: low carbon precincts. The current research activities within this program are:

- 2.1: Digital information platform for informed precinct design,
- 2.2: Integrated assessment of eco-efficiency during precinct design,
- 2.3: Precinct-level demand forecasting for distributed infrastructure,
- 2.4: Health and productivity co-benefits.

Outputs from these research activities relate to a precinct design and assessment approach, with the development of and integrated tool and resources. There are 6 projects related to program 2 that are currently underway with another 2 now complete. The Work Packages (WP) associated with program 2 are as follows. These work packages also connect with the other programs and project RP2002 is related to Work Packages 2 and 3.

WP1 – Digital information platform

WP2 – Software tool

WP3 – Designing zero carbon precincts

WP4 – As-designed vs as-operated

WP5 – Smart buildings and precincts

WP6 – Demonstration projects in Living Laboratories

It should be noted that the difference between WP4 and WP6 is that WP4 involves the comparison of designs and operation and WP6 involves living labs and data generation. Over the 7 years of the current CRC research future, there will be a need to estimate the megatons of CO₂ that CRC-related activities such as demand forecasting, PIM, health and productivity co-benefits and the precinct carbon assessment have impacted.

Summary of Relevant Outcomes to Date - A presentation by N. Holyoak

Workshops 1 and 2

The outcomes of project Workshop 1 (Holyoak, 2013) and Workshop 2 (Holyoak, 2014) have been summarised reports that provide insights into each of the domains focussing on forecasting, data, relevant research, software and more. These reports reveal that the modelling approaches for the transport, energy and water domains are mature in comparison to the waste domain. Associated with this observation is the availability of richer data sources associated with the mature forecasting tasks. Within the energy domain, demand forecasting approaches exist, but there are questions over the incorporation of behavioural elements. Longer term forecasting may be problematic, especially with the impacts of new technologies (i.e. solar PV, electric vehicles) and potential policies associated with them. The transport domain has well established base forecasting approaches, based largely on household-level datasets. A range of behaviour-inclusive forecasting approaches with differing resolutions can be applied through various software platforms with investigations into nano-scale software such as Commuter underway. TAZ definitions offer a useful approach to precinct scale forecasting with approaches now suggested for this process.

Top-down forecasting approaches are preferred for the water domain, based on population and demographic datasets. A forecasting methodology similar to that suggested by Polebitski and Palmer (2010) based on census tracts is suggested and a range of software packages are available. Representing behaviour changes pose a challenge for water demand forecasting particularly as it has been proven that water-usage behaviours are elastic and can be influenced. Modelling approaches for the waste domain are not well developed, with the need to consider the scope for inclusions and the degree to which waste is considered as a resource. Limitations on datasets for base forecasting and software pose challenges for the waste production forecasting task along with long-term policy and technology uncertainties.

Discussion on issues associated with the complete forecasting task recognising that integration of forecasting tasks for the domains introduces a range of challenges for the successful development of a modelling framework. This is emphasised by the differing nature and maturity of the forecasting approaches. All domains should consider potential interaction opportunities within their respective model frameworks and seek a cohesive integration approach.

Utilising data through a format of 'representative' or 'stereotyped' households and land uses may offer one approach to successful scenario development. Scenarios should consider time frames with the consideration that short-term forecasting of behaviour change will provide results with greater confidence when compared to longer term. The forecast resolution should be guided by the available data used in describing the precinct and in particular the nature and behaviour of the precinct in relation to household behaviour, adoption of technologies and land use mixes. In these cases, industry can offer guidance in terms of what is expected from the forecasting routines and potential policy inclusions.

Other data-handling opportunities exist with the application of GIS-based software that can represent inputs such as ABS data, Mosaic data, domain-specific spatial land-use/socio-demographic data, and networks for transport, electricity, water and waste infrastructure. In addition a GIS could offer a useful means of representing carbon outcomes from demand and behaviour change. For each domain it is essential to realise the impact of activity happening inside the precinct on what happens outside and vice versa. The question of 'where to draw the line?' arises is present in all domains, especially highlighted for the waste domain regarding material lifecycle and embedded waste. It may be impossible to accurately account for complete carbon impacts based on the precinct forecasts however, limitations need to be noted.

Participant Surveys

Project participant surveys followed on from Workshop 2 inviting those involved in the project to respond to a series of simple questions raised during Workshop 2 and needed more input. It was structured as a simple 15 minute online questionnaire containing 9 questions. The survey was conducted in early 2014 and gained a total of 8 responses. Expertise domains of the respondents is summarized in Figure 1 with the exception of one respondent who reported expertise in multiple domains of carbon - water – energy.

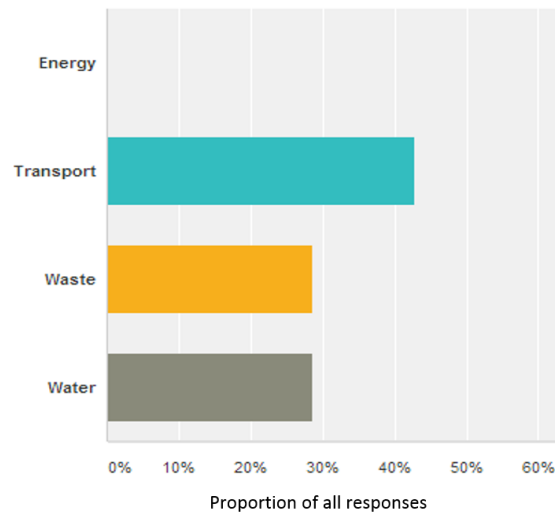


Figure 1: Expertise domains reported from respondents.

A number of datasets were identified in the survey relevant to the forecasting process in one or multiple domains. These datasets are coarsely ranked in order of importance and number of mentions in the responses.

- Australian Bureau of Statistics (ABS) datasets – Australian Census and beyond,
- Mosaic datasets,
- Household travel survey ,
- Traffic count specific ,
- Revealed and stated preference datasets in all domains,
- Lots of GIS data sets lot of transport models,
- GPS traces of person/vehicle movement,
- Freight movement data (but not for passenger travel),
- Sydney Water data on water usage and bills.

Expansive datasets such as those produced by the ABS and the Mosaic data can provide useful descriptive information on precinct populations. This data can be supported by other sets to provide further detail on behavioural aspects and other information useful to the modelling process. In order to apply the data to modelling routines, a common demand forecasting base-unit is required. At a precinct level, a number of options are available demand forecasting and Figure 2 identifies some of the more popular units.

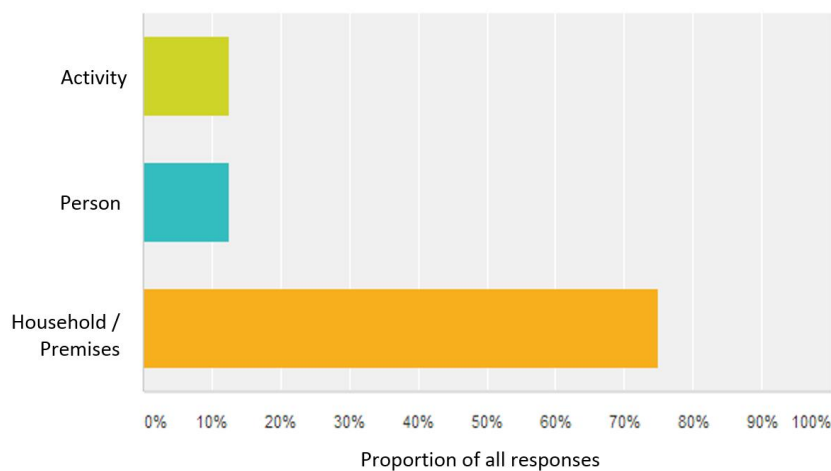


Figure 2: Base forecasting unit response.

As can be observed from Figure 2, the household (or premises when considering non-residential land use) is the most appropriate forecasting unit. Other levels may be applied but not for the principal forecasting tasks. In addition to the forecasting base unit, the resolution or adopted time-scales should also be determined for framework application. Figure 3 following illustrates the responses from a survey question directed at this issue.

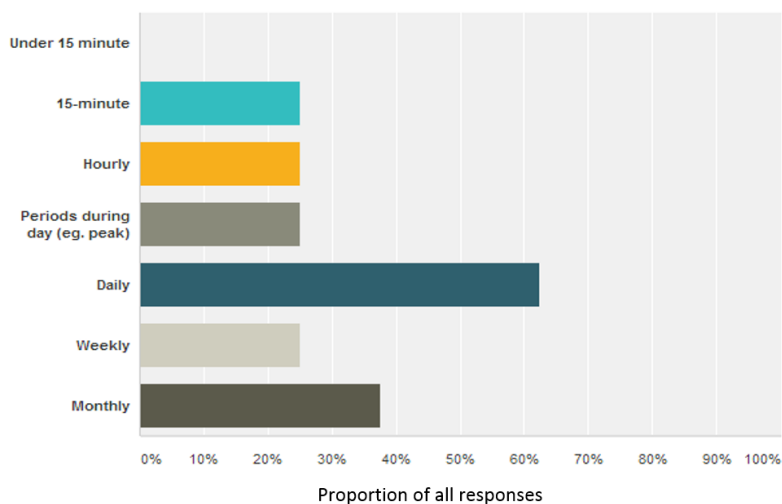


Figure 3: Base forecasting unit response.

All resolutions were popular here, and of course dependent upon the forecasting domain however the daily seemed to be marginally more accepted as the most appropriate level. One approach here is to adopt the finest level of resolution possible for forecasting and calculation purposes and aggregate to common time frames as required, eg. when compiling forecast results from the domains. Some additional comments from the survey included that “Forecasting has to be done over many time scales eg 15 min for travel time, peak energy demand, and longer periods (days, weeks) for long term planning. Weeks are important to see variations over day of week and over a given day of the week over time” and another respondent suggested that the timeframes could be longer.

The following list of potential interactions between ETWW domains at the precinct level were identified by respondents as:

- Transport-Energy: Electric vehicles,
- Transport-Energy + Waste + Water: Telecommuting/shopping/activities and in-household activity,
- Transport-Waste: Wasted time in congestion,
- Water-Waste: Waste water,
- Energy-Water: Water supply including desalination,
- Energy-Water: Distribution networks,
- Energy-Water: Waste water collection networks,
- Energy-Water: Water utilised in energy generation,
- Energy-Waste: Embodied energy,
- Energy-Waste: Recycling/reuse.

The framework will seek to maximise the possible interactions represented in the forecasting and indeed expand on this list where possible. Discussions during the workshop and identified later in this report address this specific issue. Survey respondents were also asked to identify any potential forecasting scenarios for model application. The following list identifies these, with many scenarios domain specific and rather than providing a detailed development, most suggestions identify important aspects that may be recognised in a scenario:

- Household-based: income change, car ownership change, household profile,
- Housing type and location relative to services and facilities,
- Choice of travel mode,
- Demographics and propensity to install onsite power generation (solar panels etc.) level of awareness and education,

- Long-term changes in lifestyles and attitudes,
- There are several important behavioural aspects that should ideally be included as variables in the model. However, some like income, educational attainment, profession, family situation (size of family, ages and number of children etc.),
- Awareness of and proximity to +/-ve impacts of behaviour,
- Offspring, grandchildren, pets,
- Role models or social network/capital, behaviour of immediate friends and family,
- Cultural background,
- Age, ability to perform certain tasks - walking, composting,
- Vehicle ownership, access to shared vehicles ,
- Space, size of dwelling, demographics of other occupants, the individual's role within the dwelling,
- Low demand,
- Low pollution,
- Localisation provision of essential goods and services (and polluting impacts of provision) ,
- Cheapest/most affordable lifestyle.

Other contributions included comments on the need to identify the intended primary user/customer of the tool and also that identifying factors that affect all ETWW domains and making them central to the modelling approach would be a good first step.

An ETWW Forecasting Framework Proposal

Developing a framework to estimate the carbon impacts of ETWW forecasts is the essential research task in this project. The following proposed forecasting framework is based on the outcomes of previous workshops, researcher developments and participant surveys. It has a recognition of core processes and connections with other CRC activities and work packages. Discussions and suggestions arising from this workshop have also guided the revised framework structure presented in Figure 4 with recognition of:

- The location of item 6 “Resulting Carbon Impacts” required to be outside of the PIM-GIS data management structure.
- The need for the framework to recognise presence of both the built and green infrastructure within the precinct. Green infrastructure such as parks and natural spaces is of importance to carbon impact forecasting.
- At the early stages of the framework definition, the tool will need to be able to assess precincts within regions outside of the metropolitan area (such as Roseworthy, Buckland Park, Concordia in South Australia).

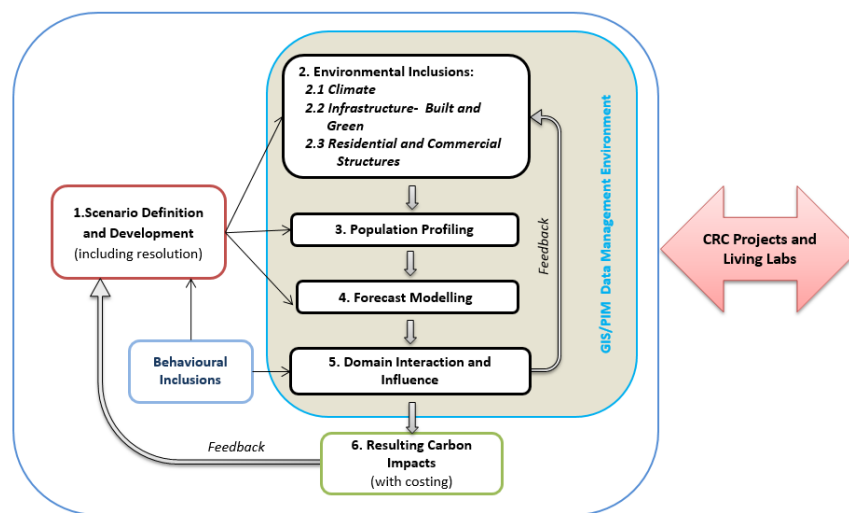


Figure 4: ETWW project forecasting framework.

The following paragraphs detail the desired requirements and considerations for each of the framework inclusions, i.e. the numbered boxes from Figure 4.

1. Scenario Definition and Development

Determination of base year and condition and the forecast year/s with their respective policy implications and recognition of potential technology inclusions. There may therefore be many combinations of future year forecast conditions. One suggestion is to present four base conditions, identified as infill, greenfield, fringe metro and regional types with inclusions for commercial and household mixed land uses. Considering the temporal dimension, forecast years should be adopted from the CRC-LCL, State Government or other external influence. Considering the need for the model to interact with CRC-LCL work packages and activities, the forecast years need to recognise CRC requirements. The original project proposal focuses on a residential precinct definition and a 10 year forecast.

Population typologies will assist in the forecasting process, allowing for a practical approach to socio-demographic data definition and modelling processes thus helping to address the challenge of quantifying the impact of behaviour. Representative definitions should be based largely on those defined in the Mosaic dataset (Experian, 2013) which defines 11 major household groups, consisting of 47 types (Figure 5). Proportions of each type within the precinct will establish the nature of the precinct population. Additional datasets will assist in developing the household’s behavioural characteristics, important for the representation of behaviour change. Matching household-level Mosaic data to household-level energy, transport, waste and water data would allow an understanding of how changes in certain household characteristics are likely to impact these domains in the future.

Groups	Types	Label	Tagline	% Household
A		Privileged Prosperity	The most affluent families in the most desirable locations	8.4%
	A01	Portfolio Management	High-spending, established families in the wealthiest suburbs	0.9%
	A02	Studded Wealth	Well educated, maturing families in prime suburbs	1.7%
	A03	Cultural Riches	Successful mid-suburban families in strong migrant communities	1.3%
	A04	Executive Residents	High-consuming maturing families in comfortable outer suburban homes	1.9%
	A05	Family Success	Well-off family households in desirable outer suburban locations	2.5%
B		Academic Achievers	Wealthy areas of educated professional households	6.2%
	B06	Informed Affluence	High income families and singles in the attractive middle suburbs	2.3%
	B07	Conscious Consumers	Comfortable one and two-person households in sought after suburbs	2.0%
	B08	Professional Knowledge	Young families with high disposable incomes in quieter suburban neighbourhoods	1.9%
C		Young Ambition	Educated and high-earning young singles and sharers in the inner suburbs	5.9%
	C09	Bright Futures	Thriving students or professionals renting flats and terraces	2.0%
	C10	Graduating Upwards	Young high-earning socialites in high-rise apartments, often close to water	1.9%
	C11	Rising Wealth	Educated and affluent young professional couples in inner city areas	2.0%
D		Pushing the Boundaries	Young families living in recent developments on the fringes of major cities	5.8%
	D12	Hard hats, Steel Caps	High income younger households in mining communities	0.6%
	D13	Cul-de-Sac Kids	Mortgaged families living in the better-value outer metro fringes	2.2%
	D14	New Lives, New Landscapes	Young families living in recently developed outer suburbs of larger cities	1.6%
	D15	Mortgaged Aspirations	Culturally diverse young families living in high-density suburban communities	1.3%
E		Family Challenge	Mixed family forms with stretched budgets in outer suburbs	13.8%
	E16	Families in Formation	Couples and families with young children living in recent outer suburban locations	2.7%
	E17	Home Entertainment	Blue-collar families living in older pockets of the outer suburbs	4.2%
	E18	Domestic Divides	Single parents and varied family structures in outer suburban communities	3.0%
	E19	Conforming Kinship	Cash-strapped late middle aged traditionalists in outer metro areas	3.9%
F		Metro Multiculture	Medium to high density areas with much cultural diversity	10.9%
	F20	Intercontinental Connections	Established Eurasian migrants in mid to outer suburban areas	3.1%
	F21	New Wave	Mixed generations of immigrants living in changing inner metro areas	1.9%
	F22	Devoted Diversity	Mature and religious close-knit families in newer metro fringe developments	1.5%
	F23	Mediterranean Style	Established low income migrant home owners around suburban retail centres	1.6%
	F24	Bilingual Backgrounds	Mixed age multicultural areas of mainly blue-collar employment	1.7%
	F25	Enclavic Origins	Culturally diverse extended families with high unemployment in the inner city	1.0%
G		Learners & Earners	Students and professionals living in high density, lower cost suburbs	4.8%
	G26	Social Networks	Students and early careerists building their futures and enjoying city life	2.5%
	G27	Strengthening Skills	White and blue-collar residents often in culturally diverse, high-density rented areas	1.6%
	G28	Asian Studies	Campus and CBD-dwelling students, often from Asia, with low incomes	0.7%
H		Provincial Optimism	Anglo-Australian blue-collar families in provincial settlements	10.5%
	H29	Approaching Retirement	Emptying nests, reducing debt and preparing for retirement	3.1%
	H30	Blue-Collar Regeneration	Older trades and labourers in changing low-priced regional areas	3.6%
	H31	Reforming Relationships	Challenged households in provincial towns and popular holiday spots	2.8%
	H32	Traditional Owners	Indigenous Australian communities and affiliated service workers in remote locations	0.9%
I		Farming Stock	Rural landowners and workers in agricultural heartlands	9.7%
	I33	Rural Lifestyles	High value farms and smallholdings surrounding major urban centres	4.2%
	I34	Off the Beaten Track	Older farming couples in hilly areas and coastal plains, often in tourist regions	1.7%
	I35	Country Pride	Established farms and traditional families on prime agricultural land	2.4%
	I36	Outback Isolates	Families farming the most extensive and remote parts of Australia	0.9%
	I37	Living off the Land	Low income, low-consuming families on large farms remote from services	0.6%
J		Suburban Subsistence	Low income, low-spending households in major regional and outer metro	11.1%
	J38	Low Equity Strain	Cash-strapped younger singles living in flats and units, often rented	2.0%
	J39	Cut-Price Living	Low-earning students and professionals in higher density locations	2.9%
	J40	Bargain Basement	Low income elderly in provincial towns and the outer suburbs	2.3%
	J41	Making Ends Meet	Older home owners in aged care communities in regional and outer metro areas	1.9%
	J42	Blue-Grey Blend	Coastal and provincial retirement communities with some younger bargain hunters	2.0%
K		Community Disconnect	Older blue-collar workers and retirees in country and coastal locations	13.0%
	K43	Same Old, Same Old	Low income, non-metro homes, accommodating older singles and couples	4.2%
	K44	Fractured Families	Disadvantaged singles living in inexpensive accommodations	1.8%
	K45	Country Town Elders	Small country towns with older singles and couples on very low incomes	2.7%
	K46	Beachside Benefit	Low income older married couples mainly in coastal areas	2.6%
	K47	Good Innings	Highly localised pockets of elderly retirees in supported accommodations	1.7%

Figure 5: Grouped household types in the Mosaic Australia data structure, [source: Pacific Micromarketing, 2014].

Household attributes defined in the Mosaic dataset are comprehensive, as illustrated in Figure 6. Mosaic datasets have been developed primarily with marketing purposes in mind, however many of the household attributes presented should enhance precinct forecasting applications especially when applied alongside ABS and Census datasets. Scenarios developed as part of other CRC-LCL work packages will provide guidance as to future trends in terms of precinct socio-demographic and population profiles.

Mosaic Australia Data Sources

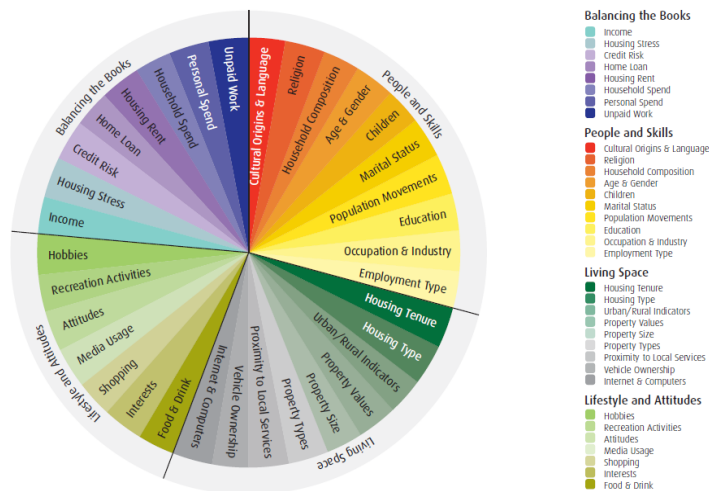


Figure 6: Mosaic Australia data types, [source: Pacific Micromarketing, 2014].

2. Environmental Inclusions

Newton et al (2013) as part of the CRC-LCL project RP2001 on 'Scoping study for precinct design and assessment tools' provide the following definition of a precinct:

'a precinct can be represented as an urban area of variable size that is considered holistically as a single entity for specific analyses or planning purposes, as well as in a contextual sense to represent the interactions that occur with elements of the surrounding urban area. It typically comprises land parcels occupied by constructed facilities (generally buildings), including open space, and often clustered in to urban zones that share some common characteristics (uses) and supported by physical infrastructure services to manage energy, water, waste, communication and transport as well as a range of social infrastructures related to health care, education, safety, retailing and entertainment'

From a model forecasting perspective this definition of a precinct suits the ABS definition of an SA1 geospatial zone classification and may also be applied to a collection of mesh-blocks. From a transport planning perspective a Traffic Activity Zone (which many transport forecasting procedures adopt) would also comply with this precinct definition. Geospatial data management and representation through GIS/PIM will assist in this and beyond into the forecasting processes.

Land-use mix within the precinct may comprise of residential, commercial, recreational, services, industrial and other land use mixes. Beyond the precinct, the forecasting framework should incorporate the influences of and external precinct components and carbon impacts.

Climate

Annual climate profiles and local forecasting tools will be an essential part of the environmental components, defining peak periods and extreme conditions, primarily for water and energy use forecasts but also to the waste production and transport needs of the precinct. The Thornthwaite moisture index (Austroads, 2004) can provide guidance on possible climate futures here.

Infrastructure – Built and Green

Built infrastructure relevant to the forecasting domains relate mainly to the networks that exist within the precinct. Some examples of these are:

- Transport – private and public, motorised and non-motorised,
- Energy – electricity, gas, locally generated,
- Water – supply, wastewater, locally supplied,
- Waste collection – recycling, landfill,
- Telecommunications and data

Internal networks will require detail in terms of location, components, attributes and operational characteristics however external connections are relevant also. Green networks, largely composed of parks including natural spaces and

recreation facilities are important to carbon impact forecasting. These networks connect with and interact with components of the built environment and infrastructure age and complexity will need to be addressed. GIS/PIM based data techniques are particularly suited to the definition of infrastructure with a geo-spatial component.

Residential and Commercial Structures

Land use within the precinct as residential and commercial structures require definition based on the land use attributes. Residential structures can again be categorised based on the attributes of:

- Land area,
- Ratios of built to green areas to accommodate density, (eg. floor area vs building footprint vs green area),
- Age,
- Efficiency measures (rainwater catchment, solar power, etc.),
- Parking provision,

Commercial or non-residential land uses need to be defined as a land use based on a manageable classification of land use types associated with the activity, such as those defined in the ANZSIC codes (ABS, 2006) including:

- Agriculture, Forestry and Fishing
- Mining
- Manufacturing
- Electricity, Gas, Water and Waste Services
- Construction
- Wholesale Trade
- Retail Trade
- Accommodation and Food Services
- Transport, Postal and Warehousing
- Information Media and Telecommunications
- Financial and Insurance Services
- Rental, Hiring and Real Estate Services
- Professional, Scientific and Technical Services
- Administrative and Support Services
- Public Administration and Safety
- Education and Training
- Health Care and Social Assistance
- Arts and Recreation Services
- Other Services

Attributes of the commercial land use are simpler than those for residential and may be described largely in terms of land/gross floor area and if any efficiency measures are in place. Public facilities such as schools, parkland or hospitals should be uniquely identified and described in the same way as commercial land uses with any particular additional descriptive relating to the scale of activity such as patients, students or employees.

Additional metrics used to describe the scale of activity relating to any particular domain may be added to the list here as defined by individual forecasting procedures.

3. Population Profiling

Internal precinct populations will be profiled in terms of household typologies, based on household resident attributes and linked to scenario development. It is possible to generate synthetic populations with well-developed methods in existence making use of readily available data such as that from the ABS. Behaviour inclusions will allow for forecasting the impacts of behaviour change and responses to scenario definitions. Mosaic may play a role in the development of these profiles.

4. Forecast Modelling

Forecast resolution will be established in scenario development stage, recognising the importance of the peak periods and seasonality, focussing on the daily forecast, and others including 15 minute, 1 hour and aggregated to monthly as required. An appropriate resolution is dependent on the infrastructure and the services that use it.

Modelling processes should make best use of existing/developed modelling tools. Some of these approaches including software include:

- Energy: Neural Network forecasting, software such as Gridlab-D, Accurate
- Transport: Strategic modelling packages such as CUBE, EMMIE, Aimsun, Commuter,
- Waste: Developing, regression techniques, time series, surveys

- Water: Time Series, ANN, geographically-weighted multiple regression such as Wentz and Gober (2007) and Polebitski and Palmer (2010) approach to census tracts, in addition to software options such as Innovyse, SimulAlt, Switch2

Precinct level models are summarised as part of the CRC’s project RP2001, (Newton et al, 2003) “Performance Assessment of Urban Precinct Design”. Data to assist in the forecasting processes may include, but is not limited to the following:

- Energy Data from Solar Cities and Low Income Energy Efficiency Program and Residential Building Energy Efficiency Standards Repository: domestic energy use profiles, Development and use of smart-meters and cognitive metering (Living Labs),
- Transport Data from household travel surveys and activity based survey data, detail required, micro-scale activity modelling, GPS data,
- Water Data from end-use surveys, historical consumption trends, BASIX, Supplier-based usage data (eg. Sydney Water and/or SA Water),
- Waste Data from council-level data, ABS, from research.

Previous framework stages 2 and 3 will be guided by the requirements of the forecasting approach adopted for each of the domains.

Living Laboratories are of special significance here with the potential to provide a rich and comprehensive data source for forecasting applications. Current potential living laboratory sites in Adelaide include Lochiel Park (figure 8), Tonsley and Bowden. Others exist in capital cities around Australia. Other locations that have greater maturity in their development such as the New Haven village (Parker, 1998) can also offer an insight into how precincts and their occupants develop over time (Figure 7).



(Source: Lindsay Oxlad).



(Source: Google).

Figure 7: Residential development at New Haven village in Adelaide



Figure 8: Residential development at Lochiel Park in Adelaide (Source: Google).

5. Domain Interactions

Interactions between the forecasting domains have largely been identified in previous workshops and surveys however a comprehensive list of interaction types appropriate for the forecasting task at a precinct scale is defined as follows:

- Transport-Energy: Electric vehicles
- Transport-Energy + Waste + Water: Telecommuting/shopping/activities and in-household activity
- Transport-Waste: Wasted time in congestion

- Transport-Waste: Waste removal vehicles
- Water-Waste: Waste water
- Energy-Water: Water supply including desalination
- Energy-Water: Distribution networks,
- Energy-Water: Waste water collection networks
- Energy-Water: Water utilised in energy generation
- Energy-Waste: Embodied energy
- Energy-Waste: Recycling/reuse
- Water-Transport: Congestion caused by burst water mains, transport of water, stormwater and the coincidence of water and transport networks, flooding
- Energy-Water-Waste: Biofuels

The relative strength of the domain connection due to the interaction will vary and the feasibility of representing the connection in a forecasting framework will need consideration and will again depend on the modelling approaches adopted.

Results of the forecast including the interaction effects may be required as a feedback information loop into Stage 2 where a redefinition/re-estimation of the environmental inclusions may be required. Alternatively, demand forecasts will be utilised by the following stage to forecast resulting carbon impacts.

6. Resulting Carbon Impacts

Carbon impacts relating to each of the four domains will be forecast using well developed tools for the estimation of carbon production. This assessment will not only involve the estimation of carbon volume but also the location of the production, most critically either within or outside of the precinct boundary. Application of the 'Economy-Wide Carbon Accounting' framework as identified by Tommy Wiedmann in Workshop 2 will be valid with scenarios compatible with the National Greenhouse Gas Inventory. This could be complemented with existing utility carbon estimation tools (especially present in the water and energy domains).

Information feedback exist from this framework stage into the first stage of scenario definition. An iterative process between carbon estimation and scenario definition will help in the development of forecast scenarios with optimal efficiency of reducing the carbon impacts of the precinct. In this way, the model users can seek scenarios with maximum effect with the applied resources or the biggest value for money in terms of carbon impacts.

Emission rates of vehicle classes - A presentation by I. Iankov.

This presentation explains how vehicle emission rates necessary for forecasting road transport greenhouse pollution are determined. At the beginning the required level of disaggregation is discussed and the consensus is reached that the best practical approach is to utilise emission rates of four vehicle classes, which are Small Passenger Vehicles (PV), Medium PV, Large PV and Light Commercial Vehicles; disaggregated by their year of manufacture. The adopted methodology allows obtaining 90% confidence interval of emission rates. The performed sensitivity analysis confirms that the obtained results are applicable for the entire range of tasks, which may be required when forecasting transport pollution at precinct level in Australia.

The presented study contributes significantly to the field of forecasting of transport greenhouse pollution because it guarantees estimating pollutions from vehicles with year of manufacture less than 2012 in accurate and confident manner. Also, it offers great flexibility by allowing exploring various scenarios for composition of road traffic by vehicle age and class.

Demand forecasting for municipal waste management (MWM): toward the integration of the waste domain in a shared ETWW tool platform - A presentation by He He.

This presentation focuses mainly on three aspects. Firstly, the general autoregressive moving-average (ARMA) model will be used in the demand forecasting of municipal solid waste management (MSWM). The concept of ARMA is that for time order $\{x_t\}$, it not only has the relevance with $\{x_{t-1}\}$, $\{x_{t-2}\}$, $\{x_{t-n}\}$, but also is disturbed by $\{a_{t-1}\}$, $\{a_{t-2}\}$, $\{a_{t-m}\}$.

The general ARMA equation is $x_t = \phi_1 x_{t-1} + \phi_2 x_{t-2} + \dots + \phi_n x_{t-n} - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \dots - \theta_m a_{t-m} + a_t$,

Where ϕ_i ($i=1,2,\dots,n$) is the autoregressive operator; θ_j ($j=1,2,\dots,m$) is the moving average operator; a_t is the Gaussian white noise. Secondly, the factors which influence demand forecasting of MSWM system involve environmental attitudes, situational variables, psychological factors and infrastructure. Actually, the MSWM behaviors which include Avoid, Reuse, Reduction and Reuse are affected by these factors. And then the MSWM behaviors result in the change of demand forecasting of MSWM system. The effects of these factors will be assessed by Input-Output model. Thirdly, the household is considered as the basic unit. Through the analysis of waste stream in the household, this research explores the relationships between waste and other three domains (energy, transport and water). From the environment perspective, a balance point may exist in the four domains, which means when the amount of energy and water rise, that of transport and waste would drop.

Developing a water demand forecasting model for estimating carbon emissions - A presentation by M Hadjikakou.

Accurate estimates of current demand trends as well as projections of future water demand are vital for water service providers as they dictate strategy and infrastructure development. Both under- or over-prediction of demand can lead to unsustainable decisions (Worthington and Hoffman, 2008). In light of the increasing frequency, severity and duration of drought events throughout Australia, the need to ensure a secure water supply for the population has been strongly emphasized (Willis et al., 2011). The use of some form of water demand forecasting model is a prerequisite if we are to meet this need. The water resources management literature is replete with diverse modelling possibilities for forecasting urban water demand in different settings, spatial and temporal scales and using a range of driving variables (House-Peters and Chang, 2011; Donkor et al., 2014). These range from simple statistical models based on historical data to complex and data-demanding system dynamics or artificial neural network (ANN) models.

The ETWW context is unique in the sense that the water demand forecasting model is to be integrated with energy, transport and waste models and must also deliver carbon estimates for a plethora of scenarios with an explicit consideration of behavioural factors. For this reason, we propose the use of a two-component water demand model which consists of a top-down component based on a geographically weighted regression model (Polebitski and Palmer, 2009; Wentz and Gober, 2007) along with an end use component based on existing data from previous Australian studies (Makki et al., 2013; Willis et al., 2011; Roberts, 2005; Loh, 2003). This allows estimates of the energy embedded in supplying water to households as well as the energy required for collecting and treating the wastewater resulting from end use. An additional attribute of such a model is its ability to estimate a change in water demand (Δ demand) associated with different precinct scenarios. In cases where the model highlights significant water demand increases which exceed current capacity, estimates of the necessary expenditure from Sydney Water will be used alongside carbon accounting methods to estimate the additional carbon associated with any infrastructural upgrade.

Breakout Sessions and Focussed Discussions

During the breakout sessions, two groups were arranged from the workshop attendees and asked to address the following set of question topics. A limited time was allowed for this task (45 minutes).

- What is the desired base modelling unit and forecast resolution? What are the issues?
- How can the forecasting approach represent behaviour change? Which types of behaviour should be represented?
- What are some of the desired outputs?
- What are some of the desired domain interactions? How can these be achieved?
- What do you see as the boundaries / limitations of the forecasting approach?
- Other comments...

The household is seen as the appropriate base modelling unit with a spatial representation within the precinct. Forecast resolution should be domain dependant with energy and transport as daily however energy modelling can occur minute by minute and aggregated. Waste may be weekly forecasts. Carbon impact estimates for all domains should recognise peak periods. Water has 1 daily peak, transport has 2 daily peaks and energy has 2 daily peaks and these are more exaggerated.

Monitoring data from living labs to allow us to monitor the levels of behaviour change influence. Surveys should be used to elaborate and enrich the data on behaviour change. This also may be gathered from living lab sites.

Carbon impact forecasts require a 'singular' demand output to provide information that can state "with this scenario for a given precinct here are the ETWW forecasts". Inter-domain interactions are an important component and users will need to know if a scenario will lead to an adverse carbon impact in one of the domains due to behaviour change related to another domain.

The credibility of model outputs may depend on the complexity of the model with graphical outputs assisting in interpretation. Beyond carbon impacts the forecasting should also provide estimates of cost and present results in a way that reflects the value for money impact. The economic impact must always be considered as well. Metric generality of results needs to be established as carbon and cost per unit (something) as outputs should be suitable for use in carbon emission models and economic analysis. One type of desired output is the potential saving that a scenario may present for the developer. An example of this may be how load management can reduce costs in the longer term.

Low carbon accounting is useful in allocating resource consumption/carbon performance related to a given precinct however there may be concerns about double counting the impacts. Care should be taken here. Strict boundaries need to be established around the precinct for model application with a recognition that all domains go beyond and below these boundaries. Results should reflect this.

Concluding Comments

This ETWW project workshop on the topic of model specification, development and integration, has delivered an integrated framework for forecasting the demands and associated carbon impacts for energy, transport, waste and water within precincts. Forecasting will focus on the household to provide base spatial unit descriptors with the temporal scale predominantly detailing carbon impacts over a typical day. Common scenarios are required for the forecasting task with necessary integration of the domains. During the workshop a number of presentations and discussions occurred on the content of previous research work, forecasting issues for the individual domains and specific forecasting issues. Recommended refinements to the original proposed framework included additional feedback loops, recognition of green infrastructure and presence of costing components.

Discussions also identified the need to utilise the living laboratories (past, present and future) as a source of data, in particular data related to behaviour and domain demands on a daily basis. Monitoring and survey exercises are recommended. The household will be the principal base modelling unit, described in terms of both the residential and physical attributes with residential typologies to be based on the Mosaic data structures. Households have different activities and therefore different carbon impacts through energy, transport waste and water. Households that appear identical can have very different behaviour and this is where the living labs can help to guide the research outcomes. Surveys and other sources of information may be possible along with existing databases such as those within Renewal SA, DPTI, SA Water and Sydney Water. There is a need to clearly define the precinct with internal and external interactions and influences, in particular mixed land uses internally. Scenario definitions will initially take the form of four base conditions, identified as infill, greenfield, fringe metro and regional types with inclusions for commercial and household mixed land uses.

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