TWISTER MYSTERIES

http://www.google.com/imgres?um=1&newwindow=1&safe=off&sa=N&hl=en&biw=1440&bih=799&tbm=isch&tbnid=-JQthyEnrWdYUM:&imgrefurl=http://www.howstuffworks.com/eye-of-tornado.htm&docid=mWmgmRi4KqcA7M&imgurl=http://static.ddmcdn.com/gif/eye-of-tornado-1.jpg&w=400&h=313&ei=iNa0UYaeCKOMygHHtYCIDg&zoom=1&ved=1t:3588,r:2,s:0,i:97

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Introduction:

The purpose of this program is to model how different attributes of tornadoes affect the damage (in dollars) done to cities, depending on city size, layout, and building densities. Tornado attributes include, movement probability, tornado life time, movement speed, strength on the Fujita scale, and whether or not they reproduce into tornado families (the occurrence of which is extremely rare). It also models how cars try and escape a tornado's path and how they are generally destroyed as a result of these storms, either directly due to the tornado's impact or due to accidents caused by cars crashing into trees, houses, buildings, or other cars in an attempt to escape.

For a visual representation, users can see the initial value of the city (based on predefined property values), the final value of the city after the tornado, and the corresponding total damage (in dollars) done to the city. The user also sees a plotted breakdown of the damage done to buildings and to houses versus the overall total damage done. Lastly, the user sees the percentage of original cars that have been destroyed, and of the cars destroyed, what percent is attributed to direct impact from the tornadoes and what percent is attributed to accidents caused by cars crashing into houses, buildings, trees, or other cars while attempting to frenziedly escape the storms.

What Can Be Learned from the Model:

The damage done to buildings depends on city layout (are buildings closer together or farther apart), their size (do taller or shorter buildings get affected more), and their material (the model assumes that the best possible material was used in the construction of houses and buildings). The model therefore attempts to see what combination of city layout and building stature are best equipped to handle tornadoes and therefore how damage can be controlled. Such a study would be especially helpful for cities that reside in Tornado Alley, as they are affected the most year-round in the United States by these fearsome storms. This way, in the future for city construction, such studies can be kept in mind when designing cities that are most prevalent to being affected by tornadoes. Since it is not feasible to re-design preexisting cities as they've already been built and are not easily changeable, this is more of a personal interest project. My overall goal from the project has been the research process of urban planning, city design and the rationale for city layouts. I also wanted to see the effect of tornadoes on cars trying to escape the storms. Tornadoes are powerful enough to wreck cars instantaneously and on average travel slower than a car driving desperately to escape it. Yet there are many accidents, or car “casualties” during tornadoes regardless. I wanted to see how tornadoes affect the breakdown of car casualties from cars destroyed directly by the tornado and cars destroyed as a result of crashing into trees, houses, buildings, and other cars from trying to escape the tornadoes.

Model Rules and Implementation:

There are three different city types that have been encapsulated by three different setup buttons. One is a large city, which has a dense layout of larger buildings. Another is a medium city which has a moderately dense downtown area on one side of town coupled with a suburban area with many houses and trees on the other side of the town. Lastly, is the small city that has a small 'shopping center' for buildings in a corner of the city with the rest of the town being a neighborhood of houses and trees that are relatively close together. Also created at setup is a tornado with the same attributes assigned to it as what the user chooses initially before setting up a city. There are also a number of cars (specified by the user) with a given speed (chosen by the user) created at the time of choosing a city setup as well. This comprises the world at setup.

There are different types of agents in the model for which breeds have been created. Houses are turtles that are smaller and worth less than buildings and only show up in the medium and small city setups. The average price for homes (gathered from Trulia.com from example cities of these sizes) in these types of cities have been assigned to houses - $125,000 in a small city and $200,000 in a medium city. Buildings are turtles that are larger than houses and have a given value depending on the city that they are set up in – $500 million in large cities, $100 million in medium cities and $20 million in small cities. Also, they show up in all three city layouts. Trees are turtles that are not commonly found in the large city setup, but are abundantly scattered about the world in the medium and small city setups. Cars are turtles that show up around the world as chosen by the user and try to escape the tornadoes at run-time. Cars are all also given a speed that they will run at which is assigned by the user at setup. Finally, tornadoes are also turtles that show up in a random location on the screen set up by a number of different attributes chosen by the user at setup. The attributes of the tornadoes, which are the most important features needed to determine the accuracy of the model, are as follows:

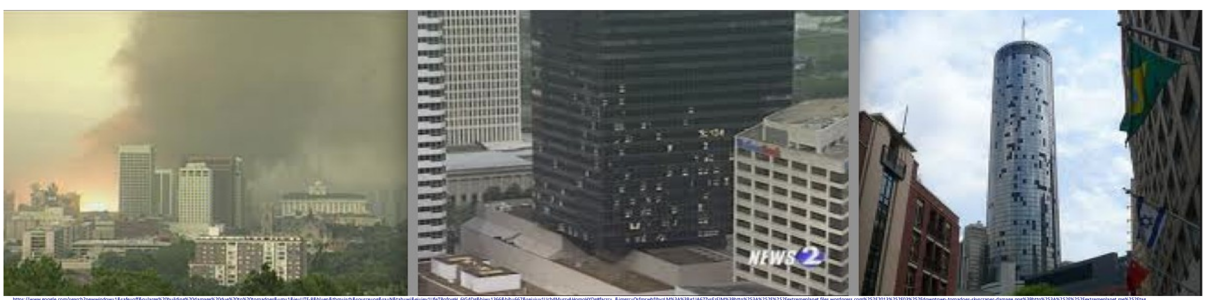
- tornado-lifetime: how long the tornado is scheduled to live (on average they last from several seconds to up to twelve minutes)
- tornado-strength: on the Fujikawa scale, tornadoes are measured from a magnitude of F1 to F5 – which is being visually depicted by size in the model
- movement-speed: how fast the tornado moves in its path (on average they move between 30 and 70 miles per hour)
- movement-probability: the probability with which the tornado will move (in a random way) at that instant – as tornadoes do indeed move probabilistically
- allow-reproduction?: tornadoes very rarely reproduce into tornado families – the user has been given the option of allowing this to happen, and if they choose to allow it then tornadoes reproduce at a 0.1% chance

The tornado lifetime has been normalized into a certain number of ticks. It was measured that one second corresponded to roughly fifty ticks. Therefore, the lifetime was normalized as (tornado-lifetime * 60 * 50 / 10). The expression was divided by ten in order to have the model run for a reasonable amount of time. Also, the tornado movement speed along with the car speed were both normalized as (speed / 100) in order to show proper, proportional movement on the screen.

Now, when the user chooses the 'go' option, the tornadoes begin moving based on the probability set by the user, in a random manner as consistent with some tornado paths. If the user has allowed for tornado reproduction, then at each tick the tornado will have a 0.1% chance of reproducing into another tornado that begins its own lifetime separately and its own path of movement. As the tornado makes its way around the world, if it encounters trees within a certain radius (depending on its strength), it will throw the tree to another location depending on its strength and movement speed. If the thrown tree hits a house or building, it inflicts a certain amount of damage ($3,000 to buildings and $10,000 to houses – arbitrarily chosen since only reference point available was through Yahoo answers which isn't deemed credible). If the thrown tree hits a car, then the car becomes immobilized, turns a black color to indicate that it has been destroyed, and adds itself to the count of destroyed cars. Cars, meanwhile, stay in the same spot unless the tornado comes approaching into a certain radius around the car (depending on the tornado's strength). The car will begin to move away from the tornado, and depending on its speed in comparison to the tornado will either get swept away by the tornado (and turn black indicating it being destroyed by the tornado), will crash into a nearby house, building, tree, or another car (and turn black indicating it being destroyed due to accident), or it will escape out of the danger radius and stop moving again. When the tornado passes over a house or building, then depending on the value of the house/building, the strength of the tornado and the amount of time that the tornado has spent in the area, a certain amount of damage will be incurred. Since the tornado only moves with a certain probability, it is possible for a tornado to stay stuck in a certain area for a while, and pass very quickly over other areas. Damage done to houses/buildings will increase exponentially the longer the tornado resides there since the structures weaken before getting damaged at even faster rate after the weakening has occurred if the tornado has been there long enough. The mathematical model used to assess damage on a house/building is ((tornado-strength ^ 3) * (e ^ (time-with-tornado / 50)) * 100000). The time with tornado is divided by fifty in order to convert the number of ticks into seconds, and is multiplied by a correction factor of 100000 to show that the damage is incurred in hundreds of thousands of dollars. If the damage done to a house exceeds the initial value of the house, then the total damage done to that house is set to the initial value of the house and the shape is black to indicate complete destruction and the shape is turned into a circle to indicate a “heap of destroyed material” if looked at from an aerial view. This is an acceptable visual as in cases throughout history, homes have been destroyed in such heaps before. An example has been shown below:

https://www.google.com/search?q=homes%20destroyed%20by%20tornadoes&um=1&ie=UTF-8&hl=en&tbm=isch&source=og&sa=N&tab=wi&ei=mOq1UfP6KZP_yQHQwoHQAw&biw=1366&bih=667&sei=m-q1UeLxINDyyAHB_IGoBg#facrc=_&imgrc=n7LzcffRbFn2SM%3A%3BocUR4odtCcw_hM%3Bhttp%253A%252F%252Fl1.yimg.com%252Fbt%252Fapi%252Fres%252F1.2%252Fu_Znd95GtvSZw_vu3DsyZg--%252FYXBwaWQ9eW5ld3M7Y2g9MjIzNTtjcj0xO2N3PTMwNDE7Zhg9MDtkeT0wO2ZpPXVsY3JvcDtoPTQ2NDtxPTg1O3c9NjMw%252Fhttp%253A%252F%252Fmedia.zenfs.com%252Fen_us%252FNews%252FReuters%252F2013-05-21T220457Z_1357549845_TB3E95L1PC0RD_RTRMADP_3_USA-TORNADOES.JPG%3Bhttp%253A%252F%252Fnews.yahoo.com%252Foklahoma-tornado-damage-could-top-2-billion-150010083.html%3B630%3B463

For a building, if 33% damage has been incurred, then the building turns light brown; if 66% damage has been incurred, then the building turns dark brown; then at 100% damage it turns black just like the houses. This too is realistic, as has been shown below in another example:

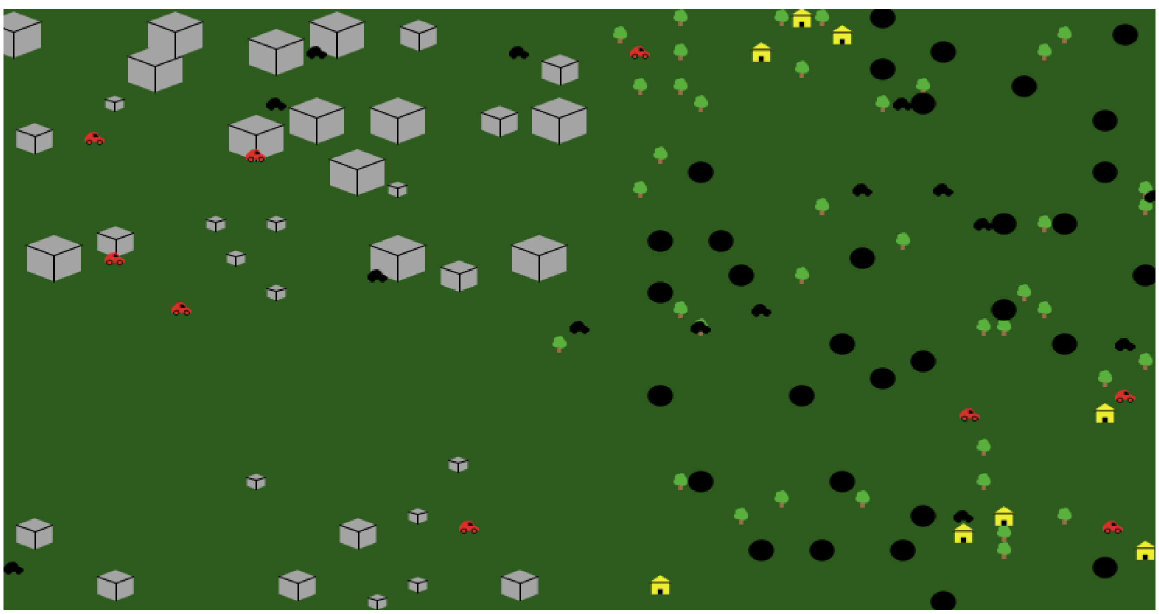


https://www.google.com/search?newwindow=1&safe=off&q=large%20building%20damage%20due%20to%20tornadoes&um=1&ie=UTF-8&hl=en&tbm=isch&source=og&sa=N&tab=wi&ei=jey1UfeTBofrygH_6IG4Dg&biw=1366&bih=667&sei=juy1Ucb4MurryAHomoHYDg#facrc=_&imgrc=OsfmrwhfJhvzLM%3A%3Bg1JA67ZysFzElM%3Bhttp%253A%252F%252Fextremeplanet.files.wordpress.com%252F2013%252F03%252Fdowntown-tornadoes-skyscraper-damage.png%3Bhttp%253A%252F%252Fextremeplanet.me%252Ftag%252Ftornado-damage-downtown%252F%3B1178%3B342

Once there are no more tornadoes in the world, that particular model run stops. The visual representation of damage shown in the plots and monitors in the Interface tab are explained in the analysis section, as are comparisons to reference patterns studied to show the model's accuracy.

Model Analysis:

The model has been constructed in a way that matches reference patterns that show various tornado strikes and corresponding damage statistics across the United States. One of the deadliest tornadoes in US history, the 1999 Oklahoma City tornado, was an F5 rated tornado that did an estimated $1 billion in damages to the city. The following is a measurement of an F5 tornado measured in a medium city setting such as Oklahoma City with a maximum lifetime setting since the 1999 tornado lasted a lot longer than the average lifetime allowed in the model. Here is the view of the city:



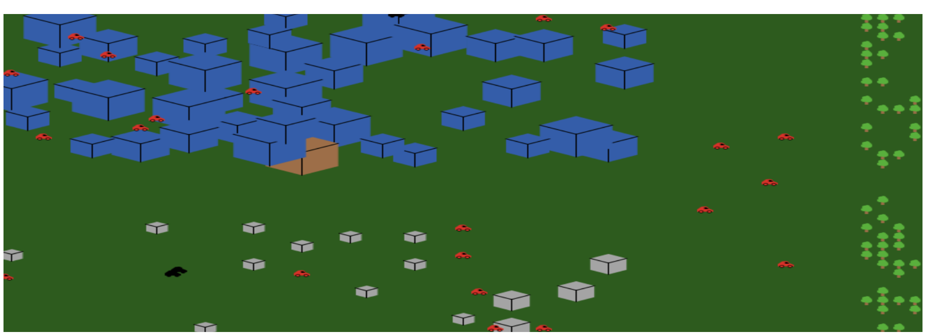
this shows heavy damage to the suburban area with a lot of car accidents. The overall damage reading is roughly $1.33 billion, which is around consistent with the expected reading of about $1 billion. Though this model showed such significant damage with just twelve minutes of running time, the real tornadoes have an infinite topology of where to run and despite lasting hours could trek through areas that are not as populated, which is one of the limitations of the model that could be fixed in an attempt to extend the model which will be discussed later.

The following is data gathered from Prevention Web as well as from Statistic Brain that shows a summary of tornado damage statistics from 1980 – 2002:

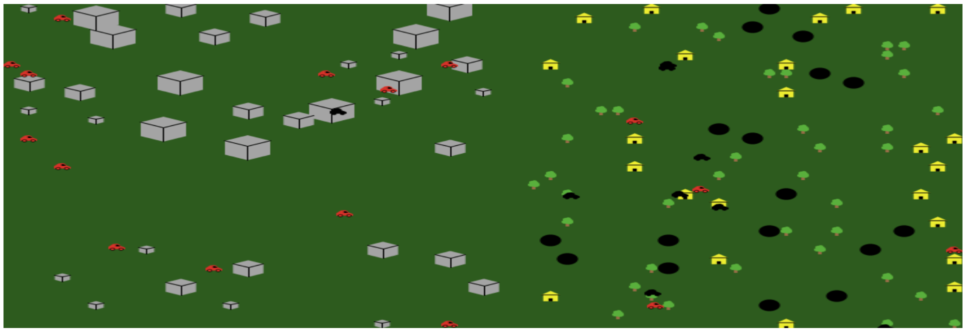
Number of events	182
Number of people killed	4,780
Average people killed per year	165
Number of people affected	12,710,204
Average people affected per year	438,283
Economic Damage	$31,510,661,000
Economic Damage (per event)	$173,135,500

Therefore, on average in the last 22 years, $173,135,500 worth of economic damage have been inflicted on cities due to tornadoes. Using average values in these model runs, the following are damage totals from all three sizes of cities, using a lifetime of 7 minutes, a strength of F3, and a movement probability of 35%:

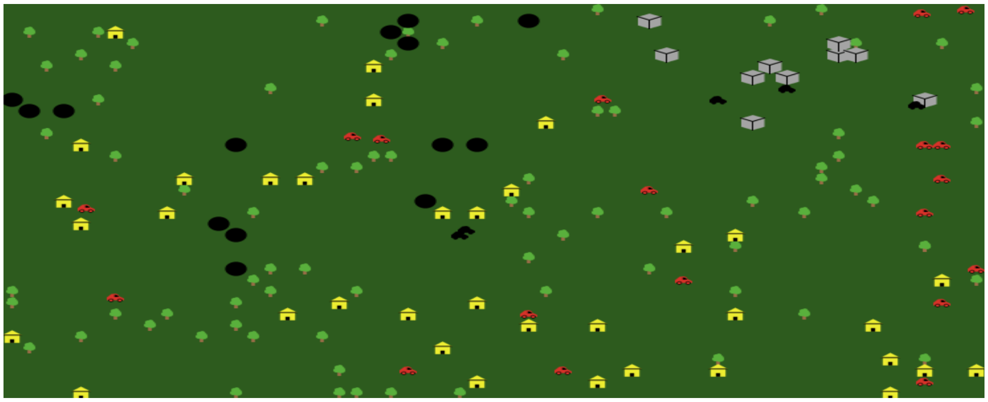
Large city ($339 million in damage done)



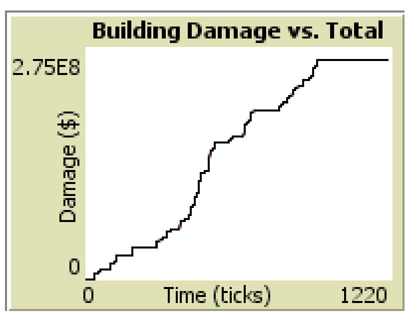
Medium city ($72 million in damage done)



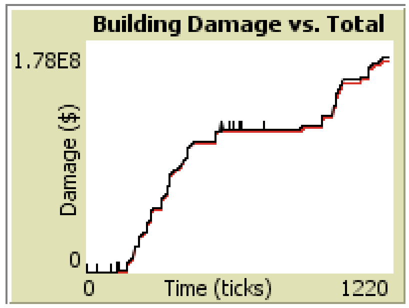
Small city ($31 million in damage done)



which makes for an average of about $147 million in damage done in these types of cities, which is about a 15.0% error. Of course, this was demonstrated with just one setting and the model can conform closer to the average with more model runs with different settings due to the central limit theorem. The large city with the densest buildings had the most damage done to it which shows that it might be best for cities to be constructed such that their layout of buildings is much sparser in order to even out the risk of multiple buildings being hit by the tornado and therefore diminishing the chance of excess damage. However, as shown by the model, though the medium and smaller sized cities were affected less dollar wise, they had a lot more visible episodes of complete destruction (more houses were totaled), which shows that smaller and medium sized cities may undergo a more thorough reconstruction project as opposed to larger cities that may need work to just fix damage but don't require complete reconstruction. That is one ambiguous part of the study which doesn't seem to have a clear answer. It was also difficult to obtain data regarding cost breakdown of houses versus buildings in certain tornado strikes, so it was wasn't worth showing the plots in the Interface tab that show house damage vs. total and building damage vs. total in this section. It is, however, helpful to see the breakdown during model runs to see the spike in damage done when the tornado enters a densely laid out area of buildings. Here is an example of a building vs. total damage plot in a large city:



As can be seen, the damage rises steadily because the tornado is more or less consistently in a densely laid out area, so damage is always increasing quickly. Now, for example, take a similar plot from a medium sized city:



Here, the damage starts small in a house-filled neighborhood. Then the sudden giant spike in damage is attributed to the tornado headed to the downtown area, where the buildings are densely packed. Then the damage flat-lines with a few tiny spikes which indicate empty areas with the occasional house getting destroyed. Then another sudden increase in damage signals the tornado moving back to the downtown area. The red line in the plot is the damage done to buildings, and the difference between the black and red lines is the damage done to houses. Clearly, most of the damage (dollars-wise) is done to buildings and the sudden increases in damage shows no difference between black and red lines, meaning that those jumps are solely attributed to buildings and the fact that the tornado is damaging them in the denser downtown area.

The other aspect that was being measured as a part of this study was the damage done to cars and how much of the destroyed cars are as a result of the tornadoes and how much is the result of accidents caused by a frenzied attempt to escape. Using the median number of cars available, and setting the car speed to be 20 mph higher than the tornado's movement speed, we get the following results for car destruction in each of the type of cities:

- Large city: 12% of total cars were destroyed, but all of them due to accidents
- Medium city: 20% of total cars were destroyed; 80% due to accidents and 20% due to direct impact from the tornado
- Small city: 32% of total cars were destroyed; 87.5% due to accidents and 12.5% due to direct impact from the tornado

This shows that most accidents that occur during tornadoes occur because of the scared and hurried attempts of drivers attempting to flee the city that they lose control of their cars and end up causing accidents which ends up defeating the purpose. According to reports during the latest Oklahoma City tornado earlier in 2013, there was a lot of traffic backed up with people attempting to leave the city and people ended up exiting their cars trying to run and escape from the tornado (NY Daily News). In fact, this was due to a meteorologist recommending to the public that the upcoming tornado was going to be extremely strong, so they should jump in their cars and try to flee before it arrives; this is advice that has come under heavy criticism since the storm took place, being called 'irresponsible' (NY Daily News). Many fact-publishing sites and authors have recommended that being in a car is, in fact, the worst place to be for people during tornadoes – the best option is to go to a nearby shelter and take cover rather than be in a car. The model further proves that people should not be on the road driving during tornadoes – they should instead be taking cover elsewhere.

Model Limitations and Future Work:

The current model has several limitations that allow for extensions which could certainly improve the accuracy and its realistic qualities. For one, the current model has the tornadoes and cars bouncing off the world edges and back into the view, which is unrealistic since tornadoes and cars have the length and width on which to travel. Therefore, implementing an infinite topology would allow for them to travel off-screen and potentially re-enter if need be which would add to the authenticity of the model. Another limitation is that cars can move all over the place in the current model and in any direction it wants to avoid the tornado. Instead, implementing a road system that cars must drive on and seeing how following traffic order would affect car casualties would be another step in improving the model's accuracy. Also, currently the cars only move away from the tornado until it exits out of its 'danger radius'. Instead, once the tornado approaches the first time, the cars should be continuing to try and escape the area until they are no longer in any danger whatsoever. Instead of creating tornadoes at setup at the start of the model run, maybe tornadoes could appear at a random time with the attributes selected at the setup and begin its course later in the model run; perhaps the user could choose where exactly to set the tornado by picking its coordinates to see how starting location affects damage.

Currently, the model is using a car destroyed toll as a proxy for human casualties. I thought the recent events in Oklahoma may make for a sensitive topic to present about at the presentation so I thought I would replace it with a 'car casualty' toll in order to model another emergent behavior phenomena for the sake of the project. However, in the future it would be great to include pedestrians and other people in the model and implement certain safe-zones in the city that people would try and reach in the event of the tornado starting randomly. Seeing how the people would scramble for safety, perhaps choosing the closest possible safe-zone but experiencing overcrowding in certain areas would make for emergent behavior as people would scramble for the next closest safe-zone and could be too late getting to safety. Seeing how this affected the death toll would certainly be an interesting and realistic possibility, especially in large, downtown areas that have many people and could easily experience overcrowding. Lastly, the current model does not try and model real tornado air-flows; instead, it focuses on other aspects of movement and makes some assumptions that have gone into the damage model. Modeling real air-flows and real rotational physics that tornado columns represent would make the model very realistic – though this would be an extremely challenging extension to make. Since there are many different types of tornadoes and movement patterns, implementing the different types of tornadoes, including multiple-vortex tornadoes would be challenging, yet would offer a very realistic view of how objects are swept up into the storm and how they are thrown about.

Conclusions:

The purpose of the model is to see how different attributes of tornadoes affect the damage (in dollars) done to cities, depending on city size, layout, and building densities. It also tries to see how cars try and escape a tornado's path and how they are generally destroyed as a result of these storms, either directly due to the tornado's impact or due to accidents caused by cars crashing into trees, houses, buildings, or other cars in an attempt to escape.

The overall picture shows that cities with high building densities and perhaps larger buildings will undergo a lot more damage in terms of dollars because the probability of the tornado hitting a structure and causing damage is very high in those kinds of areas. However, in sparsely laid out, smaller cities, though the dollar value of damage may be smaller, the need for reconstruction of the entire city will be higher as houses that are not built to withstand vast storms as tornadoes will be extremely high. Depending on the type of tornado, however, damage could be very minimal in both types of areas if the tornado stays in a movement pattern that doesn't affect buildings or houses.

Also, it shows that generally, any accidents caused by drivers trying to outrun tornadoes are generally attributed to faulty driving in a frantic attempt to escape, rather than tornadoes sweeping them off the ground first. In the evidence listed above, it was shown that though the percentage of cars that were destroyed were relatively small since on average tornadoes' movement speeds are not faster than cars, it was still shown that of the destroyed cars, most were due to accidents and not to tornadoes. The overall message from this, as has been stated by sites that will be listed below, that being in a car is the worst possible place to be during a tornado. As the NY Daily News article pointed out, the meteorologist that gave the recommendation for people to flee the tornado in their cars is getting a lot of deserved heat for an 'irresponsible' warning, showing that people should avoid cars during these storms at all costs. People should instead by finding cover in buildings or homes that have sheltered areas. The evidence shown by the model definitely backs those claims.

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Helped with average home prices and property values used in model.