

The Comprehensive Optimal Business Location Model

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Abstract

In order to ensure long run viability, a firm must understand the idea of optimal business location. In the designing of a strategy, it is important to not only evaluate the present market environment but to also account for possible future change. This paper will demonstrate the core ideas behind a comprehensive location model that will predict the optimal location for a business. The effectiveness of the model will be evaluated by using past data from Durham, North Carolina to predict current retail development. The model is determined to be successful by seeing if the trend recognized would be able to correctly identify the present location choices of firms. The model will be further used to predict the future development plans for businesses locating in the Durham area.

The Comprehensive Optimal Business Location Model

Introduction

The essential idea of the store location model is to identify and weight the key characteristics of an area that contribute to a business' success and combine them into a formula that will indicate the optimal place of establishment. The first step in the process is to identify what parameters determine a firm's success. Chi, Kao and Kuo (2010) provide an excellent breakdown of what aspects mattered most to business location in Figure 1. The parameters identified were found by comparing a successful business to the factors of the location that helped contribute to that success. A survey of 138 CVS stores in Taiwan was taken, where variables like profits and patrons per day were used to identify success. These identical firms were then compared and evaluated based on the characteristics of their location. Certain characteristics of the locations were shown to contribute differently to success. These entities were categorized by their type and relativistic impact on a business. The major groups identified were competition, convenience, availability, store characteristics, and population characteristics. Within each of these groups are subgroups that provide an even more precise analysis of a possible location. For instance, convenience is broken down into parking convenience, pedestrian crossing, sidewalk width and road width. The next step in the model requires that each parameter be evaluated for its weighted impact on the location. This calls for assigning each identified parameter a percentage value of importance with regard to the other variables. The exact weighting is determined by comparing the past successes and failures other firms given conditions to evaluate the extent to which each parameter impacted the fate of the firm. So for instance, if 100% of stores sampled were determined to be on average successful, yet 50% of them were near a library, it can be determined that proximity to a library does not significantly contribute to the success of a firm and should hence have a low contribution to the success rate formula. So long as the sample of firms is large and representative of all the variables accounted for, an accurate estimate of the relative success contribution is possible. These values can be found next to the corresponding category in Figure 1. The next step in the process is collecting quantifiable data that can be integrated into a final equation.

Data Collection

Data are collected via two methods: sampling and surveying. The first method relies on observing patterns of already established firms and recording data. Figure 2 provided by Chi, Kao and Kuo (2010) shows a list of the top observations recorded and the method by which the area is evaluated. However, in many cases it is excessive and time consuming to evaluate an area in its entirety, so sampling is used. This method relies on the idea of the law of large numbers and central limit theorem. Rather than obtaining an entire data set, statistical principles allow for values to be estimated with adequate precision given a smaller sample of that data set. This saves the firm the cost of money and time when choosing the optimal location for its business. The components encapsulated in the sample range from measuring road distances between stoplights to the presence of other businesses like a gas station and even the width of the sidewalk. All of these observations are evaluated and converted into a score ranging from 0 to 10. This allows the firm to quantitatively analyze the data. For instance, storefront visibility is a huge factor in a business' success. As such, specific road configurations as well as traffic volumes are categorized into quantitatively measurable scores. A chart showing the values for common configurations and traffic flow can be found in Figure 3. By identifying which locations are optimal with respect to roads and traffic, the firm can quantitatively analyze the probability of success from locating at that specific point. By repeating this process with the other parameters, the firm will have a way of mathematically determining the optimal location. Rather than incurring the cost of taking new data, Google Maps, Bing Maps, GIS software were used in this analysis. The majority of the physical measurements were taken by using tools provided by Google and GIS software in combination with an array of maps over various periods of time. Although this is a comprehensive analysis of the surrounding characteristics of a location, it does not evaluate the attitudes of the consumer.

The second aspect of collecting data is to take surveys of individuals who would become the primary customers if indeed the firm would locate in a particular location. This is essential because location alone is not able to perfectly predict the success of a firm. The idea behind a survey is to gauge the characteristics of the populous that would impact their consumerism. This

model uses data from the survey of 138 CVS stores in by Chi, Kao, and Kuo. We can assume that the people of Durham exhibit consumeristic traits similar to those of the average person. For that reason, surveys previously taken in these other cities, like Taiwan, can be applied to Durham. Much like the parameters above, characteristics like population density and income levels are assigned weighted values. Although the survey takes data across large areas where this particular model will be focusing on a single selected area. This means the model must consider a customer's distance threshold when commuting to the business apart from the other variables. For this particular variable, the survey showed that the maximum distance the consumer is willing to travel was negatively proportional to the square of the distance. This is a very important principle, especially in context of competition, where a similar service can often be found at a closer location to the consumer. Much like the data taken by sampling, the remainder of the survey data is converted into quantitative values that can be mathematically manipulated to create a model.

The Model

With all of the information collected, a model can be made. Rather than attempting to create a single function in terms of numerous variables, this paper takes the approach of using meshplots, or three dimensional surface plots. This is done by assigning coordinates in a matrix to longitude and latitude values that create a grid covering a targeted area. In our case the selected region is the Brightleaf Square area in Durham, North Carolina. This location was chosen because of the large amounts of maps and data available as well as the significant amount of development that has occurred in the last 50 years. Each of the parameters and values above is different for each point in this grid of locations. Much like the matrix of locations, a matrix is constructed for each value that is superimposed onto the original matrix map. Some of these layers will simply be observations taken from the sample, which then get converted into numerical values. Other layers, like that for commuting distance, will call for calculations of values given distances from every possible point of location. All of these layers will be properly weighted and added together, incorporating all of their individual contributions to create a single surface plot. As these layers of variables are added to the map, some areas of longitudes and

latitudes will begin to produce peaks and troughs. The peaks will represent the coordinates on a map where businesses are most likely to succeed and the troughs where they are least likely. Once this process is completed, the maximum values of each peak should identify the optimal location for a given firm. An example of such a matrix would be

$$M_1 = \begin{bmatrix} 0 & 1 & 0 \\ 3 & 6 & 2 \\ 4 & 8 & 5 \end{bmatrix} * .1648$$

where M_1 represents a matrix of data that might rank parking availability. Nine points in the chosen area are evaluated, with each number representing a location on a map as well as the data taken at that location. In this case the cell (3,2) has the maximum parking availability, with a value of 8 out of 10. The entire matrix is multiplied by a scaling factor that alters the value to match their proportional importance. These are the factors described above that are calculated by comparing the success rates of various businesses with specific parameters to see if there is any correlation. For parking, each additional point on the 0 to 10 scale contributed a relative .1648 points when compared to other parameters. The cell (3,2) then translates on a map the coordinates (longitude, latitude) of the optimal location. When applied on a greater scale, a data set of matrices is represented by:

$$\{M_1, M_2, \dots M_n\}$$

and the weighted parameters are the set such:

$$\{x_1, x_2, \dots x_n\}$$

where final cumulative matrix, Z , used to make a surface plot would be:

$$Z = \sum_{i=1}^n M_i x_i$$

The final absolute optimal business location is determined by taking the maximum of the final matrix Z . Other, local maxima, may exist, so the use of 3D surface plots allows the user to represent the solution as a surface that can be directly super imposed onto the area in question. The actual calculations and data are shown in the Matlab script, which is provided at the end of

this paper. Although, this identified location will only apply to a generic business. Additional factors must be considered when dealing with particular businesses, which are addressed once the model is fully established.

To ensure the functionality of the optimal location finder, the program was run from data collected off a map of Durham in 1925 (Figure 4) to see which sites back then would have been considered best. This result can be compared to the actual presence of established businesses in these sites to determine the level of functionality of the optimal location finder. The peaks in the meshplot in Figure 6 indicate that that optimal locations for businesses in 1925 were in the areas 1, 2, 3, and 4 as shown in Figure 5. The 2010 map of the same region shows that the areas identified as high business survival rate areas then are already well populated by a variety of firms. This indicates that the optimal locations identified from a map from 1925 successfully predicted the same places real firms chose to locate. Assuming these firms made marginal decisions when choosing a location such that the best spot was chosen, the areas identified must have indeed been the optimal locations. The key differences between area 1 and areas 2-4 are the size of the captured area and the cumulative value assigned to that region. The reason for this discrepancy can be explained by the cost incurred by the consumer when seeking a firms' business. This may be partially explainable by the demographic change that occurred between 1925 and 2010. There was a large movement towards racial integration, particularly in this area. The average consumer did not drive and as such the cost of business due to location was much greater. This could possibly indicate why area 1, the point of minimum cost to the consumer, became the largest center of business growth.

The cost to the consumer increases as the square of the distance traveled to do business. This means it is in a firm's best interest to locate at a point where it minimizes the cost to its consumers, thus increasing the amount of business the firm sees. The optimal point can be found by graphing the sum of the cost to all considered consumers at every point and finding the minimum of the graph produced. This is possible even when residential areas have yet to exist. The model regards undeveloped areas as residential space, although with low population density. By identifying those areas as residential, the cost to consumer is minimized while considering future consumer locations. This allows for the model to be applied to a wider range of situations. Figure 8 shows the graph of consumer cost when considering locations at every

point possible. Figure 9 is a color surface of that graph rotated to look straight down on the graph. The darkest blue areas are those in which the least cost is incurred on part of the individual to do business with a firm at that point. Notice how the darkest of the blue concentrates on the region bounded by area 1. This explains for the increased density of firms in this area compared to others. The combination of these methods allows for the prediction of both the optimal firm location and major center for commerce for almost 100 years in advance. Now that the method has been proved accurate in this case, the next step is to use the data and model to determine the future locations firms will chose.

Application and Analysis

Those places that are optimal for current development can be identified by those areas on the graph in Figure 4 that produce peaks but are not necessarily maximums. The places of interest are those locations where development is present but scarce. Such locations are areas 2, 3, and 4. This is because regions like area 1 are already well developed and are limited as to the number of new opportunities that can be found in the same location. This poses the question as to how to identify an area that is already experiencing diminishing returns with respect to future development. The solution is found by comparing those areas that are experiencing diminishing returns to the meshplot surface and identifying those characteristics that distinguish that area from another.

The solution is to find peaks where the first partial derivatives with respect to x and y of the surface found in Figure 6 are between 0 and -1. This means that the slope of the surface at these points is relatively flat, but still decreasing. Such areas are represented by orange squares near a peak, rather than sudden transitions from red to blue. Those areas where the first partial derivatives are greater than 1 or less than -1 tend to quickly transition into residential areas, halting further business expansion. Mathematically, the same criteria are such that the second partial derivatives are less than -1. Where this occurs, it can be seen as a limit or boundary where no new development will readily occur in the future. There is a greater possibility for development when the area in question transitions from commercial to residential at a slower rate. This indicates that the area has not reached a level of saturation where business

development is hindered. This concept can be graphically represented by using a vector field. Figure 10 shows a plot of the partial derivatives of the meshplot. The arrows point away from the peaks, with their lengths correlating to their respective values. The larger arrows indicate a steeper slope of the surface. Those regions bounded by arrows with values between 1 and -1 mark the future places for business development. In terms of the analyzed area, it is reasonable to hypothesize that areas 2, 3 and 4 will be key development areas in the next 50-75 years. Notice how in Figure 6 these places correlate to peaks in the graph where the first partial derivatives are between 1 and -1 and the second partial derivatives are between 0 and -1. This theory is testable by comparing these areas identified by the 1925 map to a current map of the same area.

As expected, those areas that met the correct criteria outlined above experienced the greatest amount of retain growth. The lots in areas 2, 3, and 4 that were empty in 1925 are currently filled or under development. As for area 1, Maps of Durham from 1925-2009 show that the stretch of businesses along Main Street were established much sooner than the other areas. As such, this sector was already saturated with respect to the number of firms that could possibly locate in this zone without flooding over into residential areas. Rather than experiencing new development, it was common to see the same stores change hands or get renovated.

Conclusion for the Generic Firm

All of these principles can be synthesized to create the final model that can predict where future generic retail locations will develop. Instead of collecting new, more current data, the same graphs can be used to further hypothesize the future locations of firms. For the reasons outline above, the places in which development is be expected to occur is in areas 2, 3 and 4. Of these places, that with greatest opportunity is area 4. This is determined simply by evaluating which area best fit the previously established criteria.

Using Durham as an example, this comprehensive model has proved its robustness in determining the location choices of future firms. In the generic situation, the three primary indicators to a high rate of success for a firm's given location were determined to be:

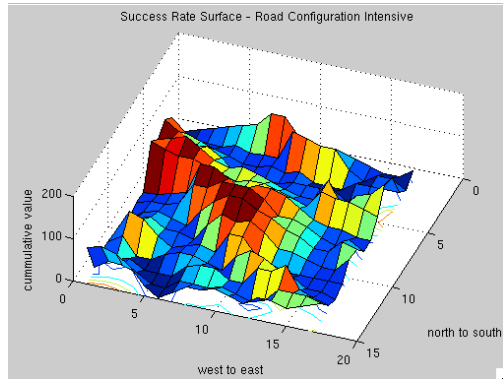
1. The given area must have a peak when looking at the meshplot of the sum of evaluative matrixes.
2. Given a highly competitive situation, a firm must understand that primary places of commerce will form where the cost to the consumer to business is at a minimum.
3. The first partial derivatives in the x and y direction must be between 1 and -1 and the second partial derivatives between 0 and -1.

These three parameters are the key to ensuring long run viability of a firm. Using Durham, North Carolina as the example, the model proved to effectively determine the “hotspots” for businesses. Although, this solution only applies to the generic firm.

Firm-Specific Malleability

The optimal location is vastly different when firm-specific factors are taken into consideration. No two firms are identical, and will hence give different weights to the most important factors of the model. For instance, a gas station will chose a location that best reduces consumer cost even if the area is already over-developed. A restaurant on the other hand will most likely chose to locate in an area already populated with other businesses, and even other restaurants alike, just because of the greater consumer exposure. These anomalies make creating the perfect optimal business location model rather difficult. Although, trends in location choices of specific types of firms can be used to help fine-tune the model. By altering the weights of the parameters, the model can be accommodated to suit the needs of a particular firm. Specific types of firms are grouped by the attributes to which they weight greater than the general firm:

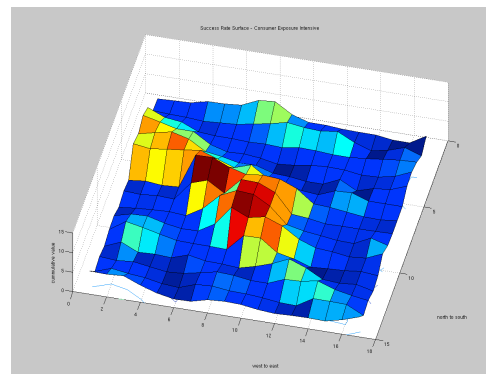
1. Road configuration intensive: This type of firm gets great benefit from exposure to traffic and storefront view to the road. Common examples are a gas station or fast-food restaurant. These types of firms are better off locating where there is the greatest storefront exposure, which is directly related to the road configuration. In this case, the convenience, availability and store characteristics weights were adjusted to produce the adjusted graph to the left. Particularly, the weights for these categories were increased to



reflect their greater importance. For instance, the convenience weight was raised from .1783 to .5349, making the impact of this attribute three times greater than before. Compared to the generic situation, the dark red peaks have become much more pronounced. This is because these areas better suit the firm's specific criteria. Note how this area, which almost appears as a straight line, follows directly along Main Street. What

this indicates is that the optimal location in this situation will be right at beginning of Main Street as it enters Bright Leaf Square. Interestingly, the firms located in this area are a gas station, two fast pizza vendors, two clubs and a bar. All of these firms are indicative of road configuration intensive firms.

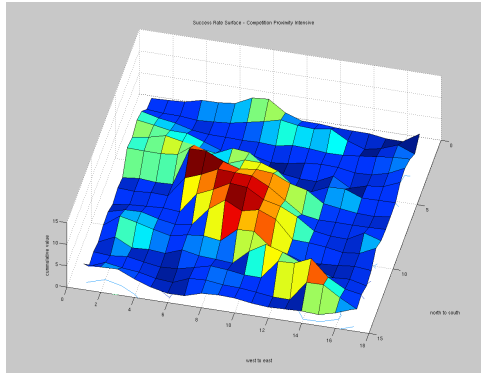
2. Consumer exposure intensive: This category of firm gives greater importance to the convenience matrix, with the addition of augmenting the importance of minimizing the cost to the consumer. Much like the situation above, the convenience weighting is increased from .1783 to .8915. An example of such firms



would be a club or restaurant. The adjusted graph can be seen to the right. The first observation is that the rough peaks surrounding the main, center peak have all been flattened. Other than the primary stretch along Main Street, no other locations indicate a greater probability of success. The only peak is in the same location as identified by the consumer cost minimization surface. This makes sense since as the location moves away from this center area, the firm would be farther away from its average customer. This is not optimal, since this type of firm relies on consumer exposure for the bulk of its business. This is an excellent example showing how it is vital that a firm is able to recognize which factors are most important to its success. This type of a firm is goes directly against the general trend. Those areas that were previously identified as places for future development exhibit no indications of growth for this type of firm. Had the firm

been unaware of this concept, it would not be able to correctly identify its optimal location.

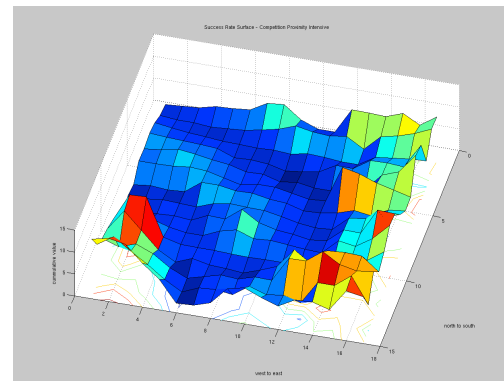
3. Competition proximity intensive: This type of firm actually benefits from the presence of competing firms due to their joint ability to attract more customers as a whole. The primary example of such a firm is a restaurant. When grouped together, the area is more



likely to draw customers. This is directly related to the consuming characteristics of the individual. The model is adjusted to this type of firm by changing the weighted parameters for competition and convenience. Both values were increased by a factor of three. Notice how for this type of firm, the adjusted graph is heavily centered on the Brightleaf Square area. The primary type

of businesses in this region are restaurants, just as the model predicted. The surprising aspect of this success surface is how the competition of other firms actually attributed to the success of neighboring business. The areas 2, 3 and 4 that were identified as future places of growth for the generic firm are almost nonexistent. This can be explained by the lack of presence of other restaurants in these areas. Rather than attempting to succeed in isolation, it is best for a new restaurant to locate near other competitors. This can be interpreted as increasing exposure to consumers who are already looking to purchase a meal. This way the business is most likely to be closest to the largest group of people looking to do business with that particular type of firm.

4. Appreciating isolation: This type of firm has minimal criteria for a location and only makes its choice with the hope that at some point the land will appreciate. Its location choice is solely based on cost minimization, rather than focusing on optimizing consumer interaction. Such a type of firm is a small factory, distribution center, or even mechanic. These types of businesses ultimately disregard factors like



convenience, store characteristics and availability. Rather, the main decision factor is competition. As such, the weighting is altered to nearly only account for competition. This parameter is increased in importance, while the others like convenience, availability and store front are decreased in weight. Unlike the restaurant example where firms prosper when congregated, this type of business is best of scattering across more rural areas. The adjusted success surface depicts just this. The main stretch along Main Street is nearly worthless to this particular firm. Rather, areas 3 and 4 as well as the entire eastern edge produce peaks, indicating the greatest probability of success. This is because these areas have developed roadways, but are scarce with respect to the number of business. This is nearly the perfect situation for a firm that chooses its location primarily based on competition. These observations cannot be compared to the actual presence of firms in these areas because they have yet to develop. Although, based on the cleared areas and construction equipment present today, it is reasonable to assume that such types of firms will be established in this area in the next ten years or so.

Conclusion

Optimal business location plays a crucial role in the establishment of a firm. A given business is bound to fail without an understanding of how the characteristics of a particular location impact a firm's success. Although there is no perfect solution that can be applied in all scenarios, there are a myriad of parameters that can be tailored to meet the needs of nearly any firm. This model allows a business to not only evaluate the present market environment but to also account for possible future change in an area. The city of Durham, North Carolina provided the example that demonstrated the power of understanding the optimal location model. This power extends beyond that of predicting sites for future successful business development, providing insight to other areas of business.

In economics, it is nearly always true that in the presence of asymmetric information there is an opportunity to profit. The asymmetry in this situation is that the model provides an empirical method to evaluating a successful area for business growth. By knowing this before it occurs, it allows the individual to capitalize through means of investment in land or

development of an area. Indeed this can be seen as a risk, since there is no guarantee that a given area will appreciate. Although, compared to the average investor, the user of this model will have a significant advantage when choosing the area in which to invest. This helps answer many questions, such as to where the next big retail area will develop.

Further applications of this model call for collecting data over large-scale areas in an attempt to predict the future development plans for businesses. For Durham, North Carolina, this would mean examining areas such as the Fayetteville corridor from highway 147 to Southpoint shopping center. The key to such an analysis would be to predict where exactly firms will most likely locate as well as what types of firms will most likely chose this location. The difficulty in this analysis is that each particular firm will chose its location with differently weighted parameters. In order to identify what kinds of firms will locate in this area, the model would have to be applied for every type of firm, similar to the outline above. Another important area of interest is the stretch from NC Central to NC-54. A model of this area would provide insight as to whether or not the dream of a continuous stream of commerce is reasonable. That said, there is one remaining problem.

This model is a passive indicator of relative probabilities of success. It is not an active predictor that can dictate a firm's location choices. The model relies on using past data to determine correlations between variables to then draw a conclusion regarding the statistically optimal location. By no means does this guarantee that the location identified is *the* optimal choice. Rather, it is the optimal location given the choices of other preceding firms. What this means is that there will always be anomalies that will force the model to adjust. For instance, an independent McDonald's establishment will rarely choose to locate in an already developed area. This is because a primary source of income to many of these fast-food chains is the lease of surrounding land to other developers, rather than the sale of food. Other firms know that McDonald's greatly attracts consumers and will chose to locate near these establishments, despite having to pay rent to the fast-food chain. This deviates from the major trends identified in the model. This means it could not accurately predict the location choices of firms like McDonald's with as great of confidence as other firms. These anomalies are indicative of many big-name businesses. Regardless, the model still proves a vital tool for smaller firms, developers and those wishing to attain an accurate prediction of how future successful businesses will locate.

Figures

Evaluation factors and their corresponding weights

Dimension	Weight	Evaluation factor	Weight	Evaluation factor	Weight
Competition	0.1922	Competitor's competition	0.4065	CVS	0.3506
		Competitor's store numbers	0.3455	Hyper market	0.3414
		Competitor's store area	0.2480	Supermarket	0.3080
Magnet	0.18	Crowd point	0.3544	Hospital	0.2882
				Market	0.2151
				Hotel	0.2139
				Restaurant	0.2005
				Temple	0.0785
		Culture and education organization	0.2086	School	0.4672
				Studying center	0.4161
				Library	0.1167
				Recreation center	0.2595
		Relaxation	0.2010	Department store	0.2390
				KTV, club	0.2348
				Cinema	0.1741
				Park	0.0927
		Government & business organization	0.1609	Financial organization	0.4133
				Office building	0.3166
				Government office	0.2701
Convenience	0.1783	Vehicle maintenance	0.0751	Gas station	0.4394
				Parking area	0.3149
				Garage	0.2456
Availability	0.1648	Parking convenience	0.3172		
		Pedestrian crossing	0.2798		
		Sidewalk width	0.2713		
		Road width	0.1317		
Store characteristics	0.1556	Crowd	0.4131		
		Stations	0.2497		
		Bus stop	0.2255		
		Car flow	0.1117		
Population characteristics	0.1291	Obvious	0.7057	Located near road intersection?	0.5283
				Store visibility	0.4717
		Store front	0.2943	Store front area	0.3427
				Store front width	0.3382
				Front door width	0.3191
Population characteristics	0.1291	Community size	0.3517		
		Income/consumption	0.3493	Consumption level	0.5335
		Population density	0.2990	Income level	0.4665
				Population growth rate	0.3694
				Population density	0.3167
				Population	0.3138

Figure 1: key parameters and weight values (Chi, Kao and Kuo)

Evaluation factor	Definition	Data collecting method
The number of visiting customers	Average daily number of visiting customers	Actual investigation
Government organization	# in the business circle	Actual investigation
Post office & financial organization	# in the business circle	Actual investigation
School	# in the business circle	Actual investigation
Studying center	# in the business circle	Actual investigation
Library	# in the business circle	Actual investigation
Hotel	# in the business circle	Actual investigation
Restaurant	# in the business circle	Actual investigation
Temple	# in the business circle	Actual investigation
Market	# in the business circle	Actual investigation
Park	# in the business circle	Actual investigation
Cinema	# in the business circle	Actual investigation
Department store	# in the business circle	Actual investigation
KTV	# in the business circle	Actual investigation
Recreation center	# in the business circle	Actual investigation
Garage	# in the business circle	Actual investigation
Parking lot	# in the business circle	Actual investigation
Gas station	# in the business circle	Actual investigation
Store front width	Size of store front width	Actual investigation
Store front area	Size of store front area	Actual investigation
Front door width	Size of front door width	Actual investigation
Store visibility	Visibility for consumers to see stores	Actual investigation
Located near intersection?	Distance between store and intersection	Actual investigation
CVS	# in the business circle	Actual investigation
Supermarket	# in the business circle	Actual investigation
Hypermarket	# in the business circle	Actual investigation
Competitor's store area	Total of competitor's store area	Actual investigation
Competitor's competition	Total of competitor's competition	Actual investigation
People flow	Total of people & bike pass over	Actual investigation
Car flow	Total of car & motorcycle pass over	Actual investigation
Station	Total of train station & bus station #	Actual investigation
Bus stop	Total of bus stop # in the circle	Actual investigation
Road width	Road width which store is facing	Actual investigation
Sidewalk width	Sidewalk width in front of stores	Actual investigation
Parking convenience	Is it easy to park around store?	Actual investigation
Pedestrian crossing	# of pedestrian crossing in circle	Actual investigation
Population	Population of the neighborhood	City publication
Population density	Population <i>D</i> of the neighborhood	City publication
population growth rate	Average yearly population growth in the latest 5 years	City publication
Income level	Average income level of the neighborhood	City publication
Consumption level	Consumption level of the neighborhood	City publication
The number of resident families	Families # of the neighborhood	City publication

Figure 2: aspects considered when sampling an area (Chi, Kao and Kuo)

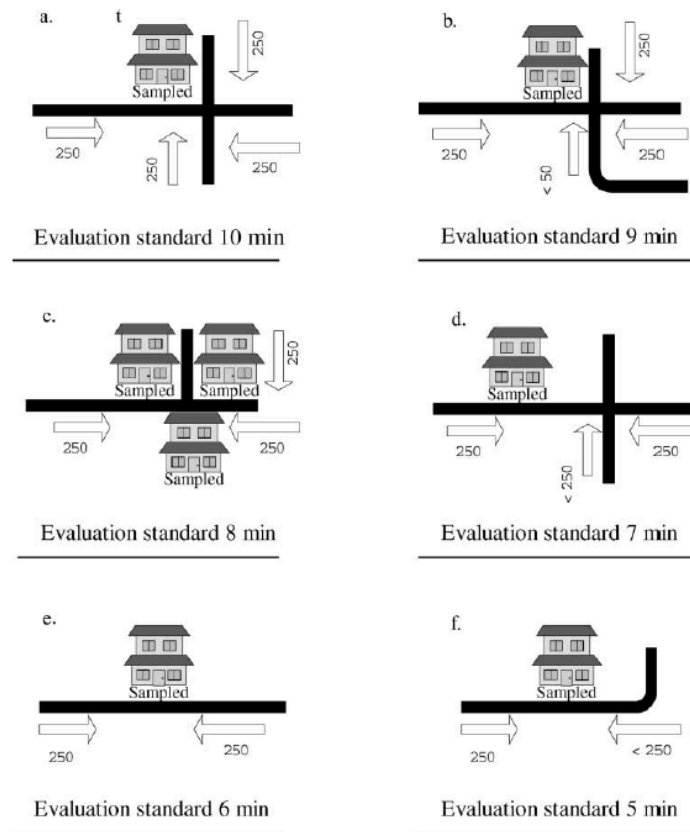


Figure 3: assigning values to specific road configurations and traffic volumes (Chi, Kao and Kuo)



Figure 4: map of Durham from 1925

Provided by Digital Durham

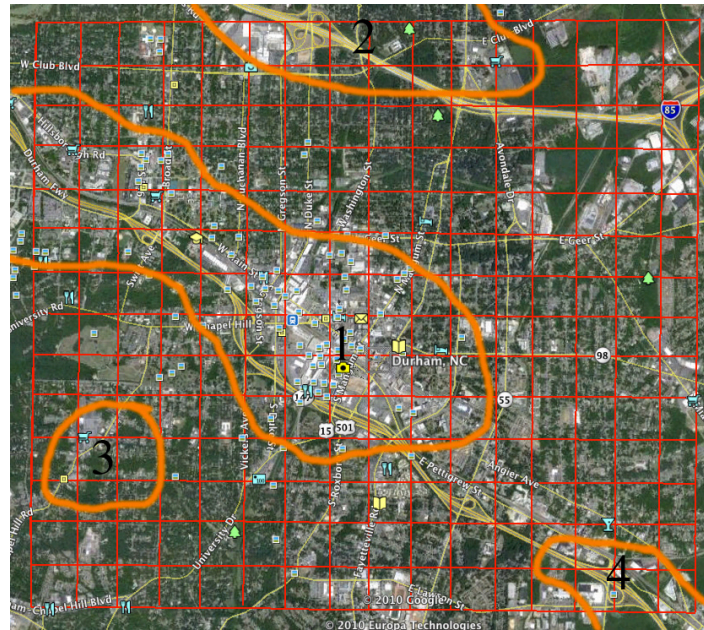


Figure 5: a map of Durham in 2009 with key areas identified (Google Maps)

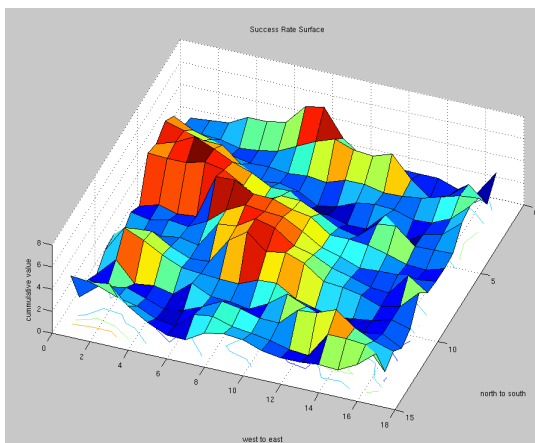


Figure 6: a 3D meshplot of cumulative data

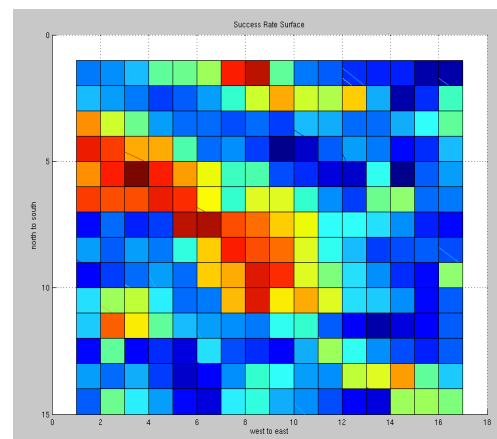


Figure 7: the colorized surface of the meshplot

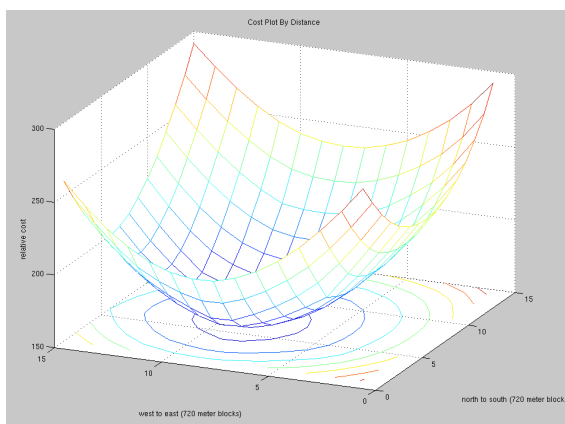


Figure 8: a surface plot of cost to the individual

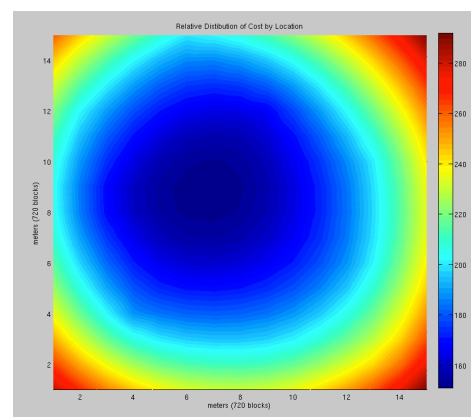


Figure 9: the colorized consumer cost surface

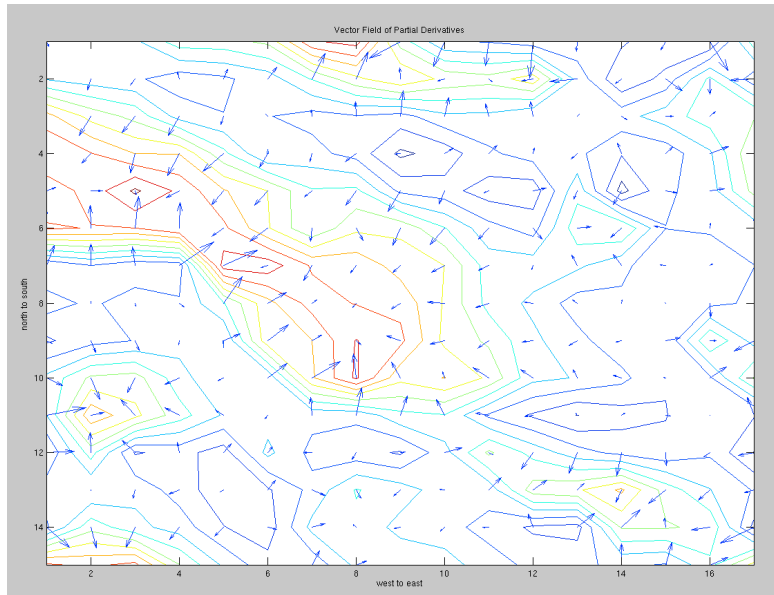


Figure 10: a vector field of derivatives of the meshplot surface

Matlab Code

```
%% Urban Economics - Econ245 :: Optimal Business Location Finder
```

```
%% By Mitchel Gorecki
```

```
clear
```

```
clc
```

```
% make matrix values
```

```
[x y] = meshgrid(1:1:17, 1:1:15);
```

```
competition = [10 9 9 9 8 6 6 7 8 9 7 5 6 10 8 8 9;
                10 10 9 6 7 6 6 8 8 8 5 4 8 8 6 8 8;
                5 6 7 8 9 10 9 9 9 8 7 6 6 7 6 8 9;
                4 5 6 6 4 5 7 8 5 5 6 7 8 9 9 5 5;
                3 4 5 4 4 6 5 7 4 5 5 3 2 5 2 2 2;
                5 4 4 5 5 6 4 5 4 5 5 4 1 2 2 4 2;
                8 9 9 8 7 3 1 1 0 1 3 5 8 8 7 8 9;
                10 9 8 6 5 3 1 0 0 2 4 4 4 6 8 8 9;
                10 10 8 6 6 5 0 0 0 0 2 3 3 4 5 3 2;
                10 9 9 9 8 8 8 5 0 1 2 3 4 5 6 7 3;
                7 3 4 5 6 8 8 6 2 1 1 2 3 4 5 8 8;
                8 7 8 9 6 5 4 2 2 2 2 3 4 4 5 8 7;
                8 9 8 9 8 10 5 5 6 6 5 5 5 6 4 7 8;
                8 7 8 8 8 9 9 6 4 4 5 6 5 5 5 5 6;
                4 3 3 5 7 8 6 4 3 4 5 6 4 4 6 7 5].*.1922;

convenience = [0 1 2 3 4 5 8 8 4 2 3 3 2 1 0 0 2;
               1 0 1 1 2 1 1 1 8 7 6 6 2 0 2 2 0;
               8 5 4 3 2 1 1 2 1 2 0 0 0 2 2 2 2;
               10 8 5 6 4 1 1 1 1 2 2 2 2 0 0 4 8;
               8 9 10 8 6 5 6 5 4 3 2 2 7 2 5 6 9;
               10 9 8 8 7 6 5 6 6 5 4 3 7 6 6 5 4;
               1 1 2 3 10 10 8 6 8 8 7 5 3 2 2 1 1;
               1 2 2 3 8 8 10 10 10 8 5 5 4 2 1 3 1;
               0 2 3 2 1 5 8 10 10 8 7 5 4 2 2 5 4;
               1 3 4 2 2 1 5 8 7 8 6 3 3 2 1 1 4;
               2 7 6 3 1 2 3 2 7 7 3 2 1 1 1 1 1;
               2 4 0 0 2 3 3 2 1 5 7 6 4 3 1 1 0;
               2 1 2 0 0 0 3 4 4 2 2 6 6 8 3 2 1;
               1 3 3 2 0 0 2 2 2 3 2 1 2 5 5 5 4;
               8 9 8 6 2 0 2 4 4 5 4 3 5 5 4 5 6].*.1783;

availability = [0 1 1 4 5 8 10 10 3 1 1 1 1 0 0 0 2;
               2 1 1 2 2 4 5 6 3 2 4 8 2 0 4 5 3;
               8 6 4 2 1 1 1 0 0 1 3 2 2 2 4 4 4;
               10 9 8 7 6 4 2 1 0 0 2 1 0 0 0 3 8;
               10 10 10 10 9 7 5 5 2 1 0 2 5 0 4 6 6;
               8 8 9 9 10 8 7 6 8 5 2 1 8 9 2 3 5;
               1 2 0 0 9 10 10 10 8 6 2 2 3 2 0 1 2;
               1 0 2 2 3 8 10 10 10 8 4 4 3 2 1 1 1;
```

```

0 0 1 2 3 8 10 10 10 8 5 4 5 3 2 8 5;
2 2 1 1 2 3 8 10 9 9 8 5 4 3 1 1 7;
2 7 6 5 4 1 1 3 5 4 3 2 1 1 1 1 0;
0 3 0 0 0 3 2 2 3 3 5 5 4 2 2 1 0;
2 1 0 0 0 0 2 5 4 4 3 7 8 8 8 3 2;
1 3 2 1 2 0 3 4 5 3 2 1 1 5 5 5 0;
8 7 8 5 3 2 2 3 5 2 1 1 2 1 0 5 8].*.1648;
character = [0 0 0 3 3 4 10 10 5 2 1 0 2 0 0 0 7;
0 0 0 2 0 4 8 9 9 8 8 8 4 0 0 4 1;
7 5 3 0 0 0 0 0 0 2 5 5 6 5 7 7 7;
10 9 8 7 5 2 2 1 0 0 2 3 3 2 3 4 5;
8 10 10 9 7 5 2 2 2 1 1 2 4 0 3 2 6;
8 9 10 10 8 4 3 8 7 3 1 2 5 6 3 2 3;
1 0 0 1 8 9 9 9 9 8 3 2 1 1 1 0 0;
3 2 2 1 2 8 10 9 9 6 4 2 1 1 1 0 0;
0 0 1 2 1 8 9 10 10 8 6 3 1 1 0 6 4;
2 8 7 2 1 1 5 9 9 9 8 6 4 2 1 3 7;
2 8 5 4 2 2 1 3 5 8 6 3 2 1 1 1 2;
0 5 1 2 0 4 3 4 4 5 8 3 2 2 1 1 0;
2 2 2 1 0 0 2 5 3 2 4 6 6 6 5 2 1;
1 6 4 3 1 0 2 7 4 3 2 1 1 8 8 7 0;
10 10 10 5 3 2 1 4 5 4 3 1 2 4 3 2 7].*.1556;
population = [5 5 5 3 2 1 1 2 2 0 2 4 1 0 0 0 2;
4 5 4 2 3 1 1 2 1 0 2 3 0 0 0 2 0;
3 4 5 3 2 2 2 3 3 4 2 2 1 0 0 1 1;
2 2 3 4 3 3 4 2 2 3 2 3 2 0 0 1 0;
2 1 5 5 5 4 3 2 2 3 2 1 2 0 0 0 2;
2 3 2 4 4 3 2 1 1 3 4 4 2 1 2 1 2;
0 2 0 0 3 7 6 8 5 5 5 6 3 2 2 1 2;
0 0 2 3 2 2 4 5 4 3 3 2 1 3 3 1 4;
0 0 1 5 4 3 4 8 5 3 4 4 3 3 3 2 2;
3 2 4 5 1 2 3 5 4 4 3 2 3 4 3 2 4;
5 9 8 6 5 3 2 1 1 1 2 3 2 4 4 3 0;
1 3 2 1 2 4 2 4 2 2 3 3 2 3 4 3 1;
2 1 5 3 1 0 4 2 2 2 2 1 1 2 3 4 2;
3 4 1 2 0 0 2 1 2 3 3 2 1 1 1 1 0;
4 4 6 3 2 0 1 4 4 5 3 3 1 1 1 0 2].*.1291;
CumMatrix = [competition+convenience+availability+character+popu
lation];
figure(1)
surfc(y, x, CumMatrix)
title('Success Rate Surface')
xlabel('north to south')
ylabel('west to east')
zlabel('cummulative value')
% remember to include tansit distances
% the only thing that really changed was the residential develop
ment...
```

```

% so we can take that into greater account

clc
clear; format short e
figure(2); clf
DataTable = [1 2.5 13.5 6;
             2 2.5 9.5 3;
             3 4 4 8;
             4 6 12.5 4;
             5 8.5 3 9;
             6 10 13 4;
             7 12 2 3;
             8 12 9 6;
             9 15 6 9];

xd=DataTable(1:end,2);
yd=DataTable(1:end,3);
vol=DataTable(1:end,4);
num = length(xd);
s = size(DataTable,1);
customers=sum(vol);
% plot of customers
figure(2)
text(xd,yd,num2str((1:s)'));
axis([-1 16 -1 16]);
title('Customer Distribution (mdg16)')
xlabel('meters')
ylabel('meters')

% Mesh plot
figure(3); clf
[x,y] = meshgrid(1:15);
Cost=0;
for m=1:s
    dist=sqrt((x-xd(m)).^2+(y-yd(m)).^2);
    cost=.5.*dist.*vol(m);
    Cost=Cost+cost;
end
meshc(x,y,Cost')
xlabel('north to south (720 meter blocks)')
ylabel('west to east (720 meter blocks)')
zlabel('relative cost')
title('Cost Plot By Distance')
min = min(min(Cost));
[a,b] = find(Cost==min);
fprintf('The least cost of distribution occurs at %0.0f blocks o
f 720 meters to the',a)
fprintf(' right of and %0.0f blocks of 720 meters up from the or

```

```

igin \n',b)

figure(4); clf
total=zeros(30);
totaln=zeros(30);
Total=zeros(30);
surfc(x,y,Cost');
shading interp
view(2)
colorbar
axis([1 15 1 15])
title('Relative Distribution of Cost by Location')
xlabel('meters (720 blocks)')
ylabel('meters (720 blocks)')

%% vector field

figure(10)

[px, py] = gradient(CumMatrix', 1, 1);
contour(v2,v1,CumMatrix')

hold on

quiver(v2,v1,px,py)

hold off

title('Vector Field of Partial Derivatives')
xlabel('north to south')
ylabel('west to east')
zlabel('Vector Field of Partial Derivatives')

```

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