MODELLING SELF-DRIVE TOURIST TRAVEL PATTERNS IN DESERT AUSTRALIA

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Abstract
Communities and local economies in the remote regions of Australia benefit greatly from the flow of tourist visitors. The majority of tourist travel occurs on the road network in these areas as a range of traveller types move between destinations. Realising the patterns of tourist flows can prove to be beneficial to planning organisations, smaller communities and individual tourist enterprises as this knowledge can assist in strategic planning processes.

Current survey databases of tourists travel behaviour along with data concerning road networks and destination locations allow us to model tourist flows in desert Australia. The resulting VRUM™ application provides illustrations of travel path, stopover locations and stopover duration for domestic and international tourists. This paper outlines the structure, processes and outcomes involved in the development of VRUM™ along with scenario modelling applications.

Key words: VRUM, tourism, traffic assignment.

1. INTRODUCTION
Local economies in the desert regions of Australia benefit greatly from the flow of tourist visitors. This provides support for businesses and in turn the local communities in which they operate. Many tourists access these remote locations by road as the self-drive modes of transport continue to be the most commonly used by tourists in Australia (Holyoak and Carson, 2008). The self-driven modes provide the traveller with a great deal of flexibility and independence when considering the destinations they visit and the route taken to access them. As a consequence it can be difficult for businesses and destinations to predict the travel patterns of multiple destination self-drive tourists (Shih, 2006).

This paper details the research progressed by the Desert Knowledge Cooperative Research Centre into modelling and visualising tourist flows in Australia. The resulting Visualising Relatively Unpredictable Movement (VRUM™) tool established in a transport planning and geographic information system (GIS) environment assists in the analysis of tourist flows such as that of multiple destination self-drive tourists in desert Australia. VRUM™ utilises the National Visitor Survey (NVS) and the International Visitor Survey (IVS) databases administered by Tourism Research Australia (2006a, 2006b) to model and represent the locations of overnight stops and the routes chosen between them. Additional representations of travel behaviour and activities can also be represented in the model environment.

2. TOURISM AND REMOTE AUSTRALIA
Remote regions of Australia are dominated by the desert region in central mainland Australia extending to include the regions in far Northern Australia. Figure 2 in a following section of this paper illustrates the areas bounded by the remote shaded region. This area contains many unique tourist attractions that include deserts such as the Simpson, Great Sandy and Tanami,

national parks such as Kakadu other attractions such as Uluru. Activity centres and accommodation clusters such as Alice Springs, Broken Hill, Mt Isa, Kalgoorlie, Coober Pedy and Darwin are also included. The activities undertaken in the region are wide ranging and include sightseeing, hiking, bird watching, four-wheel driving and so on. Many of the tourism operators are small to medium enterprises (SMEs) that, along with supporting infrastructure such as accommodation, restaurants, cafes and souvenir shops, generate wealth for local economies.

Those who visit the desert regions are composed of many traveller types including domestic Australian and international visitors, backpackers, families and retired couples. Some travellers will visit only one location as part of their itinerary but many others will journey to several destinations, undertaking a range of activities. Many of the locations in remote desert regions require more effort to reach and may have limited accessibility but in many cases this adds to their attractiveness to the tourist.

2.1. Tourism Trends in Remote Australia

The relatively poor performance of Australia's desert tourism destinations in attracting visitors during the 2000s has been previously documented (Carson and Taylor, 2009). In the years between 1999 and 2008 the number of domestic visits to desert areas declined by 10% and international visits declined by 8%. When this is compared to tourism on a National scale over the same period, domestic travel has also declined, but by just 3%, while international travel grew by 25%, a figure that includes tourism promoted by the 2004 Sydney Olympics. It is therefore evident that the desert regions have become a less attractive alternative for the tourist.

Accompanying the decline in tourists has been a reduction in transport services for the region. Air services across the remote desert regions (with the exception of several North-Western coastline towns) have steadily declined since the late 1990's. National coach companies have also experienced stress as three out of the five major companies have ceased operations over the past ten years. On top of this, the rail-based services have a limited capacity in terms of passenger volumes and service frequency. Carson and Taylor (2008) state that one key to strengthening the sector from within the desert is to identify markets which are more stable and profitable over time and which are able to be encouraged to explore new destinations and activities. Research conducted by the Desert Knowledge Cooperative Research Centre (Tremblay, 2005, Taylor and Carson, 2007a) has identified self-drive markets as having potential in this regard.

2.2. The Self-Drive Tourist

Self-drive travel modes are defined as vehicles that provide the traveller with flexibility in terms of their destination, timing and route choice. This includes modes such as automobiles that are private or rented, motor homes, motorcycles and campervans but does not include coach tourists. In 2006 more than 74% of Australian tourism trips were self-driven (Tourism Research Australia 2006a, 2006b). For this mode 80% of trips were for leisure related activities and domestic travellers (at 75% of travellers) preferred this mode more than international travellers (65% of travellers). In addition, the self-drive mode was far more common for trips involving multiple destinations over a single destination.

Self-drive tourism is often unpredictable and difficult to represent in a modelling sense. A privately driven vehicle offers the tourist a sense of independence in terms of travel timing, speed, destination choice and route choice as noted by Prideaux and Carson (2003). This behaviour is exacerbated when multiple destinations are considered as part of the tourists' journey. These multiple destination trips are particularly important for smaller and more remote destinations in Australia.

The self-drive tourism market also includes a unique type of journey-maker in the four-wheel drive tourist. Four wheel drive visitors to desert Australia have been found to have higher rates of repeat visits than other markets. These travellers often visit more destinations, take longer trips, and have higher in-trip expenditure than others (Taylor and Carson, 2007b). There are four key segments within the four wheel drive market in desert Australia (Taylor and Prideaux, 2008) that include:

- Explorers – travelling to areas away from main tourist activity,
- Activity seekers – those who use this mode to support another core activity,
- Thrill seekers – who travel to test their abilities,
- Novice – who utilise this mode for reasons of safety or for experimentation.

An understanding of the activity and behaviour of self-drive tourists, including four-wheel drive tourists, in remote Australia is important to communities in these regions. This is discussed in more detail in the later sections of this paper.

3. MODELLING TOURIST ACTIVITY

Representations of tourism activities in a modelling sense is attempted in Leiper's (1979; Lawrence, 2005) widely used tourist system model. This model however, is limited by allowing only one destination as an attraction point with other visited locations relegated to the role of a 'transit region'. Other research has been conducted by Lui, Crompton and Fesenmaier (1993), Mings and McHugh (1992) and Lew and McKercher (2002) into the typologies of trip patterns. This field of work investigates how different destinations to play different roles within the tourism journey. The resort development spectrum as described in Prideaux's (2000b) details the behaviour of travellers to multiple destinations. The traveller is allowed to first engage in the iconic activity as a priority and disperse mire widely over a period of time.

Wu and Carson (2008) published on a GIS which showed how locations of overnight stops changed according to the length of stay of visitors in Tasmania, and the clusters of destinations visited on multiple destination trips to South Australia. In New Zealand, Becken, Vuletich and Campbell (2004) developed a GIS showing the most popular routes for air travel on multiple destination trips. Outside the academic research sphere, Tourism Queensland has developed a GIS estimating the number of tourist vehicles who use specific road segments.

Knowledge of tourist travel behaviour is vitally important for several tourism business management operations as identified by Carson and Holyoak, (2008) with details provided in the following Table.

Process Area	Application Examples
Marketing	Markets may be segmented according to the trip patterns they employ. Visualising tourist movements will assist in the evaluation of marketing campaigns designed to influence dispersal or visitation to specific nodes
Information distribution	Understanding the order and direction of tourist movements will assist in making decisions about the placement of product and destination information.
Product packaging	The pattern of tourist movements suggests links between destinations and regions. Product packaging may extend beyond the boundaries of a single region to improve the total visitor experience.
Product development	Nodes with different functions in itineraries may require or benefit from different types of product. Nodes which are, or may become hubs, for example, will require accommodation, food and beverage, and service products.
Transport/ access	Changing the level of transport access to a destination may affect its relationship to other destinations. In general, destinations that act as dispersers or hubs require good entry access and a variety of ground transport options. Terminus nodes have efficient transport from places of origin, but limited transport for dispersal.
Policy	The research demonstrates substantial linkages between destinations crossing existing administrative boundaries (local government, tourism region, and even State borders). To exploit these linkages, it will be necessary to have policy leadership which not only approves, but encourages multi-regional collaborations.
Research	Understanding the spatial movements of travellers offers opportunities for conducting cost effective visitor research. Hub nodes are likely to present opportunities to collect data from a wide range of visitors to regions outside that hub, for example. Nodes which are closer to the end of trips may be useful for measuring visitor satisfaction with previously visited nodes.

Table 1: Applications of Visitor Flows Information.

In summary, the modelling of tourist activity and in particular the travel path adopted by tourists as they travel between destination locations is critical for the successful deployment of tourism-based policy strategies. GIS based models can greatly assist in the interpretation of these modelling activities.

4. NATIONAL AND INTERNATIONAL TOURIST SURVEY DATA

An essential component of the VRUM model development is the database developed by Tourism Research Australia developed from the International Visitor Survey (IVS) and National Visitor Survey (NVS). Each survey included approximately 25 000 respondents each year from 2000 to 2004 and 40 000 respondents in 2005 and 2006. The unit record files in these datasets provide information concerning travel made by domestic and international travellers within Australia. Typical information on the travellers themselves and their behaviour is also collected as summarised in (but not limited to) the following Table.

Data Type	Descriptor
Personal	Gender Country or origin / Australian residence Annual Income Employment status Lifecycle stage
Journey Related	Size and composition of the travel party Travel modes Purpose of travel Stops and duration Accommodation used Major attractions visited Activities undertaken Expenditure

Table 2: Data types present in the IVS and NVS database.

The information contained within this database is essential to the modelling operations carried out in VRUM as detailed in the following sections of this paper.

5. VRUM™ MODELLING OF SELF-DRIVE TOURISTS

The following diagram illustrates the data and processes that are involved in the VRUM application.

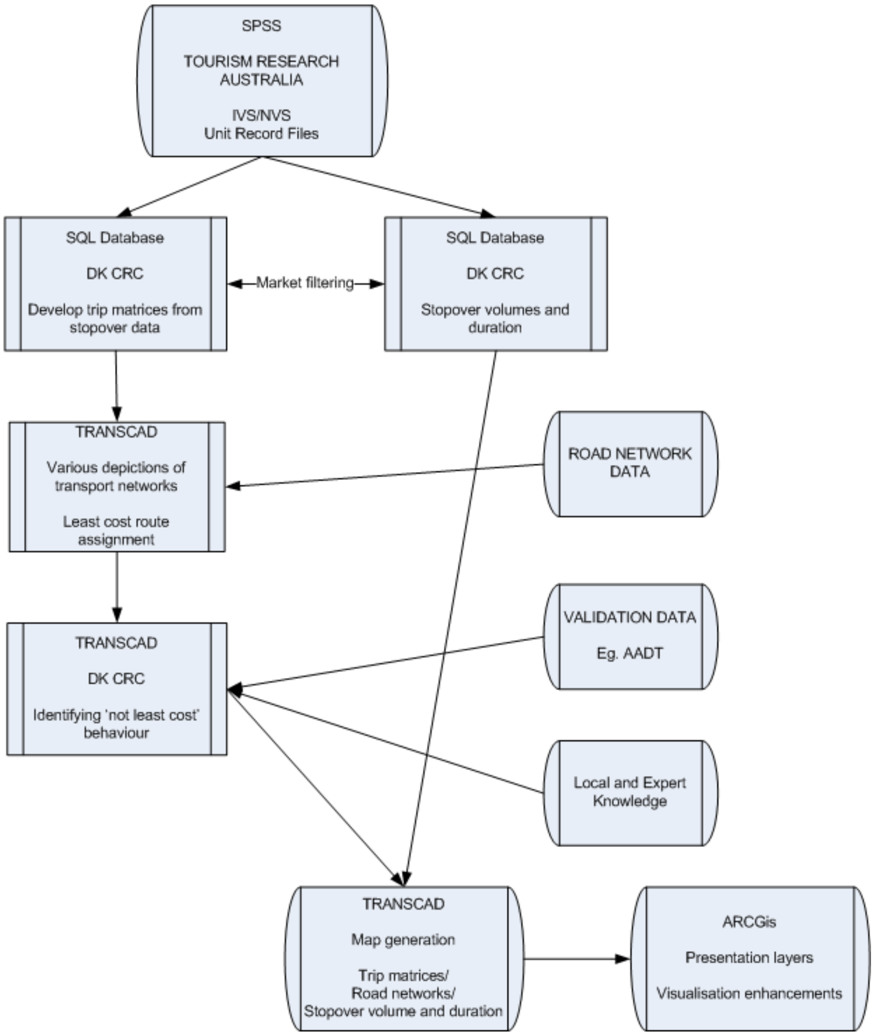

Figure 1: VRUM™ modelling architecture.

The VRUM modelling architecture follows a structured algorithm that allows for user intervention and a range of modelling output types and formats as described int he following sections of this paper.

5.1. Data Input and Market Filtering

At the start of the modelling process, the raw IVS and NVS unit record files are provided in an SPSS data format. The data at this stage is presented as large, structured files with a great deal of information relating to aspects of the tourist travel however it is not in a format that is readily acceptable to a transport modelling process. From here, the model accepts the data into an SQL database environment for manipulations and derivation of the trips matrices and stopover data. The market filtering process operates within an SQL environment and may be applied individually to the trip related or stop related data.

The data filtering process is unique to VRUM™ modelling architecture as it provides a link between the raw IVS and NVS unit record files to the following TransCAD routines. Just as important, the market filtering provides an opportunity for the user to interact with the modelling algorithm to identify the type of travel characteristics for inclusion in the results. In order to model tourist travel patterns in desert Australia it is important to perform an initial database filtering to gain only the appropriate journeys for the modelling task. In the case of the self-drive tourist visiting desert regions, these journeys are defined as those that have at least one overnight stop in the desert region and are achieved by self-drive tourists travelling on the road network. The self-drive tourist is a sub-set selected from the 13 possible modes that include car, motor-home, coach, air, train and many other.

5.2. Network Definition

Tourist destinations are represented by a total of 475 Urban Centre Localities (UCL's) across Australia. These locations are connected for the self-drive tourist by a road network supply that provides for all major and strategic tourist movements across Australia, including road classes that range from high capacity freeways to desert tracks that are significant for outback tourist travel. Overnight stopover locations are also defined by the UCL configuration, as it is assumed that the vast majority of accommodation is provided at these localities. The following figure illustrates the UCL and road network configurations for all of Australia included in VRUM with the desert or remote region shaded.

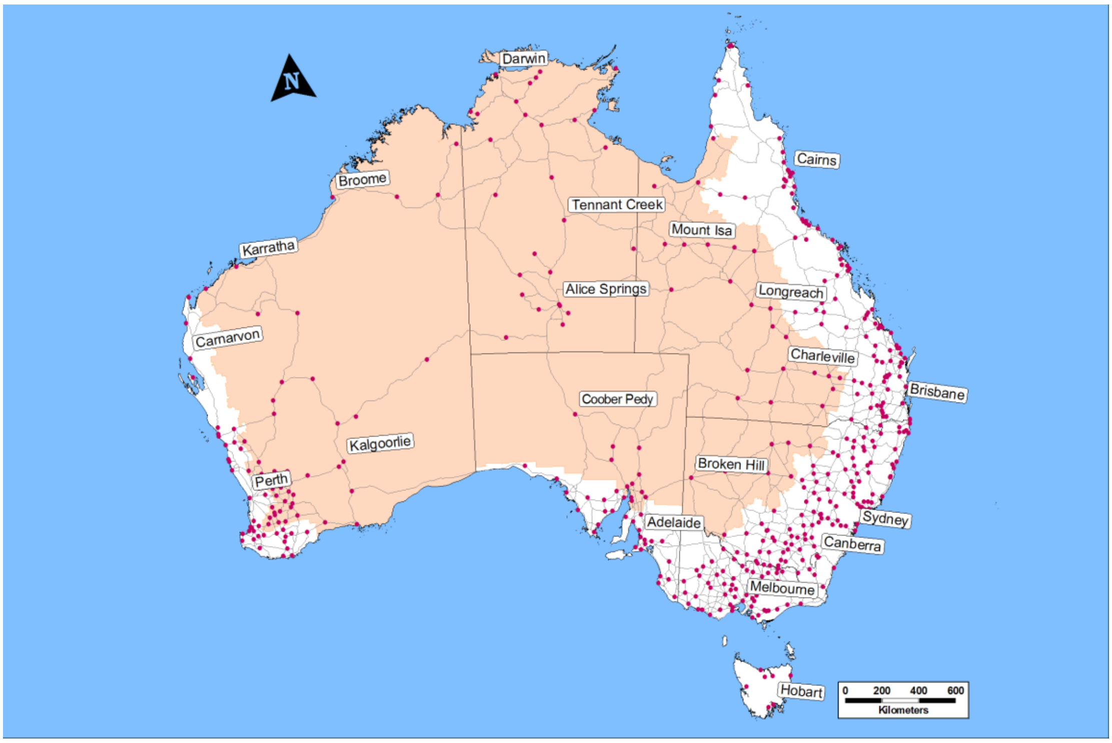

Figure 2: Australia's UCL and road network configuration.

From a total of 475 UCL's in Australia, 121 exist in the remote areas and are sparsely distributed. Some concentrations exist closer to Perth and Alice Springs with vast regions in the West without UCL's or a defined road network. The remainder that lie outside of the remote area are clustered around East Coast, South Eastern and South Western parts of Australia. The road network is denser in these areas also.

5.3. Continued Modelling

Tourist travel behaviour is represented in VRUM by the journeys occurring between UCL's and the stopovers that take place at them. Initially, all complete 'round-trip' journeys are disaggregated into their respective trips between a single origin and destination (OD). The market filtering option allows for sub-sets of the database to be established based on characteristics of travel and traveller profile. For example, sub-sets may be based on select destinations, accommodation types, expenditure, or travel purpose.

A trip matrix is compiled from all single OD tourist movements and provides a record of the total travel demand. This is added to with the development of stopover records assembled from the same IVS/NVS database. Stopover information summarises the overnight stop activity at each UCL as total volumes of tourists and average overnight duration.

At the core of the VRUM modelling environment is the TransCAD transport planning software (Caliper, 2004). TransCAD contains a variety of transport planning modules which in this case are utilised to interpret tourist movements and assign trips to the road network. The software combines this with a GIS engine with specialised extensions to enable an accurate and efficient model development process. As with any other GIS, the interface provides a graphical solution that is easily interpreted and allows the user to perform many different types of spatial analysis. The wider VRUM architecture is also supported by SQL programming language, and ArcGIS software (Price, 2008).

The principle purpose of the TransCAD operation is to accurately match the tourist travel demands (ie. trip matrix) with the road network supply. For TransCAD to achieve this, a route assignment algorithm is employed based on developing minimum cost paths between origins and destinations. An all-or-nothing type assignment with a stochastic element (Ortuzar and Willumsen, 1994) is utilised and cost is represented as road network travel times.

6. DATA ANALYSIS FUNCTIONS

The data analysis capabilities within VRUM™ are principally associated with the creation of customised tourist trip matrices and resulting network travel patterns. The visualisation of these within the GIS environment allows for the interpretation of results. The customisation processes can be broadly categorised into:

- *Geographic:* where irrespective of the data source, trip matrices can be customised geographically. Geographic customisation queries include:
    - All records where a specific location or combination of locations was included as an overnight stop or point of origin, and
    - All records where a specific road segment was likely to have been used.
- *Temporal:* this includes both producing snapshots of activity in a particular time period, and producing ‘difference plots’ which describe change in trip patterns between two time periods.
- *Trip Length:* occurring in two ways; either by filtering for records with a total trip length of specified nature (following, for example, Olsen’s (2003) classification of short break, short tour, long tour, grand tour), or by filtering for records where a particular period of time was spent in one or more selected locations.
- *Traveller Characteristic:* there is also the capacity to produce customised trip matrices based on traveller or trip characteristics included in the specific data sets but not in the minimum data set. The IVS and NVS, for example, allow customisation by specific mode of travel (caravan, hire vehicle etc), demographics of traveller, size of travel party, purpose of trip and so on.

VRUM™ may also be used to investigate hypothetical scenarios. Trip matrices can be constructed from a series of assumptions about changes in consumer behaviour. We might estimate changes in travel patterns if a particular location became unavailable for an overnight stop, or a particular road segment became unusable. The system can make decisions about the most likely alternative routes taken by travellers, given an assumption that they would still choose to travel to the other destinations on their existing trips. It may also be possible to estimate travel patterns if new nodes were entered into the network (new road segments, new locations).

7. VRUM™ OUTPUT EXAMPLES

The outputs from TransCAD can be best summarised through the presentation of mapping and related images that depict the tourist travel behaviour. This is achieved with the production of thematic mapping that presents the volume of movement and the stopover activity at the UCL destinations. Included GIS capabilities in the software enable these illustrations.

Tourist travel during over the 2004 to 2006 period is depicted in the following illustration for the entire mainland region of Australia. Once again the shaded region represents the remote area and only self-drive tourists with at least one overnight stop in the desert region are represented.

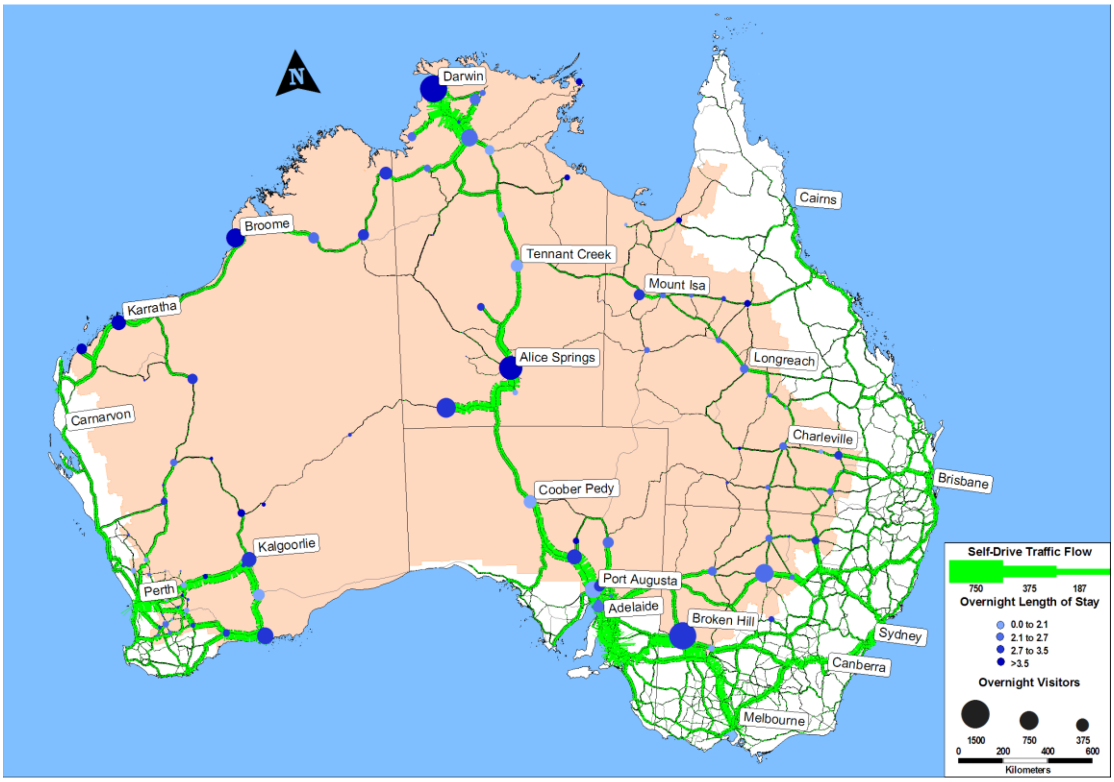

Figure 3: Self-drive tourist travel flows and stopovers for desert journeys in Australia.

In the previous figure, the weight of the flow lines are representative of the flow volume and at the stopover locations, the size of the point is representative of tourist stopover volume with shading indicating average stopover duration (darker for longer durations). From this figure, stopover ‘hubs’ can be identified at Darwin, Alice Springs, Uluru (just

West of Alice Springs), Kalgoorlie and Mildura (south of Broken Hill). The tourist flow routes converge on the cities of Darwin, Adelaide, and Perth as they have a close proximity to the outback regions with the route between Alice Springs and Uluru also popular. Many other conclusions may be drawn from this figure, demonstrating its usefulness in communicating VRUM™ modelling results.

TransCAD also allows for a comparative analysis with the construction of a difference plot to illustrate the tourist flow differences when two outputs are compared. In the case of the following Figure, the flow difference is calculated between the 2000-2002 year cohort estimation and 2004-2006 year cohort.

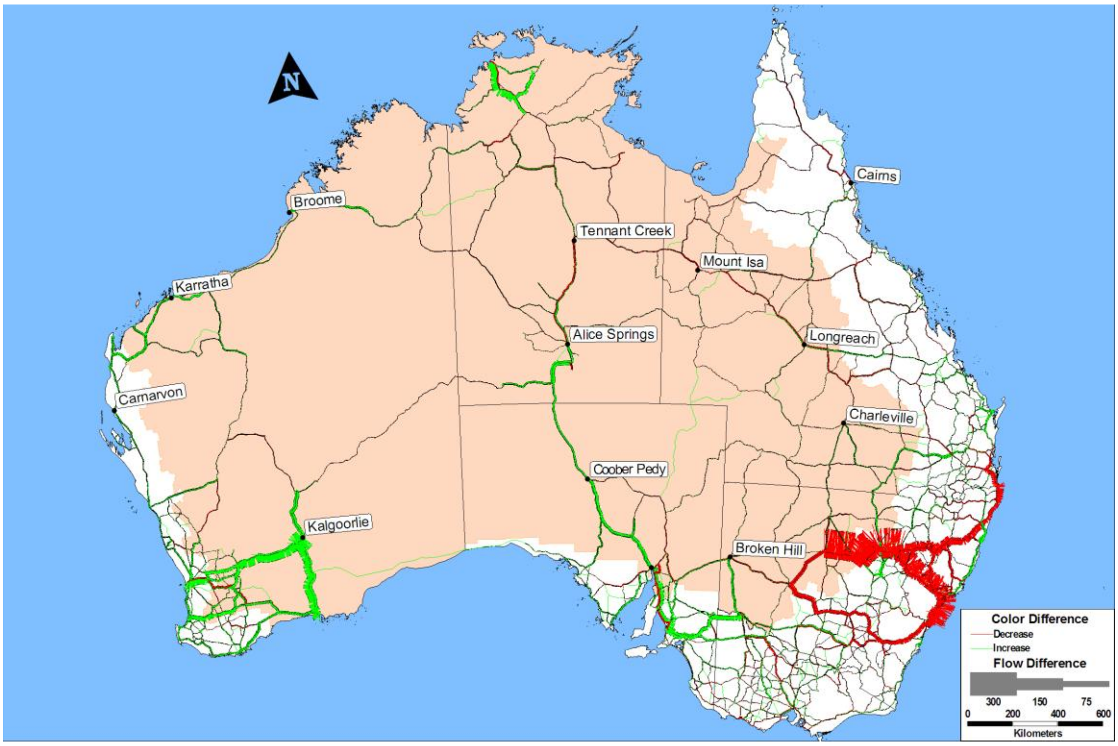

Figure 4: Tourist flow difference plot between the 2000-2002 and 2004-2006 year cohorts.

From the previous figure, it can be seen that the change in travel patterns over time are quite dramatic in many places. The most obvious change is the substantial decrease in traffic in the south east corner leading out from Sydney to Broken Hill. Increases in travel as indicated by the green coloured line can be noted around the three capitals of Darwin, Adelaide and Perth, with the Perth region (and out to Kalgoorlie) experiencing the greatest increase. There may be several reasons for this change including the growth in popularity of low-cost airlines and changes in population growth.

Through the market filtering processes identified and detailed earlier in this paper, it is possible to produce modelling results and subsequent illustrations that focus on travel associated with a select tourist destination. In the following figure, tourist journeys that stopover in the North-Western town of Kununurra are filtered and modelled in VRUM™.

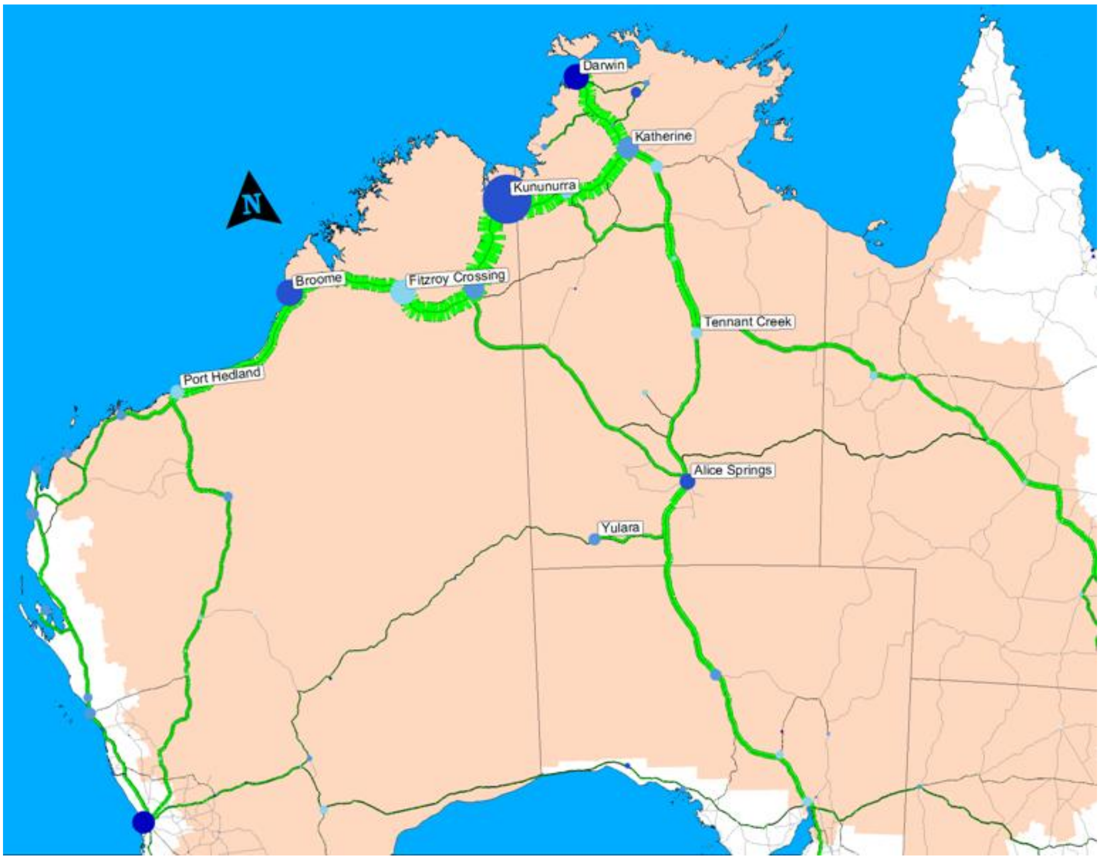

Figure 5: Kununurra filtered tourist activity.

From Figure 5 it is observed that many of the journeys stopping in Kununurra also pass through Darwin to the East and extend to Alice Springs and across Queensland toward the Eastern seaboard. To the West much of the travel extends toward Broome and then beyond to Perth in the South Eastern corner of Australia. Tourist operators in Kununurra can utilise such a map in marketing strategies for example.

At a more detailed scale, an intersection diagram such as that illustrated in the following figure can provide more information on tourist movements as select localities.

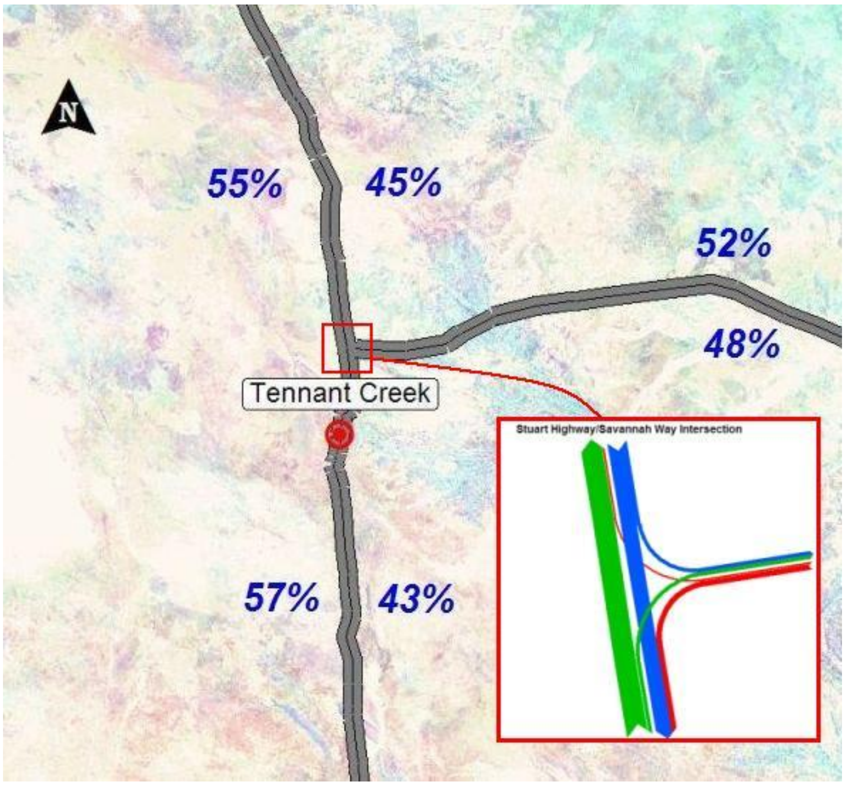

Figure 6: Intersection diagram example.

In the previous figure, the intersection diagram (bordered in red) provides detailed information at the junction of the Stuart Highway and the Savannah Way in central Northern Territory. This representation allows for a representation of the through and turning movements at the intersection with the use of link bandwidths. Figure 6 also shows that it is possible to include additional postings such as the proportion of flows along the road links as an alternative to the bandwidth attribute.

8. CONCLUSIONS AND FURTHER RESEARCH

Current tourism trends have highlighted the importance of self-drive tourist activity in the remote regions of Australia. The ability of the VRUM™ modelling suite to represent this and other traveller behaviour provides those in the tourism industry with a valuable tool to develop successful business management strategies. VRUM™ takes advantage of existing databases in the creation of GIS-based mapping applications capable of scenario development and visualisation of directional travel flows across Australia. Future potential for this research extends into policy analysis with the possible integration of discrete choice routines associated with, for example, the response of tourists to fluctuating fuel prices. Other research may develop the inclusion of alternative travel modes such as trains, coaches and flight paths.

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