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# Integrating Roadway Dynamics into a Systems Model of Urban Decay

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By

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# Introduction

As the human race evolved into what is currently is, certain aspects of our daily lives have changed to accommodate our evolution. We have moved on from our tribal days from an evolutionary standpoint and kept this group or team mentality about ourselves that makes us want to live in closer proximity to others. This is because the sense of protection on a psychological level is something every human yearns for to a certain extent. It is for this reason that cities and urban centers are the cornerstone of every civilization. From Athens to New York City, urban centers develop because people are able to live independent lives while also remaining closer to others. The amount of people living in urban environments has been steadily increasing over the years and consists of almost half of the world's current population.

Once urban centers were built up and established, it was up to roadways to join said environments and ecosystems together. Roads were one of the few ways to bridge societies and cultures, by allowing people to move quickly and effectively through lands. Since there were less immigration policies, people were able to travel more freely as far as they could walk. This, in term, allowed for the creation of more cities because people could voyage with less restraint. People are now limited to what their cars can travel, but can still go as far as they are able to move to new cities and start new lives. It is important to note that without roads, there would most likely be less urban centers inside the nations of the world.

There is clearly a symbiotic relationship between roadwork and city growth. As a city gets larger, there will be more roads built in and around the area to make travel easier. Likewise, the more roads there are in a given area, the more likely it is a city will be built in that area to take advantage of the preexisting roadwork systems. Typically most cities originated close to coastal lands because they were more accessible to more forms of transportation. Once road

systems were built and established, more cities were able to be built inland because of improved methods of transit. When looking at it this way, it is clear to see that there is a relationship between roads and urbanization.

The goal of this paper is to further explain the relationship between roads and urbanization with a Systems Analysis Model. Urban planning is something people have been exploring for centuries and I believe that my findings could benefit both old and new cities by emphasizing the importance of roadways. To show and explain this in the best possible way, I will be using Jay W. Forrester's Urban Planning Model and expanding it by implanting my own roadway loops to the system. It is my belief that as the amount of roads increase in and around an urban environment, it will first lead to growth and prosperity for the area. After a while, due to certain factors that will be explained later, there will be a peak followed by a decrease in this prosperity. Towards the end, there will be a leveled amount of growth that reaches a stasis and no longer increases nor decreases. I will be looking specifically at three main aspects of urban society that I believe will be impacted the most: Population, Business, and Housing.

The paper will be broken down into three major sections. The first will be a review of literature pertaining to related subjects. I am not the first one to look into the subject, so understanding what others opinions are could prove to be beneficial. I will be looking into papers focused on roadways and infrastructure in relation to urban growth and decay. The second section will be an analysis of the Forrester Model. This section will consist of a focused explanation of Forrester's Urban Planning Model, his dissertation, and his results. The third and final section of this paper will be a description of my model. This will include my explanations for what I added to the prior model and the effects it had on the system. I will also include the

results of the numerous tests I will be running to test the models effectiveness. All of these sections will hopefully enlighten the reader about urban planning and its importance.

## Literary Review

The first article I would like to mention is "U.S. Roads, Bridges are Decaying Despite Stimulus Influx" by Gary Stoller. This was an online news article written in 2013 written for USAToday.com and it pertains to the struggle Americans face in relation to poor infrastructure. The parts of infrastructure he focused on were roads and bridges, but had an in-depth chart noting the percentage of roads in good, fair, and poor condition within each state. He emphasizes that only 38% of roadways in the US are considered to be in good condition and the funding to fix or maintain the roads has been increasing with little results. The specific example explaining this situation was Interstate 70 in Missouri, which is in poor condition. It is noted that, "The highway is full of cracks, potholes and does not drain well when it rains …It has to be one of the most dangerous stretches of highway in the United States."[1] Allegedly rebuilding and fixing the highway would cost close to $2-$4 billion. With people paying taxes to fix these roadways and having to pay personal property damage once a vehicle is damaged, Mr. Stoller believes we are in a lose–lose situation that can only get worse.

The next article I wanted to discuss was "An Economic Analysis of Transportation Infrastructure Investment" by the National Economic Council and the President's Council of Economic Advisors. This study run by the United States Government in 2014 believes that a high quality transportation network is vital for an economy to flourish.[2] These systems can help businesses transport and manage goods more efficiently. They note that the cost of road projects has been relatively flat since 2011 and these projects create a wide variety of jobs to complete. After roadways are completed, there tends to be a boom in local economic development. The real

crux of what it noted is that they confirm that about 65% of roadways in the nation are rated as "less than good" condition.

Jeffery Lindley wrote a few articles discussing roadways and their effects on urban society, but the main one I was to review is "Urban Freeway Congestion Problems and Solutions: an Update". This article was written in 1989, but discusses that in both 1984 and 1987 projections were made about projected congestion on urban freeways in 2005. Within just a 3 year span, the projected amount of delays, wasted fuel, car costs, wasted fuel, and freeway miles for 2005 had increased.[3] Even though the projections were based on a worst case scenario, Lindley believed that these dramatic increases in projection meant that motor vehicles are a near unpredictable stock and would most likely continue to grow at a high rate. Since he believed that usage of cars would continue to rise, he makes note of plans that could help maintain this issue. The main ones he believed would help were a widening of lanes along with low cost improvements to roadways. Lindley also believed that a reduction of cars on the roads by encouraging alternative transportation would also help.

"Generated Traffic and Induced Travel" by Todd Litman attempts to explain the importance of understanding the concept of generated traffic when wanting to build more roadways to reduce congestion. Generated traffic is defined in the article as, "The additional vehicle travel that results from a road improvement, particularly expansion of congested urban roadways." Litman believed that traffic congestion maintains an equilibrium and that by expanding roadways, you are only encouraging more automobile use. He alleged that roadways are costly to build and maintain with few short term benefits and moderate long term benefits. If people continued to ignore generated traffic, however, they could be harmed by longer travel times and inconsistent congestion due to increased road usage. Litman closes his paper with the

indication that, "Ignoring generated traffic results in self-fulfilling predict and provide planning: Planners extrapolate traffic growth rates to predict that congestion will reach gridlock unless capacity expands. Adding capacity generates traffic, which leads to renewed congestion with higher traffic volumes, and more automobile oriented transport and land use patterns. This cycle continues until road capacity expansion costs become unacceptable."[4]

Anothony Downs wrote "Stuck in Traffic: Coping with Peak-Hour Traffic Congestion" explaining that congested roads waste a rider's time and costs them money. He notes that they are a problem in America and will only get worse as cities continue to grow and more people begin using cars. Downs also believes that more roads will only cause more congestion. While increasing housing densities may help a little, he believes that the only real way to reduce congestion is reduce the amount of cars on roads.[5] The only way to do this effectively, Downs believed, would be enacting negative social policies such as increased gas taxes and highway tolls. While this would help decrease congestion, it would also be extremely disliked by people and business and have a lot of pushback.

An article that also discusses the negative impact of roadways in urban environments is "Beltways: Boon, Bane, or Blip? Factors Influencing Changes in Urbanized Area, 1990-1997" written by David Hartgen and Danial Curley. They explain that many major cities have added beltways over the past few years as cities have continued to grow. Many people believe that this growth may have to do with the addition of these new beltways, which the authors try to disprove using stepwise regressions. Their study revealed that urban areas without beltways actually grew faster than those with beltways. They believe that it is employment opportunities that factor into growth of cities and that as a city expands, it will naturally deal with their traffic problems by having a larger road network.[6]

Another article that questions investments in roadways is "An Analysis of the Relationship between Highway Expansion and Congestion in Metropolitan Areas" by Surface Transportation Policy Project. When reviewing the investment in road capacity through Texas, they discovered that metropolitan areas that invested heavily in expansion fared no better than areas that spent a little. Congestion, delays, and fuel usage were very close between these areas which implies this is not a good investment. The authors of the project note, "There is substantial evidence that demonstrates that building new roads often increases congestion. A well-established body of research shows that new lanes tend to get filled up with new traffic within a few years, particularly if surrounding routes are also congested."[7] They believe that adding more roads just creates more induced traffic, which is the prior theory, and this still affects highway users negatively. It is also noted that these road projects can directly and indirectly cost people in the metropolitan areas thousands with little gain, therefore making it a bad investment.

"Urban Decay, Austerity, and the Rule of Law" was written by Brent White, Simone Sepe, and Saura Masconale. It discusses the recent failures of urban centers like Detroit, Baltimore, and San Bernedino. The authors believed that almost 33% of roads in urban spaces were in a poor or mediocre condition.[8] These poor conditions, such as potholes or large cracks, could cause congestion and traffic jams. While cities do produce a lot of money, they also have a lot of obligations and cannot afford the costs urban planning or repairs entail. These inabilities to handle said problems are factors that help lead to urban decay due to dissatisfaction. They believed that this urban decay and unhappiness by those who remained in the urban areas are what caused the increased chances of unrest in these failing cities.

David Schrank, Shawn Turner, and Timothy Lomax wrote "Estimates of Urban Roadway Congestion- 1990 Interim Report" as an attempt to quantify mobility in urban areas. In this

study, they reviewed 50 urban areas within the country broken into 5 regions and studied many factors such as vehicle-miles of travel, urban area information, and facility mileage. They explained that congestion is related to population and all of the cities they looked at had an increase in population during their review. This meant that congestion in all areas was also increasing. They found that the cost of congestion was high, on both individuals and cities.[9] There was more of an effect on older cities and cities located in the Northeast region. While populations were increasing as a whole, there were minor trends of emigration and damage to local business. The authors determined that the amount of roadways needed for a constant congestion that people would accept would be near impossible for most urban areas. They believed the only solution with an increasing population would be to focus on congestion maintenance rather than decreasing congestion.

"Urban Growth and Transportation" is written by Gilles Duranton and Matthew Turner and is an analysis of roadways in urban centers over a 20 year period from 1983-2003. The goal was to investigate the role of interstate highways on urban centers in the US. They note that about 20% of household income is devoted to infrastructure in some form and wanted to see if it was being used properly.[10] As more money was invested in interstate highways, employment tends to increase as well. They also discovered that road projects are allocated to cities when there is a negative shock in the population in an attempt to attract more people. At the same time, they determined it is important to understand how much space is necessary in building a road. As simple as it sounds, the authors determined many roads in urban areas are not built in the ideal places or positions. Similar to others, Duranton and Turner found that an increase in roads does not decrease traffic, but increases it because it encourages people to buy cars and use the new roads. Their final analysis was that roadways are built where labor is cheap, not where a roadway

is needed. This implies that the people allocating money are at fault for poor roadway design, which leads to poor urban planning and infrastructure.

In "The 2002 Urban Mobility Report", written by David Schrank and Timothy Lomax, discusses the issues related to urban congestion by identifying trends. They believe that it is impossible to make roads to solve this problem because people are beginning to drive at too fast of a rate, and thus should invest in maintaining the roads they already have. The authors explain that, "On average, about two-thirds of the traffic on the roads during peak driving times experience congestion. This amount has doubled over the 19 years of data in this study."[11] It is also a belief of theirs that it is essential to try and decrease the amount of people using roadways. The best way to do so, according to them, would be to encourage different ways to commute to work. Alternative transit, adjusted work hours, and telecommuting are suggested ways to get people off the roads. They also believe that adding tolls to roads is a smart decision, as it will reduce usage while funding ways to fix the roads. While they do believe funding to maintain roadways is important, they note that government is not paying anywhere close to what they need.

"Innovative Roadway Design Making Highways More Likeable" is an article by Peter Samuel about how we are investing poorly in our roadways, especially in urban areas. That is to say we are trying to build inefficient roadways, which are wasting space and congestion inducing. He suggests that we build more skyways and underground road systems to save space on the ground for housing and business. Also, he believes that we need to change current roadways by making a unanimous width to save space. Samuel has the notion that replacing one way road schemes and intersections with arterials would improve efficiency and reduce

congestion.[12] By making smarter decisions on how to invest roads and their connections, we can hopefully improve congestion problems.

Todd Litman's "Determining Optimal Urban Expansion, Population and Vehicle Density, and Housing Types for Rapidly Growing Cities" explains the variables cities should consider when they are in the process of expanding. Litman believed that roads were important in the growth of cities. He has the notion that expanding along already existing roadways in the area is more cost efficient and could increase accessibility. There was also a notion he brought up about "complete street principles", which means that they should be able to accommodate a diverse set of users from cars to pedestrians.[13] This, Litman believed, would increase road longevity and the demand to repair damaged roads. He closed his section on roads explaining that roads should be managed for high value trips and space efficient transportation. He recommends have a special lane for buses only to encourage its usage. His idea was by doing this, you can increase total ridership and benefit for a given roadway.

Robert Cervero's and Mark Hanson's "Road Supply-Demand Relationships: Sorting out Causal Linkages" attempts to explain road supply and demand using causal modeling in California. In their research, the author's determined that carbon monoxide concentrations, race, and political ideology determines road supply.[14] When there is lower air quality, a response to add more roads occurs. Although this may sound counterintuitive due to cars releasing carbon monoxide, it is actually because by adding roads you will be reducing congestion and therefore improving traffic flows. From their research, typically Caucasian upper class counties get roads before minority ones. This is due to the belief that Caucasians would know how to benefit more from the roads then their counterparts, maximizing utility for them sooner. Finally, it was determined that Democratic Governors tend to be in power when there is an increase in road

supply. This is most likely because Republican candidates run on a more conservative budget which would exclude costly projects like this. The piece also stresses the notion that for every bit of induced traffic, there is just as much reduced traffic occurring. It explains that we just do not take note of the success as much as the anomaly.

"Road Supply and Traffic in California Urban Areas" was written by Mark Hansen and Yuanlin Huang about the relationship between roads and traffic. They report that areas with more roads tend to attract more people. This is most likely because the people coming in have more opportunities to get where they are going thanks to the roads. They also brought up that more highways increase vehicle-miles-traveled.[15] This is important because it means that people are traveling further in a given vehicle when using said vehicle. This could be anything from commuting to errands and implies a confidence in the road systems. The writers explain that more roads will reduce bottlenecks, increasing local urban travel. It is also explored and noted that areas with higher income tend to benefit from roads at a faster rate.

In the article "New Highways, House Prices, and Urban Development: A Case Study of Toll Roads in Orange County, CA", Marlon Boarnet and Saksith Chalermpong study the Orange County Toll Road network and its effect on the local area. They look at and find support in the economic theory that predicts land values and house prices to be higher in locations with more employment opportunities and travel destinations. Highways bring in business and connect destinations, helping both factors. Improvements to highways influence land prices and higher priced land will most likely be developed for quality housing. Accessibility to highways and their benefits increases homebuyer's value for the land. The authors concluded that, "Highways improve accessibility, that accessibility premium will be reflected in higher land prices

(And ceteris paribus, higher house prices), and higher-priced land will be more densely developed."[16]

Robert Cervero wrote "Road Expansion, Urban Growth, and Induced Travel: A Path Analysis" to challenge the notion that roads are a poor investment in California. He directly challenges the idea that "you can't pave your way out of traffic congestion" by explaining, through real data and modular research, that travel speeds and urban development increase with roadway investments.[17] In both a short term and long term model, he was able to show that there was indeed a positive relationship. He emphasized that, "Whether new roads are on balance beneficial to society cannot be informed by studies of induced demand, but rather only through a full accounting and weighing of social costs and benefits." Cervero believes that a lot of people's disdain for road investments is misplaced. His conclusion emphasizes that roadways do not cause congestion or air pollution, but cars do. He wholeheartedly believes that investments in infrastructure would lead to decreases in both problems.

"Impact of Highways on Property Values: Case Study of the Superstition Freeway Corridor" by Jason Carey explores the benefits of investments in highway construction and maintenance. He found that construction of new freeways reduces travel time and reduces operating costs for the average vehicles. Carey found a trend that property values tend to increase around, but not next to highways because the people living in those houses can live further from their jobs.[18] This, in term, increases developers building houses by highways and the land around highways increasing. He also found that population surges occur following freeway construction because people have a choice of where they want to live and easier travel paths.

The article "Do Highways Matter? Evidence and Policy Implications of Highways' Influence on Metropolitan Development" was written by Marlon Boarnet and Andrew

Haughwout about the history of highways and their effects on urban centers. Originally, highways being built in the 50s and 60s would have a significant increase on housing values due to the attractiveness. From the 70s to today, the highways had either little increases at best or decreases to houses in the vicinity to them. This is because cars improved and priorities changed for families during the gap in time. However, the authors note that highways planning should be a priority for cities and their people.[19] Since all businesses are not in the same area, highways help them and their clients travel around faster. Even though housing is less affected, it is still shown that highways affect population and employment opportunities in a positive way. It is noted that even though highways can be good, it is not always the best thing. Sometimes using the limited urban space or finances on other projects could be just as useful.

"Road to Growth: The Case for Investing in America's Transportation Infrastructure" is an article written by Doug Oberhelman, the Chairman and CEO of Caterpillar, Inc. While I do know and believe that Mr. Oberhelman has a bias in infrastructure investment, he does have a right to give input. This article, from the Business Roundtable, tells readers that the US roadways are underperforming. Oberhelman notes that, "Following a strong public commitment to investing in world-class physical infrastructure in the mid-20th century, public investment in most infrastructure systems has tapered off or flat-lined, while demand for high-performing, high-capacity systems has grown."[20] We are currently ranked 16th in the world when it comes to infrastructure, with our competitors ranked ahead of us. The report notes that 42% of roads are considered to be congested and that the average commuting time to work in America is higher than any other nation at 48 minutes per day. He believes that this factors into a loss of money that makes businesses more selective in where they would locate. This notion makes Mr. Oberhelman believe that this is a spiraling situation where everyone is losing money by doing

nothing. He concluded that, "Reinvesting in infrastructure presents policymakers with a unique opportunity to revitalize American growth."

Antonio Estache and Grégoire Garsous wrote "The Impact of Infrastructure on Growth in Developing Countries" to discuss this subject on a larger scale. While many articles were focused on the national perspective, this article does the opposite and focus' on a solely international perspective. I find that this is equally important because it shows what other parts of the world are prioritizing and innovating. The authors state that the better quality and quantity of infrastructure can directly raise productivity of human and physical capital.[21] While they are less impactful for developed countries because they already have a plethora of them, roads in developing countries can be critical for trade and efficiency. The amount of travel can help raise awareness by reducing regional and even bordering differences. While the payoffs are slow for infrastructure due to the costs to build, it is usually one of the longer lasting and more beneficial things for a poor country to invest in.

## Forrester's Model

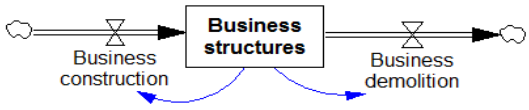
Jay W. Forrester is a revolutionary systems scientist from MIT. He has written numerous works about urban growth dynamics since the 1960s and does not have an optimistic viewpoint about the subject. Since his book, titled "Urban Dynamics", Forrester has made it clear that cities and urban centers are growing at an unsustainable rate.[22] He believes that because cities were not made by city planners, they were doomed to fail from the beginning. The main problems with urban planning on the city's side, Forrester believes, are in: monetary investments to the system, tax laws in the environment, population density for the city, zoning laws in the city, and setting realistic goals.[23] As for individuals, Forrester believes that they should accept the social changes

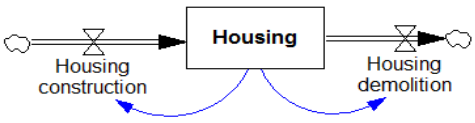
that must occur to benefit the city, even if it contradicts moral reasoning. Only by decreasing a given cities population can it succeed as many investments will otherwise be spent upon welfare programs rather than infrastructure. If these problems are not addressed and the social mentality does not change, then our cities and urban society are doomed to continue failing.

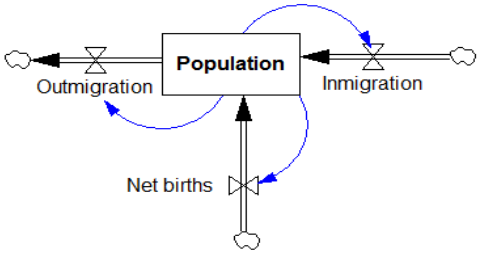
Forrester's Urban1 Model addresses the growth and decay of cities that occur within their lifetime. The model itself focuses on what Forrester believed to be the most important factors: businesses, houses, and population. I will now spend the rest of this section explaining the logic of the loops in the system and what they mean in an overall perspective of the urban environment.

The first layer that is shown depicts the key elements in their basest form. That is to say, each section is disconnected and has an inflow and outflow of simple loops. These loops, if given a scenario with unlimited resources, would continue to grow and decay at an exponential rate. The first stock I will examine is Business Structures. The Business Construction Loop says that as the amount of business structures increases, the amount of business construction increases as well. This makes sense because it could be the beginning of a business district of a city or something like that. With more construction comes more business structures, and so forth in the cycle. On the other side there is the Business Demolition Loop. This notes that the more business structures there are, the more business demolition takes place. This also makes sense as this could be when a business district gets too expensive and businesses are forced to leave or a business exceeds its usefulness. The next set of loops I will look at are the ones related to Housing. As the amount of housing increases, the amount of housing construction also increases. This is noted as the Housing Construction Loop. The sense is that houses are usually built around each other, so this could be the start of a neighborhood. As there are more houses, there becomes

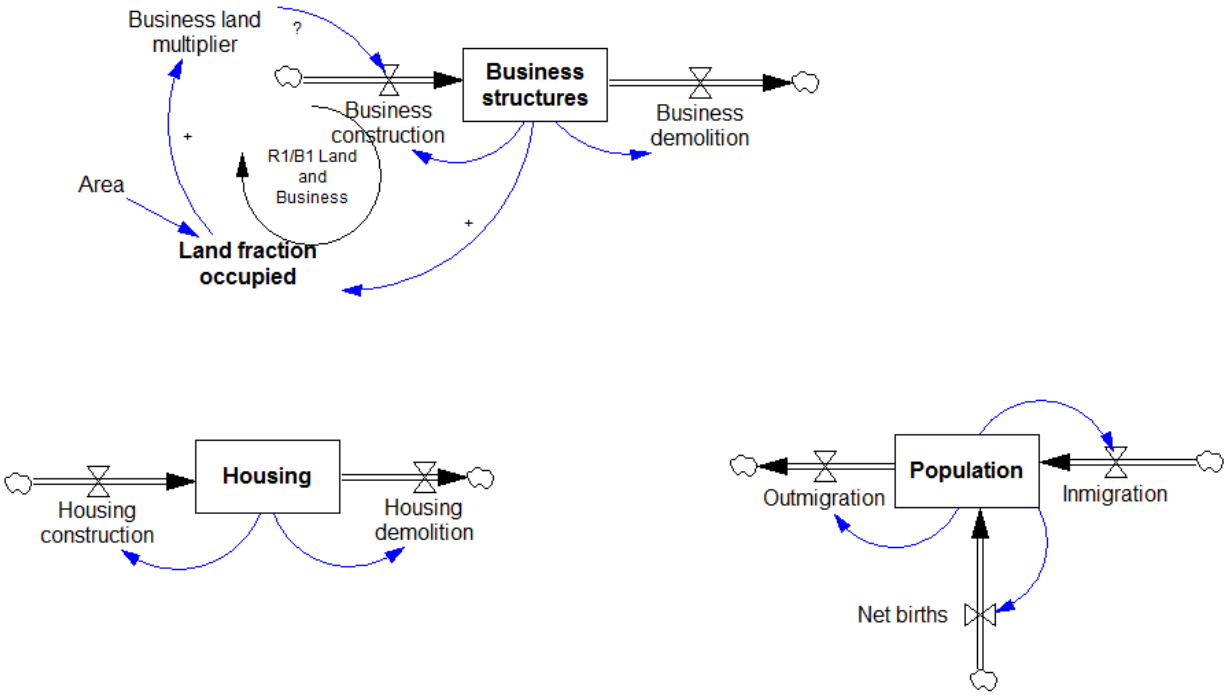
a sudden demand to build more. Similar to business structures, there is an outflow from the stock going towards housing demolition, which is known as the Housing Demolition Loop. This would be the point in time when urban centers are losing people and have too many houses. The demolition process could be a project to make more space for something considered more desirable for the remaining residents. The Population stock is the most interesting because it has three factors affecting it. The idea that when population increases "inmigration", denoted as the Inmigration Loop, will increase is something that will happen when a city is growing. At first, when more people come into a city, there is an increase in opportunities that will in term attract more people. Following this logically, as the population within a city increases the amount of births will increase which is the New Birth Loop. The births of people will then increase the population that created them. Finally, as the population increases the amount of "outmigration" will follow. This is the point in a city's lifecycle where its residents no longer benefit from living in the area and look elsewhere for opportunities causing the Outmigration Loop. While all of these factors do not currently affect one another, it is not much of a stretch to see where connections can be made.



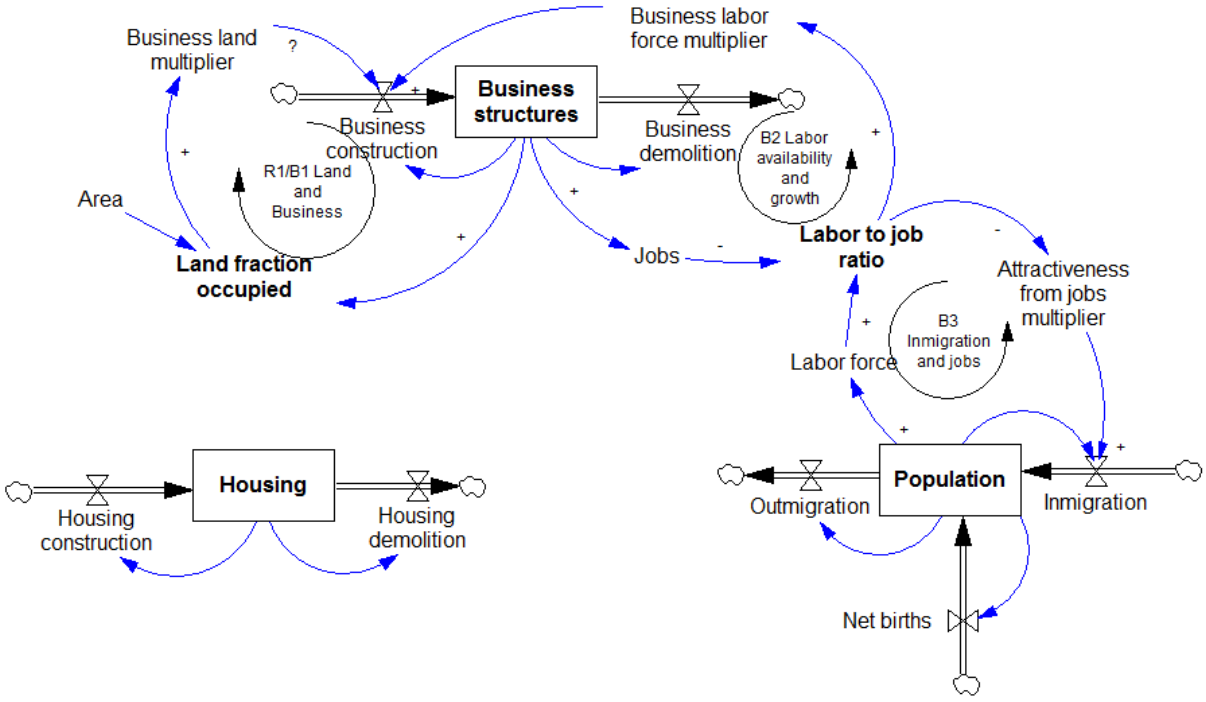
The next layer shows the first major loop in the Urban1 Model, the Land and Business Loop. Arguably one of the most important loops in the entire system, it emphases the growth of business and its effect on the rate of business construction based on the amount of land available. This is significant because the simple loops deal with unlimited resources, the more advanced loops to follow have limited resources and constraints that will help emphasize the decay of cities. The first section of the loop states that as business structures increase, the land fraction occupied also increases. In simpler terms, as businesses grow they need more physical space to work efficiently. Following that, as the land fraction occupied increases, the business land multiplier increases. That is to say as the amount of land occupied is increasing, the prospect that it is going to be used for businesses will also increase. The final and most interesting part of this loop says that as the business land multiplier increases, it will increase and decrease the business construction. This might sound contradictory, but it explains the shift in a city's desire and need for businesses. When a city is growing and trying to be more attractive to people, it will want this so be a positive relationship and increase the amount of construction. Later on in a city's lifecycle, a lot of the land will already be built on so the desire to construct more will decrease even though the multiplier will be increasing. This will affect the rate of business construction and thus the amount of business structures, completing the loop. Because of the transition from increased construction to decreased construction, the loop itself transforms from a reinforcing loop to a balancing loop. This helps explain the change in the graph from an increase in business structures to the eventual collapse.




The third layer has two loops present. The first is Labor Availability and Growth and the second is Inmigration and Jobs. The Labor Availability and Growth Loop is a balancing loop that explains the job markets effect on business structures. The first piece of this loop states that as the amount of business structures increases, jobs will increase. This makes sense because the more businesses there are in a city, the more people they will need to hire to complete their work. The next piece of the loop notes that as jobs increase, the labor to job ratio decreases. The reasoning behind this is that jobs in the labor to jobs ratio is the denominator and an increase in the denominator will cause the overall value to decrease. In the context of businesses, it would mean that as the amount of jobs increases there will eventually be more jobs available then the workforce to fill all of these jobs. As the labor to job ratio increases the business labor force multiplier will improve as well. This tells us that as the amount of workers compared to the availability of jobs increases, it is implied that the size of the labor force will also increase. In perspective, this means that there is a demand for more jobs. The next piece of the loop suggests

that as the business labor force multiplier increases, the amount of business construction will also increase. It's this inherent relationship tells us that as there is more labor desiring work, there will be more businesses constructed to benefit from the workforce. This loop once again ends with business construction directly affecting the amount of business structures in a city. There are no longer any important loops affecting the business structure stock in the Urban1 Model.

The Inmigration and Jobs loop attempts to explain population's effect on the job market. The loop begins by telling us that as population increases, the labor force increases as well. This idea seems logical as more people in a city would also mean more people who can work. The next piece of the loop states that as the labor force increases the labor to job ratio will also increase. Whereas jobs in the prior loop was the denominator, the labor force in this loop is the numerator. That means as the numerator increases, the ratio will also increase and be more favorable. This would imply that the more people there are willing to work, there will be less jobs available. Next, as the labor to job ratio increases, the attractiveness from jobs multiplier will decrease. Once again, this is a logical conclusion to make. It tells us that as there are more people then there are jobs, less people will feel attracted to the city. This is because expenses in a city are already high, so the possibility of not having work would only be problematic for an individual. The penultimate piece of the loop states as the attractiveness from jobs multiplier increases inmigration will increase. This does make sense because the more jobs there are, the more people will want to come into the city to work at them. The loop closes with inmigration connecting to population. This loop is considered a balancing loop, as it will fluctuate in a city's lifetime.

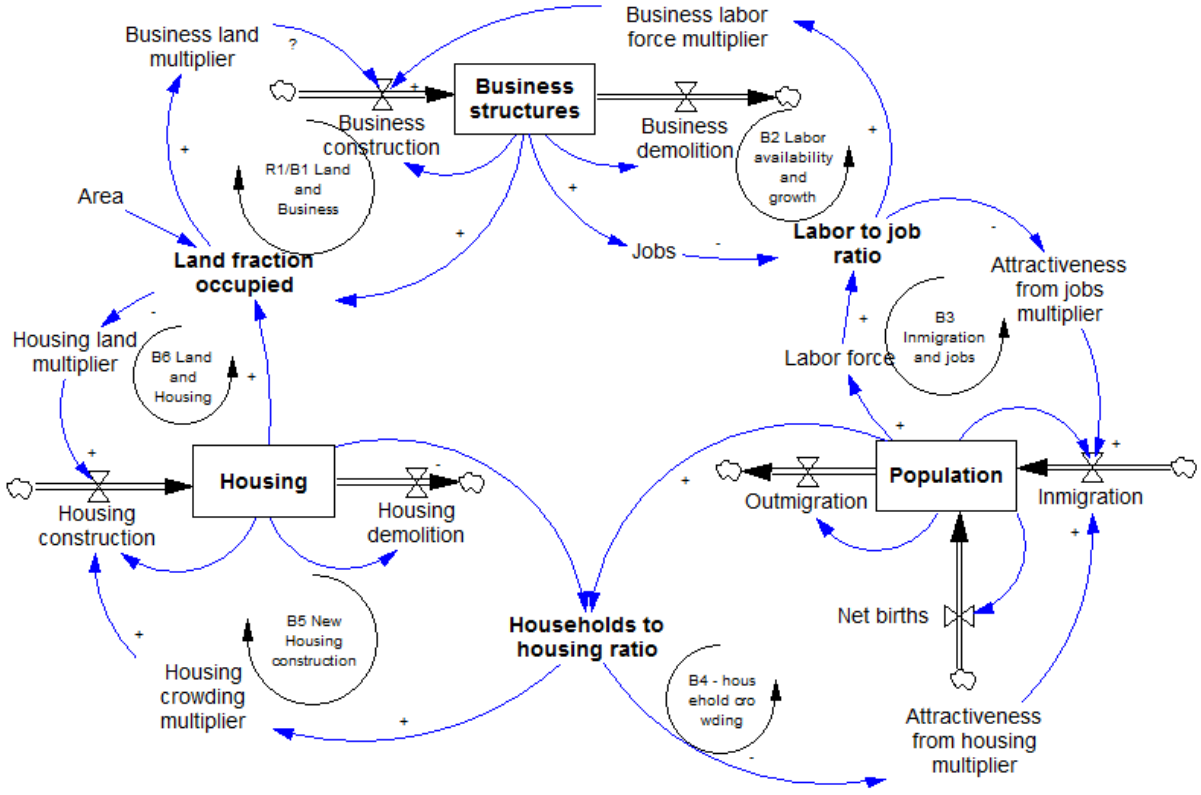



The next layer for the Urban1 Model shows us the last of Forrester's loops. Here we see the: Household Crowding Loop, New Housing Construction Loop, and the Land and Housing Loop. The Household Crowding Loop is a balancing loop that explains how household availability affects inmigration. The first piece of the loop notes that as population increases the households to housing ratio also increases. It's a ratio that simply describes how many people will be living inside a given house. This tells us that as more people move into an urban center, they will most likely crowd together into a single house. Next, as the households to housing ratio increases the attractiveness from housing multiplier will decrease. This makes sense because as more people are forced to live in the same houses, they would not want to live in that neighborhood. As attractiveness from housing multiplier increases inmigration will increase following it. There is not much of a stretch here, as people will want to move in to areas that meet their needs. This means that the more attractive a housing area looks, more people will want to move in around there. The loop finishes with inmigration directly affecting population.

The New Housing Construction Loop includes a factor that was slightly changed from the original Forrester Urban1 Model. What is now known as the Housing Crowding Multiplier was originally named the Housing Attractiveness Multiplier. The reason for this change stems from Forrester's "Attractiveness Principle" which states that attractiveness and unattractiveness, while sounding nice, have little impact on the empirical data. Because of this, both are essentially equal with no value. Due to this logic, Forrester named this piece of the loop Housing Attractiveness Multiplier even though the results should make the proper name Housing Unattractiveness Multiplier. It is for this reason the name was changed to the Housing Crowding Multiplier, so it could be the same idea but more understandable. This being said, the New Housing Construction loop starts with housing increasing and the households to housing ratio decreasing. In laymen's terms, as the amount of houses increase in the city less people will have to live together. The next piece summarizes that as the households to housing ratio increases, the housing crowding multiplier will increase. Again, the households to housing ratio specifically describes the amount of people living in a given house. It makes sense that as this ratio increases, the more crowding will occur. Next to last, as the housing crowding multiplier increases, the housing construction will increase. As there are more people being crowded into houses, then there will be a greater demand for houses to be built. The loop concludes with housing construction feeding into housing. This loop is a balancing loop, so the trends stated will ebb and flow as time progresses.

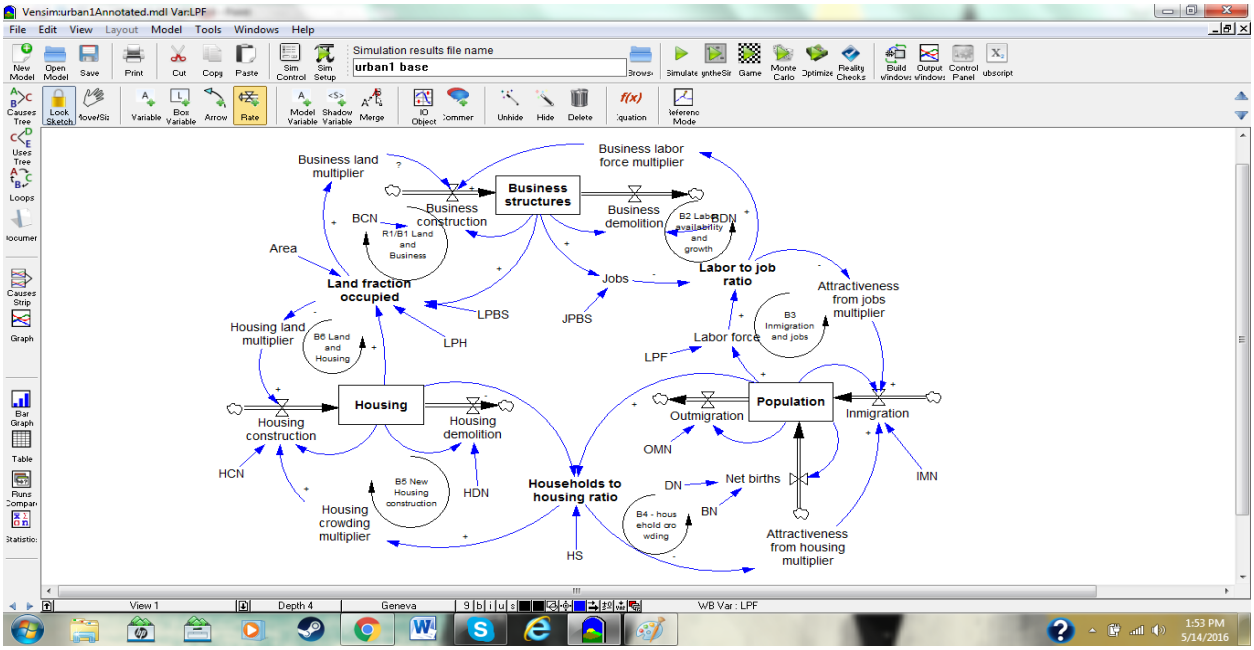
The final important loop of note in the Urban1 Model is the Land and Housing Loop. This balancing loop inspects the amount of housing that could be built in a city considering the limiting factor of available space. The initial piece of the loop declares that as housing increases, the land fraction occupied also increases. This means that as more houses are built, more space is

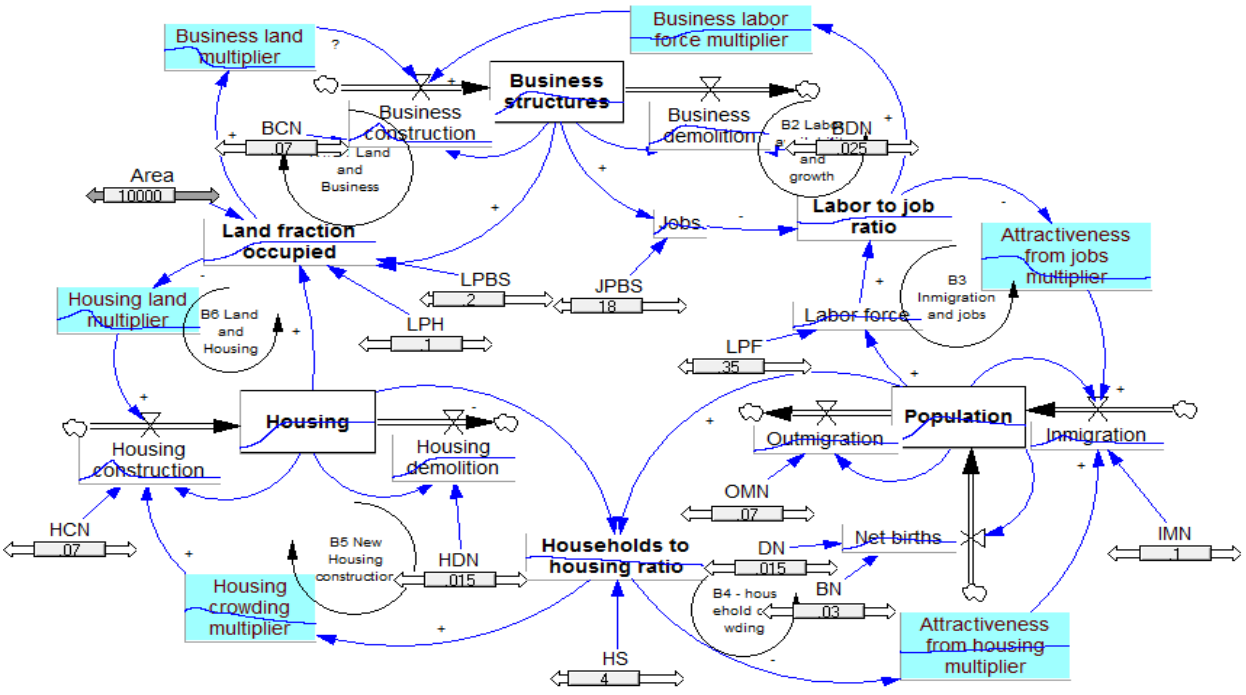
occupied. It is important to note that with the limiting factor of the city area, housing and business structures are competing for space to build. Next in the loop, as the land fraction occupied increases, the housing land multiplier decreases. That means once the land in the city is occupied, less house can be built because the lack of space. Once the housing land multiplier increases, housing construction will also increase. The loop concludes with housing construction feeding into the amount of houses being built.



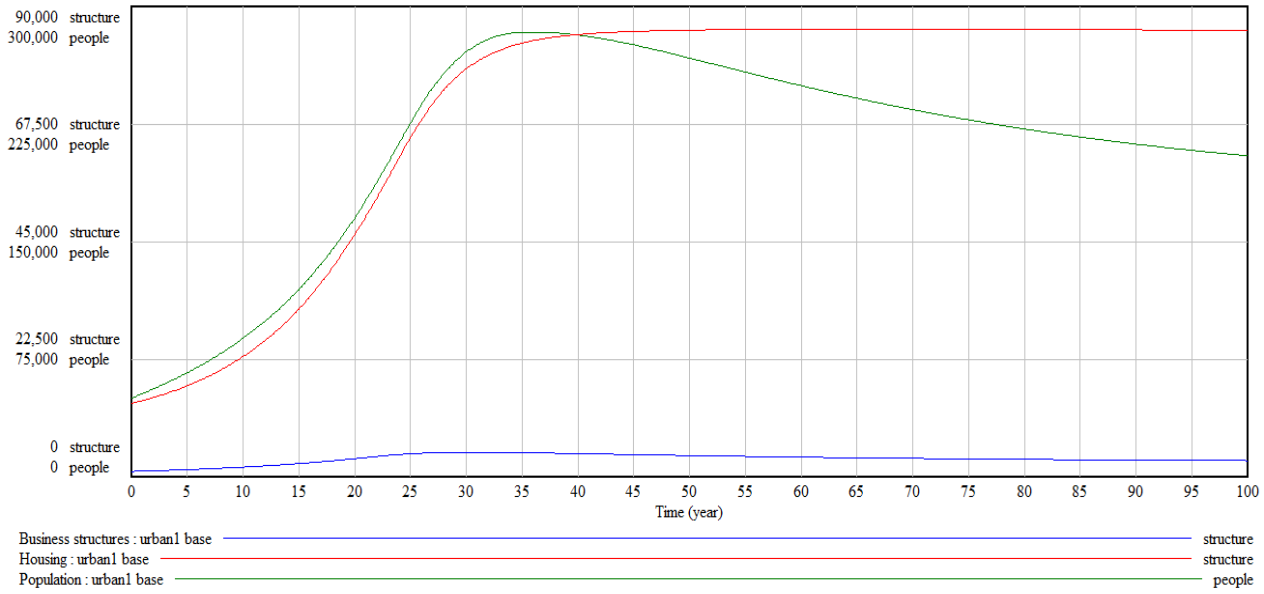

The final layer of the Urban1 Model revels a number of influences and constants that connect and factor into the inflows, outflows, and ratios. The intent of these impacts is to add constants to all of the formulas and ratios involved. As mentioned earlier, the model will operate naturally without any constraints. This will cause both growth and decay to grow exponentially without any setbacks. The problem, however, is that this is not realistic. In a real city, there are

limiting factors to growth and decay. The factors shown in the final layer work to help normalize the data and will add the real world aspect to the model. It is because of these limiting factors that the model will give us desirable and realistic results. The pictures below show a completed model and a model with the constants shown.



With ending this section, the question arises what this model actually clarifies. In a fashion similar to Forrester's dissenting opinions about unsustainable urban growth, the Urban1 Model shows these ideas in a simplistic fashion. As shown below, housing will actually almost level out over time and remain almost constant. Business structures, the least in quantity of any factor, tend to grow for 25 years but then hits a decline. The biggest factor that changes is population, which grows rapidly during the period of growth. After roughly 35 years, however, we see that there is a large decline in the population that continues over time. This is the period of urban decay that begins when the cities are becoming more of an inconvenience. In response, there tends to be a period of outmigration from cities in an attempt to reap urban benefits from afar. This is when things suburbs start construction to benefit everyone. With all of the loops acting as balancing loops at some point, this shows that once growth hits an apex, in this case around 25 – 35 years, there will most definitely be a steady decline. At first it is fine because the city can handle the extra businesses, people, and housing. Of anything, it is encouraged as the city feels it gains more than it loses from these factors. Once it hits the apex, however, it is too late to change their policies dynamically. This is when the decline occurs, as all of the prior benefits helping growth are now undesirable and helping decay. As Forrester notes, this is too late for a change to transpire and the city is forced to deal with their decisions. It is at this point that businesses and the population start to leave the urban environment. This proves that the Urban1 Model supports the ideals that Forrester wrote about in his numerous works about decay through unsustainable growth.




## Forrester's Model with Roadways

While Forrester's Model does do an excellent job in portraying uncontrollable growth and urban decay, it does not tell us the full story. It is true that businesses structures, housing, and population are all important factors in a given city and portraying growth. What the model does not show, however, is the importance of roads. Roadway structures are an important factor due to their necessity. When was the last time you went to a city and saw a dirt pathway for cars to ride on? Or when was the last time you went to an urban environment and didn't see a road being repaired? The reason we see so much of this is because roads help make transportation easier for everyone and are almost as necessary to a city as its population. Roads are often one of the most overlooked and underfunded parts of city infrastructure. It also proves to be a costly element to maintain.

The goal of my model is to depict the same practice and premise of Forrester's Urban1 Model, but with the added effect on roadways on all of these factors. The design of my added structure is similar to the one's I described about Forrester's Model. The main stock is titled

Roadways with an inflow of Roadway Construction and an outflow of Roadway Destruction. There are arrows connecting Roadways to both of these flows, which depicts our simple loops. Roadways begins with a base value of 1500 miles, which is 15% of the total area of the urban landscape.[24] The reason for this is because through research I found that the average urban environment takes up around this amount. The Roadway Construction loop implies that as more Roadways increase, the amount of Roadway Construction increases. This makes sense because as a city grows, it will need more roads in general for its other stocks. It could also describe that as the amount of roadways increase, the amount of construction projects for repair also increases. Inversely, the Roadway Deconstruction loop describes that as the amount of roadways increases, the amount of deconstruction will also decrease. This could be explained in that as roadways increase, some roads may become obsolete. This could lead to their destruction to make space for more serviceably beneficial replacements. It could also explain that as the amount of roadways increase, it becomes harder to repair and maintain a certain quality.

The first loop I will explain will be the Land and Roadways Loop, which explains the relationship between roadways and the space available to construct. The first piece of this loop suggests that as roadways increases, the land fraction occupied will also increase. This expresses that as more roads are built, the more space will be occupied. It makes sense because as more roads are needed, the more space is equally needed to satisfy construction. The next piece of the loop notes that as the land fraction occupied increases, the road land multiplier will decrease. That would convey as the amount of land being occupied increases, less would be roads. While I do believe that roads are an important factor, it does make sense that allocation for space would be prioritized by business structures and housing. To guarantee useful roads, you need businesses and people who will use them. After this piece of the loop, the following piece notes that as the

road land multiplier increases, the amount of roadway construction will also increase. What this explains is that once the demand for roads increases, the construction of said roads will also increase to meet the expected amount. The loop concludes with construction influencing roadways positively, as more construction would increase the quantity of roads. Due to these polarities, this loop is considered a balancing loop and will have an increase followed by a decrease.

The next loop to explain will be the Business Desire for Roadways Loop. This loop is two-fold as it requires information from both Business Structures and Roadways. The first part of the loop I will start with states that as business structures increases, the amount of business roadways needed will also increase. This is an important factor to understand, as all businesses need a certain quantity of roads to perform their objectives efficiently. The next section of this loop denotes that as business roadways needed increases, the business roads needed to roadway ratio will also increase. The simple reason for this is because for the ratio, business roads needed is the numerator and the increase would correlate. A more clarified reason would be that the increased need for roads by businesses would affect construction. Related to this, the next piece of the loop I will be explaining notes that as roadways increase, the business roads needed to roadway ratio would decrease. This too could simply be explained that roadways are the denominator in the ratio and their increase would lead to a decrease. Another way of explaining it would be that as there are more roads being built, businesses would not need to push for more construction. After these pieces feeding into it, the following piece of the loop notes that as business roads needed to roadway ratio increases, then roadway attractiveness for businesses will also increase. This relationship tells us that once businesses get the roads they desire, the city will become more attractive to new businesses. It is sound logic, as businesses often want to be

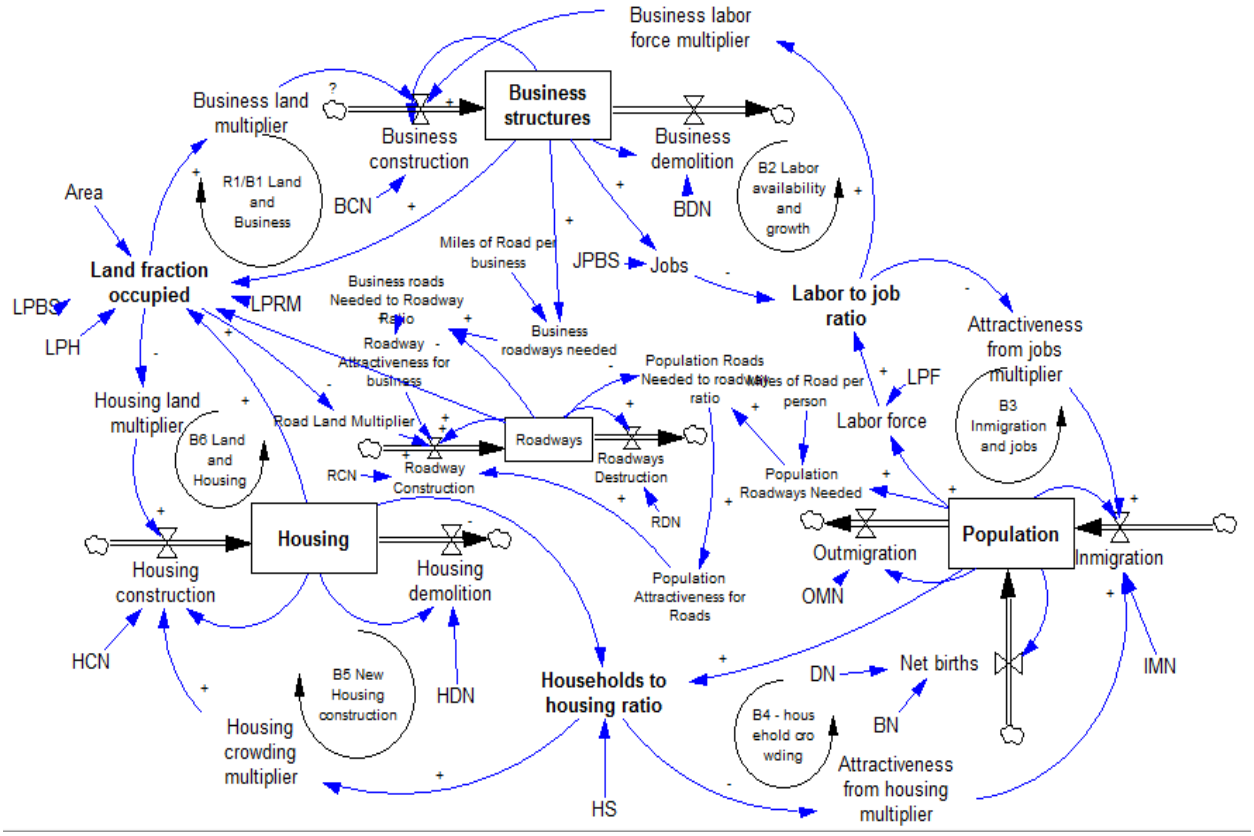
in a good locations that would encourage growth. By this reasoning, a responsive city area that builds roads in order to help businesses would be preferred. This leads to the penultimate part of the loop, which says that roadways attractiveness for business would increase roadway construction. The relationship suggests that the nicer roadways seem to be for businesses, the more construction will take place. Since business is important for any city to grow, it makes sense that the construction of roadways would increase in an attempt to increase business interest in the given city. The loop once again ends with roadway construction increasing roadways, as the loop will be impacting the rate of construction. This loop is also a balancing loop.

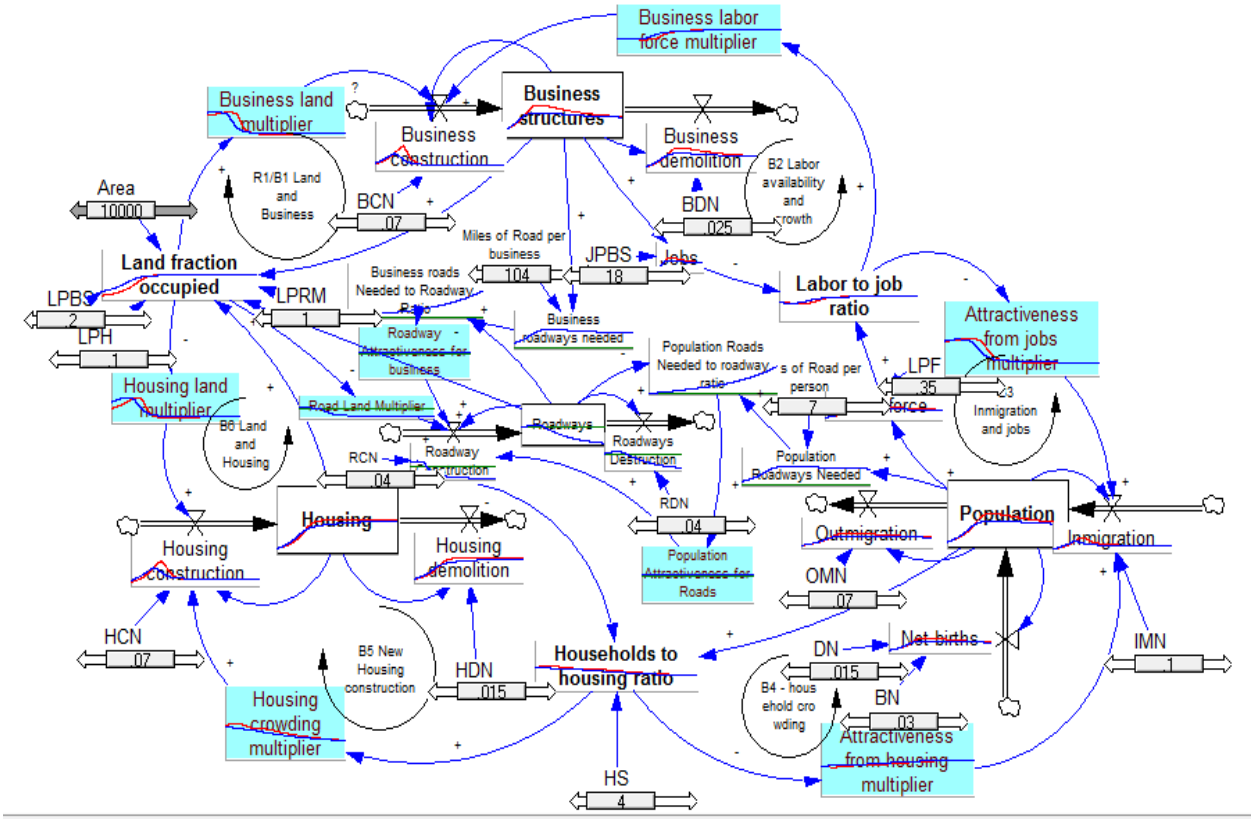
The final loop that I added into the Urban1 Model is Population Desire for Roadways Loop. This loop works in a similar fashion to the pervious loop, but looks at the Population's effect on Roadway Construction. This loop begins with the notion that as population increases, population roadways needed will also increase. This tells the reader that as more people come into the city, there will be a greater need for roadways. The next part of the loop states that as the population roadways needed increases, the population roads needed to roadway ratio will also increase. With an increase to the numerator, it could also mean that as roadways needed increases the desire to build more roads also increases. At the same time as this prior piece of the loop is happening, as roadways increase the population roads needed to roadway ratio will decrease. Similar to the corresponding ratio in regards to business, this section explains that as roadways are being built the desire for more roads will decrease. It makes sense because the population only needs a certain amount of roads to fulfill their daily needs. The next piece of this loop says that as the population roads needed to roadway ratio increases, the population attractiveness for roads also increases. This is telling us that as people are getting the roads they need, the more people will be satisfied by the roads they have. This is important to understand

because this leads into the next section, which is as population attractiveness for roads increases roadway construction will also increase. It is this section that tells the reader that as the population's satisfaction with roadways increases, they will also want to make more roads. This leads to the end of our final loop which tells us again that as roadway construction increases, roadways also increase. With this loop also being a balancing loop it is important to note that there will be large increases when the city is growing, but there is also a decline following the city's decay.

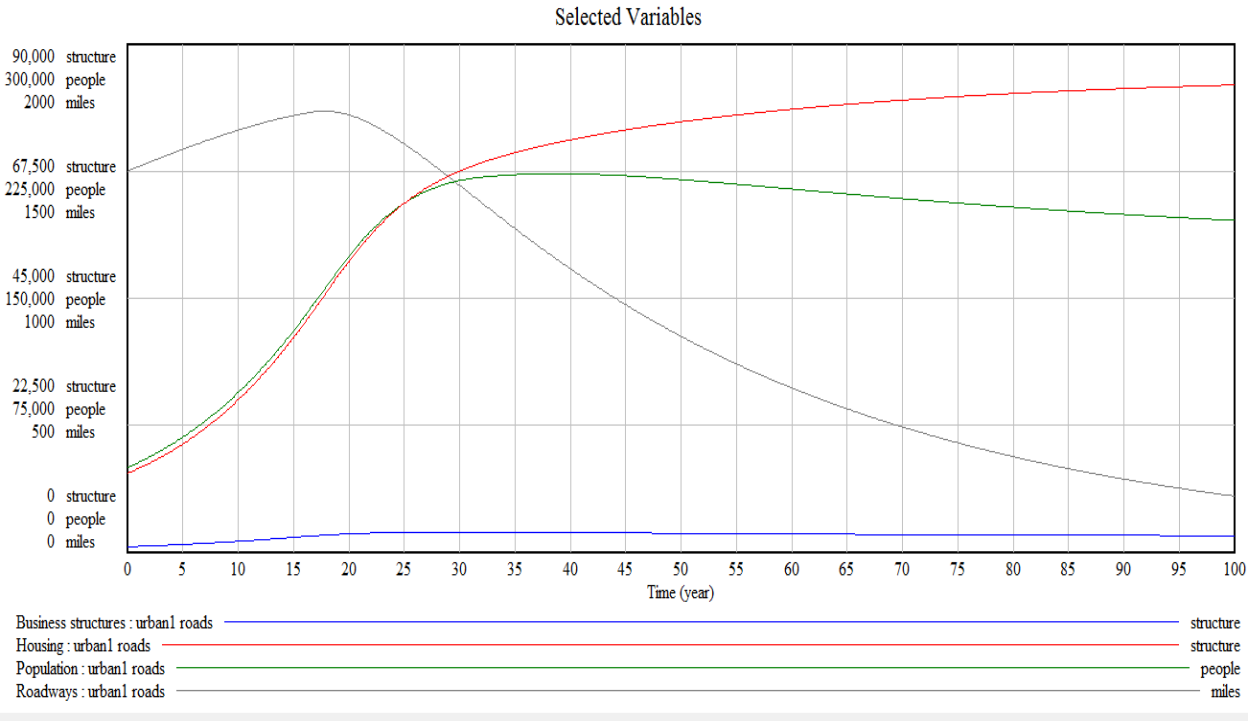
Now that I've explained all of my loops, the next part I will go over is all of the constants I have added to make my model work. In the prior section I mentioned that constants were essential to the Urban1 Model because it allows us to normalize the data and make the information more pertinent. Since the model was made in the late 1960s, the constants I added were formulated based on information from 1970. This will give the results and ratios a proximity and realism compared to the others. For both RCN and RDN, I used .04. The reasoning behind this is that roadways last about 25 years on average from the research I did.[25] All I did was take 1, being a healthy roadway, and divide it by 25 years of longevity to get .04. It also makes sense that the rates of construction and destruction are similar, if not the same, because of the rate of repair or lack thereof would be slowly decreasing over time. Finally, it also makes sense because with both being equal you would be able to see the effects of other factors on the rate of construction better. LPRM, or the land per roadway made, was determined to be a flat 1 acre/mile. This constant helps affect the land fraction occupied and tells it how much land is needed for a given road. The reason for this amount is because a two lane mile of road in the real world is a lot greater than an acre, but the space for housing is greater than .1 acre and businesses is greater than .2. To make thing proportional, we decided to scale roadways back to a

reasonable amount for the model to run properly. For the calculations regarding miles of road per person and miles of road per business, we need more information from this time period. I decided to gather information about New York City due to it being the largest city in the world and the large amount of data recorded. Mainly, we will need the miles of road in 1970 in NYC, population of NYC in 1970, and the amount of businesses in 1970. According to the New York State Statistical Yearbook from 1971, the amount of roadway miles in New York City was 5,578 which I rounded to 5,600 miles.[26] The population in New York City was roughly 7,800,000 people according to the decennial census.[27] The amount of total businesses in New York City around this time is 540,000. Being the specific information was difficult to find, it is going to be implied that the amount of businesses is identical to the amount of business structures. To calculate the miles of road per person, we simply divide roads by population. Once we do this, we multiply the answer by 10,000 to convert it into modular information. This gives us an answer of 7 miles per person that they would need to be efficient. In a similar fashion, to get miles of road per business we would divide roads by business. When we do this, we once again multiply the answer by 10,000 and get a result of 104 miles per business. This gives us all of the constants for the new Urban1 Model with Roadways added. Pictured below is the complete Urban1 Model with Roadways added to show all of the loops and constants present in the model. Also, there is a complete model with the constants and trends shown.

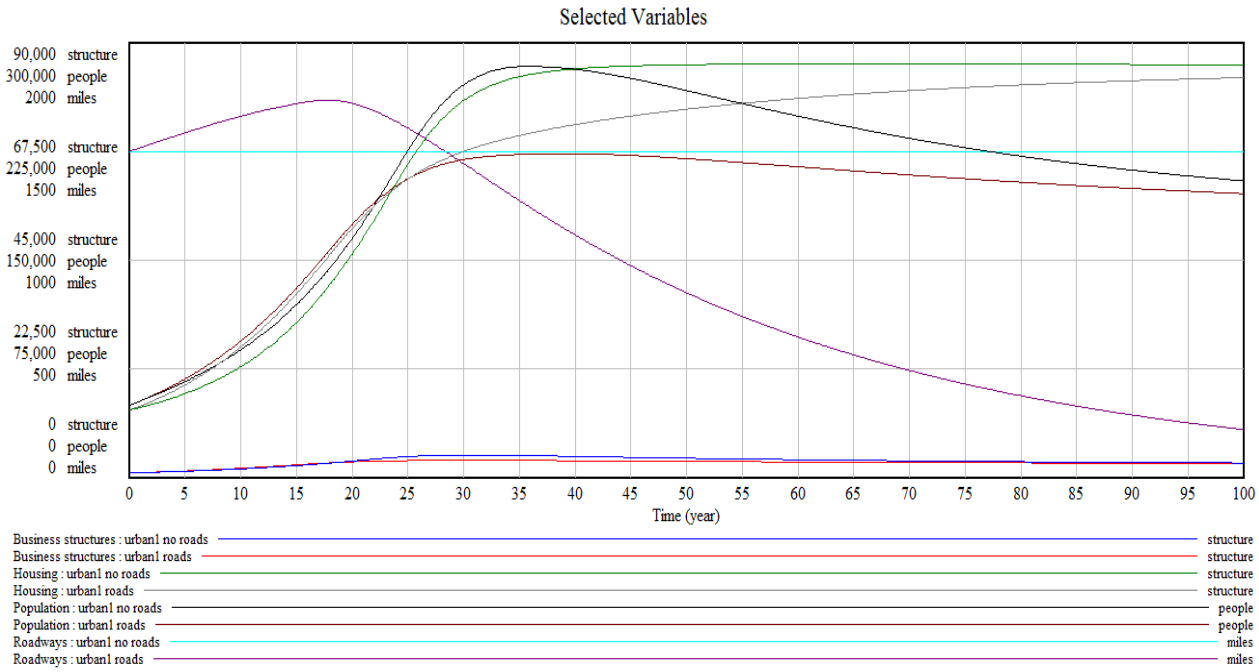

Business labor force multiplier
Business land multiplier
Business structures
Business construction
Business demolition
B2 Labor availability and growth
R1/B1 Land and Business
Area
BCN
BDN
Miles of Road per business
JPBS
Jobs
Land fraction occupied
LPBS
LPRM
LPH
Business roads Needed to Roadway Ratio
Business roadways needed
Labor to job ratio
Attractiveness from jobs multiplier
Roadway Attractiveness for business
Population Roads Needed to roadway ratio
Miles of Road per person
LPF
Housing land multiplier
B6 Land and Housing
Road Land Multiplier
Roadways
Roadway Construction
Roadways Destruction
Labor force
B3 Inmigration and jobs
RCN
RDN
Population Roadways Needed
Housing
Population
Outmigration
Inmigration
Housing construction
Housing demolition
Population Attractiveness for Roads
OMN
HCN
B5 New Housing construction
HDN
Households to housing ratio
DN
Net births
IMN
B4 - household crowding
BN
Housing crowding multiplier
Attractiveness from housing multiplier
HS


Business labor force multiplier
Business land multiplier
Business structures
Business construction
Business demolition
B2 Labor availability and growth
Area
10000
R1/B1 Land and Business
BCN
07
BDN
025
Miles of Road per business
JPBS
18
Jobs
Land fraction occupied
LPBS
2
LPRM
1
LPH
1
Business roads Needed to Roadway Ratio
104
Business roadways needed
Labor to job ratio
Attractiveness from jobs multiplier
Roadway Attractiveness for business
Population Roads Needed to roadway ratio
s of Road per person
7
LPF
35
force
Housing land multiplier
B6 Land and Housing
Road Land Multiplier
Roadways
Roadway Construction
Roadways Destruction
Inmigration and jobs
RCN
04
RDN
04
Population Roadways Needed
Housing
Population
Outmigration
Inmigration
Housing construction
Housing demolition
Population Attractiveness for Roads
OMN
07
HCN
07
B5 New Housing construction
HDN
015
Households to housing ratio
DN
015
Net births
IMN
.1
B4 - household crowding
BN
03
Housing crowding multiplier
Attractiveness from housing multiplier
HS
4

When running this base model, we can see that there is definitely a similar trend present in the original Urban1 Model. While graphing these variables, we see that all the variables tend to have the same trends. Business structures are still increasing, but seem to slowly decline after around 25 years. The population operates the same with an increase for around 35 years and then a decrease over the rest of the shown time. Housing, oddly enough, seems to be increasing over the time span consistently. Roadways start higher than the other factors, which makes sense because they are necessary to both businesses and population within a city. They continue to increase for around 17 years, but then take a sharp decline for the rest of the shown timeframe. This is telling us that there are too many roadways in urban environments and that by 20 years, cities will be unable to build or maintain their roadways in a proper fashion. In my opinion, this is a serious problem because roadways decreasing in quality will affect the interest of new businesses and population to come into a city.

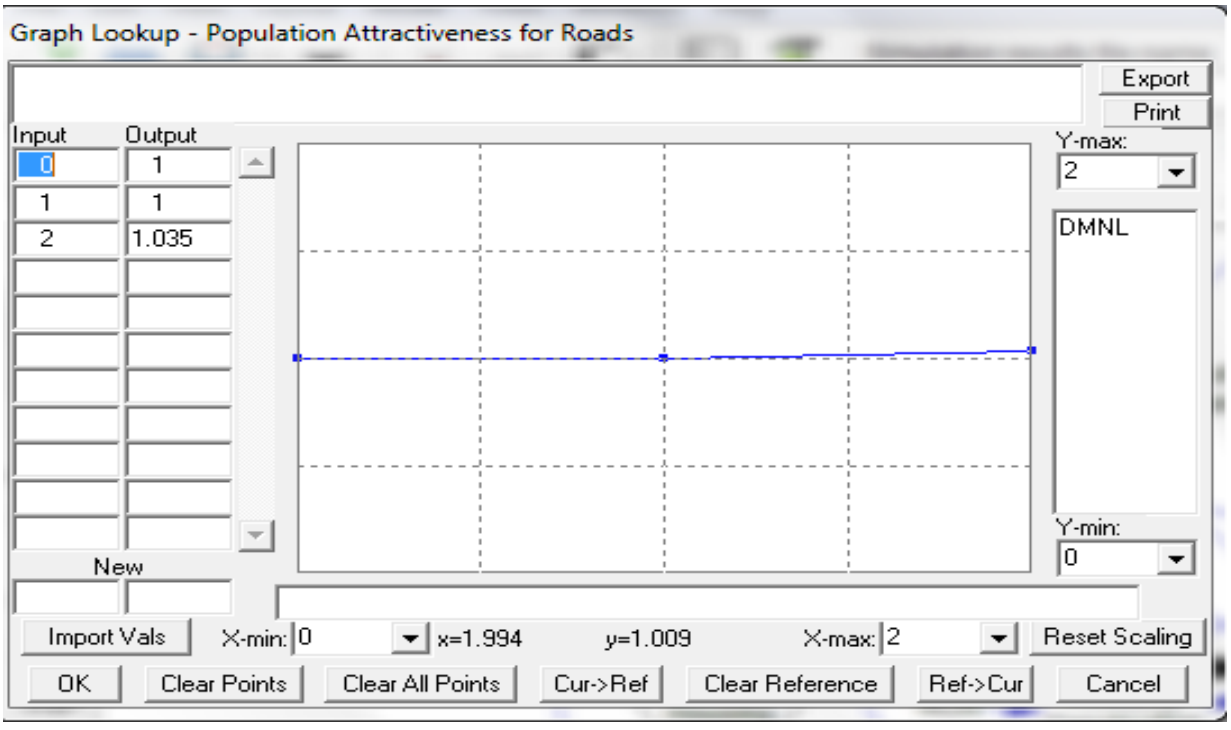


The next part I would like to discuss is the differences between the Urban1 Model and the base Urban1 Model with Roadways. While I have speculated what the effects would be, the graph below shows information of the two prior graphs put together. I was able to do that by using the Urban1 Model with Roadways implanted and shut down the effect of Roadways. By looking at this graph, you can really see the effects of Roadways on the cities. Business structures seem to be the least affected, but the one with roads is slightly lower than the one without roads due to the loss of space. Housing with roads is a lower than housing without roads, but also continues to increase while housing without roads seems to level out. This could be because while houses are competing with space for roads, they do allow people to get into cities more easily. This increase of ease of entrance could increase the housing demand. As for population, the amount of people in the urban environment with roads is a lot lower than people without roads. This could be because more roads lead to more transportation options and the growth of suburbs. This shows that there is a place for consideration for Roadways in the Urban1 Model.

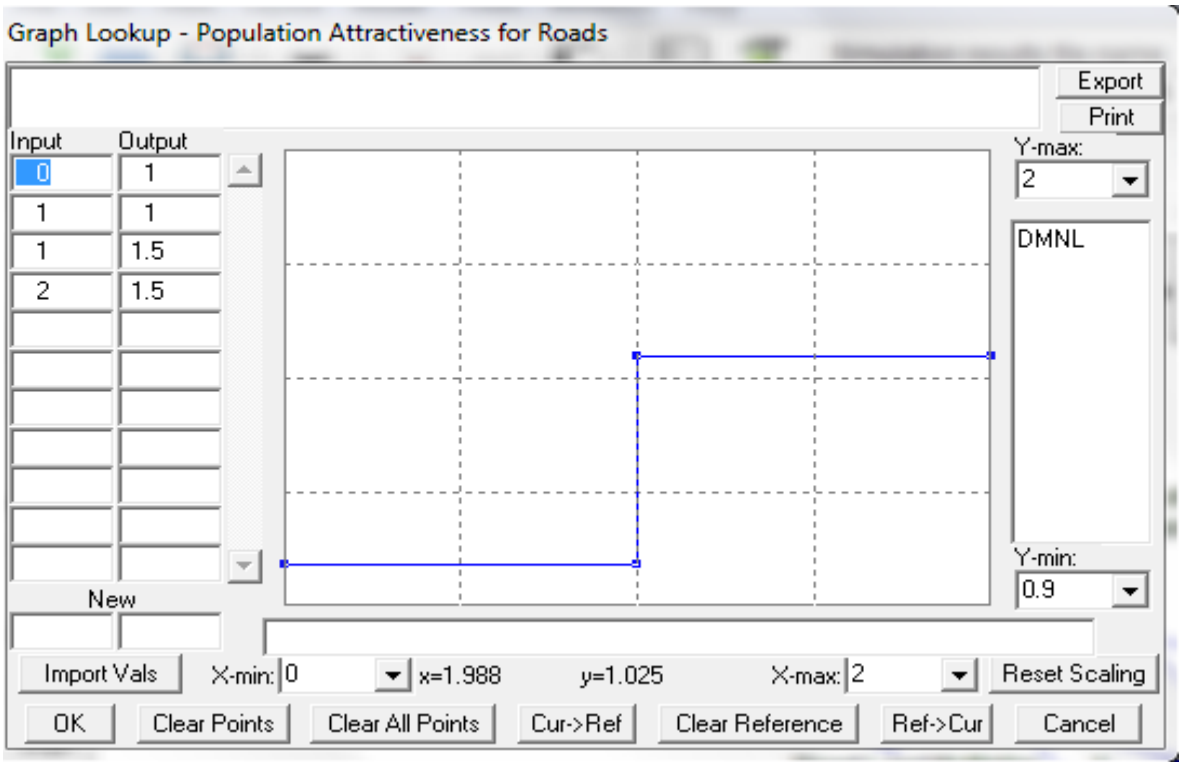


The next part of this section will discuss other runs with different effects on the new model. The reason we do this is to compare the base runs of the new model to the base runs of the original model. This will show Roadways direct effect on the Urban1 Model, especially relating to the space available to build. The reason we do other runs is to test the elasticity of the model. For this I will be running the model by adding positive shocks to a number of multipliers in the model, specifically: Population Attractiveness for Roads and Roadway Attractiveness for Business. By looking at the results with these shocks, we can see if the model is proper and sustainable.

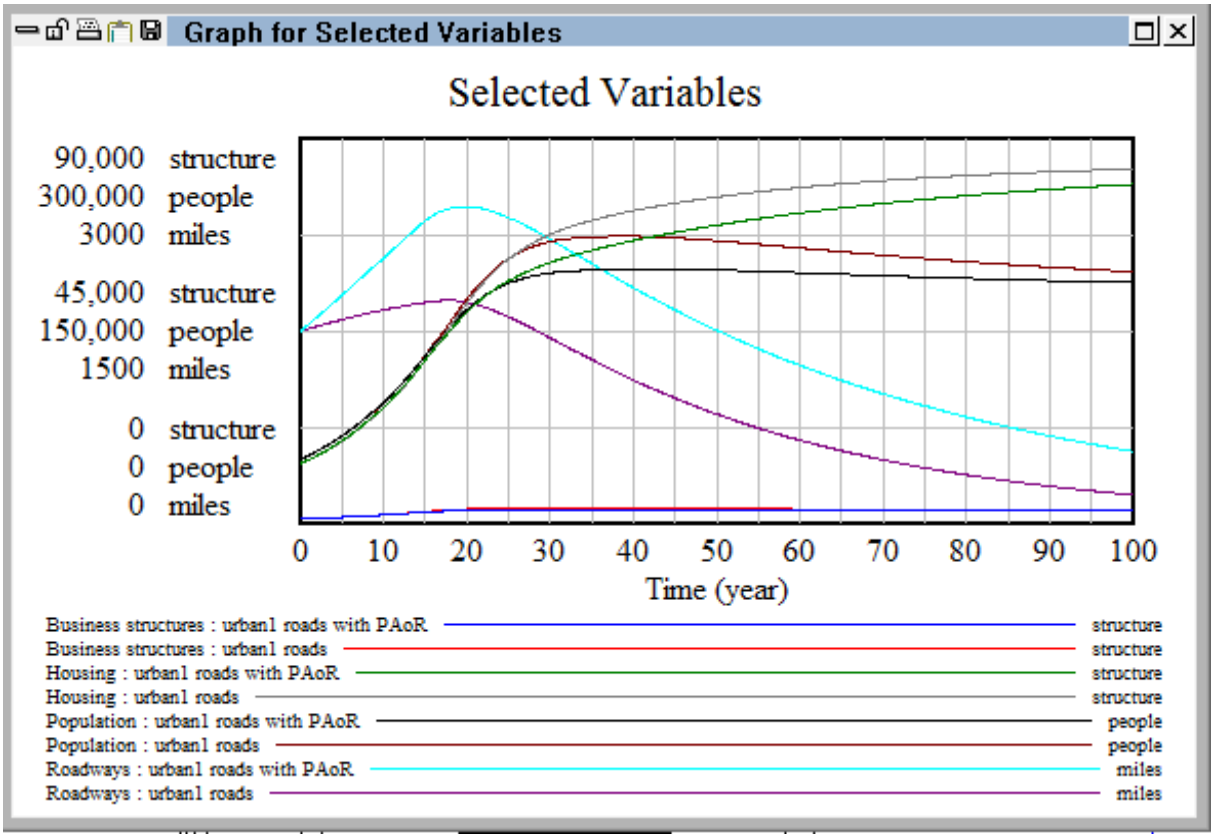
The Population Attractiveness for Roadways in the base model is shown below. What this is saying is that when people have more roads then they need and the exact amount they need, the amount of construction desired by the population will remain constant. When they have less roadways then they need, the population will increase the output to 1.035, meaning that they will increase construction by 3.5%.



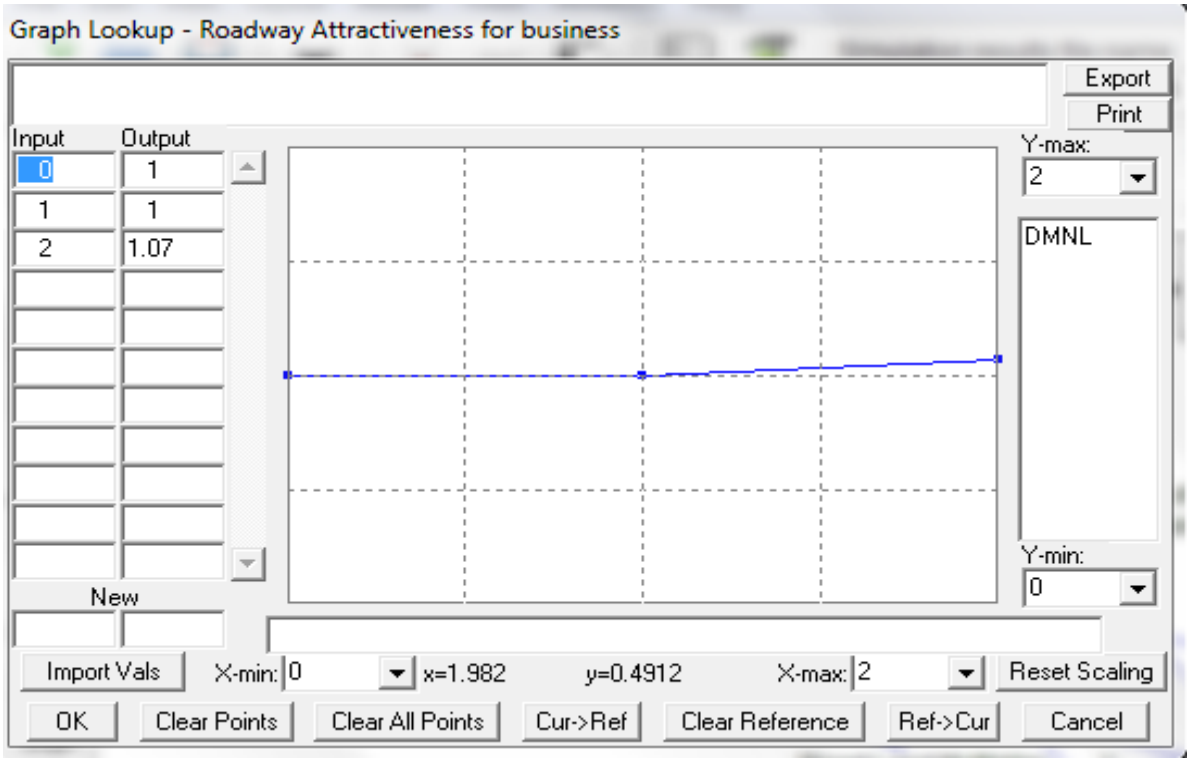
To really test the elasticity of the new model, I increased the construction that will occur to 1.5 when the population is satisfied and when they desire more roads. In respect to construction, this would mean we are building roads 50% faster than before. The reason for this big change compared to the modest base amount is because this is an extreme scenario. I named the new model run Roads with PAoR, meaning roads with Population for Roads affected.



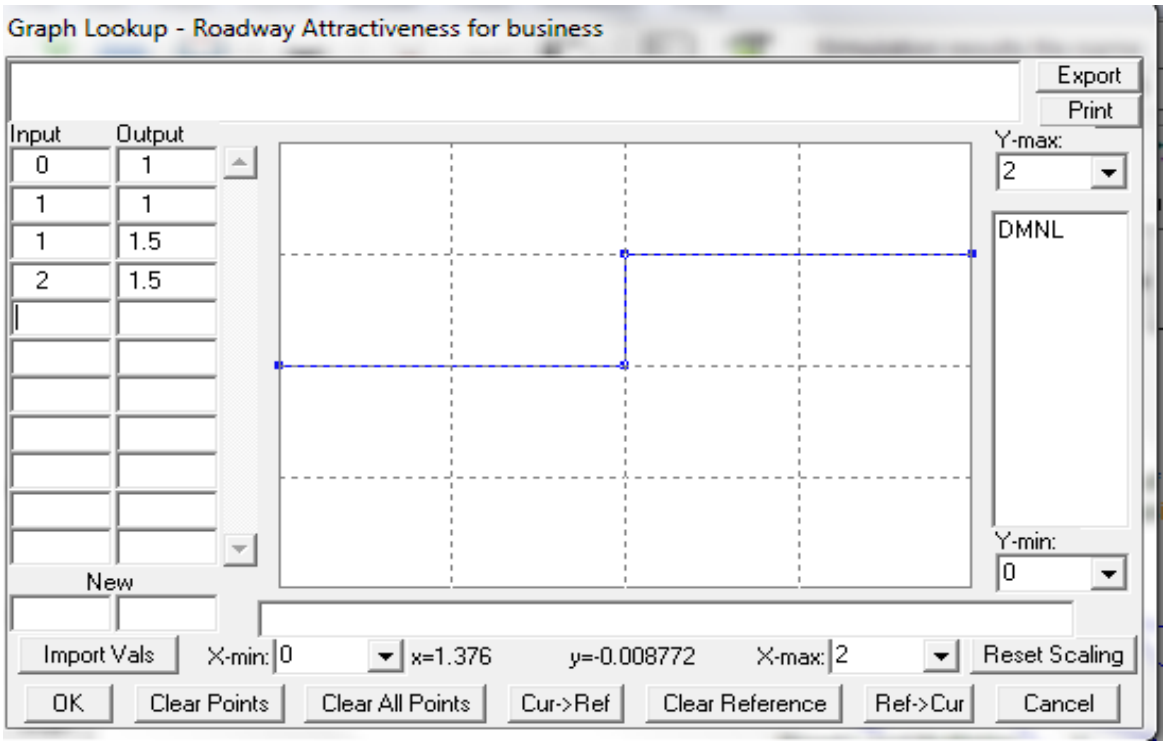

When looking at the graph comparing the base run to the new run, we can clearly see a difference in roadways. With a higher demand for roadways, more are built compared to the base run. Housing and Business structures are decreased to make more space for the roads that are needed. The population for the new run is actually lower than the base run, but it seems to level out instead of a decay like the base run. Even though there is a dramatic change, you can clearly see that the stocks are trending in a similar fashion. This is important and shows us that the model seems to be operating efficiently, even in exaggerated situations.



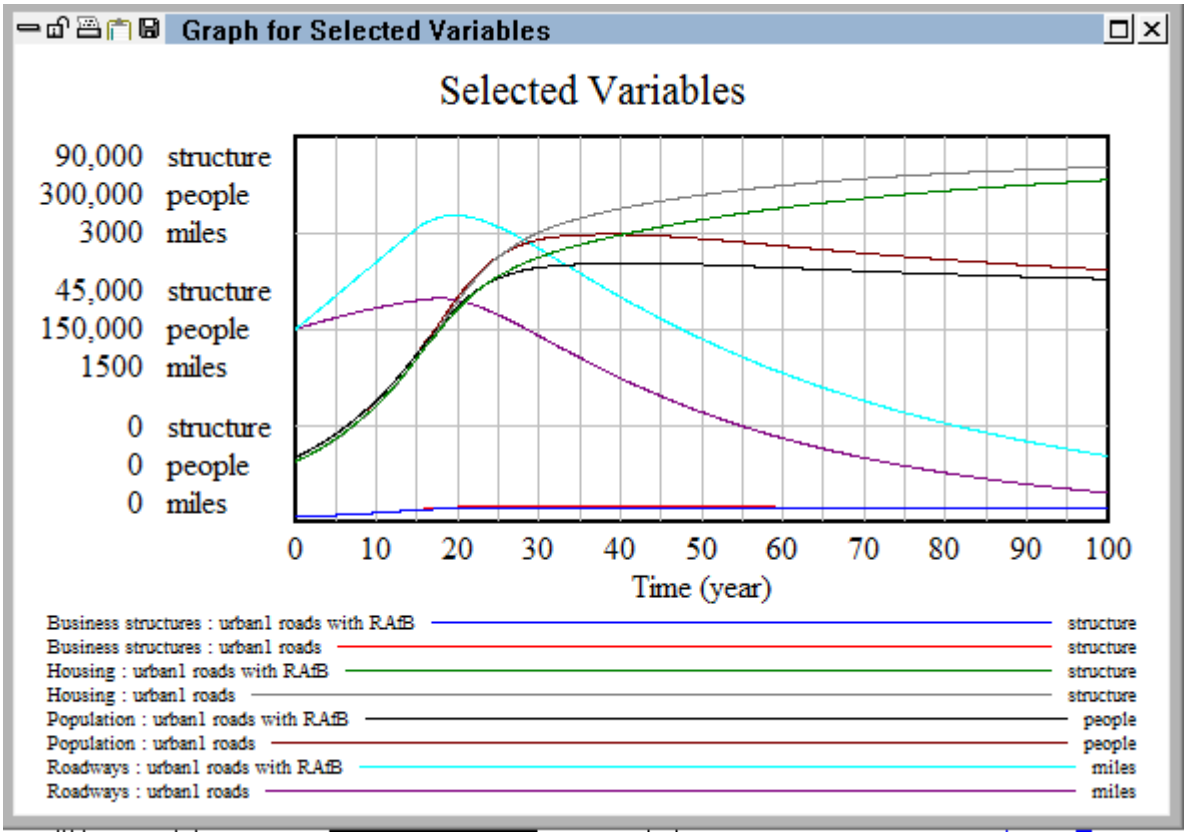

The Roadway Attractiveness for Business in the base model is shown below. What this is saying is that when businesses have more roads then they need and the exact amount they need, the amount of construction desired by the population will remain constant. When they have less roadways then they need, the population will increase the output to 1.07, meaning that they will increase construction by 7%. Compared to the population factor, businesses will be able to construct roads twice as fast. The reasoning behind this is that businesses will typically have more control in roadway construction and maintenance then a single person.




I increased the construction that will occur to 1.5 once again, but in this case when businesses desire more roads to be built. This means we are building roads 50% faster than before. Once again, the reason for this big change in comparison to the modest base amount is because we need extreme scenario compared to a more realistic one. I named the new model run Roads with RAfB, meaning roads with Roadway Attractiveness for Business changed.




There is once again a difference between the base run and the modified run with a positive shock in this factor. Once again, we are seeing that Housing and Business structures are lower in the new run compared to the base because we need more space for the added roads. The population is lower, but seems to level out more compared to the base run. Roadways are higher than the base model because of the increased construction. Oddly enough, this new run seems to look almost identical to the other run in comparison to the base. This is because of the increased amount I chose being the same, and both factors affect the construction rate of roadways in the same manner. That being said, we once again see that the model trends in the same ways as before, showing that it is running properly.




## Conclusion

With all of this evidence, we need to ask ourselves what this all means and what it effectively shows us. I believe this evidence tells us that Roadways are an equally important factor in a model of urban decay. This is because Roadways take up a limited space, which also compete with Housing and Business structures, in a city. The trend in cities and the world as a whole seems to be periods of significant growth of roadways, but then ineffective upkeep plans. This causes an increased decay that will do nothing but negatively affect all parties involved. While cities do have a bunch of benefits for people, the unsustainable growth noted by Forrester seems to be an unavoidable tendency that many environments are facing today. I believe the notions and beliefs mentioned by authors like Robert Ceverro declaring the overall benefits of roadway growth are important. That being said, the ideas put forth by authors such as Todd

Litman about the adverse effects of roadways is something to also consider. It is for this reason, I believe that cities must consider adding additional roadways on a case by case basis before simply expanding. Similar to what Forrester said, I believe we will only continue enhancing urban decay if we continue to grow cities road systems at an uncontrollable rate without having a valid strategy. I hope that the information I portrayed and explained would be considered before continuing the recent trend of overwhelming development and deterioration.

# Works Cited


1. Stoller, Gary. "U.S. Roads, Bridges Are Decaying despite Stimulus Influx." *USA Today*. 29 July 2013. Web.
2. National Economic Council and the President's Council of Economic Advisers. An Economic Analysis of Transportation Infrastructure Investment. July 2014. Web.
3. Lindley, Jeffrey A. "Urban Freeway Congestion Problems and Solutions: An Update." *ITE Journal* (1989): 21-23. Web.
4. Litman, Todd. *Generated Traffic and Induced Travel*. Print.
5. Downs, Anthony. *Stuck in Traffic: Coping with Peak-Hour Traffic Congestion*. Print.
6. Hartgen, David, and Danial Curley. *Beltways: Boon, Bane, or Blip? Factors Influencing Changes in Urbanized Area Traffic, 1990-1997*. Print.
7. "An Analysis of the Relationship Between Highway Expansion and Congestion in Metropolitan Areas." (1998). Web. <http://www.daclarke.org/AltTrans/analysis.html>.
8. White, Brent T., Simone M. Sepe, and Saura Masconale. "Urban Decay, Austerity, and the Rule of Law." *Emory Law Journal* 64.1. Web.
9. Schrank, David L., Shawn M. Turner, and Timothy J. Lomax. "Estimates of Urban Roadway Congestion - 1990." *Interim Report* (1993). Web.
10. Duranton, Gilles, and Matthew A. Turner. "Urban Growth and Transportation."*Review of Economic Studies* (2011). Web
11. Schrank, David, and Tim Lomax. "The 2002 Urban Mobility Report." Web.
12. Samuel, Peter. *Innovative Roadway Design Making Highways More Likeable*. Print.

13. Litman, Todd. "Determining Optimal Urban Expansion, Population and Vehicle Density, and Housing Types for Rapidly Growing Cities." *World Conference on Transport Research* (2016). Web.
14. Cevero, Robert, and Mark Hanson. "Road Supply-Demand Relationships: Sorting out Causal Linkages." (2000). Web.
15. Hansen, Mark and Yuanlin Huang. "Road Supply and Traffic in California Urban." *Transpn REX-A* 31.1 (1997). Web. <http://www.lgc.org/wordpress/docs/freepub/community_design/focus/road_supply_CA_urban_areas.pdf>.
16. Boarnet, Marlon G., and Saksith Chalermpong. "New Highways, House Prices, and Urban Development: A Case Study of Toll Roads in Orange County, CA."*Housing Policy Debate* 12.3 (2001). Web. <https://www.innovations.harvard.edu/sites/default/files/hpd_1203_boarnet.pdf>.
17. Cevero, Robert. "Road Expansion, Urban Growth, and Induced Travel." *APA Journal* 69.2 (2003). Web.
18. Carey, Jason. "Impact of Highways on Property Values: Case Study of the Superstition Freeway Corridor." Web.
19. Boarnet, Marlon G., and Andrew F. Haughwout. "Do Highways Matter? Evidence and Policy Implications of Highways' Influence on Metropolitan Development." (2000). Web.
20. Oberhelman, Doug. "Road to Growth The Case for Investing in America's Transportation Infrastructure." *Business Roundtable* (2015). Web. <http://businessroundtable.org/sites/default/files/2015.09.16 Infrastructure Report - Final.pdf>.

21. Estache, Antonio, and Grégoire Garsous. "The Impact of Infrastructure on Growth in Developing Countries." *IFC Economics Notes* (2012). Web.

22. Forrester, Jay W. *Chapter 18: Towards a National Urban Consensus*. from Mass, Nathaniel J. *Readings in Urban Dynamics: Volume 1*. Print.

23. Forrester, Jay W. *Chapter 19: Control of Urban Growth*. Print. from Mass, Nathaniel J. *Readings in Urban Dynamics: Volume 1*. Print.

24. *Answers.com*. Web. <http://www.answers.com/Q/What_percentage_of_a_city_is_used_for_roads>.

25. *Alphapavingtexas.com. Web.* <http://www.alphapavingtexas.com/faq-answer/what-is-the-average-lifespan-of-asphalt/>.

26. *New York State Statistical Yearbook - 1971*. Web. <file:///C:/Users/MW191577/Downloads/NYC Miles.pdf>.

27. *City of New York & Boroughs: Population & Population Density from 1790*. Web. <http://www.demographia.com/dm-nyc.htm>.