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This is the Published version of the following publication

Tariq, Muhammad Atiq Ur Rehman, Hussein, Maha and Muttal, Nitin (2021)  
Smart city ranking system: A supporting tool to manage migration trends for  
Australian cities. *Infrastructures*, 6 (3). ISSN 2412-3811

The publisher's official version can be found at  
<https://www.mdpi.com/2412-3811/6/3/37>

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## Article

# Smart City Ranking System: A Supporting Tool to Manage Migration Trends for Australian Cities

Muhammad Atiq Ur Rehman Tariq <sup>1,2,\*</sup> , Maha Hussein <sup>1</sup> and Nitin Muttill <sup>1,2,\*</sup>

<sup>1</sup> College of Engineering and Science, Victoria University, Melbourne, VIC 8001, Australia; Maha.Hussein@live.vu.edu.au

<sup>2</sup> Institute for Sustainable Industries & Livable Cities, Victoria University, P.O. Box 14428, Melbourne, VIC 8001, Australia

\* Correspondence: Atiq.Tariq@yahoo.com (M.A.U.R.T.); Nitin.Muttill@vu.edu.au (N.M.)

**Abstract:** A key driver of Australia's economic development is through promoting migration. A strong bottleneck to achieve the targets is a disproportional concentration of population in the metropolitan cities. To avoid congestion in these cities, emphasis is being given at the government level to promote the regional cities. With different city ranking systems, this study tries to identify linkage between the city ranking and people's preference to live there. The proposed ranking system uses six components, namely, economy, mobility, environment, people, living, and governance. A comparison is done between the ranking systems by first assigning the same weightage to the six components and then assigning different weightages based on people's preferences. This study considered 112 Australian cities, which were ranked by considering their performance based on the non-weighted and weighted parameters. Analytical Hierarchy Process is then used to assign the priorities/preferences of the components, factors, and indicators. The study also incorporates clustering technique to address the issue of missing data/information that is a typical problem with small cities where missing data is a common issue. The results of the comparison demonstrate that assigning weightage to ranking parameters makes the city ranking closer to the preference of people to live in a city. It is also recommended that the city ranking system and urban governance should have closer connection to each other. The lowest performing city ranking parameter should be given higher preferences in urban management and development plans.



**Citation:** Tariq, M.A.U.R.; Hussein, M.; Muttill, N. Smart City Ranking System: A Supporting Tool to Manage Migration Trends for Australian Cities. *Infrastructures* **2021**, *6*, 37. <https://doi.org/10.3390/infrastructures6030037>

Academic Editors: Ahmed W. A. Hammad, Assed N. Haddad and Carlos A. P. Soares

Received: 9 February 2021

Accepted: 2 March 2021

Published: 8 March 2021

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**Keywords:** smart cities; preferred cities; smart city ranking; Australian regional cities; imputation of missing data; analytical hierarchy process; data clustering; z-score

## 1. Introduction

The world population is expected to double with 70% of the population living in cities by 2050 [1,2]. As urbanization continues to grow, the demand for improvements in the cities services increases to accommodate for these predicted urban growths. Through the concept of developing smarter cities, the concern of urbanization can be addressed as the factors covered by smart cities, ensures a sustainable urban development [3–5]. It can be concluded that population increase creates opportunities, yet challenges will also be faced if not prepared for it correctly. Cities are not just a place to live in and work, they are “area of emotional attachment” as each city has their own “personalities”, “traditions”, and “attractions” [6]. Therefore, it can be concluded that the concept of urban sustainability and smart city have been a potential solution to solve the problems concerning urbanization [7].

### 1.1. The Concept of Smart Cities and Rankings

The definition of a Smart City has “no universally accepted definition” as it means “different things to different people”. Kuru et al. [8] indicate that the agreed definition of smart city is not available as there is no “best formula” to transform each city into a smart city [2,8–10]. The general concept of Smart Cities seems to be a simple one, however it is far

from the actual definition [11]. The term “smart” is commonly used for marketing purposes to associate devices with terms like user-friendly and user perspective-centered [12–14]. Although, the concept of Smart City is still developing, the idea has experienced much debate as there are many ways to interpret a Smart City [15,16]. It can be referred to as a smart technology that increases quality of life (QoL) between the lives and the environment of cities [8,17]. The smart city concept has gained “popularity” recently as cities are starting to use “digital technologies and data” to implement a smarter city [18]. The idea of creating a smarter city involves development in the key factors including but not limited to, energy, water, transportation, public health and safety and other key services [19]. As each city aim to improve by imposing an innovative project, its success relies on the stakeholders to contribute and make these changes effective.

The “smart city” concept is not a recent development. It made its first occurrence in mid-1800’s in the American West self-governing cities [20]. A hundred years ago, only 20% of the world’s population were living in urban areas [21]. This percentage was only 34% in 1960, and was 55% by 2018, and by the middle of the 21st century it is anticipated to increase to 70% [1,21–23]. In the 1990s, it then became a concept of “smart growth”, mainly focusing on the transport, mobility, and planning factors [24,25]. By the 21st century, smart cities began to gain a “serious interest” by governments across the world, mainly due to the new innovative technologies [9,26]. The concept of “smart city” become generally accepted in 2009 when introduced by IBM, which has also helped the promotion of sustainable development [8,27].

As technology is constantly improving the implantation of a new ranking system will help smaller cities to identify their areas of improvement. By comparing cities on a smaller scale, it allows each city to see how they perform within their major city. This become more effective, as improvement can be made on smaller scales across the major city, which will have a higher impact on the major cities’ rankings. Whilst only having performed best in one factor, cities claim themselves to be “smart”. The significance of such ranking system allows for each smaller city to see how they rank according to other smaller cities nearby. By being able to see each cities strength and weakness, cities can make changes accordingly to improve and perform their best.

### 1.2. Australian Regional Cities

Australia is suffering from disproportionate population concentrations and vast distances [28]. The division between metropolitan and regional areas is causing societal, economic, and political issues [29,30]. Not only the internal migration but the immigrants from the other countries prefer to settle in metropolitan cities [31]. The high concentration of population in two of Australian cities, Sydney and Melbourne, is causing many administrative issues for Australian government [32–35]. These two cities are also the main hotspot for tourism. Australia is consisting of seven states/territory namely New South Wales (NSW), Queensland (QLD), South Australia (SA), Tasmania (TAS), Victoria (VIC) and Western Australia (WA), and the Northern Territory (NT) plus the Australian Capital Territory (ACT). Australian population is distributed extremely disproportional. For example, the populations of either of cities (Sydney and Melbourne) is more than the total population in all other states excluding the QLD that has almost same population as in Melbourne. The same disproportion of population can be observed within all states between their metropolitan cities (regional/state capital city and surrounding cities) and the remaining (regional) areas/cities.

The main reason for population increases in Australia is migration of people from around the globe. Migration may occur for many reasons which may depend on a positive or negative outcome to a person’s life. Parr concluded that internal migration mainly occurs within Australia due to life events such as post-school education or employment [36]. These are also linked to family and friends as they are what make a place “feel like home”. Health facilities in rural areas are inferior in quality [37,38]. Health and amenities are the main reasons for old age population to move to Victorian and New South Wales regional

areas [39]. Same is the case of natural hazards, where communities are more prone to these hazards due to inadequate communication and infrastructure setups [40]. These regional rural areas suffer the food security issues as well [41].

Tourism and the proximity of the areas to coast and metropolitan cities are effective factors to achieve internal migration gains [42]. Argent et al. concluded that creativity and amenity are the strong factors to trigger internal migration but the employment is far stronger than these [43]. Due to the discussed factors, various studies have supported the fact that the young population tends to move to the capital cities [44,45].

Australian government is putting serious attempts for sustainable development of Australian cities. The government have initiated several incentives to promote population growth in regional areas. Australian government initiated “The Smart Cities and Suburbs Initiative 2019” with AUD 50 million funds to enhance the livability, competitiveness, and development of Australia’s cities and towns [46]. In addition to incentives, many marketing and promotional attempts to promote the Australian regional areas have also been observed over the time [47–49].

Human capital, which is not just the population but a set of skills, knowledge, capabilities, and the productive attributes embodied in people [50], is the main focus of regional development in addition to the services [44]. This always for ways to create new and improve existing services [51,52]. The level of smart development is unbalanced in different cities, which makes it difficult to rank with those that are balanced [51]. As a plan to advance the smart city movement in Australia, Smart Cities Council have hosted an “Australian Smart Cities Awards” to recognize and encourage more smarter cities in Australia. Some of the improvements included free public Wi-Fi; training 3500 students in coding; connecting business to high-speed, high-capability networks; introducing smart bin and water meters, parking and sensors to monitor wildlife and waterways to create a more livable city, etc. [53].

### 1.3. Research Questions

Development of regional smart cities is a major challenge for the Australian government. Narrowing down the gap between a typical smart city definition and an attractive destination to live is significant. The task becomes even difficult when these small regional cities are lacking the data for the ranking purpose. The presented research targets to identify the effectiveness of smart city ranking system and preferred city ranking system in relation to develop and promote the regional areas. The research addresses the following concern:

*“Whether the smart city/preferred city ranking processes can be considered as an effective indicator for human capital attraction within Australian context?”*

## 2. Literature Review

Due to the “dramatically” changing population of Australia, Graeme [32] suggested for information technology development to be made, which will “tie people and industry” less to the major metropolitan parts of Australia. There is no doubt a link exists between what city people prefer to live in and how smart that certain city is. Anthopoulos and Fitsilis claimed that a competition between cities appears to transit to a smart competition with the modern developments [54]. Rolfe et al. [44] identified the high salaries as an effective motivational factor for the workers to work in regional areas.

### 2.1. Different Ranking Systems

A number of attempts have been made to rank cities based on different parameters, amongst them the most popular ones are “competitiveness cities”, “livable cities”, “sustainable cities”, global cities” and “intelligent cities”, etc. [6,21,55–58]. These attempts cover “smart economy”, “smart mobility”, “smart environment”, “smart people”, “smart living”, and “smart governance” [24,59–61]. Most recent concept of ranking is the “Global Power City Index” by Memorial Foundation. The Foundation has published ranking the major cities of the world based on their “magnetism or comprehensive power to attract people,



capital, and enterprises from around the world” every year since 2008 [56]. The multidimensional ranking system is based on the functions like economy, research and development, cultural interaction, livability, environment, and accessibility [56]. Lin et al. [62] did a reliability analysis to test the reliability of current ranking system. Similarly, a comparative study between three ranking models was performed by Benamrou et al. [63]. Wu [57] developed an “intelligent ranking” system for Chinese cities. Due to the difficulty and variety of living standards, the research and development on “livable cities” has attained much attention [55]. The Arcadis view city selection is not based on the “elite cities”, rather it creates opportunity for cities to make development on the goal for a more sustainable city [6].

Each ranking system has a variety of factors to rank a city. Intelligent cities use the indicators Environment and Urbanism, Governance and Public Service, Economy, and Industries, Informatization and Innovation Human Resource [57]. Livable ranking system access cities based on safety, economy, environment, education, health, transportation, recreation, population density and public utility [55]. Sustainable cities index uses the factors people, planet, and profit [6]. Mohanty et al. used components like smart citizen, smart infrastructure, smart building, smart transportation, smart energy, smart health care, smart technology, smart governance, and smart citizen [61].

## 2.2. Choice of Indicators and Weightages

There are currently different concepts other than smart cities, which are used to rank cities based on various factors. The choice of indicators must be correlated to “city’s problems” for an easier reading of how cities rank when compared to others [58,64]. Such as studying the effect of energy and waste producers, air pollution, population growth, and livability conditions though a “well-balanced, integrated and socially equal communities” and job opportunities [64–67]. Batten ranked 50 cities to compare their environmental impact and financial stability [6]. The economist in its report ranked 120 cities for the years 2012–2025 by comparing their competitiveness mainly based on business, environment and the ability to attract talent and visitors [21]. Similarly, the global power city index, ranks 48 major cities based on their “comprehensive power to attract people, capital, and enterprises” [56]. Worawej et al. [55] used a slightly different ranking approach by focusing on a single median class city instead of multiple cities. In the economist ranking system, eight factors are assessed; economic strength, physical capital, financial maturity, institutional character, social and cultural character, human capital, environment and natural hazards, and global appeal [21]. The importance of each factor was weighted by a percentage ranging from 5% to 30%. Sassen selected multiple indicators for global economic cities [68].

There are a number of models that evaluate a smart city at present, which identifies each city “smartness level and increase their competitiveness”, which becomes “very important” for stakeholders [62,63]. The consistency of these systems is important to avoid “unreliable” studies which may affect the future development [62]. The comparison of cities may seem beneficial for tourism; however, this is not the case for all included cities without an accurate analysis of each city’s differences [69]. As a result of these ranking system, cities only utilize the results in favor of their city and disregard the results that show their weaknesses.

Oversimplification may occur when assigning same weightage to six components (economy, mobility, environment, people, living, and governance) of a smart city as it may not identify the real preferred cities. Yadav et al. [70] concluded that applying an equal weightage “was not justifiable logically” for decision making process. Similarly, Bernardon et al. [71] were able to identify the option that were best fit for remote controlled switches, whereas Yadav et al. concluded that the technique gives a “more optimistic value”. In case of smart city ranking, a weightage metric should be done as just adding up the measure will not produce meaningful data to represent the overall performance of cities [72].

According to Xiangrui et al. [73], the Analytical Hierarchy Process (AHP) can be used for both prioritization and ranking the indicators. By proceeding with the technique of AHP, each component/indicator will result in a weightage value assigned to identify its importance amongst the rest. An in-depth analysis was performed by Nripendra et al. [74] to weight the factors in terms of importance using the Analytic Hierarchy Process (AHP) technique. The results show that amongst the six selected barriers, governance is the most significant, followed by economic, technology, social, environmental, legal, and ethical. A similar approach was done by Wang and Chi [75], following AHP as well as gaining 16 expert options to rank the criteria. However, slightly different results were observed, which presents economy on top, followed by society, environment, mobility, and energy.

Due to the ability of AHP to provide more convincing results. Our case studies compare the two ranking systems with and without assigning weightages for appropriate decision making to obtain the final smart score.

### 2.3. Missing Data Issue for Small Cities

The ranking systems established so far, involve extensive analysis of data to assess the performance of cities. When developing a ranking system for smaller cities a large amount of data is required for best results [52]. However, due to this large amount of data needed, it may be difficult to source as not all data may be available. Which therefore may limit the number of indicators that can be used to rank cities. The limitation of data was also questioned by Leye et al. as the collection of data is essential for systems to be developed [51]. That makes the availability, reliance, and accuracy of data as a pivotal factor in smart city ranking system. With the high reliance of data needed for each city, the collection of this information may seem unreliable due to the “careless annotation or malicious data” of the sources [76]. As a result, this limits the number of cities and indicators used for the ranking system. A usual challenge that may occur is only partial ranking can be found [77]. As a strategy to overcome the lack and unreliability of data, it is recommended that a large scale of data should be collected and integrated [51].

A clustering technique a simple approach but there is no single clustering method that works universally well in all contexts. The idea of clustering involves grouping similar data set which can then be used to address the missing values [78]. A simple type of clustering is “imputation” where missing values are either replaces with zero or average values of row / column [78–80].

### 3. Smart City Ranking of Australian Regional Cities

Based on extensive research and discussion mentioned above, the final detailed methodology has been developed as part of this study. The methodology has been developed with a wide range of cities covering Australia wide. The process of indicators selection has been established to ensure as many indicators are considered with the limitation of data available for Australian regional cities. The anticipated results for this study should present the areas for improvements are for each city. The methodology developed can be divided into the following steps:

1. Ranking criteria;
2. City selection;
3. Data collection;
4. Data processing;
5. City ranking scores;
6. Analysis.

The flow process of the methodology is shown in Figure 1.

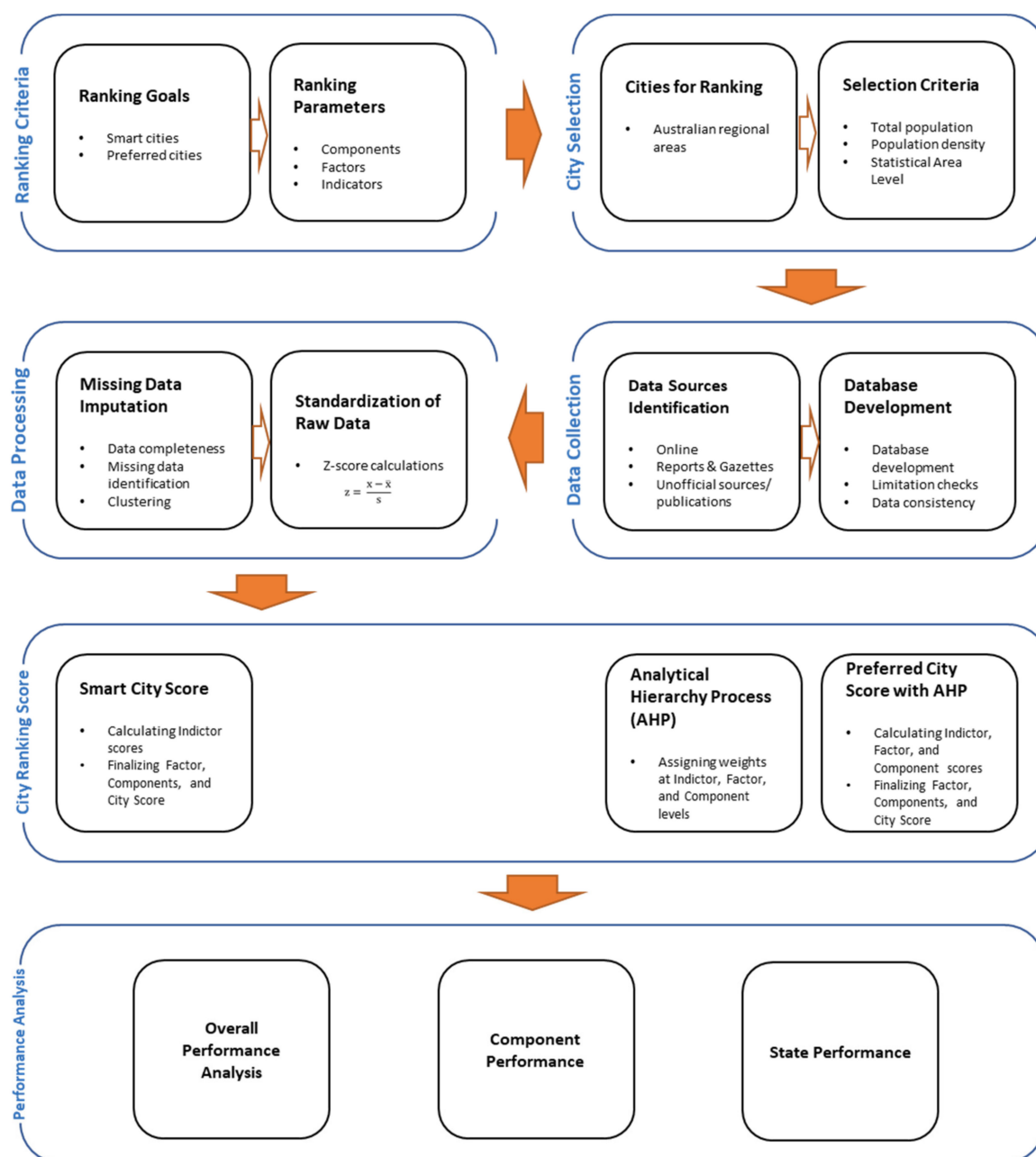


Figure 1. Schematic layout of defined methodology.

### 3.1. Ranking Criteria

As discussed in Section 2.2 the ranking criteria depends on the aims of the ranking. This study aims at comparing two ranking systems, “Smart Cities” versus “Preferred Cities”. The goals of both ranking systems are described in the following section. However, same ranking parameters are used for ranking but with assigning priorities in case of preferred cities.

### 3.1.1. Ranking Goals

Smart cities ranking target to compare the performance of each city in every component of smart city aspect, e.g., economy, governance, environment, livability, mobility, and people. These components are assigned same weightage to calculate the smart score. Whereas the preferred cities ranking includes the preferences of people towards their choice of an ideal city to live. Not only the local authorities, but small and medium enterprises, corporations, utility providers and civil society groups develops the smart cities [81]. Therefore, the ranking perspective must include all aspects of cities' functioning. The procedures to assign rankings are described in the following section.

### 3.1.2. Ranking Parameters

A smart city ranking may be significant for political decision making, organizational strategy planning, human resource management, and living choices [62]. As the number of ranking systems are increasing with time, each ranking system has different levels of components, which depends on the goals of the ranking system [61,77]. However, a common theme for smart cities includes society, economy, environment, and governance [61]. The smart city measuring parameters should be "carefully chosen" as these characterize cities to be identified though their strengths and weaknesses [77]. Based the types of indicators used, the outcomes of the ranking vary on a large scale. Following components are evaluated in presented research for both cases.

- **Governance** is defined by the decision-making and public services of stakeholders. Being an essential component for smart city plan, it allows for citizens to keep the decision and implementation process clear.
- **Economy** is a component that influences multiple factors to improve a city, including business life, faster ways to locate business services, participate in urban development, increase GDP, and creating jobs.
- **Environment** is designed to improve the sustainability by considering clean energy, clean air, and clean waterfront. Conditions to contribute a smart environment is by decreasing the air pollution, water pollution, and CO<sub>2</sub> emissions.
- **Livability** is entailed to improve the lives of the people. It allows for people to have a better health care, safety, quality of housing, social cohesion, and other activities in society.
- **Mobility** relates to the movement of people and good around the cities. Safe transportation system and ICT accessibility are essential to allow people to get from one place to another.
- **People** are the ones who can create an economy, education system, and transportation. Though multiple indicators such as level of education, academic, and technical degrees and additional training, as well as the ability to communicate in multiple language for the social harmony of the society.

Details of components, factors, and indicators are presented in Figure 2. Along with weightages and brief definitions of indicators.

Components	Factors	Indicators	Definition
Economy	Entrepreneurship	New Businesses/Total	Total number of new businesses
		Large Businesses/Total	Total number of large businesses
		Self Employed Trend	Number of non-employing businesses
		Total Businesses Trend	Total number of businesses
		Patent&Trademark Apps Trend	Total number of Patent and Trademark Applicants
	Infrastructure	Business Entry Rate Trend	Total number of business entries
		Building Approvals Trend	Total private sector dwelling units
		Dwelling Worth	Median sale prices of houses
	Productivity	PSHouse Worth/Dwelling	Median sale prices attached Dwellings
		Gross Product/Cap	Per capita gross domestic product (GDP)
Wage Price Index WPI		Measures change in price of labour	
Unemployment Rate TrendInversed		Total rate of unemployed people	
Governance	Government Funding	Gross Capital Gains mil Trend	Gross Capital Gains paid by taxpayers
		Pensions/ Allowances Trend	Total number of people who claim pension or assistance from government
		Sports&Rec mil	Sum of Administration, Venues, Participation and special events and other services
	Participation	Total Assistance Trend	Total number of people who receive assistance from government
		Enrolled Voters	Number of people enrolled to vote in elections
		Votes HOReps	Number of votes for House of Representatives
	Community Engagement	Votes Senate	Number of votes for Senate
		Community Incentive	Number of Community support groups
Environment	Energy Initiatives	Community Programs	Number of Social groups
		Renewable Energy by 2020	Rate of renewable energy to be acived by 2020
	Pollution	Net Zero emissions by 2050	predicted rate of net zero emissions to be acived by 2050
		Air Quality week average	Week average of air quality
		C Equivalent TrendInversed	Emissions from greenhouse gases with their global-warming potential
	Water	GreenHouse Gas Emi Trend Inversed	rate absorbing infrared radiation emitted from Earth's surface
		Aquatic Biota Index Inversed	indication of water quality of environment
		River Enviro Index	indication of river quality of environment
	Environment Management	Water Development	Satisfaction of the people water developemnt
		Management Expenditure Per Capita	Environment Management Expenditure by Local Government per person
	Renewable Energy	Protection Expenditure Per Capita	Environment Protection Expenditure by Local Government per person
		Solar Installations Trend	increase in solar panel installations from previous year
		Solar Hot Water Trend	Increase in Solar Hot Water installation from previous year
		Suburbs w/ >50% solar Installs	Percentage of suburb with more than 50% solar installation
Solar Households (%)		Percentage of dwellings with solar installed	
Capacity/ Capita (No hydro) (kWh/Capita)		Large-scale wind and solar capacity per capita for renewable energy	
Renewable Electricity (%)	Percentage of the current renewable energy usage		
Livability	Affordable Housing	Median Sale Price (2016) (Trend)(Inversed)	Median sale price of houses
		Rent (Inversed)	Average monthly household rent payment
		Mortgage (Inversed)	Average monthly household mortgage payment
		Mortgage < 30% Income	Households where mortgage repayments are less than 30% of household's income
		Rent < 30% Income	Households where rent repayments are less than 30% of household's income
	Housing Utilization	Person/Household	Average household size
		% 2+ Beds needed	Dwelling with extra bedroom needed
	Employment Opportunity	Employed Percentage	Total rate of employed people
		Participation Rate	Total rate of participation from people
		Unemployment Rate	Total rate of unemployed people
	Safety	Assault	Experienced physical or threatened assault in last 12 months
		Break-ins	Experienced actual or attempted break-in in last 12 months
		Safe Travel Home	Feel safe to travel home alone during dark
		2+ Crimes/yr	More than 2 crimes have occurred in 12 months
	Health	Private Health Trend	taxpayers who have private health insurance
		Male Life Expectancy	Male life expectancy at birth
		Female Life Expectancy	Female life expectancy at birth
		Excellent Self Health	Total number of people who have excellent self-health
	Income	Median Income	Median employee income
		Mean Income	Mean employee income
		Disposable Income wklymid	median disposable household income
		1000-2000 %	Percentage of people earning \$1000 - 1999 per week

Figure 2. Cont.

Mobility	Public Transport	Train Network	Satisfaction of the people with the train network
		Bus Network	Satisfaction of the people with the bus network
		Taxi	Satisfaction of the people with the taxi network
		Utilization to work/study	Number of people who use transport for purpose of work or study
		Utilization outside of work/study	Number of people who use transport for purpose other than work or study
		Train-Tram to Work %	Percentage of people who use both train and tram to get to work
		Bus to Work %	Percentage people who only use the bus to get to work
	Road Network	Roads	Satisfaction of the people with the roads
		Car Acc/100,000ppl (Inverse)	Total number of car accident per 100,000 people
		Car to Work %	Percentage people who only use the car to get to work
	Accessibility	Population Density/km2	Total number of people per 1 km2
		Cars/1000ppl	Total number of passengers per 1000 people
		Av Distance to Work/Study <5km	Average commuting distance to place of work
		Multiple to Work %	Used more than one transport method to get to work
	Connectivity	Computer/Household	Number of computers per household
		Internet Conectivity	Internet accessed from dwelling
People	Knowledge intensive employment	Science/Technical Services	Professional scientific & technical service (%)
		Post School Qualified	Percentage of people with high school level qualification
	Level of Qualification	Above BA Degree	Percentage of people with bachelor's degree
		Above BA Degree	Percentage of people with degree above Bachelor
		Managers	Percentage of people with the manger's role
		Professionals	Percentage of people with the Professionals role
		Technicians	Percentage of people with the Technicians role
	Cultural Awareness	Languages Spoken	Speaks a language other than English at home
		Library Visits	Number of libraries visit in 12 months
	Active Lifestyle	Art and Museum Visits	Number of Art and Museum Visits visit in 12 months
		Cultural Tolerance	Toleration towards different cultures and ethnic groups
		Bike to work	Percentage people who only use a bike to get to work
		Walk to work	Percentage people who only walk to work
	Participation	Enrolled Voters	Number of people enrolled to vote in elections
		Organised Sport	Participate in a sport as a hobby

**Figure 2.** Selection of Components, Factors, and Indicators for evaluation (AHP weightages applied at each level, shade intensity shows lower weightage).

### 3.2. City Selection

The research aims at the ranking of Australian regional cities (refer Section 1.2). The selection of Australian regional cities was carried out from Significant Urban Area (SUA) list, which are defined and maintained by the Australian Bureau of Statistics [82]. Targeted areas are described as Statistical Area 2 as per the nomenclature of Australian Bureau of Statistics (ABS). For metropolitan cities (SA–3), only one represented SA–2 is selected for analysis to provide better presentation to regional cities. Table 1 represents the criteria selection for the regional cities to ensure accurate and consistent analysis of each city. Based on the criteria, 112 cities were selected for the ranking and comparison purpose.

**Table 1.** Selection criteria for the comparison of Australian cities.

Criteria	Description	Range
1	Total population	>10,000 < 700,000
2	Population density	>50 person/km <sup>2</sup>
3	Statistical Area Level	Statistical Area 2
4	Limit on Greater Cities	Not more than one SA–2 from each greater city

### 3.3. Data Collection

Most of the data were collected from ABS trusted government website. Enormous efforts were required to develop error free database by removing errors and inconsistency in data. Common tasks for data included adjusting names and ensuring codes in Statistical Area 2 (SA–2) for consistency of results. The most recent data available were collected to provide the most up to data ranking system possible. Several indicators were difficult to find at a SA–2 coverage level. Where possible data for these cities were found at a coverage level of SA–3 or SA–4 however for those cities where neither SA–2 nor SA–3



was available the data of its “Greater Capital City Statistical Area” is used. Table 2 shows the various sources of data used for the ranking in presented research work, Table 3. shows the number of indicators used for each coverage level. Further detail about the data source is provided in Appendix A.

**Table 2.** Data Source for analysis.

Type of Data	Coverage Level
1410.0—Data by Region, 2013–2018	Statistical Area 2
Disposable income 2011	Statistical Area 2
Patent & Trademark Apps 2015–2016	Statistical Area 3
Gross Capital Gains, 2015–2016	Statistical Area 3
Life expectancy at birth 2017–2019	Statistical Area 4
Greater Capital City Statistics	Greater Capital City Statistical Area

**Table 3.** Number of indicators from different coverage levels.

Number of Indicators	Coverage Level Used
47	Statistical Area 2
1	Statistical Area 3
2	Statistical Area 4
40	Greater Capital City Statistical Area
90	Total

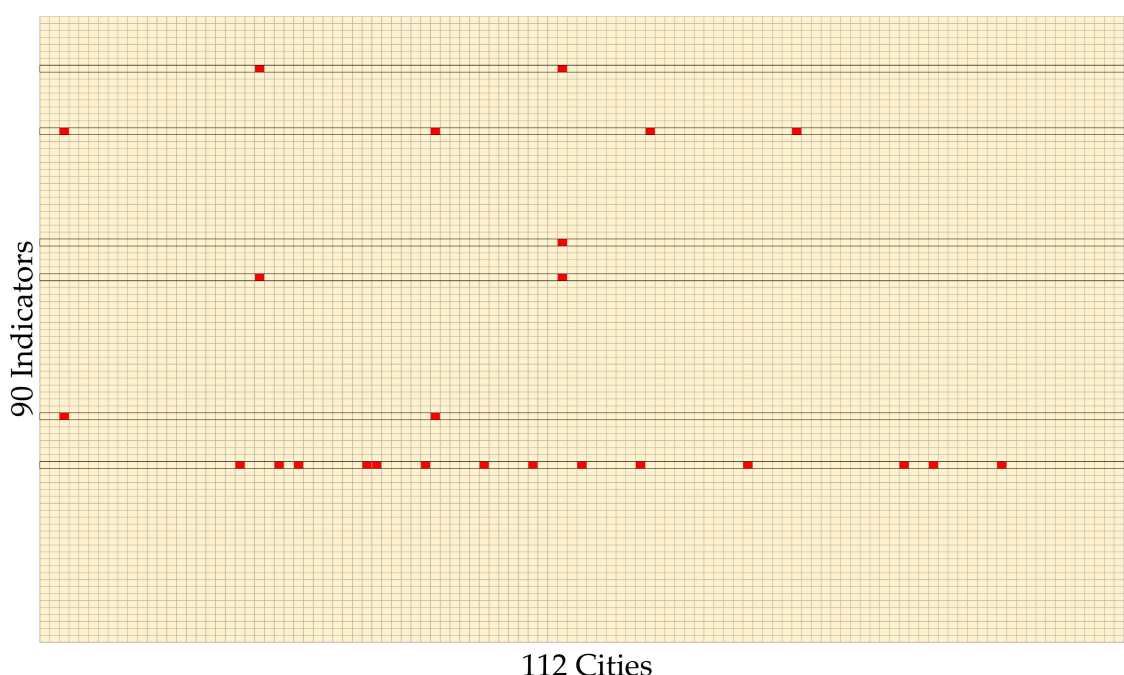
### 3.4. Data Processing

Once the data were collected and a database was developed for the further analysis, the missing values for few cities were identified. Clustering techniques was used to replace the missing values. Before performing AHP/Smart scoring, the data were standardized to carry out the further steps.

#### 3.4.1. Imputation of Missing Data

From a total of 10,080 data values, 26 values were identified as missing. Fortunately, the missing data are not great; however, these missing values still need to be replaced for having a full set of data to ensure reliability of scoring results. Figure 3 illustrates the data missing in the total data set. The missing values are represented with red boxes.

For the imputation of missing values, the first step involves the evaluation and temporarily removing the remaining data from the indicators with a missing value [83]. This allows the cities to be ranked with the equal data at the factor level. As a result, a total of six indicators scores are temporary removed for the comparison purposes (refer Figure 3). The next step involves clustering of similar behaving cities, where the indicators are grouped and treated to estimate a missing value. With missing indicator, the cities are grouped at factor level and are sorted in ascending/descending score order. This allowed to identify the cities with similar characteristics. The average value of similar performing cities can be used for the missing indicator of the target city. This process is repeated for each of the 26 missing values.



**Figure 3.** Missingness map showing the 26 missing values for 6 indicators.

### 3.4.2. Data Standardization

Due to the range of different values of each indicator, performing standardization is inevitable. All indicator values are standardized using Equation (1), which transform each indicator into a score that allows for analysis despite the difference in units matrices. This involves standardizing indicators scores with an average value of 0 and standard deviation of 1. Using the values obtained through the AHP mentioned earlier, weightages are applied to these final values. This allows for the higher priority of components factors and indicators to have a higher percentage of the score and vice versa. A test is done ranking the cities based on the standardization scores alone and compared with the values with standardization with AHP. This allows for use to see if significant changes will be made to the ranking which will represent a better accuracy of results.

$$z = \frac{x - \mu}{\sigma} \quad (1)$$

Equation (1): Standardization of indicators using Z-Score  
where:

$z$  = Smart Score

$x$  = Output

$\mu$  = Mean

$\sigma$  = Standard Deviation

### 3.5. City Ranking Score

Once the data are standardized, these indicators are combined to calculate the factor scores and consequently average component score are estimated. The sum of all components for each city is presented as the final smart score for each of the 112 cities. City ranking is carried out under two approaches, one by assigning same weightage at the indicator, factor, and component levels and second with weightage assigned using AHP. As mentioned previously, the step of clustering has been performed to overcome the issue of missing values. The standardization of score along with AHP has allowed for data scores to be scored consistently according to the AHP weightages assigned.

### Analytical Hierarchy Process (AHP)

As a result of this technique a weightage will be given which represents the importance for each indicator within the data set. For the accuracy of the ranking system these weightages are used during the averaging stage to present a more desirable ranking for each city. Once the conceptual framework is developed and weightage hierarchy set up, the next step is to obtain the rulings about the pairwise priorities. Five participants were contacted to identify the relevant importance of indicators, factors, and components. To ensure more accuracy with this technique, the AHP is applied to each level which include components, factors, and indicators. Qualitative inputs from the participants were converted into equivalent importance score by averaging the score of participants. Table 4 represents the scale used for this comparison.

**Table 4.** Scale used to represent the importance of various indicators, factors, and components considered in AHP.

Quantitative Importance	Qualitative Description
1/9	Not important
1/7	
1/5	
1/3	Less important
1	
3	Equally important
5	
7	
9	Extremely important

The next step is to determine the importance of each criteria against all other criteria using the intensity values from the Table 4. This task is performed by employing pairwise comparison. The process is repeated once at the components, six times at factor level and 26 times at indicator level. The algorithm used for the AHP is as follows:

$$A = \begin{matrix} & \begin{matrix} c_1 & c_2 & c_3 & c_n \end{matrix} \\ \begin{matrix} c_1 \\ c_2 \\ c_3 \\ c_n \end{matrix} & \begin{pmatrix} 1 & a_{12} & a_{13} & a_{1n} \\ 1/a_{12} & 1 & a_{23} & a_{2n} \\ 1/a_{13} & 1/a_{23} & 1 & a_{3n} \\ 1/a_{1n} & 1/a_{2n} & 1/a_{3n} & 1 \end{pmatrix} \end{matrix} \quad (2)$$

where  $c_1, c_2, c_3$ , and  $c_n$  represent the criteria for evaluation. Each value above the diagonal matrix of 1 are obtained from the scale. Result format of this matrix are shown below. This requires 33 of the above algorithms to be performed, where a weightage matrix is obtained from each in our case.

$$W = \begin{matrix} \begin{matrix} c_1 \\ c_2 \\ c_3 \\ c_n \end{matrix} & \begin{pmatrix} w_1 \\ w_2 \\ w_3 \\ w_n \end{pmatrix} \end{matrix} \quad (3)$$

### 4. Performance Analysis

In the final outcomes, smart city ranking produced slightly different results than the one where preference weightages were applied through AHP. Figure 4 shows the smart ranking of cities in descending order whereas Figure 5 shows the preferred cities in descending order. The next section presents an in-depth discussion of the overall ranking of the cities.

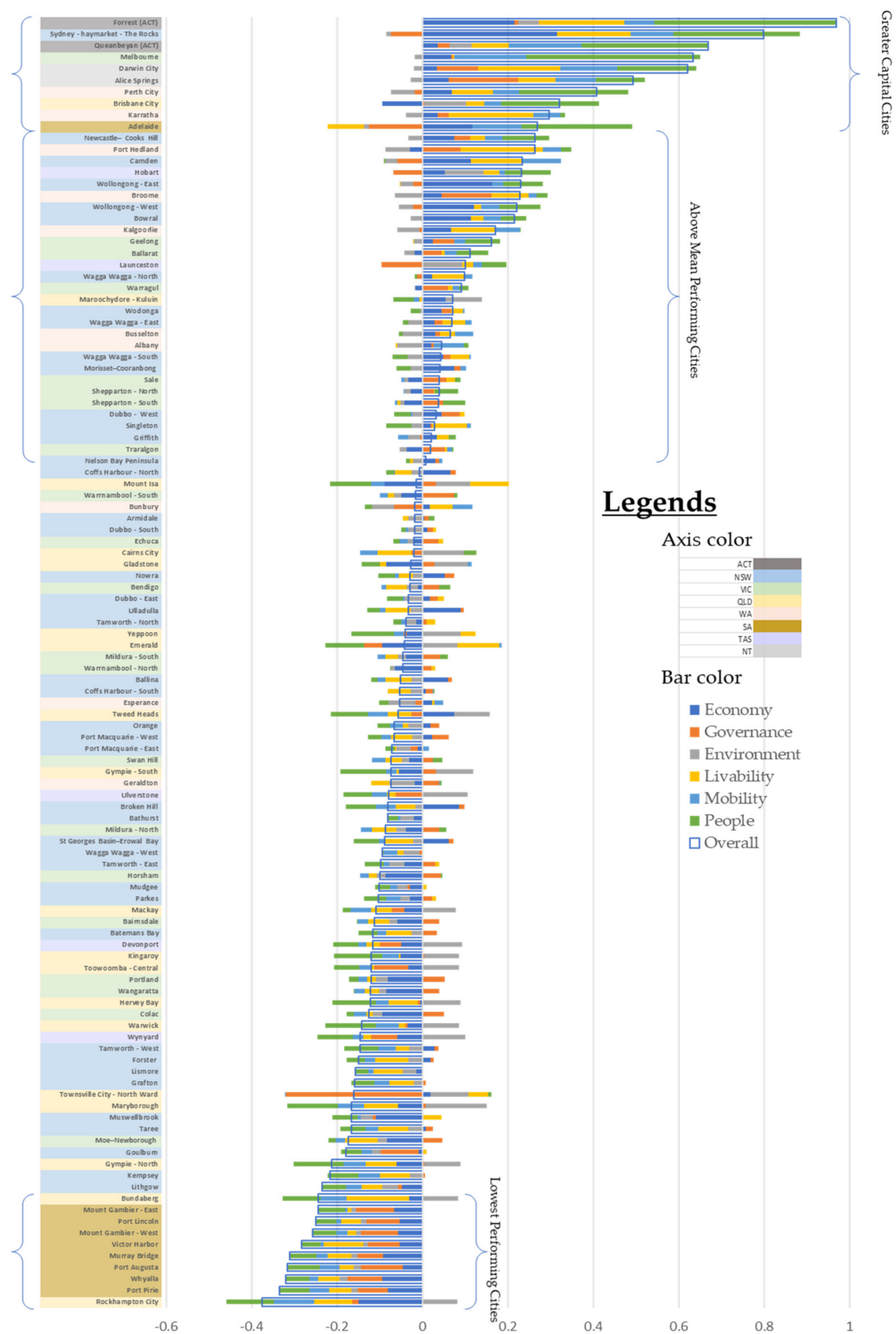


Figure 4. Smart score in descending order for 112 cities.

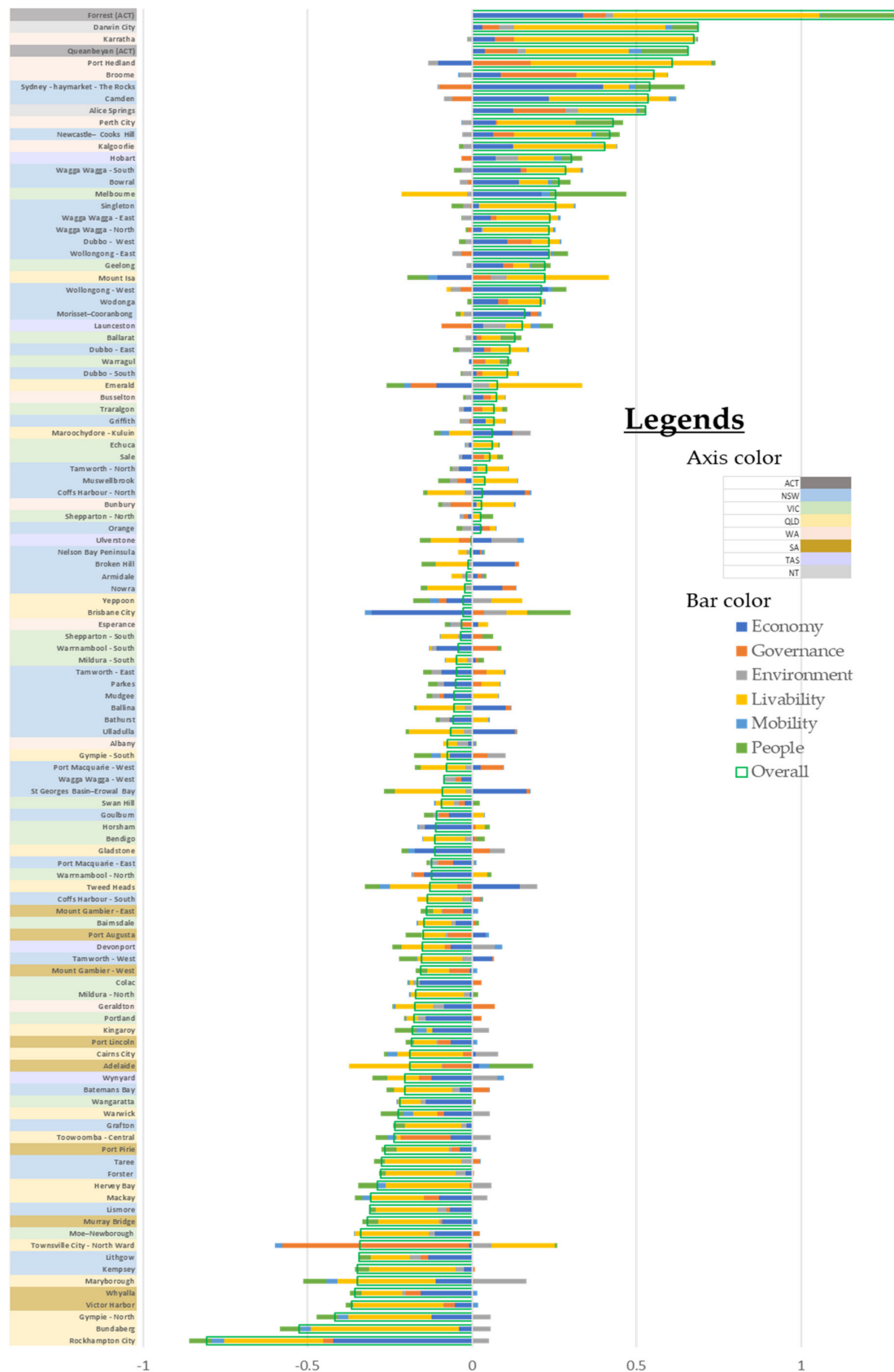


Figure 5. Preferred Cities arranged in a descending order.

#### 4.1. Overall Performance

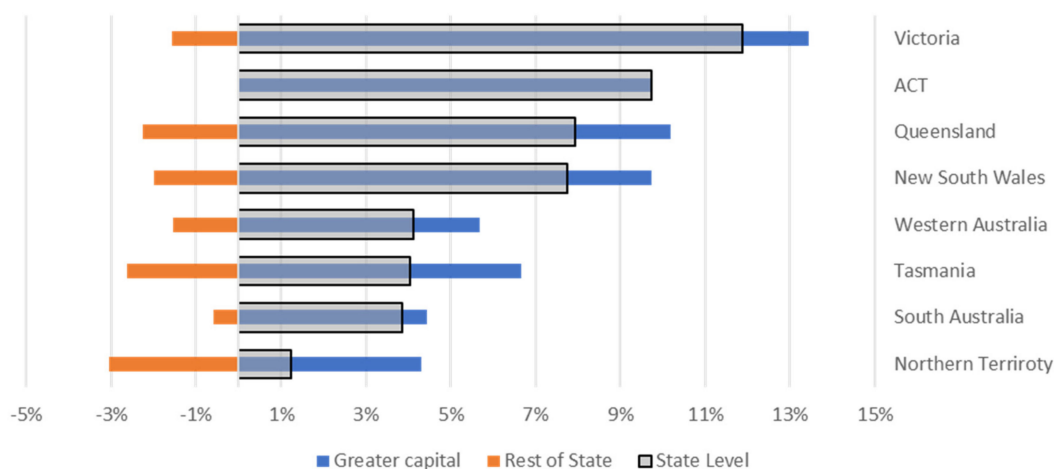
The overall results from Figures 4 and 5 shows that the greater cities from all states are standing at the top being amongst the smartest cities of Australia. However, these cities also expressed exceptional higher scores as compared to other cities, which is evident from the skewness of both graphs that shows more cities below the average with negative score.

The other significant observation is the similar performance of various cities within a state. Following the greater cities, the group of cities that performed above the mean is mainly consisting of cities from NSW, Victoria, and Western Australia. In the same fashion, the worst 10 cities are from South Australia. Whereas Queensland's and Tasmania's cities performed quite fairly.

Figure 5 shows that assigning weightages to the indicators, factors, and components changed the results extensively. The maximum impact of preferences was observed for Adelaide, which scored among the top position for smart city ranking but secured 88th position among the preferred cities due to its poor performance in people and governance.

Another indicator of people's preference is the number of cities qualified the selection criteria. NSW, VIC, QLD, and WA attracted more population and developed cities due to various economic, climatic, and supporting conditions.

Figure 6 demonstrate the growth rates of Australian states over the last decade. The overall growth rates are compared with the growth rates of capital cities with rest of the states' cities. Population growth rate over Australia remain 14% for the last decade. Except for VIC, all other states show lower growth rates that shows the dominant growth rate of VIC. Whereas all regional areas expressed negative growth rates that shows the failure of even growth of Australian cities. Figure 6 closely match our results at the overall performance of cities of different states.



**Figure 6.** Population growth rate of states, greater capitals, and rest of state areas over the last 10-years.

#### 4.2. Performance at the Component Level

At the component level, some prominent trends are observed within different states. For example, almost all cities performed above the average or below the average in many of the components in different states. Figure 7 provides the performance of selected cities in all components, whereas Figure 8 provides their performance under preferred cities criteria. Figure 9 provides a comparison at the overall level.



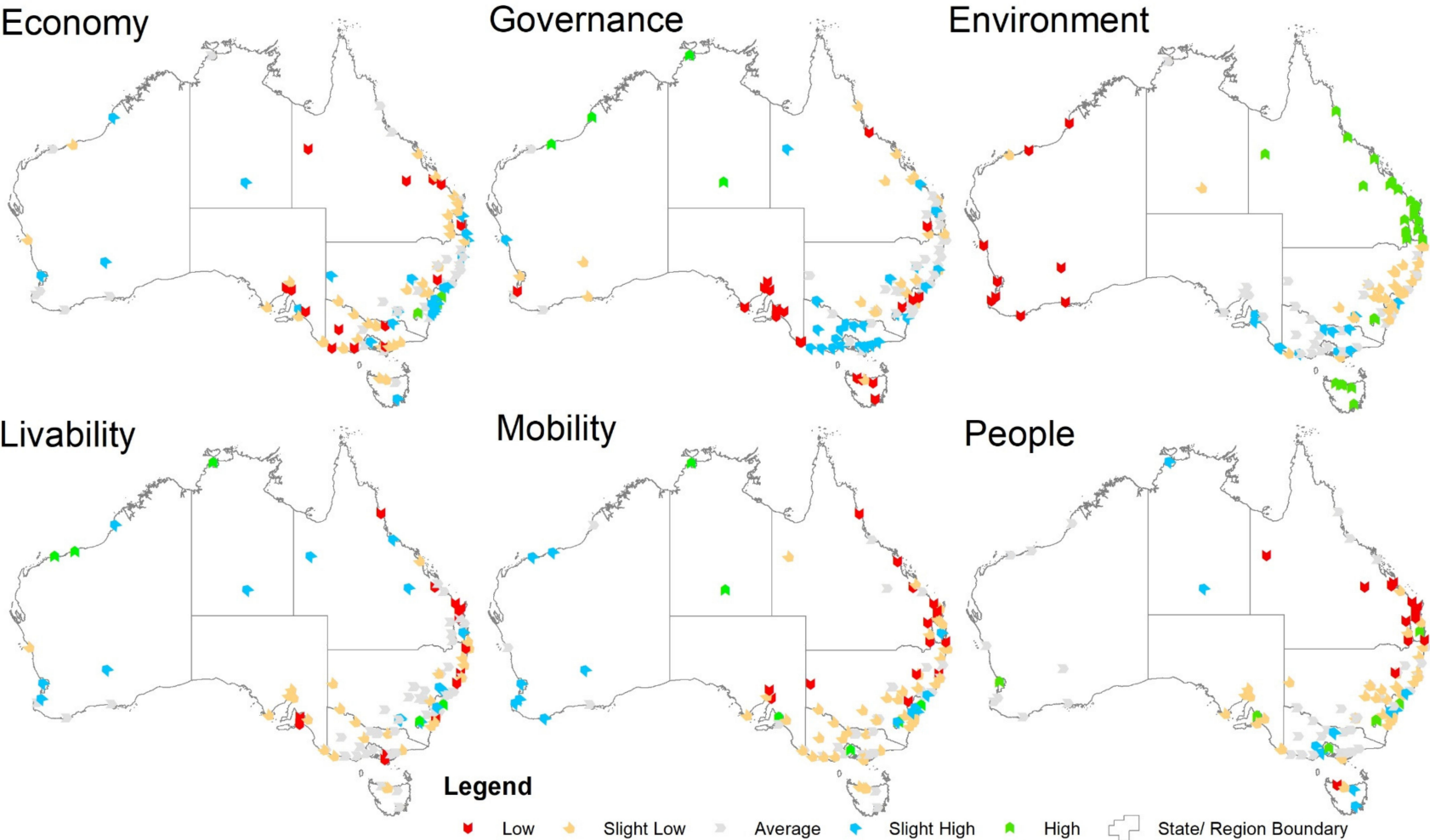


Figure 7. Smart cities performance in each component.

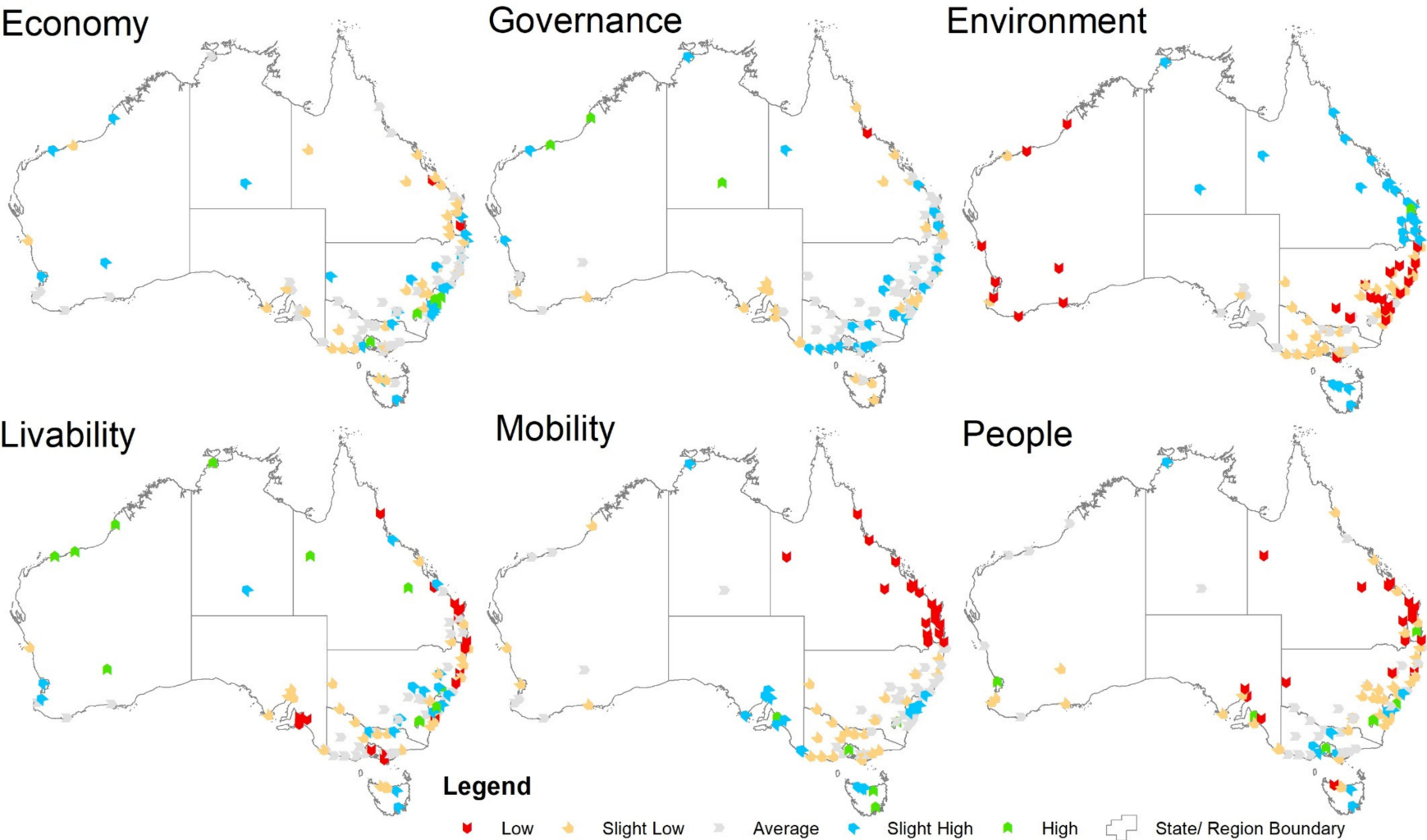


Figure 8. Preferred cities’ performance at the component level.

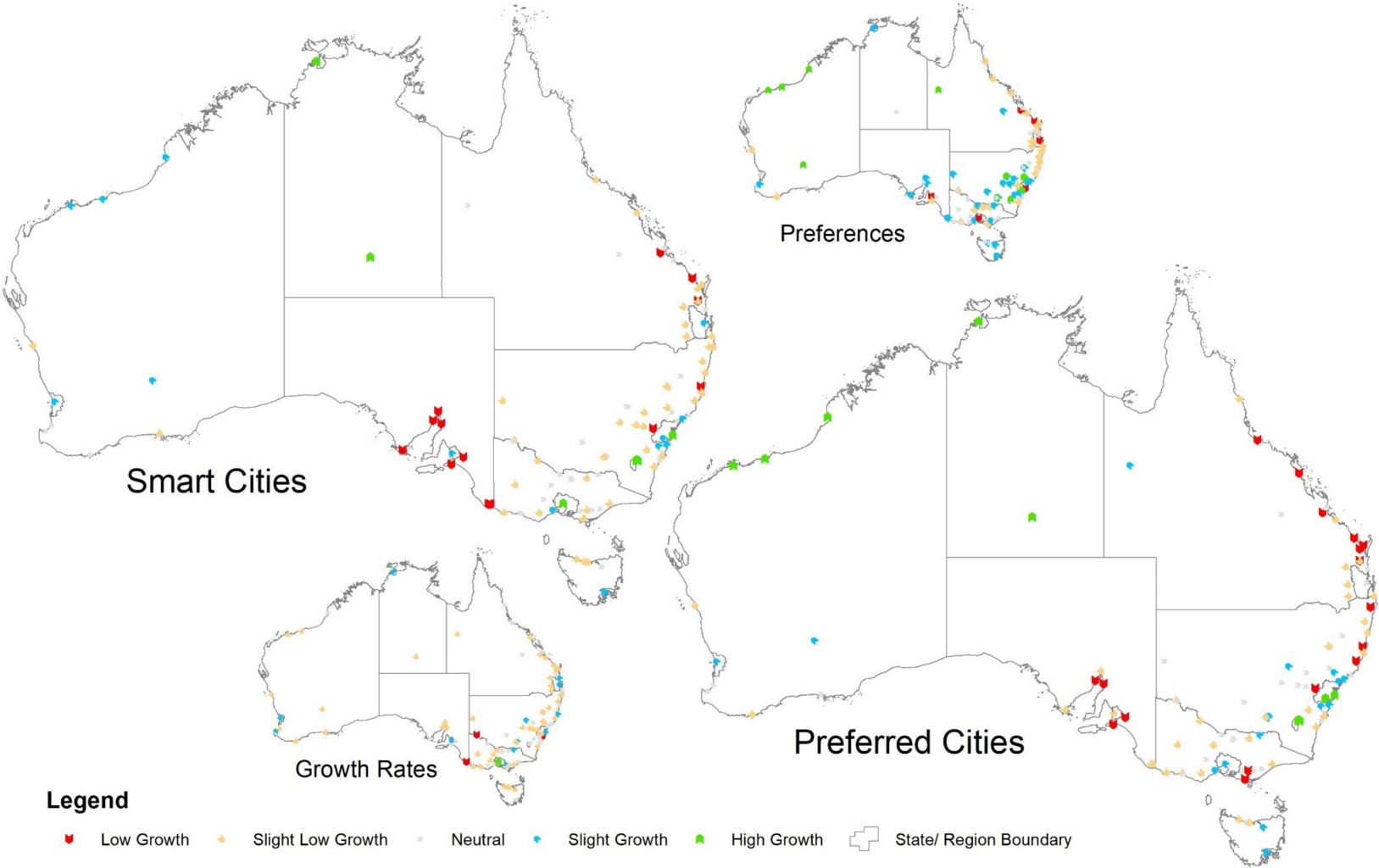


Figure 9. A spatial distribution of Smart Cities and Preferred Cities with the preference weightages and growth rates of last 10-years (Not to the scale).

Economy is the only component where all greater cities scored high. Majority of cities from NSW and SA performed better in economy component. Except for the greater cities in VIC, QLD, and SA, almost all regional cities underperformed. In preferred cities, SA is the state that performed overall slight poor or average. QLD and VIC also performed below the average for most of the cities in preferred cities.

SA performed exceptionally poor in governance component along with TAS having a similar behavior, whereas VIC and NT performed above average throughout the state. Remaining states expressed a mix behavior in different cities. All cities of TAS and SA performed average or below average in preferred city ranking.

All cities of Tasmania and QLD performed well above the average in environment component. All cities from WA performed among the worst followed by the poor performing cities in NSW and NT. A clear grouping of QLD, TAS, and NT for better performance and NSW, WA, VIC, and SA poor performing states clearly under preferred city ranking.

Livability is the component that expressed the highest correlations with the population growth and had the highest weightage in calculating the preferred cities ranking. SA and NT cities performed well for livability component. VIC is the worst performing state followed by TAS and QLD. WA and NT performed well, and SA performed poor under preferred city ranking.

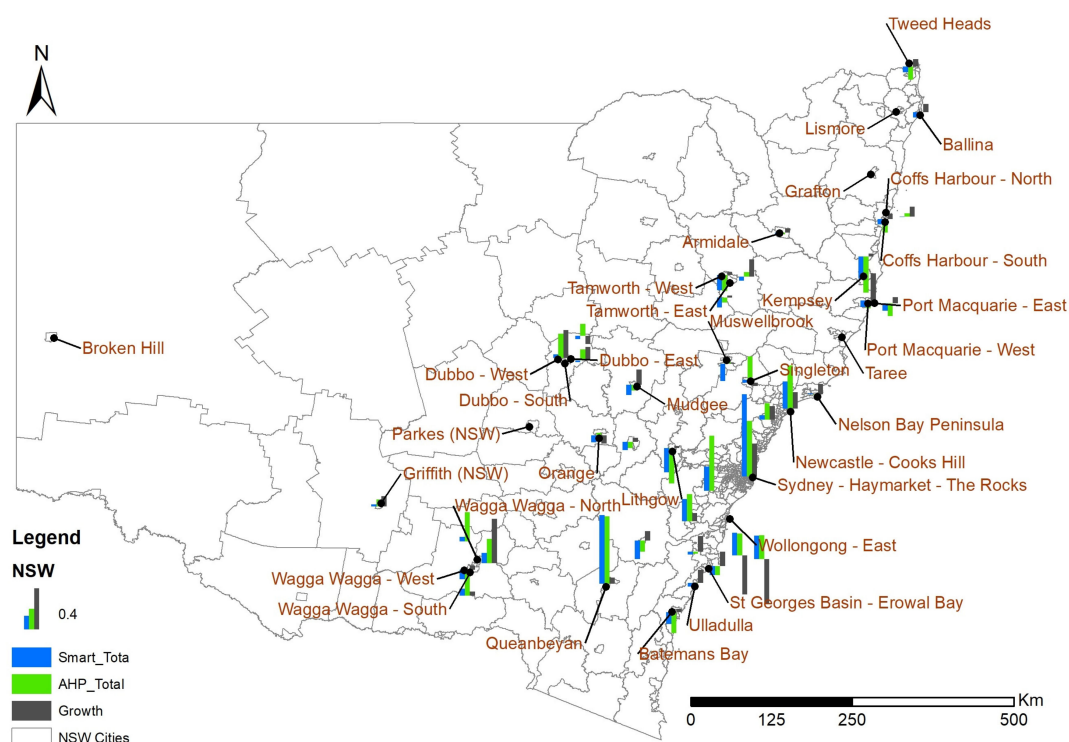
NT and SA cities expressed satisfactory performance along with the greater cities (except Hobart) for mobility component. Excluding greater cities, QLD and SA cities performed poor or slight poor for mobility whereas all cities of TAS and VIC performed average or slight lower. QLD being the worst for all cities under preferred city ranking. VIC and WA also performed slight poor for all cities except Melbourne. All cities of TAS and SA performed well for mobility under preferred city ranking.

People component had outstanding score for greater cities of Sydney, Melbourne, Canberra, Brisbane, Perth, and Adelaide. VIC has a few cities with slight good and average score. WA has all cities with average score. QLD has average, slight low, and low scoring cities. NSW and TAS expressed a full range of behavior for their cities. People component had worst performance for all non-greater cities of QLD, WA, and SA under preferred city ranking.

Economy and environment almost behaved inverse to each other. Queensland, Victoria, and Tasmania performed better in Environment and were low performing in for economy, whereas the behavior of West Australia, NSW, and Northern Territory, was totally opposite by performing better in economy and poor in environment.

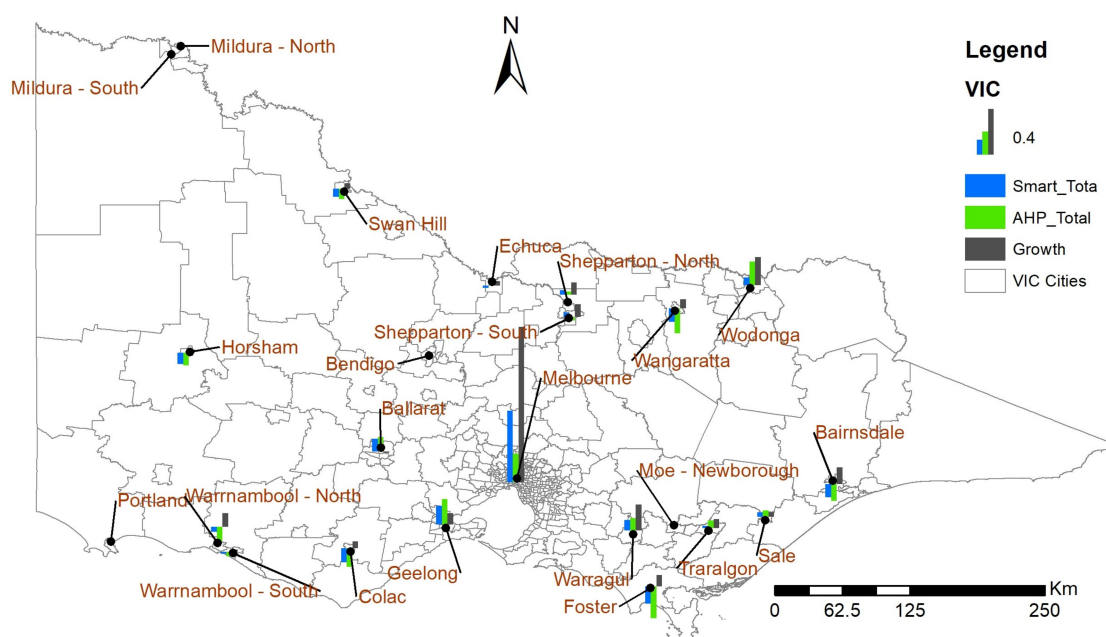
#### 4.3. Detailed Analysis of States

Following the city selection criteria, 44 cities were analyzed from New South Wales. Haymarket, from the Greater Sydney and Queanbeyan (adjacent to Canberra) remained outstanding for smart ranking scores. Other than the Wollongong (East and West), which might have migration towards Sydney, all cities in the NSW have observed an increase in population over the last decade. Figure 10 demonstrate the behavior of NSW's cities.



**Figure 10.** Smart Score of 44 cities of NSW along with Preference Score and 10-year population growth.

In Victoria, the highest growth rate is observed in Melbourne that got the highest smart score (refer Figure 11). The performance of Melbourne is outlier Except for the Mildura, a border city with significant reduction in population, no city observed any significant growth or reduction in population. Newborough is the least smart and least preferred city in Victoria.



**Figure 11.** Performance of 23 cities of Victoria in terms of smart score, preference, and population growth.

18 cities from the Queensland were evaluated. Except the Greater Brisbane and Maroochydore–Kuluin (part of Sunshine Coast), all 16 remaining cities performed below

the average cities' performance. The similar or even worse performance is observed for the population growth. The results are shown in Figure 12. Rockhampton city is not only the lowest smart scorer but lowest preferred city in Queensland but the lowest overall in Australia among the cities ranked in our study. This is the city that shows 16% reduction in population over the past decade.

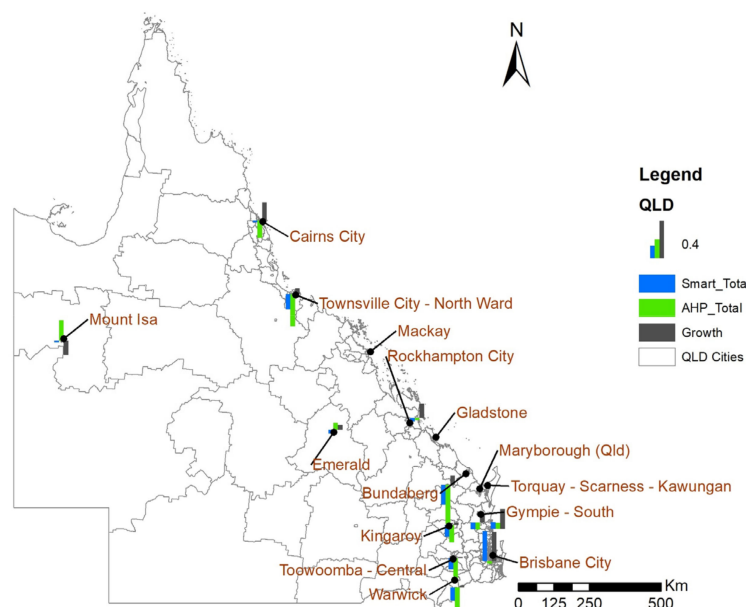


Figure 12. Smart city performance, Preference, and population growth of Queensland's 18 cities.

10 cities of Western Australia qualified the city selection criteria. As in all states, the greater city (Perth) performed as the smartest city and observed the highest growth rate in last decade. Other than Perth and Busselton, all other cities experienced around the average population growth. Figure 13 shows the performance of Western Australian cities.

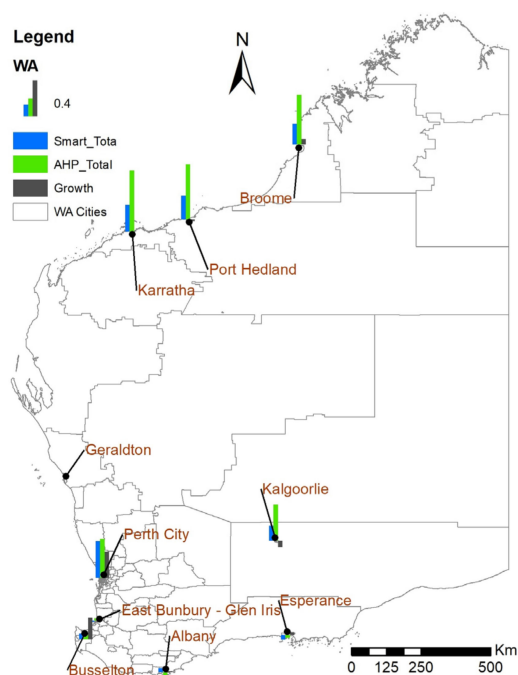
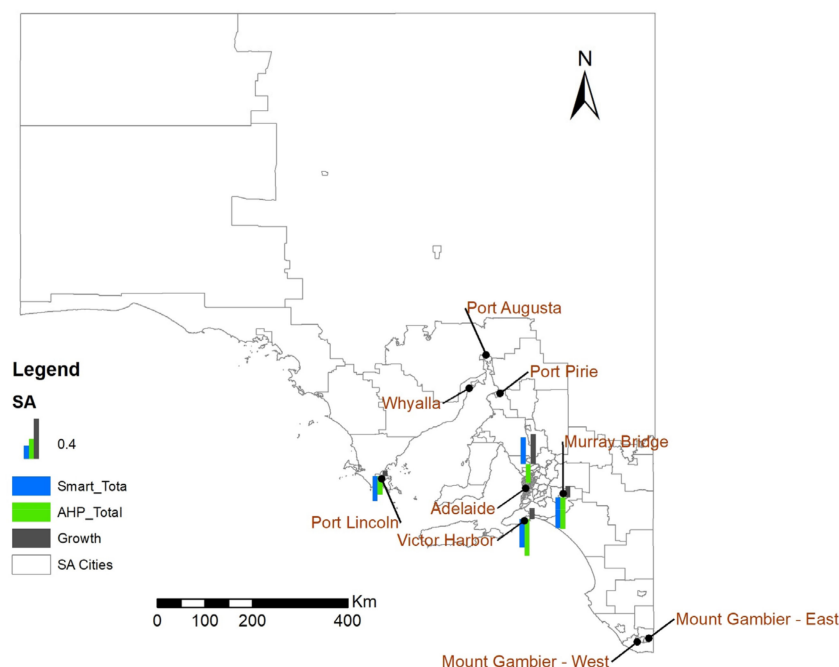


Figure 13. Smart and preferred city rankings of Western Australian 10 cities and the population growth rates.

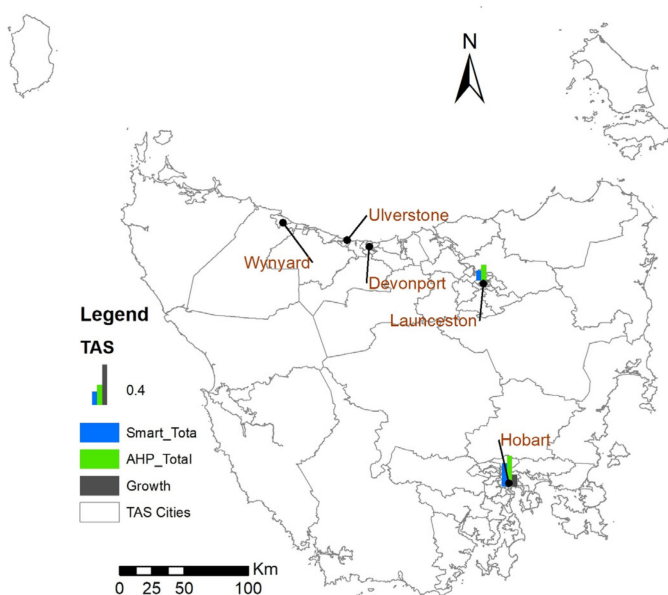


South Australia had nine cities selected for ranking. Greater Adelaide remained the smartest city. All other cities performed below the average score. Figure 14 shows that growth rate of all cities in this state fluctuate around the average.



**Figure 14.** Smart and preferred city rankings of South Australian 9 cities and the population growth rates.

5 cities of Tasmania are analyzed. Hobart emerged as the smartest city followed by Launceston. Except Hobart, all other cities experienced below average growth rate. Figure 15 depicts the smart score, preferences, and growth rates of Tasmanian cities.



**Figure 15.** Five smart cities of Tasmania with preference and growth rates.

## 5. Conclusions and Recommendations

The comparison of smart score and preference score shows that the difference of development and facilities between the metropolitan cities and regional cities is huge.

Government's regional areas incentives are not affective and have not been producing positive results. The government must prioritize the development of regional cities to ensure an even development over the country and avoid concentration of human capitals in greater cities.

Performance analysis of different components reveals that in many cases, majority of the cities secure similar scores within a state. These similar trends within same state maybe because of the indicator data that are collected at SA–3, SA–4, or at the state level or these trends may reflect the policies and strategies of the state governments.

Smart city ranking and Preferred city ranking, both appeared to be effective in terms of evaluating the performance of a city. A Preferred city ranking appears more meaningful and effective. However, a more comprehensive and detailed Preferred city ranking is recommended to obtain more in-depth understanding of Preferred cities.

It was observed that the cities which secured better in environment, were not able to secure high smart scores. These cities do not perform considerably in economy as well. This trend advocates an emphasis on the sustainable development to avoid overstressing of a component over the other.

Smart scoring can be considered as a guideline for the development of a city and a region as well. As the smart city ranking considers almost all components of an area's development. Another positive aspect of smart city ranking is that the ranking process is comparative, and the human capitals migrates based on comparative opportunities and facilities.

Developing a connection between the smartness of a city and its ability to attract human capital is relatively a new idea. The research has made an initial attempt and the hypothesis needs a long way to establish further strong correlations. A statistical approach was used in this research. Whereas physical-based modeling can be used to validate the results in the future. In addition to the smartness of a city, there are multiple other factors (e.g., climate, location, and geopolitical factors) and incentives that attract human capital. Therefore, these initial results of this research can be considered provisional owing to inherent uncertainties. It is recommended to include more factors under different scientific evaluation methods for more cities to develop more strong correlations in future studies.

**Author Contributions:** Conceptualization, M.A.U.R.T., M.H. and N.M.; Data curation, M.H.; Formal analysis, M.A.U.R.T. and M.H.; Investigation, M.A.U.R.T.; Methodology, M.A.U.R.T.; Project administration, M.A.U.R.T.; Resources, M.A.U.R.T.; Software, M.A.U.R.T. and M.H.; Supervision, M.A.U.R.T.; Validation, M.A.U.R.T.; Visualization, M.A.U.R.T.; Writing—original draft, M.A.U.R.T., M.H. and N.M.; Writing—review & editing, M.A.U.R.T. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A

**Table A1.** Describing the data sources used in the research.

Indicators	Data Source	
New Businesses/Total	GCCSA	Economy and Industry
Large Businesses/Total	GCCSA	Economy and Industry
Self Employed Trend	GCCSA	Economy and Industry
Total Businesses Trend	GCCSA	Economy and Industry
Patent & Trademark Apps Trend	portal.aurin.org.au	Patent applicants & Trademark applicants
Business Entry Rate Trend	GCCSA	Economy and Industry

Table A1. Cont.

Indicators	Data Source	
Building Approvals Trend	GCCSA	Economy and Industry
Dwelling Worth	GCCSA	Economy and Industry
PSHouse Worth/Dwelling	GCCSA	Economy and Industry
Gross Product/Cap	41,020 Eco.Indicators	Table 2
Wage Price Index WPI	41,021 Eco.Indicators	Table 3
Unemployment Rate TrendInversed	GCCSA	Education and Employment
Gross Capital Gains mil Trend	portal.aurin.org.au	gcg reportd by taxpayers
Pensions/Allowances Trend	GCCSA	Income
Sports&Rec mil	4147 Gov Funding	Page 10
Total Assistance Trend	GCCSA	Income
Enrolled Voters	<a href="http://aec.gov.au">aec.gov.au</a>	Actual enrollement
Votes HOREps	13,700 Trust	Table 2
Votes Senate	13,700 Trust	Table 2
Community Incentive	Social Survey	Table 3.3 (A81)
Community Programs	Social Survey	Table 3.3 (A112)
Renewable Energy by	Renewable Energy By State	Page 6
Net Zero emissions by	Renewable Energy By State	Page 6
Air Quality week average	breezometer.com	breezo meter
C Equivalent TrendInversed	Australia Progress	Table 11
GreenHouse Gas Emi Trend Inversed	13,700 Sustain Enviro	Table 1.2
Aquatic Biota Index Inversed	4614 Aus Enviro Issue	Page 6
River Enviro Index	4614 Aus Enviro Issue	Page 7
Water Development	Australia Progress	Table 9
Expenditure Per Capita	46,110 Enviro Protection	Page 11
Expenditure Per Capita	46,110 Enviro Mgmt	Page 18
Solar Installations Trend	GCCSA	Land and Environment
Solar Hot Water Trend	GCCSA	Land and Environment
Suburbs w /> 50% solar Installs	Renewable Energy By State	Page 4
Solar Households	<a href="http://pv-map.apvi.org.au">pv-map.apvi.org.au</a>	Mapping Australian Photovoltaic installations
Capacity/Capita No hydro kW/Cap	Renewable Energy By State	Page 4
Renewable Electricity	Renewable Energy By State	Page 4
Median Sale Price Trend Inversed	GCCSA	Economy and Industry
Rent Inversed	GCCSA	Family and Community
Mortgage Inversed	GCCSA	Family and Community
Mortgage <30% Income	GCCSA	Family and Community
Rent < 30% Income	GCCSA	Family and Community
Person/Household	GCCSA	Family and Community
+ Beds needed	GCCSA	Family and Community

**Table A1.** *Cont.*

Indicators	Data Source	
Employed Percentage	GCCSA	Education and Employment
Participation Rate	GCCSA	Education and Employment
Unemployment Rate	GCCSA	Education and Employment
Assault	41,020 Other	Table 2
Break-ins	41,020 Other	Table 2
Safe Travel Home	Social Survey	A174
+ Crimes/yr	Social Survey	A187
Private Health Trend	GCCSA	Health And Disability
Male Life Expectancy	3302055001DO002_2017-2019 Life tables	Table 2.1
Female Life Expectancy	3302055001DO002_2017-2019 Life tables	Table 2.1
Excellent Self Health	Social Survey	A133
Median Income	GCCSA	Income
Mean Income	GCCSA	Income
Disposable Income weekly mid	portal.aurin.org.au	median disposable household income synthetic estimates
1000–2000%	GCCSA	Income
Train Network	Each States Satisfaction In.	Satisfaction Index
Bus Network	Each States Satisfaction In.	Satisfaction Index
Taxi	Each States Satisfaction In.	Satisfaction Index
Utilization to work/study	ATTA—Transport by State	Table 2.2
Utilization outside of work/study	ATTA—Transport by State	Table 2.7
Train-Tram to Work	GCCSA	Family and Community
Bus to Work	GCCSA	Family and Community
Roads	13,700 Built Environment	Table 1
Car Acc/, ppl Inverse	41,020 Health Indicator	Table 2
Car to Work	GCCSA	Family and Community
Population Density /km	GCCSA	Population and People
Cars/ppl	GCCSA	Economy and Industry
Av Distance to Work/Study	GCCSA	Family and Community
Multiple to Work	GCCSA	Family and Community
Computer/Household	41020 Other	Table 2
Internet Connectivity	GCCSA	Family and Community
Science/Technical Services	GCCSA	Economy and Industry
Post School Qualified	GCCSA	Education and Employment
BA Degree	GCCSA	Education and Employment
Above BA Degree	Social Survey	A253

Table A1. Cont.

Indicators	Data Source	
Managers	GCCSA	Education and Employment
Professionals	GCCSA	Education and Employment
Technicians	GCCSA	Education and Employment
Languages Spoken	GCCSA	Population and People
Library Visits	Social Survey	A122
Art and Museum Visits	Social Survey	A122
Cultural Tolerance	Social Survey	A154
Bike to work	GCCSA	Family and Community
Walk to work	GCCSA	Family and Community
Enrolled Voters	13,700 Participation	Table 1
Organized Sport	41,020 Other	Table 2

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