Summary (Team 71672)

The world is becoming increasingly urbanized - small cities are developing rapidly, and large cities are growing larger and more populated. By 2050, the percentage of people living in cities is expected to reach 66.4%, a 22% increase from today's percentage [20]. Cities in the United States and Australia will particularly notice the growth, with current urbanization rates of 82% and 90%, respectively. Principles of smart growth can be used to address the issues of increased population. To address city plans for growth over the next 30 years, we first defined a metric to measure the success of smart growth. We used van Rijsbergen's information retrieval effectiveness measure to combine pairs of quantitative measures of the growth principles that were significantly related. We then summed all of the resulting measures, under the assumption that each principle of smart growth was equally important. We applied this metric to the current growth plans of two cities: Boulder, CO, USA and Canberra, ACT, AUS. After evaluation of their current growth plans, we developed growth initiatives for both cities, and evaluated the expected outcomes of the new plans with our metric. For Boulder, these initiatives included rezoning land for mixed use, redeveloping residential areas, instituting vacancy taxes, increasing public transportation, and increasing community programming. For Canberra, the initiatives included rezoning new mixed use areas, partnering with private developers, increasing community engagement, and expanding bus routes. In both cities, we rated our proposed initiatives with our smart growth metric. Each city saw an increased score compared to the score the current city plan received. Our metric proves very easy to use: all that is needed is census data that is easily found. On the other hand, we note that our model may be oversimplified due to equal weighting of each growth measure, and the subjective nature of some of measures. Our growth plan for each city also proved inefficient in accommodating a 50% increase in population in each city. Additional data could be used to improve our proposed initiatives so that they could be effective for larger population increases and to improve our quantifying metric to better reflect how well the city is planning using smart growth principles.

Sustainable Cities Needed!: Applying Smart Growth Principles in Boulder, CO, USA and Canberra, ACT, AUS

ICM Contest Question E

Team # 71672

January 23, 2017

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1 Introduction

Smart growth is a strategy used to direct sustainable development of cities, particularly those that face rapid urbanization. Smart growth can be evaluated using the three E's of sustainability - Economically prosperous, socially Equitable, and Environmentally Sustainable [2]. More specifically, smart growth can be defined in terms of ten principles [2]:

1. Mixed land uses
2. Taking advantage of compact building design
3. Creating a range of housing opportunities and choices
4. Creating walkable neighborhoods
5. Fostering distinctive, attractive communities with a strong sense of place
6. Preserving open space, farmland, natural beauty, and critical environmental area
7. Strengthening and directing development towards existing communities
8. Providing a variety of transportation choices
9. Making development decisions predictable, fair, and cost effective

10. Encouraging community and stakeholder collaboration in development decisions

Two cities that have already made considerable efforts in smart growth development, and that have the potential to improve through future growth plans, are Boulder, CO, USA, and Canberra, ACT, Australia. In this paper, we propose growth plans for both of these cities, first by analyzing their current growth, and then by suggesting improvements. In Section 2, we outline a metric we created to quantify the level of success of smart growth in each city. In Section 3, we discuss the current growth plans of Boulder and Canberra, and we evaluate their current success by referring to our computed metric. In Section 4, we then propose a plan for future growth of each city, based on the 3 E's of sustainability, the 10 principles of smart growth, and the current growth plans. In Section 5, we assess how our growth plans hold up to a 50 percent increase in population. Finally, we address the strengths of our model and its outstanding issues.

2 A Metric for Smart Growth

In developing our smart growth success metric, we first developed one metric for each of the ten principles. These metrics were based on the data available for the two cities, and some are more mathematically precise than others. Since the most recent growth plans available for Boulder and Canberra were developed or updated in 2010 and 2012 respectively, we decided that current city statistics were appropriate to evaluate the success of those plans. We use a modification of van Rijsbergen's information retrieval effectiveness measure [9] to merge the metrics for principles that are strongly related, then sum these combinations and compare the result to an optimal value. This is our metric for the level of success of smart growth plans.

1. Principle 1 is about mixed use land. We identified the ratio of land zoned for mixed use by the city to the city's total land. Based on current values, we determined that an optimal, achievable value for this metric is 0.15.

2. Principle 2 concerns building compactly. We found a paper that computed compactness of European cities, in part using population density in people per square mile [17]. We use population density (divided by 2000 as neither of our cities will end up with a population density higher than this, even if the population is increased by 50%

by 2050). The number of people living in an area can easily represent how compactly the buildings in the area are built. The optimal value for this metric is, then, 1.

3. Principle 3 is about availability of diverse housing. We focused on affordable housing and looked at the planned percentage of newly available housing intended to be permanently affordable according to each city's growth plan . The optimal value for this metric is 25%, or 0.25.

4. Principle 4 identifies that neighborhoods should be walkable, meaning that both workplaces and stores should be in close proximity to residential areas. We use the percentage of people in each city who walk to work as this metric. The optimal value is 25%, or 0.25, which should account for people living in and near mixed use areas. As such, this logically correlates with Principle 1.

5. Principle 5 is to develop and maintain the character of individual neighborhoods. This proved to be very difficult to quantify. Our metric is to examine how this goal is described in the cities' growth plans and rate their dedication to the goal subjectively on a scale from 0 to 1. The optimal value is 1.

6. Principle 6 is to preserve open space, farmland, etc. We look at the ratio from open land to total land in the city. The optimal value, which we determined based on the current level of open space in the cities studied, is 0.75.

7. Principle 7 suggests redeveloping existing communities instead of building on new land (greenfield development). We did not find data on the extent that each city is doing this currently, so we settled on assigning a rating from 0 to 1 based on the stated goals in their growth plans. The optimal value is 1. Since Principles 7 and 5 both concern existing neighborhoods, we have correlated them.

8. Principle 8 is about providing alternative methods of transportation. We use the percentage of people in each city who use an alternative method (i.e. not driving alone) to commute to work. The optimal value for this is 100%, or 1. This is correlated with compact building design, as building compactly allows more space for bicycle lanes, pedestrian trails, bus depots, and train stations.

9. Principle 9 is about making smart development decisions. One factor of this is that a city is willing to work with private developers on new development. We subjectively rated this on a scale from 0 to 1 based on the cities' growth plans. The optimal value is 1.

10. Principle 10 concerns engaging community members in development planning. We searched the city growth plan web pages for unique means for community members to give feedback on the plans. We counted these unique means and divided the totals by 12, as we concluded that 12 different ways that are easily found by us (people relatively unfamiliar with the city government websites) should be more than sufficient for community members to provide feedback. The optimal value for this is 1. This is correlated with Principle 9, as another factor of Principle 9 is making development choices that the community will expect and be satisfied with.

As stated above, we correlate Principles 1 and 4, Principles 2 and 8, Principles 5 and 7, and Principles 9 and 10. To combine these metrics, we use a modification of the following effectiveness measure, originally intended for use on precision P and retrieval P, two variables which interact [9].

$$E = 1 - \frac{1}{\alpha\frac{1}{P} + (1-\alpha)\frac{1}{R}}$$

We weighted each correlated metric equally, so we set $\alpha = 0.5$. Because a higher value for each of our principle metrics corresponds to a higher level of success, used only the second term, made positive. For metrics a and b, then, this gave us the equation

$$S_{a,b} = \frac{1}{0.5\frac{1}{a} + 0.5\frac{1}{b}} = \frac{2}{\frac{1}{a} + \frac{1}{b}}$$

We then summed the results from each of these four pairs, as well as the metric values for Principles 3 and 6, to obtain a success rating

$$S_{tot} = S_{1,4} + S_{2,8} + S_{5,7} + S_{9,10} + S_3 + S_6$$

Finally, we computed the optimal success rating using the optimal values for each metric to be $S_{opt} = 4.1875$. We compare the computed success rating to the optimal success rating to obtain our final, fractional success level L:

$$L = \frac{S_{tot}}{S_{opt}}$$

We use L to evaluate the success of both the current and proposed growth plans for each city.

3 Current Growth Plans

3.1 Boulder, CO, USA

Boulder's growth plan is the Boulder Valley Comprehensive Plan, last updated in 2010 [10]. We will evaluate how the city is satisfying each smart growth principle.

1. Currently, Boulder has 5% of its land area zoned as commercial or mixed use [13]. Thus, $< 5\%$ of its land is zoned as mixed use.

2. Boulder has a population density of 1107 people per square mile calculated from city population and area (including open space in the city area) [13]. It is also worth noting that Boulder typically limits buildings, particularly residential buildings, to three stories (35 feet) [18]. This limits the current capacity for housing and redevelopment.

3. The median detached home sale price in Boulder is approximately $750,000 [13]. The city plans to preserve existing mobile home parks and to add permanently affordable housing until 10% of the housing stock is permanently affordable [10].

4. Boulder's older, western neighborhoods are predominantly walkable and bikeable, while other parts of the city are not. The city's growth plan specifies plans to make neighborhoods more walkable and develop more pedestrian trails [10]. In 2011 (the date of the last readily available survey) 8.3% of Boulder's working population walked to work [11].

5. Boulder's building height restrictions help to preserve views of the nearby mountains [16], which helps to maintain community character. The city's growth plan cites several specific neighborhoods that each have distinct styles (e.g. the historic downtown area) and specifies that it will ensure that both redevelopment and any greenfield development will fit into the neighborhoods.

6. Boulder has 71 square miles of open space as compared to 25.8 square miles of city space [13]. It is dedicated to preserving "natural areas, environmental and cultural resources, critical ecosystems, water resources, agricultural land, scenic vistas and land for passive recreational use," as well as a defined boundary between rural and urban areas [10].

7. Boulder plans to complete new development and redevelopment primarily in areas where public services already exist (i.e. in existing communities). There is little open land in Boulder that has not already been designated as preserved open space [10]. Therefore, redevelopment is Boulder's most viable option.

8. Boulder has more than 300 miles of bike lanes, paths, and shoulders [15]. It is served by the Colorado Department of Transportation's Regional Transport District (RTD) public transit system, which consists of local and regional buses as well as light rail trains. Boulder intends to continue working with RTD to encourage alternative means of transportation and reduce traffic [10]. A commuter light rail train route from Denver, the nearest major city, to Boulder is also under construction [19]. In 2011 (the date of the last readily available survey) 36.8% of Boulder's working population commuted to work using a method other than driving alone [11].

9. Boulder encourages private development that fits with the city's other goals [10]. It also requires private developers to construct city infrastructure that would directly benefit their project [14].

10. Boulder encourages community engagement in its development decisions. We easily found 10 unique means for community members to engage with and provide feedback on development planning [12].

Table 1 summarizes the metrics described above, as well as the final success level of 0.7753.

3.2 Canberra, ACT, AUS

The latest growth plan for Canberra was proposed in 2012 by the Australian Capital Territory Government, which outlines outcomes for 2030.

1. The ACT's current plan to increase mixed land uses includes development of existing city centres to create more concentrated centres of commerce and living. The plan does not outline an exact target for land designed for mixed use, but it is clear from the city land map that very little land area is currently zoned for mixed use [5]. We approximate this as 5%.

2. Canberra has a population density of 1161 people per square mile calculated from the city population and area [4]. The government plans

Metric	Value
P1	0.05
P2	0.5535
P3	0.1
P4	0.083
P5	1
P6	0.733
P7	1
P8	0.368
P9	1
P10	0.8333
L	0.7753

Table 1: Table of individual metrics and final success level for the current growth plan of Boulder, CO, USA

to use the area around existing transit routes to concentrate housing and commerce development [4]. These initiatives will allow for higher population density and compactness.

3. The ACT introduced an update to the Affordable Housing Action Plan Phase III in 2016, outlining cost thresholds for affordable housing [6]. This plan maintains the requirement that 20 % of new housing must meet these thresholds [6].

4. About 4.5% of people in Canberra walked to work in 2011 (according to the most recent, readily accessible survey) [3]. However, people in Canberra rely heavily on vehicle transportation. The ACT's plan outlines goals to increase walking commutes by creating more mixed land spaces, and by developing walking networks around existing rail lines.

5. The ACT government seems concerned with creating new attractive communities with the hope of creating larger centres of commerce and living. In particular, the government suggests making neighborhoods more focused towards healthy living [4].

6. The ACT government plans to create new open spaces and maintain existing ones. The mention the need to "enhance Canberra's system of public spaces, providing vibrant, pleasant urban parks and places

that everyone can enjoy by ensuring they are safe and accessible..." [4]. In 2008 (the most recent, readily available data), the percentage of open space to total area in Canberra was 63.4% [1].

7. One of the 9 key strategies in the ACT Plan includes ensuring that everyone has access to "services and opportunities for social interaction by reinforcing the role of group and local centres as community hubs" [4]. However, community development seems more directed towards new, attractive, communities [4]. Thus, the value for this metric is 0.5.

8. As stated above, transportation by car is still prevalent in Canberra, despite the relatively new development of a light rail system. According to the survey from 2011, 15.8% of people used transportation other than driving alone to commute to work [3].

9. The ACT government plans to bring new jobs into existing communities, and therefore willing to work with private developers. The plan states that the government should provide a framework for private sector innovation and investment [4].

10. Canberra didn't have as many readily accessible means for community contribution as did Boulder. On the community engagement and city planning sites, we found 6 distinct ways for the community to offer feedback on city initiatives [7] [8].

Table 2 summarizes the metrics described above, as well as the final success level of 0.5882.

4 Proposed Growth Plans

Boulder and Canberra can adjust their growth plans to accommodate a population that continues to increase over the next 30 years. Using our metric, we determined optimal values for each of the smart growth principles for both Boulder and Canberra. To reach these optimal values, we propose the following growth plans for Boulder and Canberra.

4.1 Boulder, CO, USA

Our proposed growth plan for Boulder involves encouraging the city to continue some initiatives that it already has in place, and adds the follow-

Metric	Value
P1	0.05
P2	0.5805
P3	0.2
P4	0.045
P5	1
P6	0.634
P7	0.5
P8	0.158
P9	1
P10	0.5
L	0.5882

Table 2: Table of individual metrics and final success level for the current growth plan of Canberra, ACT, AUS

ing five additional initiatives that are key in adhering to the smart growth principles:

A Rezone and redevelop land for mixed use that is currently zoned for residential or commercial use only

B Redevelop current residential neighborhoods to include higher density and more affordable housing, such as townhouses and apartments

C Increase public transportation by finishing the light rail between Boulder and Denver and providing additional bus routes and buses per route around the city

D Discourage home owners from leaving their houses vacant by implementing a vacancy tax

E Create more community programming, particularly for youth and young adult age groups, to foster a strong sense of community within their neighborhoods

These apply to the ten smart growth principles as follows:

1. Ideally, Boulder would have 15% of its land area zoned as mixed use by 2050. Since Boulder does not have additional land that it can expand to with new buildings, it will have to redevelop existing areas

to make them mixed use areas. One way to do this is to rezone areas that are currently residential neighborhoods, particularly those near downtown, as mixed use land areas. Additionally, areas with less stringent height restrictions could be rezoned for mixed use land. Taller buildings can accommodate multiple uses, such as retail and residential, by having different uses of the building on each floor.

2. In order to accommodate population increase, Boulder must increase building density to provide enough housing and commercial buildings. Boulder is projected to increase its population density to 1230 people per square mile in the next 30 years as the total population climbs. [13]. One way to accomplish this goal is to increase housing density in residential neighborhoods. Density could be increased by decreasing lot sizes and replacing old houses with town houses or small apartment buildings that can accommodate many more tenants in the same amount of space. In 2015, the residential rental vacancy rate was 4.4% [13]. Decreasing this vacancy rate would also help increase population density.The city could encourage people rent out their vacant houses by creating a tax on vacant properties, incentivizing owners to seek out renters. Additionally, the city could incentivize building additional housing on existing property, such as microhouses, to increase housing density.

3. As the population increases, Boulder should ideally have 20% of its housing qualify as low-income housing. In order to accomplish this goal, Boulder should focus on building townhouses and apartment buildings. This initiative would help increase population density and improve city walkability, because it would allow lower-income people to walk to work instead of having to commute from outside city limits. Apartments could be built in areas where the height restrictions are less stringent, and townhouses could replace detached houses in residential neighborhoods near downtown.

4. Ideally, 15% of Boulder's residents would be able to walk to work. This increase would be a result of the city creating more walkable neighborhoods by rezoning residential areas for mixed use. Also, increasing housing density near downtown would allow more people to walk to work and retail locations, because they would live closer to commercial areas.

5. As the population density grows and more people move into exist-

ing neighborhoods, it will become more difficult for communities to maintain their current identities. Since some neighborhoods will be rezoned for mixed land use and different demographics will occupy new housing, some current residential areas will not be as quiet and quaint as they are now. This smart growth principle may suffer slightly as the communities grow, but over time, a new sense of community will be developed around the new and old residents in each community. Boulder should also maintain its community centers, such as public parks and recreation centers. As the population increases, the city should consider building additional community centers and recreation centers to maintain its current ratio of community members per community center. As such, we assign this metric a value of 0.8.

6. Boulder currently has 73.3% of its total land area as open space land [13]. As the population grows and there is an increased need for housing and commercial buildings, there may be proposals to rezone some open space land for these buildings. However, in following with the smart growth principle of preserving open space, Boulder should not develop any of its current open space land.

7. Boulder has little to no surrounding land to expand to, so it is already focused on redeveloping existing areas. This redevelopment should include introducing mixed land areas to areas that are currently residential only. Also, redeveloping existing neighborhoods allows communities to maintain their current sense of community and can increase the population density in the area to accommodate the additional people who want to live in the city. This metric has a value of 1.

8. Boulder should increase availability of public transportation as the population increases. By 2050, Boulder would ideally have 45% of its commuters use a mode of transportation other than driving to arrive at work. As the amount of low income housing in Boulder increases as part of our proposed smart growth plan, there will be higher demand for public transportation by those who cannot afford personal cars. Boulder can reach this goal by continuing its collaboration with RTD to provide buses around the city. Also, Boulder should continue its efforts to build a light rail train route between Boulder and Denver to aid commuters traveling much farther for work.

9. Boulder should continue its public-private partnerships for new developments [10]. As the city redevelops residential areas with higher building density, construction should be done by private companies that align with the smart growth principles the city is adhering to with its development. This metric has a value of 1.

10. Boulder is already doing well in asking for community feedback on development decisions. As the city works toward the development plan presented above, city officials should ensure the plans are transparent to citizens, and that that all citizens understand the smart growth principles to which the plans adhere. This metric has a value of 1.

The results of our proposed growth plan for Boulder are summarized in Table 3, including a computed success level of $L = 0.8338$, an increase of 0.0785 from Boulder's current growth plan.

Metric	Value
P1	0.15
P2	0.615
P3	0.2
P4	0.15
P5	0.8
P6	0.733
P7	1
P8	0.45
P9	1
P10	1
L	0.8338

Table 3: Table of individual metrics and final success level for our proposed growth plan for Boulder, CO, USA

4.2 Canberra, ACT, AUS

Our proposed growth plan for Canberra includes five initiatives:

A Rezone and redevelop land for mixed use; loosen building height restrictions

B Develop new, mixed use areas on at most 10% of current open space

C Partner with private developers to build affordable housing in a cost-effective manner

D Expand express bus routes and offer businesses discounted bus passes

E Offer more opportunities for community engagement in development planning and advertise these opportunities effectively

These initiatives relate to the 10 smart growth principles (and our metrics) as follows.

1. Ideally, 15% of Canberra's city area would be zoned for mixed use. Canberra's current plan includes converting some urban areas to mixed use. We recommend also redeveloping some of its current residential areas to mixed use areas. This will help to prevent excessive greenfield development and promote preservation of open space. The little greenfield development that Canberra then does should also be in areas newly zoned for mixed use.

2. In the next 30 years, Canberra's population density is expected to grow to 1455 people per square mile [4]. This growth will result in more housing demand. Redeveloping some urban and residential areas for mixed use should alleviate this to some extent. Enforcing a less stringent height restriction on buildings than is currently present will also allow more space for building upwards, resulting in a more compact city.

3. Canberra's current plan for affordable housing aims for 20% of new development to be affordable. We believe that Canberra could aim higher and reach our optimal value of 25% permanently affordable housing. We believe that Canberra should focus on redeveloping current areas to be higher-density (e.g. building townhouses instead of detached houses). Having mixed-use areas will help with this, as in Boulder, since low-income people could walk to work more easily, reducing their overall expenses. To encourage this, Canberra's government should offer tax benefits to private developers who are willing to complete construction of affordable housing at a discounted rate.

4. Canberra should aim to have 15% of its working population walk to work. This should account for most people living in existing and new mixed use areas, near existing and new mixed use areas, and near commercial/industrial areas.

5. We suggest that Canberra keep the intent to preserve distinctive neighborhood character, but not value this above redeveloping property for mixed use and building more housing. Thus, we anticipate a decrease of the value of our metric to 0.8.

6. 63% of Canberra's land area is currently open space. While, ideally, Canberra would maintain all of its open space, we decided that it is more realistic that it will need to use some of it for greenfield development due to the large population increase. We are setting a hard cap on this development at 10% of the current open space area. This would reduce the amount of open space in Canberra to 57.06% of the city's total land.

7. Our plan for Canberra involves a focus on, but not a total devotion to, redevelopment of existing communities. It would be very difficult to redevelop Canberra enough to allow for the large influx of new residents while also maintaining community character without also developing on open land. We plan for Canberra to convert the (maximum) 10% of open space that it develops to mixed use areas. We estimate that the new value of our metric should, then, be 0.75.

8. While the optimal proportion of the working population that commutes to work using alternative transportation methods is 100%, Canberra's current proportion is only 15.8%. We recommend that Canberra's public transit system add more express bus routes between outer areas of the city and the city's center. To accompany this, they should offer businesses bus passes for their employees at a discounted rate. Affordable transit will make employees more likely to commute on public transit. We estimate that Canberra will reach a metric value of 25% of commuters using alternative transportation methods.

9. Canberra should continue to partner with private developers, particularly in building affordable housing. This metric value should remain at 1.

10. Canberra should better publicize existing opportunities for community members to give feedback on development plans. We found these somewhat difficult to track down. In addition, Canberra should offer more of these opportunities, including but not limited to mail surveys, pop-up events, and discussions in individual subcommunities/neighborhoods. Canberra could, then, reach the ideal metric value of 1.

The results of our proposed development plan for Canberra are summarized in Table 4, including a success level of $L = 0.7443$, an increase of 0.1561 from Canberra's current plan.

Metric	Value
P1	0.15
P2	0.7275
P3	0.25
P4	0.15
P5	0.8
P6	0.5706
P7	0.75
P8	0.25
P9	1
P10	1
L	0.7443

Table 4: Table of individual metrics and final success level for our proposed growth plan for Canberra, ACT, AUS

4.3 Comparing Initiatives

We see from the results from the two previous subsections that our plan for Boulder results in a higher success level than our plan for Canberra, but that our plan for Canberra was a more significant improvement over Canberra's current plan than our plan for Boulder was over Boulder's current plan by nearly a factor of 2. We computed new metrics based on examining the effects of each individual initiative. The results are summarized in Table 5, where ΔL is the success level L of the city's current growth plan subtracted from the success level L after adding one of our individual initiatives.

We rank our initiatives for Boulder from best to worst in the order E, C, D, A, B. According to our metric and these results, the most influential element to the success of smart growth is increasing community programming, particularly through youth and young adult outreach (E). Increasing public transportation (C) and decreasing the number of vacant properties (D) both improve the smart growth of Boulder with the given metric. The initiatives to rezone land for mixed use land (A) and to redevelop residential neighborhoods (B) have a negative impact on Boulder's smart growth

Initiative	Boulder		Canberra	
	L	ΔL	L	ΔL
A	0.7549	-0.0204	0.6351	0.0469
B	0.7319	-0.0434	0.5436	-0.0456
C	0.7893	0.0140	0.5995	0.0113
D	0.7786	0.0033	0.6543	0.0661
E	0.7970	0.0217	0.6678	0.0796

Table 5: Table of the effects of individual initiatives on success level for Boulder, CO, USA and Canberra, ACT, AUS

according the metric, because they negatively affect community identities as they allow more people to move into neighborhoods.

We rank our initiatives for Canberra from best to worst in the order E, D, A, C, B. Better, more accessible community engagement (E) is key to smart growth success in Canberra, as is improving the public transit system (D). Building new developments on open space (B) is, ultimately, slightly detrimental to the city's smart growth success level because it involves new development on open space, but we feel it is unrealistic for this not to occur in Canberra. We defined Canberra initiative B to minimize the negative effects of such new development.

5 Population Increase

5.1 Boulder, CO, USA

Boulder's population is projected to increase by 22,166 people by 2050 if growth continues at the current rate, which is a 20.7% increase from the current population [13]. If the population were to instead increase by 50% over the next 30 years, the city would not be able to provide housing and space for all the additional people, even using our smart growth plan. Since the 50% increase in population is much larger than the projected 20.7%, the city will be able to keep up with its predicted growth but not with the hypothetical situation of 50% growth. With 50% growth there will not be enough housing or land on which additional housing could be built. In order to build enough housing, the city would have to change the height requirement on buildings to allow for upward expansion or decrease the land designated for open space to provide enough space to build new housing. If open space land was redesignated to provide for the additional population,

new developments should be zoned for mixed land use, so that new neighborhoods are walkable and adhere to smart growth principles. This would match our proposal for 15% of city land to be mixed land use, though our proposal bases this change on rezoning commercial and residential land rather than open space. Public transportation to these locations would also have to increased. This could be accomplished by creating new bus routes throughout the city and by increasing the number of buses that currently run on each route. Additional buses would also need to be added to Boulder to Denver routes to account for the additional number of commuters who may work in Denver and live in Boulder. These initiatives would help Boulder reach the goal of 45% of people commuting to work by some form other than driving set forth by our proposal.

5.2 Canberra, ACT, AUS

Canberra's projected growth in the next 30 years is approximately 25%. If it continued at the same rate, it would increase by 41.7 by 2050. A population increase of 50% by 2050 is certainly larger than the projected growth of Canberra, but not by a huge margin. Our plan would likely result in housing shortages. We attempted to minimize use of open space in new development, but if Canberra grew 50% by 2050, we believe that the amount of redevelopment required to avoid eliminating more than 10% of the current open space is unrealistic. Canberra would likely need to expand further into open space, which is not accounted for in our plan. The city would also need to further expand mixed use areas and the public transit system to encourage alternative transportation methods and avoid significant increases in traffic. The 15% mixed use zoning that we identified as Canberra's goal might need to be increased to 20%. The public transit system would need to be expanded and advertised proportionally to the city's growth, similarly to our plan. Our initiative for community engagement would, most likely, be fine as is. In summary, the growth plan for Canberra that we proposed would need to be altered slightly in order to accommodate this level of growth.

6 Model Strengths and Weaknesses

The main strength of our model is that it is relatively easy to use. To calculate the objective portion of our metrics, one simply needs data that is easily found in census reports and news articles (i.e. commute statistics,

land zones, etc.) or goal data determined through analysis of the city's potential and needs. The subjective portion concerns the city's initiatives, which can be found in the city's plans or proposed in one's own plan.

One weakness of our model is subjectivity. Due to a lack of quantifiable, empirical data relevant to some of the smart growth principles, we defined the corresponding individual metrics as subjective rankings on a scale from 0 to 1. As such, they were highly dependent on what exactly the wording was in the city growth plan documents, and they are somewhat imprecise.

Another weakness is that we weighted components equally. After we correlated each related pair with our S measure, we summed the pairs and the remaining two uncorrelated metrics without weighting them. This led to metrics like those for principles like community engagement being more important for the final success level than ones like mixed use land and alternative transportation. Considering carefully the relative importance of the principles and applying appropriate weights could make our model better.

7 Conclusion

Boulder, CO, USA and Canberra, ACT, AUS both expect population growth over the next 30 years. In order to accommodate additional people, each city has proposed a long term growth plan based on the projected population growth to help the city achieve the three E's of sustainability. Many elements of each city's growth plan already adhere to the ten principles of smart growth. Boulder already has initiatives to increase the amount of affordable housing within the city limits by 10%, add pedestrian paths and maintain the bike path system, maintain the 71 square miles of open space, and further develop public transportation through buses and a light rail [10]. Canberra has plans to increase area zoned for mixed land use, construct new housing, maintain land designated as open space, and continue to develop public transportation through a light rail system.

We rated each city's current state according to our smart growth metric to determine how successful each city is in achieving smart growth. Boulder received a score of 0.7753 and Canberra received a score of 0.5882. From these results we noted that Canberra has more room for improvement in achieving smart growth principles than Boulder, though both cities must continue to consider the ten principles in order to achieve sustainability with population increase. In order to better achieve the ten principles of smart growth, we proposed new plans for city growth over the next 30

years. We also considered how our proposal for each city would succeed if the population in each city were to increase by 50% rather than 21% and 25% for Boulder and Canberra, respectively.

Our proposed growth plan for Boulder includes five key initiatives that together could improve the smart growth metric of the city to 0.8338. The five elements of the plan are rezoning and redeveloping land for mixed use, redeveloping current residential neighborhoods, increasing public transportation, eliminating vacant houses, and increasing community programming and youth outreach. We proposed ideal values for each of these five initiatives to reach by 2050 to sustainably support the increasing population.

Similarly, we proposed a growth plan for Canberra with five key initiatives that could improve its smart growth score to 0.7443 if all initiatives are implemented together. The five elements are rezoning land for mixed land use, loosening building height restrictions, developing on land that is currently open space, constructing additional affordable housing, expanding public transportation with buses, and offering more community engagement pathways.

If both Canberra and Boulder grew by 50% by 2050, our growth plans would have to be modified. This population increase would not be too problematic for Canberra, with initial housing shortages that could be resolved with small increases in mixed use land, and an intensified need for high quality public transit. However, a population increase in Boulder is more problematic. We project that even with a rezoning of open space, an increase in height requirement, and increased transit, Boulder would likely face a sizable housing shortage. Boulder provides a cautionary example for smart growth; smart growth principles should be implemented soon with the current state of our rapidly urbanizing world.

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