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SUITABILITY ANALYSIS OF A NEW HIGH SCHOOL IN THE CITY OF CALABASAS

A thesis submitted in partial fulfilment of the requirements
For the degree of Master of Arts in Geography, GIS Program

By
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DEDICATION

To my younger brother, Massoud,

Gone but not forgotten

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ABSTRACT

SUITABILITY ANALYSIS OF A NEW HIGH SCHOOL IN THE CITY OF CALABASAS

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As the population of the city of Calabasas grows, the demand for a new high school is amplified. The selection of an optimal location for a new campus is a challenging decision for the city, as well as for the school board, given the cost and formidable challenges for both the initial implementation as well as any required future changes.

GIS-based Multi Criteria Decision Analysis (MCDA) is a procedure for transforming and combining data and value judgments (preferences) to evaluate a set of alternatives with respect to project's relevant criteria. This paper forwards a recommendation for a new high school using a variety of methods campus location. The problem is formulated by using a combination of Weighted Linear Combination (WLC), and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). WLC is used to determine the relative importance of criteria. In reaching a final selection with regard to the most suitable area, the scores of alternatives are quantified by means of the TOPSIS method.

1. 0 - INTRODUCTION

In recent years, the increasing population in Los Angeles County has prompted consideration for housing and public sector services. LA County is the most populated county in the nation, with twice as many people as the second most populated county in the nation, Cook County, IL; and almost three times as many as the third-place holder, Harris County, TX. In fact, Los Angeles County's population exceeds that of 44 states.

The City of Calabasas located in western Los Angeles County, has had a remarkable population growth in the last decade. Based on information provided by the U.S. Census Bureau, the population of the city during the last decade has risen at a rate of 15% from 20,033 to 23,058, well in excess of the statewide rate of 10% (Table 1).

Residential and commercial land development also flourished during the 1990s throughout the United States (Riebsame, Gosnell and Theobald 1996). This growth also took place at a higher than normal rate in the city of Calabasas. Between the year 1995 and 2000 Calabasas witnessed the construction of 1452 new residential dwellings. According to city's housing program, the city is required to build an additional 521 residential dwellings during 2006-2014.

A high rate of population growth inherently creates a demand for public sector services including education and health. Based on studies conducted (Bloom, Canning and Chan 2005), education and development of a skilled work force is a strong contributing factor to economic growth. A decline in the quality of education can have significant negative impact on sustained economic growth (Ladd and Rivera-Batiz 2006). Education has been shown to be an integral part of the process of delivering increased rates of economic growth and prosperity (Bredt and Sycz 2007).

The availability of pedagogical space is one of the most basic elements necessary in providing access to education. Class size, one correlate of space availability, is another fundamental requirement of structured teaching and learning. Various research studies have been conducted on the relationships between class size and student performance. Regardless of methodologies used, they have all shown a significant negative correlation between large class sizes and student performance (J.J. Arias and Douglas Walker 2004; Watts and Lynch 1989 and Raimondo, Esposito and Gershenberg 1990).

The high-school-age population (14-18 years old) of the city of Calabasas has risen 29.3% between 2000 & 2010. This rate was almost twice as high as the general population growth of the city during the same period (US Census Bureau 2000 & 2010). Meanwhile, there was also an increase in the number of classrooms with 30 students or more, between 2007 and 2009. However, counseling and support staff, as well as school facilities have remained at the 2000 year levels.

An overcrowded classroom has many negative impacts upon both educators and students. It is not an optimal environment for learning and thus, often creates an adverse impact on education, learning and society. Jane Reed, a Calabasas parent posted the following comment on the school's website:

“As a parent of a student at Calabasas High School, I am very concerned about the education my child won’t be getting from overcrowding classroom size, especially in the science department classrooms” (Calabasas High School Website)

Long-term sustainability is an integral factor that must be given extensive and serious consideration in the planning process. Multiple factors such as size, access, costs, location, and elevation must be taken into consideration. The land suitability analysis based on the various specified criteria is an effective method to utilize (Joerin, et al. 2001). During the last few years, site selection and land suitability has become a less complicated assignment for the planners given the development of Geographic Information System (GIS), and sophisticated computer technology.

This study is intended to improve the quality of site selection for a new high school in the city of Calabasas by integrating the Multi-Criteria Decision Analysis (MCDA) and Geographic Information System (GIS) as a system for management, manipulation, representation and analysis of geo-spatial data to facilitate and cut down costs in the site selection process.

Table 1- Population Growth during 2000-10

City of Area	**2000**	**2005**	**2010**	**Growth Rate (2000-10)**
Calabasas	20,033	21,925	23,058	15%
Los Angeles City	3,694,820	3,744,829	3,792,621	2.64%
Los Angeles County	9,519,330	9,758,886	9,818,605	3.14%
California	33,871,648	35,278,768	37,253,956	9.98%

2.0 – BACKGROUND

2.1 – Study Area

The City of Calabasas, in Los Angeles County, lies in the hills west of the San Fernando Valley, and is the gateway to the Santa Monica Mountains National Recreation Area in Northern Los Angeles County (Figure 1).

The city with an area 13.3 square miles, is centered upon the following coordinates: 34° 8′ 17″ N, 118° 37′ 39″ W (34.138333, -118.660833). The topographic conditions in the city of Calabasas are varied, consisting of differential hillside terrain with numerous valley and arroyo conditions. The highest elevation is approximately 2,800 feet and the lowest elevation is 500 feet (City of Calabasas General Plan 1993).

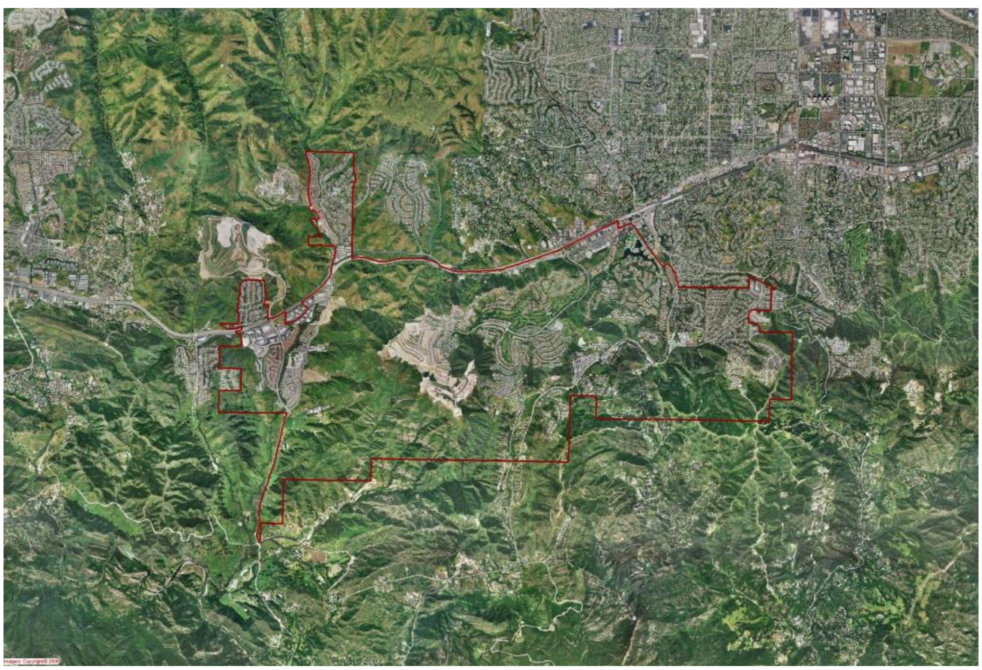

Figure 1- Aerial Photo of City of Calabasas

There has been a rapid growth in the city’s population in the past decade (currently at 23,058 approx.). The median age of the city is 40.5 years, and the percentage of population under 18 years-old is 25.3%. It is also essential to note that the number of households with members under 18 years old, form 40% of the total households of the city (U.S. Census Bureau 2010).

City of Calabasas currently has 6 public schools including three elementary schools, two middle schools and one high school all of which are a part of the Las Virgenes School District (Figure 2). Calabasas High School (CHS) was built on 39 acres of land in the southern section of the city in 1975. It serves Calabasas and portions of West Hills and Hidden Hills. CHS is bounded by residential development to the north and east, Mulholland Highway to the south, and Old Topanga Canyon Road to the west. The school served 2,024 ninth through twelfth grade students during the 2006-07 school year. The overall average class size was 28 students with a pupil-to-teacher ratio of 25:1. The pupil-to-teacher ratios in science and social science were 32:1 and 34:1 respectively. As of the 2008-09 school year, the school had an enrollment of 2,130 students and 77.8 classroom teachers for a student-teacher ratio of 25.6.

The school building is comprised of 171,571 square feet. In addition to six permanent buildings which house classrooms, the campus consists of 12 portable classrooms, a gymnasium, a theater, a cafeteria, a library, athletic fields, three teacher lounges, and three computer labs. A plan was in effect to construct a new ten-classroom building in the 2007-08 school year, to replace the older modular facilities on campus. However, this project was never implemented. Instead, in March 2010, the Calabasas High School Performing Arts Education Center was proposed by the Las Virgenes Unified School District located on the campus of the existing Calabasas

High School. This project started on June 17 2010, and was completed in October 2012.

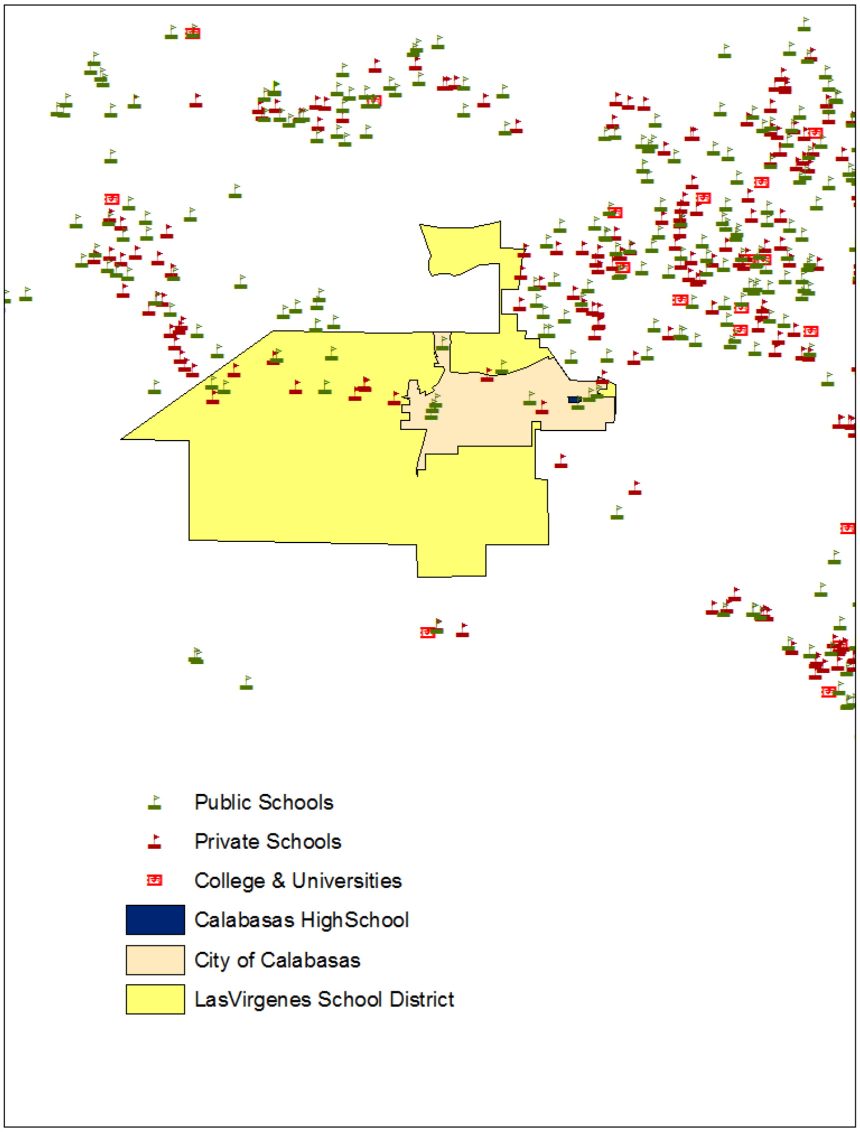

Figure 2- Las Virgenes School District

On the other hand, the current number of students in the city's elementary schools have increased; therefore we can expect a higher number of students heading to the city's high school. Based on CHS's current capacity, it will not be able to accommodate these numbers. A reduction in state funding to schools, has also resulted in a decrease in the number of teachers and support staff (LAUSD, Calabasas High School, 2012-13).

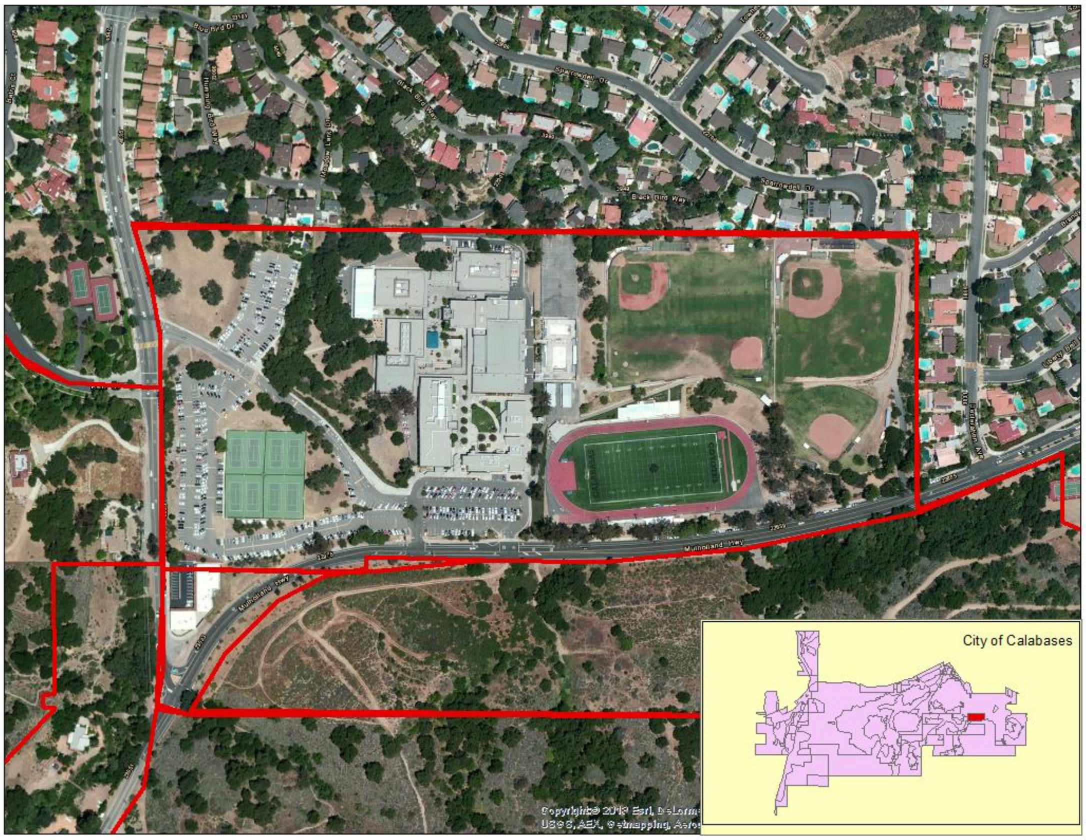

Figure 3-Aerial Photo of Calabasas High School

2.2 – Objective and Research Question

The combination of the outlined factors contributing to the projected number of students who will be attending CHS in the coming years, together with the fact that the size of the CHS facility has remained unchanged while the faculty and support staff has decreased, necessitates a study and planning of a new site to service the growing high school age population and provide the optimal class size which has been shown to provide a better learning environment (Arias and Walker 2004).

The purpose of this study is to confirm the necessity of a new high school in the city of Calabasas and to devise an effective method for the selection of the ideal site, noting the importance of sound decision making in the early stages and the possible impact that it may have on the subsequent developmental process.

The primary research question for this study is: where is the best location for a new high school? The framework of land use suitability analysis is built upon the concept of multicriteria evaluation. Multicriteria decision analysis (MCDA) techniques involve the evaluation of several criteria or attributes to meet a specific objective (Eastman et al. 1995, and Jankowski 1995). There is a voluminous body of literature providing an overview of the evaluation criteria for public and private facility location problems (Malczewski and Ograyczak 1995; 1996). Several studies worldwide, have used multicriteria analysis to determine site selection. In Canada MCDA technique and GIS were used to identify suitable land for housing (Boroushaki, and Malczewski 2008). In South Africa, a study was done using multicriteria analysis to evaluate areas for development based on four specific land use categories, each with its own set of criteria (der Merwe, and Hendrik 1997). Valchopoulou, Sielleos, and Manthou (2001) overviewed evaluation criteria for warehouse site selection decision. Vahidnia, Alesheikh, and Alimohammadi (2009) discussed the evolution criteria suitable for hospital site selection.

In order to answer the research question, an analysis of the requirements affecting school site selection was performed. Guidelines used by other researchers to find a reliable list of criteria for the said site selection were incorporated into the preliminary analysis. The criteria used in this study were selected based on their relevance to the study area. Six criteria were identified for this purpose, which in order of importance are:

1. distance from existing high school;
2. population under 18 years-old;
3. land use;
4. proximity to major roads;
5. slope;
6. proximity to restaurants.

California Department of Education states school sites should not be located in an industrial zone. Given that there is no industrial zone in the city of Calabasas, distance from industrial and risk/hazard analysis is not included in this analysis

1): Proximity to the existing high school

Proximity to the existing high school is the most important criterion in site selection for the new high school. In accordance with rational resource allocation, the new high school location should be at a suitable distance from the existing high school. Since the current high school covers the eastern part of the city, it is only logical that the new campus should serve the western part.

2): Population under 18 years- old

Schools should be conveniently located for the student populations they serve; therefore the population distribution is an important criteria. Since it is essential that the new campus serve a specific target demographic, it should be closer to the residential areas with a higher population under 18 years-old.

3): Land Use

It is very important to identify how to coordinate the site selection for the new high school with the city land use planning. Current and projected zoning and land use should be compatible with the use of the site for a school. Land parcels should be available at an affordable cost. The most favorable situation is one in which the intended parcel is public land and is made available at no cost to the district or donated by a private entity.

4): Proximity to major roads

Another important factor in site selection is access to roads. The *California Code of Regulations*, *Title 5*, Section 14010(e), states: "The site shall not be adjacent to a road or freeway that any site-related traffic and sound level studies have determined will have safety problems or sound levels which adversely affect the educational program." However, we should not overlook the fact that the school should be located in an area that would minimize the commute time to the school for parents and students. Thus, access to a road of sufficient capacity is important. The

California Department of Education has not established legal limits for highway setbacks near schools, however, experience and practice indicate that a distance of at least 2,500 feet is advisable when explosives are transported by the nearby road, and at least 1,500 feet when gasoline, diesel, propane, chlorine, oxygen, pesticides, or other combustible or poisonous gases are transported on the road.

5): Slope

The overall slope of a site should be flat enough to allow for ease of construction, and yet be steep enough for proper site drainage. A flat terrain is the easiest and least expensive to build on. On the contrary, a rolling or sloping terrain is more difficult and more expensive for construction. By using the natural slope of the ground, the drainage and sewage disposal systems can be designed to result in lower construction and maintenance cost. As a rule, slopes of 0-10% are desirable and easy to build on (Albuquerque Public Schools, 2014).

6): Proximity to Restaurants*

Students prefer to have access to fast food or coffee shops within a short walking distance from their school. In this study, databases of restaurants near the city of Calabasas were geocoded to examine their locational patterns.

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*: Restaurants include: full-service restaurants, fast food restaurants, and coffee shops

3.0 – LITERATURE REVIEW

3.1 – GIS-based Multicriteria Decision Analysis

Multicriteria decision analysis (MCDA) is a group of techniques for structuring and evaluating decision alternatives based on multiple attributes and objectives (Voogd, 1983). MCDA approaches have capability to integrate numerous notions of decision problems. They enhance communication and expedite the process reaching concurrence and determining the most suitable options (Boroushaki and Malczewski, 2010).

Geographic information systems (GIS) furnishes various potent tools for the decision-makers to capture, manipulate, analyze, and manage spatial information. GIS are applied to determine suitable areas for land development. Two decades ago, the functionality of GIS was essentially limited to utilizing (overlaying) existing digital map data to define areas which may concurrently meet the requirements of the determined criteria. Overlays are an adequately suitable tool when dealing with suitably defined siting criteria but may pose limitations when dealing with information that is not deterministic (Craver, 1991).

The integration of multicriteria decision analysis techniques with GIS is a procedure which transforms and combines geographical data and value judgments (the decision-maker's preferences) to evaluate a set of alternatives with respect to relevant criteria (Malczewski, 1999). This method combines all important spatial criteria, and illustrates the most suitable location for a certain land use on a map.

It has been argued that GIS-based multicriteria decision analysis can potentially increase collaboration among stakeholders in the decision-making process by providing flexibility that may be used for analysis, comprehension and re-evaluation of a decision problem (Boroushaki and Malczewski, 2010).

3.2 - Pairwise Comparison Method

The pairwise comparison method established by Satty (1980) for determining factor weights in the Analytic Hierarchy Process (AHP). This method involves pairwise comparison to create a ratio matrix. It takes the pairwise comparisons as an input and produces the relative weights as output. The weights are determined by normalizing the eigenvector correlated with the maximum eigenvalue of the reciprocal ratio matrix (Malczewski 1999).

The pairwise comparison method involves the three following steps:

1): Development of a pairwise comparison matrix

The method uses a scale with values range from 1-9 to rate the relative preferences for two criteria (Table 2).

Table 2- Scale for Pairwise Comparison

Intensity of Importance	Definition
1	Equal importance
2	Equal to moderate
3	Moderate to importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to extremely strong importance
9	Extreme importance

Source: Saaty (1980)

2): Computation of the criterion weights

The computation of weights involves three operations, first sum the values in each column of the matrix, then each element in the matrix should be divided by its column total (the resulting matrix is referred to as the normalized pairwise comparison matrix). Afterwards, computation of the average of the elements in each row of the normalized matrix should be made which includes dividing the sum of normalized scores for each row by the number of criteria. These averages provide an estimate of the relative weights of the criteria being compared.

3): Estimation of the consistency ratio

Estimating the consistency ration helps determine if the comparisons are consistent or not. The process uses a several step process. First, determine the weighted sum vector by multiplying the weight for the first criterion times the first column of the original pairwise comparison matrix, then multiply the second weight times the second column, the third criterion times the third column of the original matrix, finally, sum these values over the rows. Second, determine the consistency vector by dividing the weighted sum vector by the criterion weights determined previously. Third, compute lambda ($\boldsymbol{\lambda}$) which is the average value of the consistency vector and Consistency Index (CI) which provides a measure of departure from consistency and has the formula below:

$$CI = (\boldsymbol{\lambda} - n) / (n-1)$$

Finally, calculation of the consistency ratio (CR) which is defined as follows:

$$CR = CI / RI$$

Where RI is the random index and depends on the number of elements being compared (Table 3). If CR<0.10, the ratio indicates a reasonable level of consistency in the pairwise comparison, however, if CR $\geq$ 0.10, the values of the ratio indicates inconsistent judgment.

The need to consider only two criteria at a time and the ability to present in a spreadsheet format is considered to be a great advantage of this method (Kirkwood, 1997). Another utility is the ease of which it can be incorporated into a GIS-based decision making procedure (Eastman et al. 1993).

Table 3- Random Inconsistency Indices (RI) for n=1,2,………, 15

n	RI	n	RI	n	RI
1	0.00	6	1.24	11	1.51
2	0.00	7	1.32	12	1.48
3	0.58	8	1.41	13	1.56
4	0.90	9	1.45	14	1.57
5	1.12	10	1.49	15	1.59

Source: Saaty (1980)

3.3 – Decision Rules

A decision rule is a procedure that provides ordering for alternatives (Starr and Zeleny 1977). Decision rules determine how best to order alternatives or to rank alternatives based on desirability. It integrates the data and information on alternatives and decision maker's preferences into an overall assessment of the alternatives. Specifically, the decision rule orders the decision space by means of a one-to-one or a one-to-many relationship of outcomes to decision alternatives. This means that a given course of action (alternative) has a corresponding certain consequence (one-to-one relationship) or uncertain consequences (one-to-many relationship). A multicriteria decision problem requires ordering the set of outcomes to determine the decision alternatives yielding these outcomes (Malczewski 1999).

3.3.1 – Weighted Linear Combination

The weighted linear combination (WLC) approach is the most commonly used GIS-based decision rules technique (Hopkins 1977, Tomlin 1990, Eastman et al 1993, Heywood et al 1995, Malczewski 1999). One of its most common applications is to solve land use/ suitability analysis, site selection, and resource evaluation problems (Hobbs 1980, Han and Kim 1988, Eastman et al 1995, Herzfeld and Merriam 1995, Lowry et al 1995).

WLC, otherwise known as weighing, is based on the concept of a weighted average in which continuous criteria are standardized to a common numeric range, and then combined using a weighted average. The decision maker determines and assigns the weights of relative importance directly to each attribute map layer. The total score for each alternative is the product of the importance weight assigned to each attribute multiplied by the scaled value given for that attribute to the alternative and then summing the products over all attributes. The scores are calculated for all of the alternatives. The one chosen is that with the highest overall score. The method can be executed using any GIS system with overlay capabilities. The use of the method allows the evaluation criterion map layers to be combined in order to determine the resulting composite map layer. Both raster and vector GIS environments can be used to implement this technique.

With the weighted linear combination, factors are combined by first applying a weight to each factor, followed by a summation of the results to yield a suitability map:

$$S = \sum w_i \, x_i$$

Where S is suitability, w_i is weight of factor i, and x_i is the criterion score of factor i.

This method is highly popular mainly due to the ease associated with its implementation within the GIS environment using map algebra operations and cartographic modeling (Tomlin 1990). The method is intuitive, simple to comprehend and thus appealing to decision makers (Hwang and Yoon 1981, Massam 1988). However, GIS implementation to WLC is often used without a thorough awareness of the assumptions underlying the method. In addition, it is occasionally utilized without full understanding of the meaning of two elements of WLC, i.e., the weights assigned to attribute maps and the procedures for deriving commensurate attribute maps

(Malczewski 2000). In many case studies the WLC model has been applied inaccurately and with unreliable results because the analysts (decision makers) either disregarded or lacked a full understanding of these elements. Hobbs (1980), Lai and Hopkins (1989), Heywood et al (1995) and Chrisman (1996) provide discussions on some aspects of the incorrect use of the method.

3.3.2 – Order Preference by Similarity to the Ideal Solution

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) decision making tool was developed by Yoon and Hwang (1981). The TOPSIS method is derived from a simple and intuitive idea that the best alternatives should have the closest proximity to the positive ideal solution as well as the farthest distance to the negative ideal solution. The ideal solution should have a rank of one, while the worst alternative should have a rank approaching 0. Yoon and Hwang assumed if each attribute takes a monotonically increasing or decreasing variation, the definition of an ideal solution becomes simple. The goal is to define a solution which has the shortest distance from the ideal solution in the Euclidean distance (Triantaphyllou 2000, and Garvey 2008). Chen (2000) extended the TOPSIS for group decision making in a fuzzy environment. The importance of weights of various criteria and ratings of alternatives with respect to these criteria are considered as linguistic variables that are assessed by a decision making group.

TOPSIS is a method of compensatory aggregation that compares a set of alternatives by identifying weights and normalizing scores for each criterion and calculating the geometric distance between each alternative to the ideal alternative. Since the parameters of the criteria are often of incongruous dimensions in multi criteria problems, normalization is usually required (Yoon, and Hwang 1995). Compensatory methods such as TOPSIS are able to provide a more realistic method of modelling since they allow trade-offs between criteria. A poor result in one criterion can be neutralized by a good result in another criterion. Non-compensatory methods, which include or exclude alternative solutions based on hard cut-offs do not afford the user the same flexibility (Greene, Devillers, Luther, and Eddy 2011).

According to Malczewski (1996) although TOPSIS can be implemented in both raster and vector GIS environments, it is more suitable for the raster data structure. The application of the TOPSIS method involves the following steps (Malczewski 1999):

1. Determine the set of feasible alternatives.

2. Standardize each attribute map layer by transforming the various attribute dimensions (x_{ij}) to undimensional attributes (v_{ij}). This transformation allows for comparison of the various layers.

3. Define the weights (w_i) assigned to each attribute - the set of weights must be such that

$$0 \leq w_i \leq and \sum_i w_i = 1$$

4. Construct the weighted standardized map layers by multiplying each value of the standardized attribute layer v_{ij} by the corresponding weight w_i, each cell of the layers contains the weighted standardized value v_{ij}.

5. Determine the maximum value ($v_{+j)}$) for each of the weighted standardized map layers (the values determine the ideal point); that is, $v_{+j} = (v_{max1},\ v_{max2},\ \ldots..v_{maxn}\ )$.

6. Determine the minimum value (*V-i*) for each weighted standardized map layer (the values determine the negative ideal point); that is, $v_{-j} = (v_{min1},$ $v_{min2},\ \ldots\ldots,\ v_{minn}\ ).$

7. Using a separation measure, calculate "the distance" between the ideal point and each alternative. A separation can be calculated using the Euclidean (or straight-line) distance metric:

$$s_{i+}=[\ \sum_i(v_{ij} - v_{+j)}2]\ 0.5$$

8. Using the same separation measure, determine "the distance" between the negative ideal point and each alternative:

$$s_{i-}=[\ \sum_i(v_{ij} - v_{-j)}2]\ 0.5$$

9. Calculate the relative closeness to the ideal point (C_{i+}) using the equation

$$C_{i+} = \frac{s_{i-}}{s_{i+} + s_{i-}}$$

$0 < C_{i+} < 1$ that an alternative is closer to the ideal point as C_{i+} approaches 1

10. Rank the alternative according to the descending order of C_{i+} ; the alternative with the highest value of C_{i+} is the best alternative.

4.0 – RESEARCH STRATEGY

4.1 - Data

Mapping requires reliable data sources. The data required for this study was acquired from collected or existing data from different sources. To form the geodatabase for the city of Calabasas, data was collected from the City of Calabasas general plan which was implemented to create a land use map for the city, determine the location of the existing high school, and city boundaries. The required demographic data was acquired from United States Census Bureau. In addition, to demonstrate that Calabasas High School is overpopulated, classroom size was obtained from Las Virgenes school district.

To illustrate the slope of the city, National Elevation Dataset (NED) was generated from U.S. Geological Survey (USGS) website. NED source data are selected from an ever-growing inventory of standard production USGS Digital Elevation Model (DEM). Further, Aerial Photo was obtained from Landsat 7, 2003 for Los Angeles County from USGS website.

The list of restaurants was obtained from North American Industry Classification System (NAICS) 2012, under sector 72 (Accommodation and Food Services). Search area was based on City of Calabasas zip code (91302) and its neighboring cities such as Topanga (90290), Woodland Hills (91364, and 91367), and Agoura Hills (91301). Finally, to create a map of major road networks in the city, data was obtained from United States Department of Transportation.

4.2 – Methodology

A cartographic modeling approach in which a set of map operation is performed on input maps of a study area to create a spatial model, is the main principle underlying land use suitability analysis (Tomlin 1990, and Malczewski 2004).

Suitability analysis can be conducted in GIS by using either a vector data or a raster data model. There is a preference for the use of a raster-based, or grid-based method in cases where the input data varies over a continuous surface such as vegetation, elevation, or soil. An important part of the multi-criteria decision analysis is the selection of criteria that has spatial reference (Malczewski, 1996). In this study, the vector data were directly converted into raster format using NAD_1983_HARN_StatePalne_California_V_FIPS_0405 spatial reference with Meter Linear Unit. To convert vector feature classes to raster format for proximity to the existing high school, major roads, and restaurants, the Euclidean Distance Tool was used (Figure 4-6).

One of the most common raster-based techniques for generating land suitability maps, is a language based on matrix algebra known as map algebra. Each raster grid, or input map functions like a matrix variable in an algebraic equation. Selected operators and/or functions are available to be applied to these variables in order to yield output maps (Tomlin, 1990, DeMers 2002, Malczewski 2004).

There are a variety of GIS software packages available with raster-based tools for managing, producing, analyzing, and combining spatial data. In this study, The

Environmental Sciences Research Institute's (ESRI) ArcGIS 10.1 was used to generate a map for each criterion as well as the final suitability maps.

Figure 4- Euclidean Distance to the Existing High School

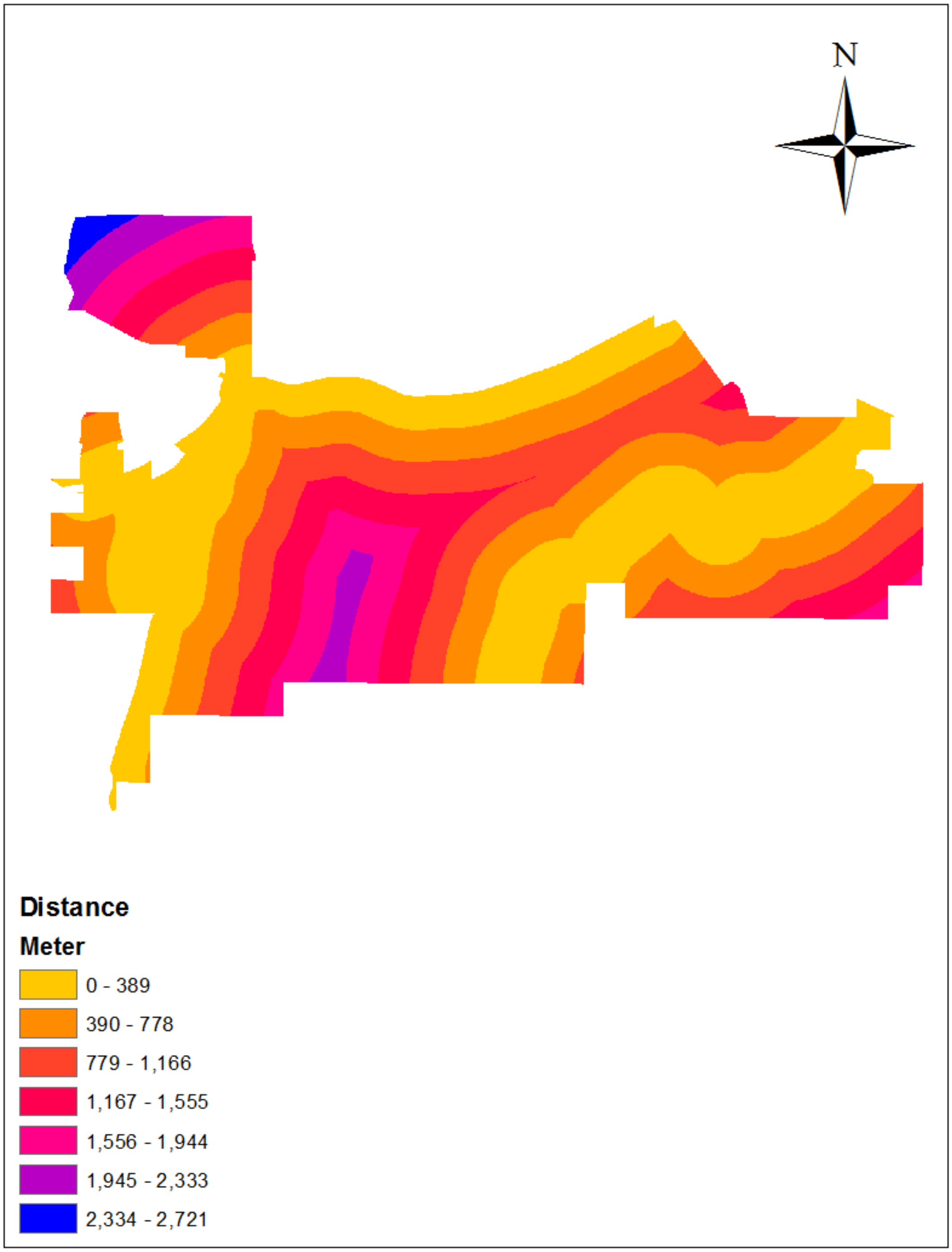

Figure 5 –Euclidean Distance to Major Roads

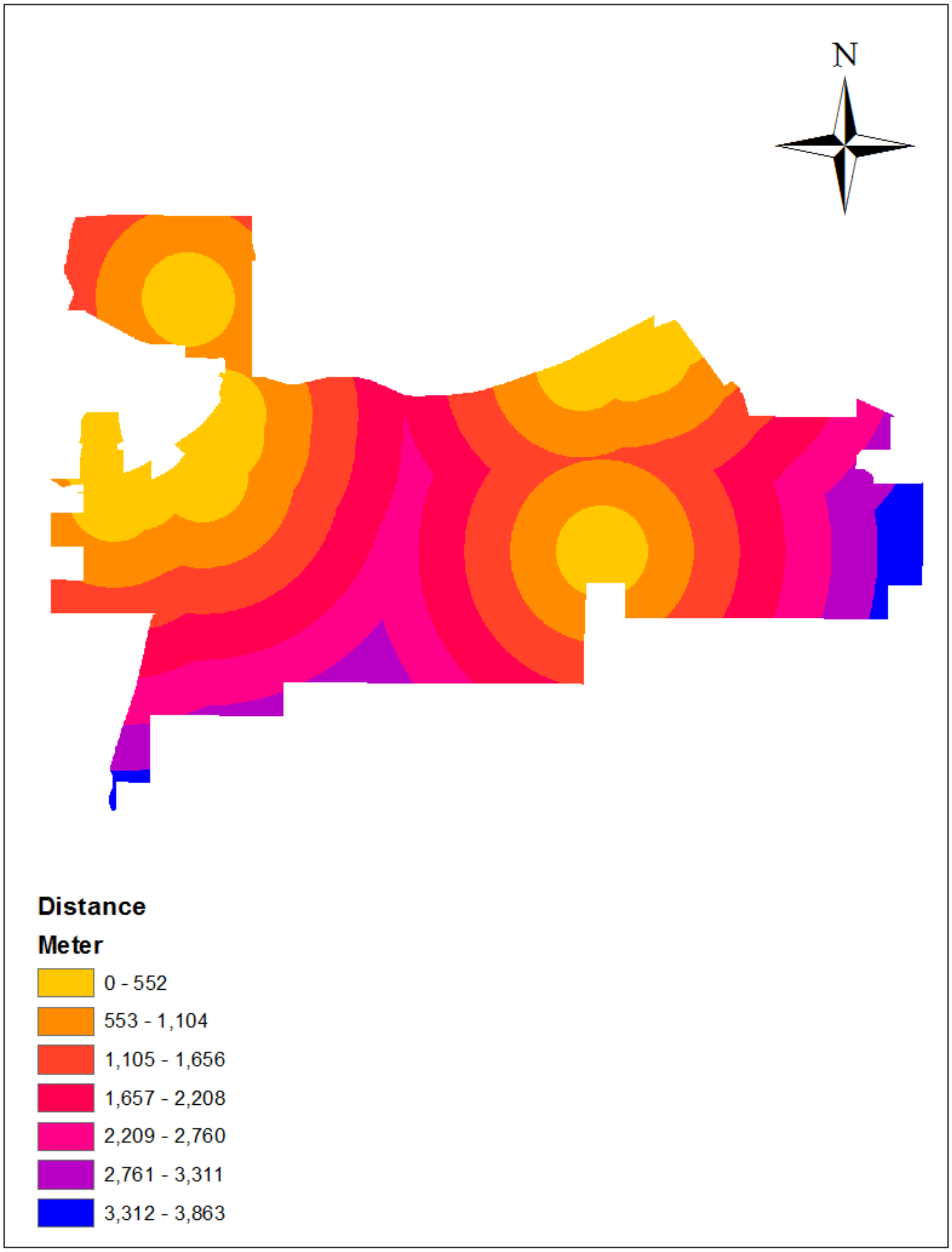

Figure 6 – Euclidean Distance to Restaurants

4.2.1 - Decision Criteria

Land-use suitability analysis is a method for determining the optimal future land uses based on a set of constraints, preference, or predictors (Malczewski, 2004). Previously, hand-drawn overlay maps were used to conduct these studies. More recently however, GIS technology has become integral to the process in analyzing and mapping large datasets (Whitley and Xiang 1993). The GIS approach of analysis enables the integration of several overlay maps, or of maps indicating various criteria (e.g., slope, distance to nearest road, soil type), to result in a final overall suitability map of the study area (Hopkins 1977, Tomlin 1990, Malczewski 2004).

There are many factors that go into the selection of a site as the potential location of a school campus. In this study, six criteria were identified. The first criterion is proximity to the existing high school. This factor is essential to maximum coverage. To best satisfy this requirement, the new campus must be within the city, but at a maximum distance to the existing high school. Population under 18 years –old, which includes current and future high school students, is an important criterion as well. Land availability also, has a substantial influence on site selection. Land use patterns will determine the appropriate land use for a proposed site based upon the general plan.

Proximity to roads has a significant influence on site suitability in terms of access. In this study, a Census Feature Class Code (CFFCC) is used to identify the most noticeable characteristic of a feature, and five categories of feature class "A", Road, are selected as a major roads.

A15: Primary road with limited access or interstate highway, separated

A21: Primary road without limited access, US highways, unseparated

A25: Primary road without limited access, US highways, separated

A31: Secondary and connecting road, state and county highways, unseparated

A35: Secondary and connecting road, state and county highways, separated

Slope is another important feature to consider. The site should be fairly level with some topographic relief that can provide opportunities for learning area development. The overall slope of a site should be flat enough to allow for ease of construction and circulation, and yet be steep enough for proper site drainage. Slopes less than 10 percent are considered excellent (Figure 7). The priority of slope is not as significant as distance to the existing high school or population to be served. Slope is less important because the cost of levelling the site can be incurred only once. The last criterion is proximity to restaurants and fast food outlets.

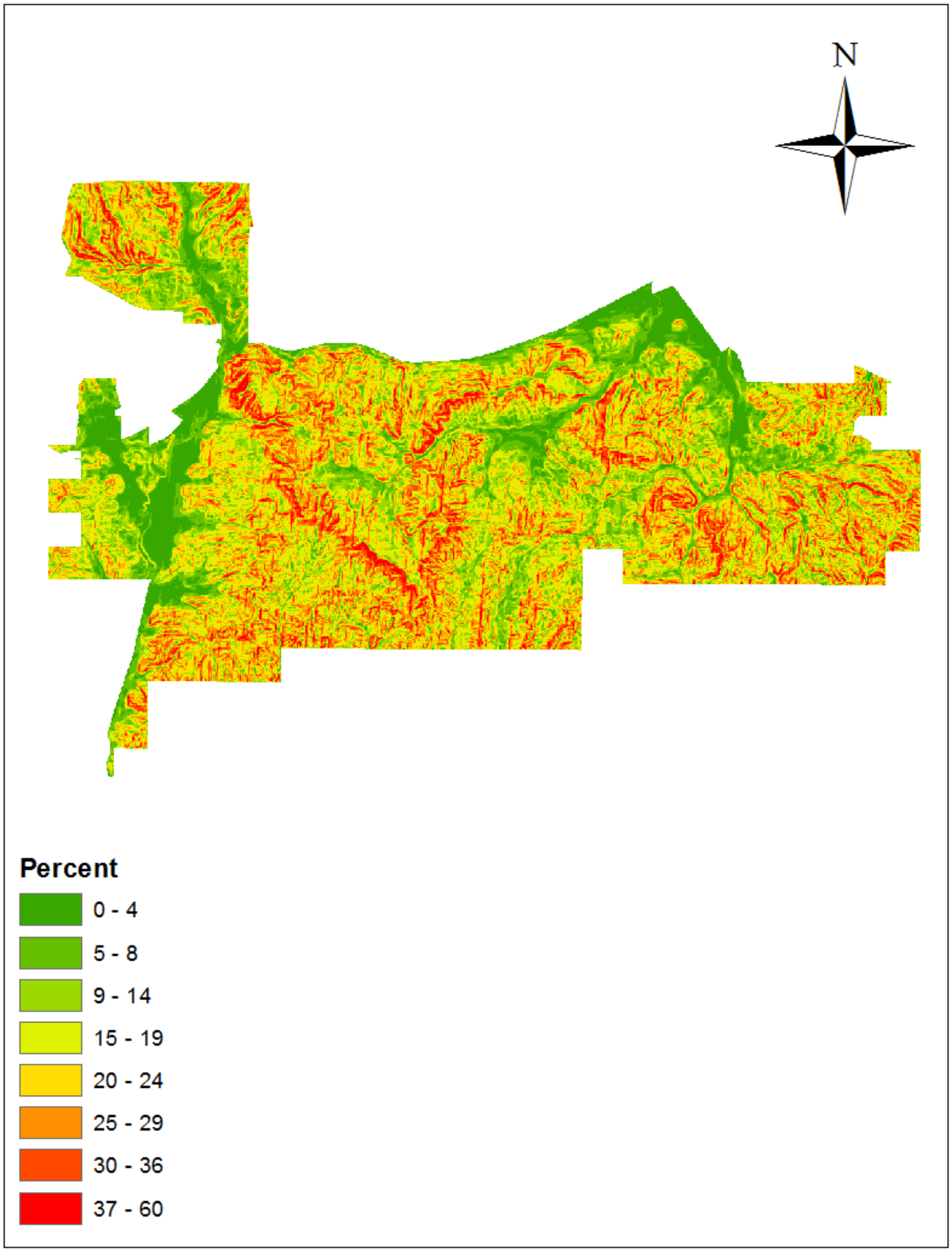

Figure 7- Slope Map of the City of Calabasas

4.2.2 - Standardization of Criteria

In many analyses, especially those utilizing quantitative and qualitative data, the criteria scores need to be standardized (Carver, 1991). Variables are considered benefit criteria if the more desirable values are the higher values. Conversely, cost criteria are variables in which the more desirable values are the lower values. To be precise, in order to combine the various criterion maps layers, the scales must be comparable. A number of approaches can be used to make criterion map layers comparable (Malczewiski 1999).

The linear scale transformation methods convert the raw data into standardized criterion scores. A number of linear scale transformations exist (Voogd 1983, Massam 1988). Hwang and Yoon (1981) and Malczewski (1999) have used the maximum score and the score range procedures. In this paper, the same procedures have been used for standardization of criteria. The simplest formulae for standardizing the raw data is to divide each raw score by the maximum value for a given criterion; that is:

a) $$X'_{ij} = \frac{X_{ij}}{X_{\mathrm{j}}^{max}}$$

b) $$X'_{ij} = 1 - \frac{X_{ij}}{X_j^{max}}$$

Where X'_{ij} is the standardized score for the *i*th object (alternative) and the *j*th attribute, X_{ij} is the raw score, and X_{j}^{max} is the maximum score for the *j*th attribute. The value of standardized scores can range from 0 to1. The higher the value of the score, the more attractive is the criterion value (equation a), if the criterion is of the minimization type (the lower the score the better performance), equation b is used.

Since each criterion has a different value, a table was prepared and the criteria were determined as maximum or minimum (Table 4). In order to integrate and utilize the qualitative values of land use, they must be changed to quantitative values. Based on *California Department of Education regulations,* schools should be closer to residential area and farther from business and commercial areas. Therefore, the values were re-categorized in 5-point categories from the best (1) to the worst (5). The first category with value 1 was all areas with residential land use, the second category (value 2), was open spaces, the third category (value 3) , included public facilities such as recreational centers, or libraries. The forth category, covering business and commercial areas with value 4, and the last category , 5, was assigned to mountainous and hills sides because of safety considerations during the rainy season which may cause landslides and water runoff.

Table 4 - Maximization and Minimization of Criteria

Criteria	**Value**
Distance to the Existing High School	Maximization
Population under 18 Years-Old	Maximization
Land Use	Minimization
Proximity to Major Roads	Minimization
Slope	Minimization
Proximity to Restaurants	Minimization

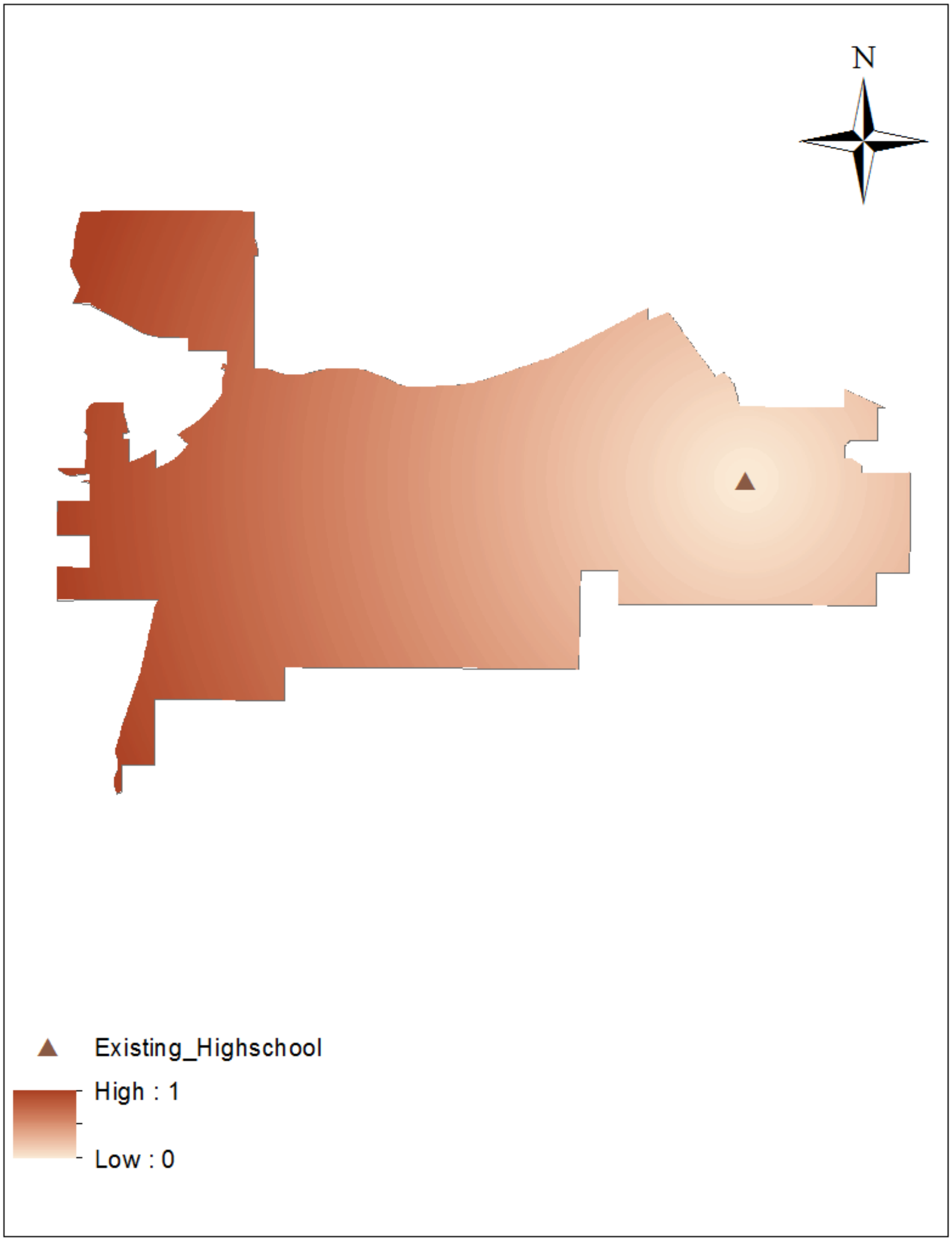

Figure 8- Standardized Distance to the Existing High School

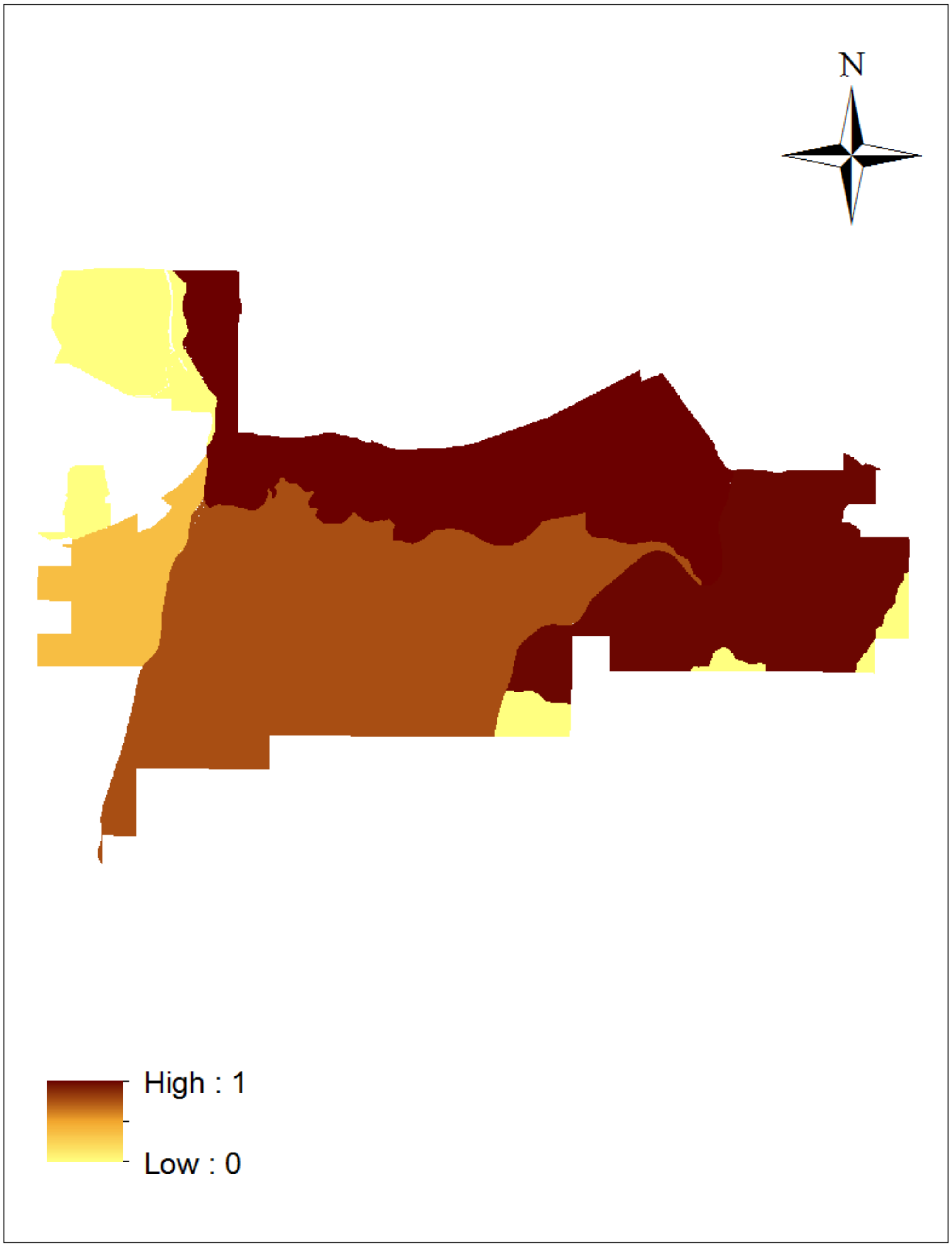

Figure 9- Standardized Population Under 18 Years-Old in 2010

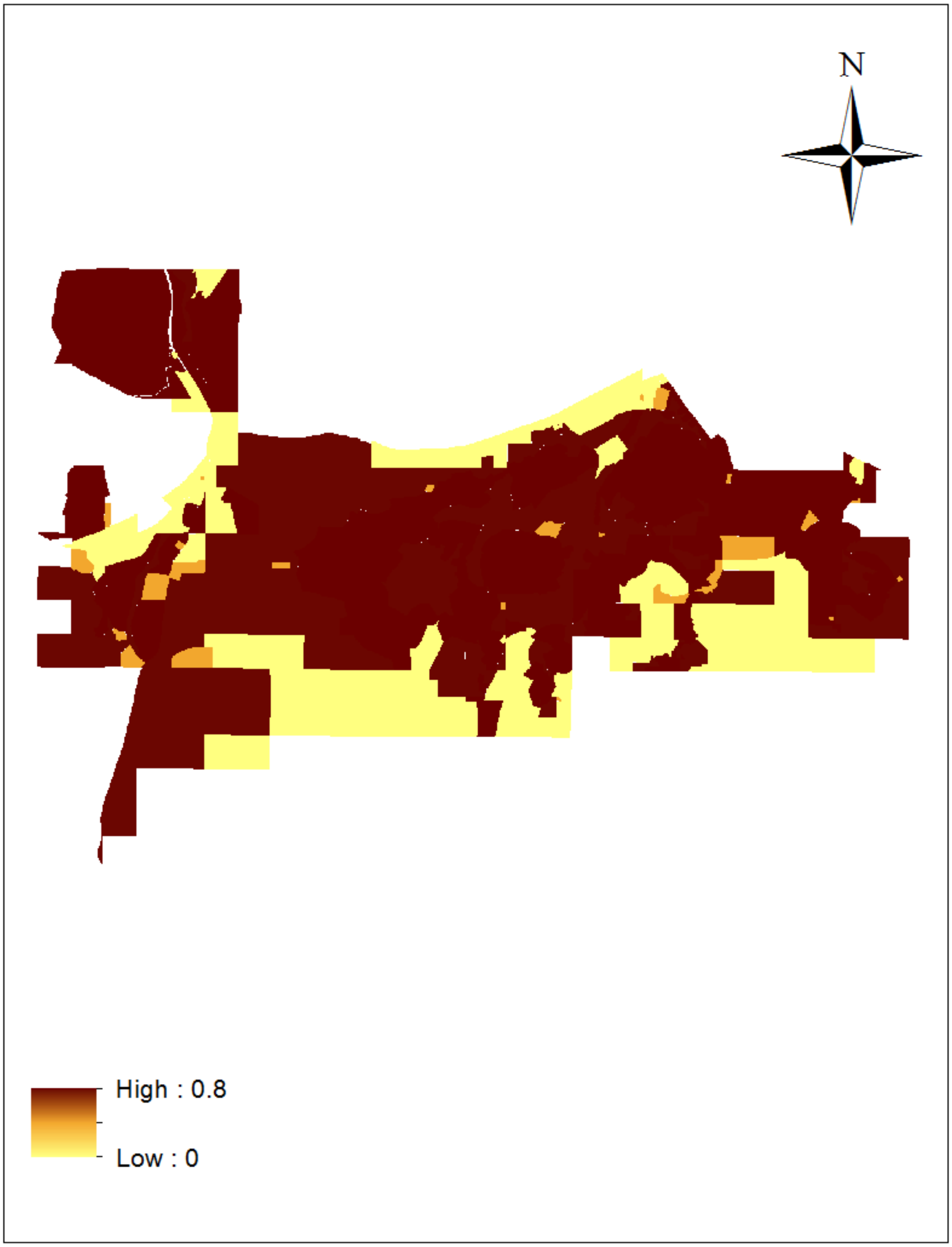

Figure 10- Standardized Land Use of the City

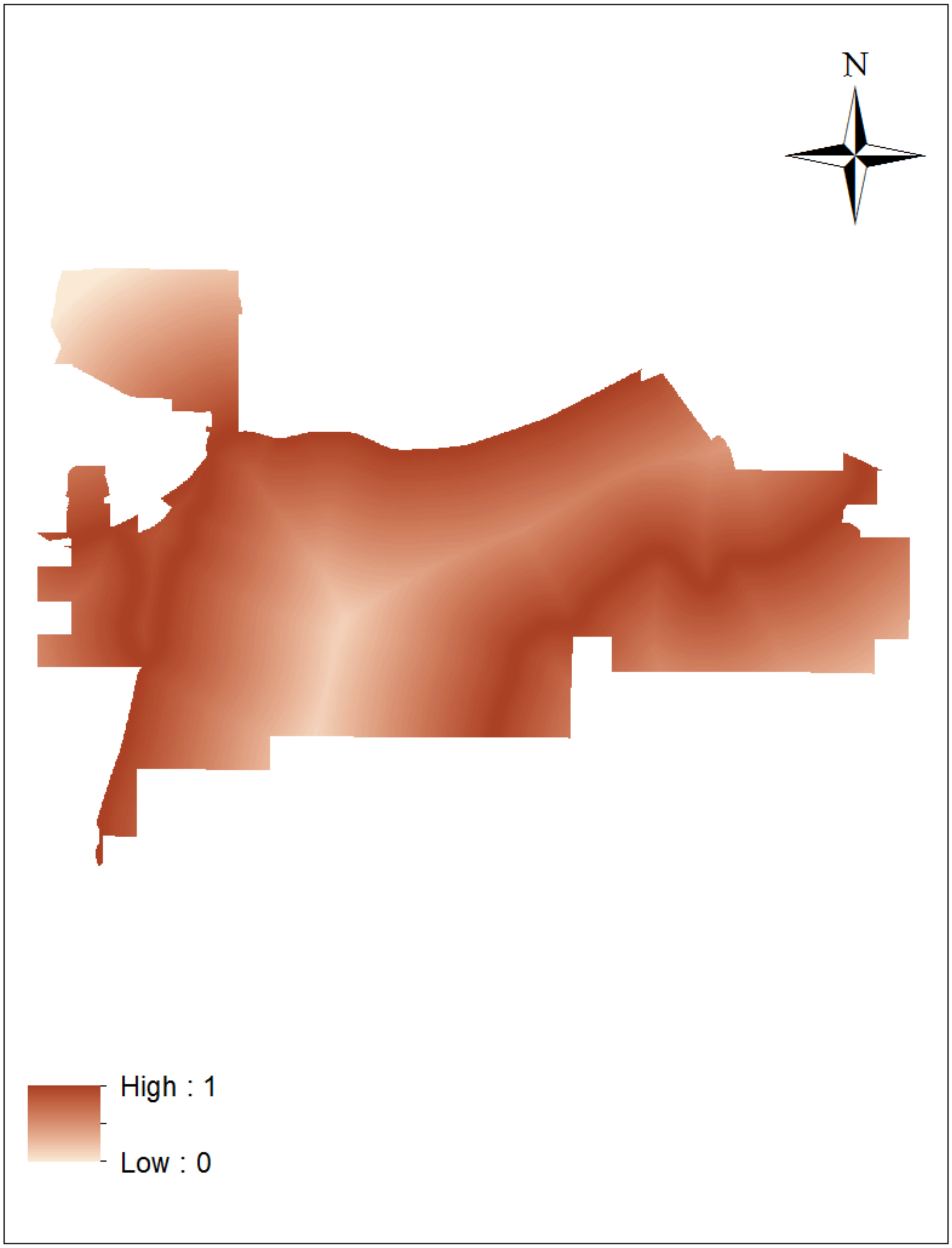

Figure 11- Standardized Proximity to Major Roads

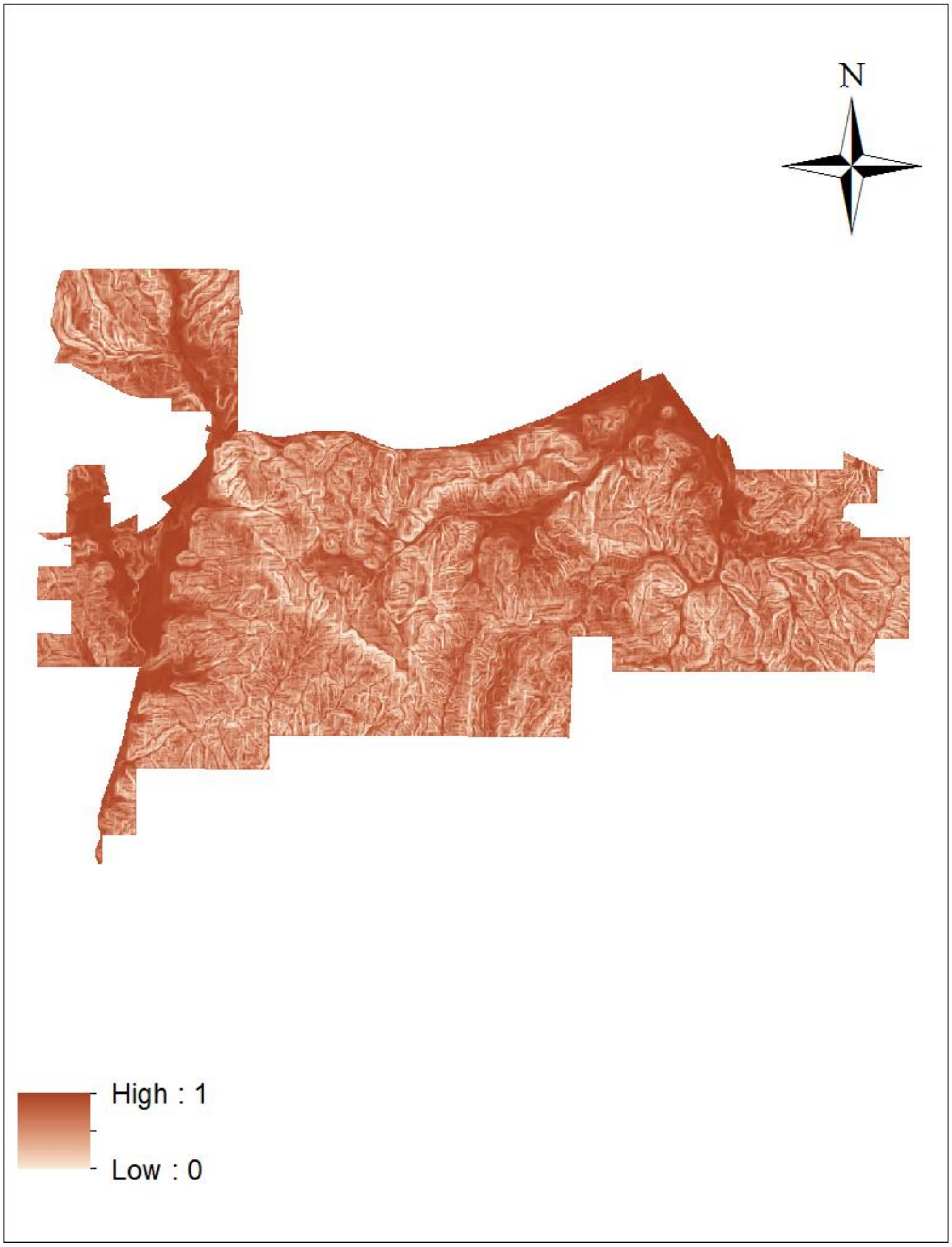

Figure 12- Standardized Slope of the City

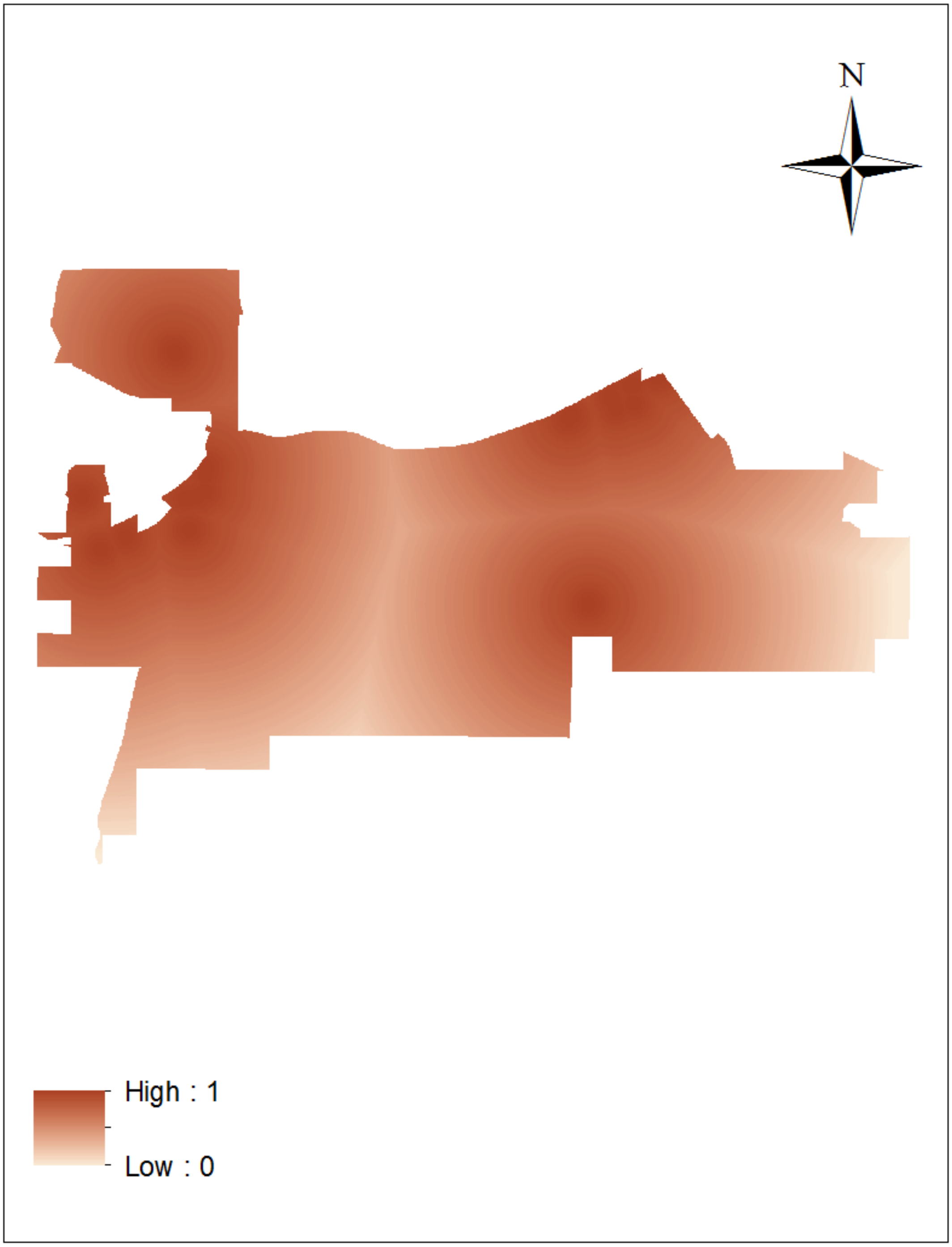

Figure 13- Standardized Proximity to Restaurants

4.2.3 - Criterion Weights

Land use decisions require the incorporation of public opinion, thus creating a need for a method that would allow and account for stakeholder input. An integral part of the suitability analysis involves weighing each of the input maps or factors relative to its importance in the final outcome of the model (Lyle and Stutz 1983).

There are four different techniques for assigning weights which are ranking, rating, pairwise comparison, and trade-off. (Malczewski 1999). Ranking (arranging in rank order), is the most simple of the four methods to use, however it is limited in that the results can only be viewed as an approximation of the true weights. The rating method in which weights are estimated based on a predetermined scale is also a relatively simple method and is sometimes criticized for its lack of theoretical foundations. The pairwise comparison method and trade-off analysis methods offer much more precision in terms of calculating weights and both have underlying theoretical bases; however, research has shown that the pairwise comparison technique is simpler to use and just as effective as trade-off analysis (Maczewski 1999).

For this analysis, factors selected to evaluate the land suitability, were standardized using the pairwise comparison method. In this process, each factor is rated for its importance relative to every other factor using a 9-point reciprocal scale. This leads to an $n \times n$ matrix of rating where n is the number of factors being considered (Eastman 1999).

1/9	1/7	1/5	1/3	1	3	5	7	9
extremely	very	strongly	moderately	equally	moderately	strongly	very	extremely

less important → more important

The value given for the factors was based on requirements for suitability analysis a new school and reviewed from different literature. Distance from the existing high school is of greater importance compared to proximity to restaurants and fast foods. Since the matrix is symmetrical, only the lower triangular half actually needs to be filled in. the remaining cells are then simply the reciprocals of the lower triangular half.

Table 5- Pairwise Comparison of the Evaluation Criteria

Criterion	Distance to Existing High school	Population Under 18	Land Use	Proximity to Major Roads	Slope	Proximity to Restaurants
Distance to Existing High School	1					
Population Under 18	1/2	1				
Land Use	1/3	1/2	1			
Proximity to Major Roads	1/4	1/3	1/2	1		
Slope	1/5	1/4	1/3	1/2	1	
Proximity to Restaurants	1/6	1/5	1/4	1/3	1/2	1
Total	2.449	4.283	7.083	10.833	15.500	21.000

In this study, suitability analysis for a new high school has been developed using Fuzzy WLC and pairwise comparison methods. Deriving weights for the selected map criteria is the base requirement for applying Fuzzy WLC method. This weighting method was based on prior studies in site selections, Calabasas' General Plan, and stakeholders' preferences. In this process, six criteria have been identified, and pairwise comparison method is used to in determining the weights for the criteria in Excel 2013 environment. The steps involves to derive criterion weights are in details in Appendix A.

Table 6- Determining the Relative Criterion Weights

Criterion	Derived Weight
Distance to the Existing High School	0.379
Population Under 18 Years-Old	0.249
Land Use	0.161
Proximity to Major Roads	0.103
Slope	0.065
Proximity to Restaurants	0.043
Total	1.000

Table 7- Determining the Consistency Ratio

Criterion	Consistency Vector
Distance to the Existing High school	6.214
Population Under 18 Years-Old	6.200
Land Use	6.112
Proximity to the Major Roads	6.029
Slope	6.043
Proximity to Restaurants	6.093

Next step is computation of values for lambda ($\boldsymbol{\lambda}$) and the consistency index (CI). The value of lambda is simply the average value of the consistency vector:

$$\boldsymbol{\lambda} = 6.214+6.200+6.112+6.029+6.043+6.093/6= 6.116$$

$$\mathrm{CI} = 6.116\text{-}6/6\text{-}1= 0.023$$

The consistency index (CI), provides a measure of departure from consistency (Malczewski 1999).

$$\mathrm{CR}= 0.023/1.24= 0.019$$

Because the CR < 0.10, a reasonable level of consistency can be said to characterize the pairwise comparison.

4.2.4 – Creating Final Map Using Weighted Linear Combination Method

The method that introduced the use of pairwise comparison for determining factor weights is Weighted Linear Combination (WLC). Once the form of the value function is identified, the transformation of the raw attribute maps into the value maps is a matter of simple map algebra manipulation (Malczewski 2000). The WLC is a method that necessitate standardization of the suitability maps, assigning the weights of relative importance to the suitability maps, and then combining the weights and standardized suitability maps to obtain an overall suitability score "(Malczewski 2004). In this regard, WLC model is implemented within the GIS environment using map algebra operations.

To complete the analysis, the raster calculator was used to find the ideal locations to build the new high school. Therefore, six criterion maps were integrated by applying weights as criterion weights:

[Distance to Existing High School]*0.379 + [Population under 18 Years Old] *0.249+ [Land Use]*0.161 + [Proximity to Major Roads]*0.103+ [Slope]*0.065+ [Proximity to Restaurants]*0.043

The result of this integration shows potential sites (ranked from best to worst) that could be suitable for building a new high school (Figure 14). Most suitable areas are in the darkest green color, and the least suitable areas are in orange shades. The areas deemed least suitable by using the stated criteria, are in the eastern part of the city.

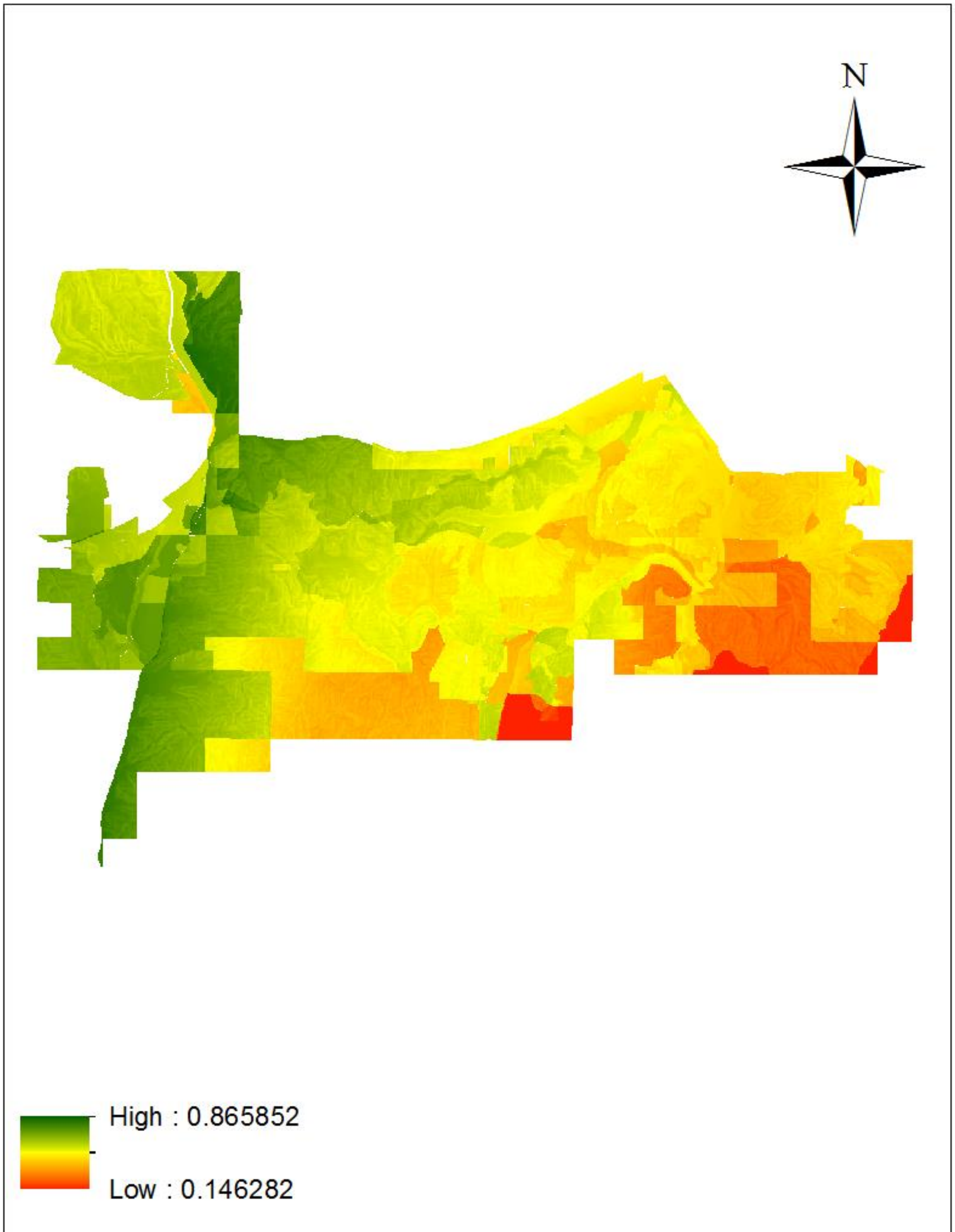

Figure 14- Land Suitability Using WLC Method

The next step, is the determination of cut-off point. The cutoff value gives an indication of how many principal components should be considered significant. In this study, the cutoff point is 15% which means the suitable lands should be within top 15% of the highest value. Therefore, sites that fall within this area will be classified as suitable or a Boolean 'True', and those outside as unsuitable or a Boolean 'False". To calculate the cutoff point, first the range of highest and lowest value should be computed (0.865852-0.146282= 0.71957). Second step is computation of 85 % of the value (0.71957*0.85 = 0.6116345), and last step is adding the lowest value to the calculated percentage (0.146282 + 0.6116345= 0.7579165).

In ArcMap, Raster Calculator tool is selected to enter the following equation into weighted linear combination layer.

FinalMap_WLC >= 0.7579165

The resultant map is a raster layer containing only ones and zeros. The regions with a value of one represents suitable areas for the high school, and those regions with a value of zero are areas that have not met the required threshold and are not among the top 15 percent areas. The total number of cells with the value one is 40609; therefore the total suitable area is 3,580,580.8 square meters.

4.2.5 – Creating Final Map Using Technique for Order of Preference by Similarity to Ideal Solution

Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), is a multiple criteria method used to determine solutions from an unlimited set of alternatives. The basic principle is that the chosen alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution.

Maclzewski (1999) has introduced ten steps for the application of this method including: determination of feasible alternatives, standardization of each attribute map, definition of the weight and assigning to each attribute, constructing the weighted standardize may layers, determination of maximum ,and minimum values for each of the weighted standardized map layers, calculation of the distance between the ideal, and negative ideal points to each weighted standardized map layers, calculating the relative closeness to the ideal points and finally, ranking the alternatives which the highest value of the closeness is the best alternative.

As it was explained in pairwise comparison method, six alternatives were determined. TOPSIS requires that the values contained in different criterion layers be transformed to comparable units. The criterion layers may have qualitative (e.g. land use) and/or quantitative (e.g. slope) properties. Each criterion has been converted to numerical values, weighted and standardized. This process was done using WLC method.

Given the standardized map layers, each layer is multiplied by a weight of 0.379, 0.249, 0.161, 0.103, 0.065, and 0.043 assigned to the distance to the existing high school, population under 18 years-old, land use, proximity to major roads, slope, and proximity to restaurants criterion respectively.

The ideal and negative ideal were derived from the standardized weighted layer by using create constant raster tool. Once the ideal and negative ideal map layers were created, the next step is to calculate the separation measures between each alternative (cell) and the ideal and the negative ideal. This step was achieved by using the following exponents:

Ideal Point: s_{i+}=[$\sum_i (v_{ij} - v_{+j)} 2$] 0.5

Negative Ideal Point: s_{i-}=[$\sum_i (v_{ij} - v_{-j)} 2$] 0.5

The next step was to compute a measure of the relative closeness of each alternative to the ideal. This was performed by adding the two separation measures map layers and then by dividing the separation from the ideal map layer by the resulting layer to obtain the relative closeness to the ideal. Finally, the rank operation was performed on the closeness to the ideal map layer. The result of this process indicates that the best area is characterized by an outcome of 0.858.

As illustrated on Figure 15, most suitable areas are in the darkest green color, and the least suitable areas are in orange shades. The least suitable areas according to this formula are in the eastern part of the city.

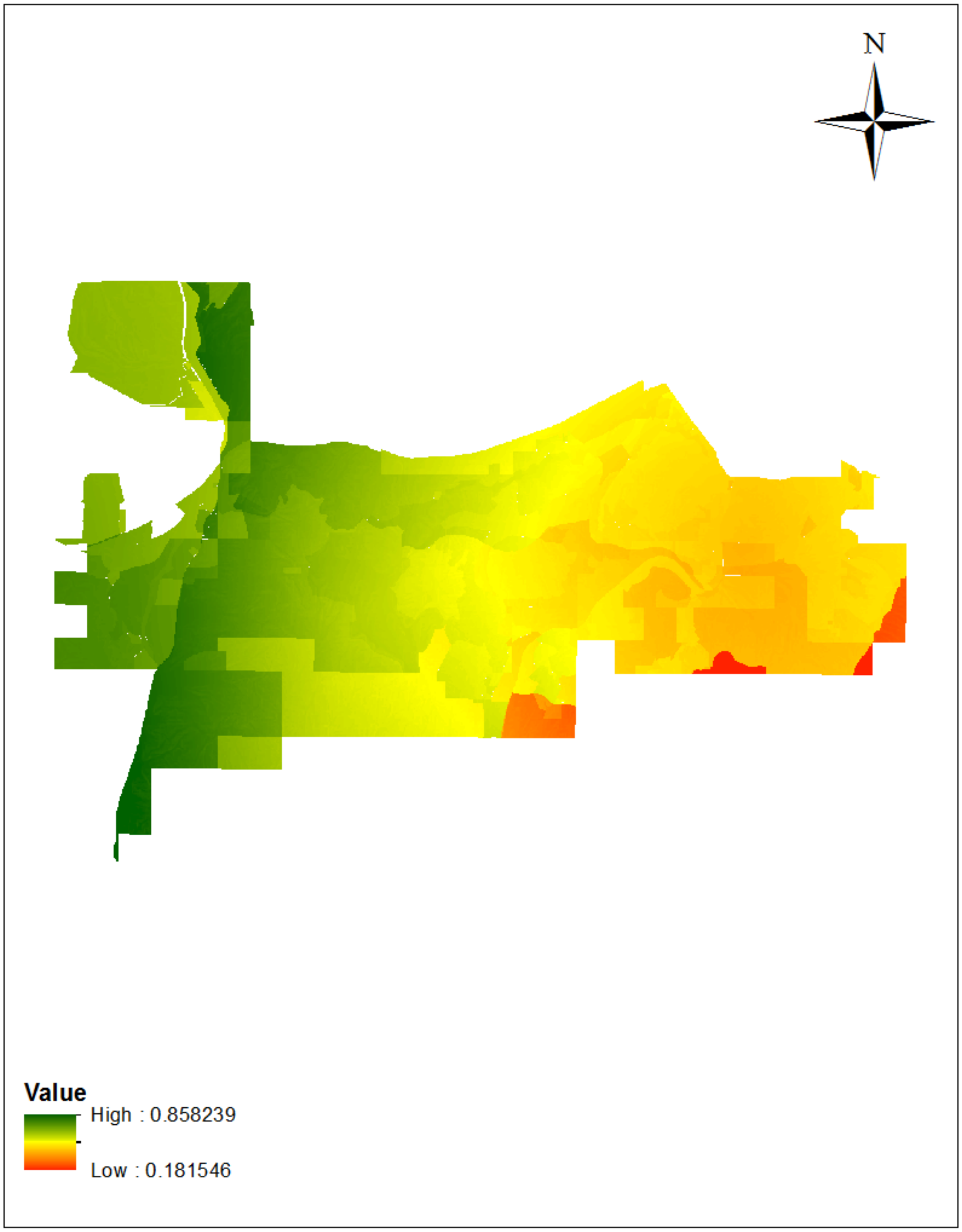

Figure 15 - Land Suitability Using TOPSIS Method

As discussed earlier, the next step is the determination of the cut-off point. In this method, the cutoff point is 15% as well and sites that fall within this area will be classified as suitable or a Boolean ‘True’, and those outside as unsuitable or a Boolean ‘False”. First, the range of highest and lowest values are computed (0.858239-0.181546= 0.676693). The next step is computation of 85 % of the value (0.676693*0.85 = 0.575189), and last step is adding the lowest value to the calculated percentage (0.181546+ 0.575189= 0.756735).

In ArcMap, the Raster Calculator tool was used to generate a TOPSIS suitability surface using the following equation :

FinalMap_TOPSIS >= 0.756735

The resulting map contained only ones and zeroes. One represent suitable areas, and zero designating areas that have not met the conditions required by the analysis, and therefore fail to count among the top 15 percent area. The total number of cells with the value of one is 37047; therefore the total suitable area is 3,266,511.7 square meters.

5.0 – RESULTS

The purpose of this study was to find the optimum site for a new high school in Calabasas, by using a series of sound criteria. The counts and locations of cells within maximum values are relatively close to each other using both the WLC and TOPSIS methods. After the comparison of the two output maps, the most suitable locations for a new high school would be in the western region of the city stretching from in the vicinity of Las Virgenes road.(Figure 16, and 17).

North of the optimum site, is a region surrounded by large residential areas and a newly built development, with a high percentage of population under 18 years-old. Based on the criteria used in this analysis, the middle section of the optimum site somewhere in vicinity of A.E.Wright is found to be the most suitable area. It is a flat area with a slope of less than 15 percent. Additionally, its proximity to Las Virgenes road, and residential areas and its distance to the existing high school renders it well suited and convenient.

The vacant parcels in City of Calabasas include open spaces. The optimum site is surrounded by open spaces resource protection (OS-RP). In 2008, and adoption was added to the city General Plan for re-designation of open space to non-open space use (municode 2014). Appendix B lists requirements for re-designation in detail.

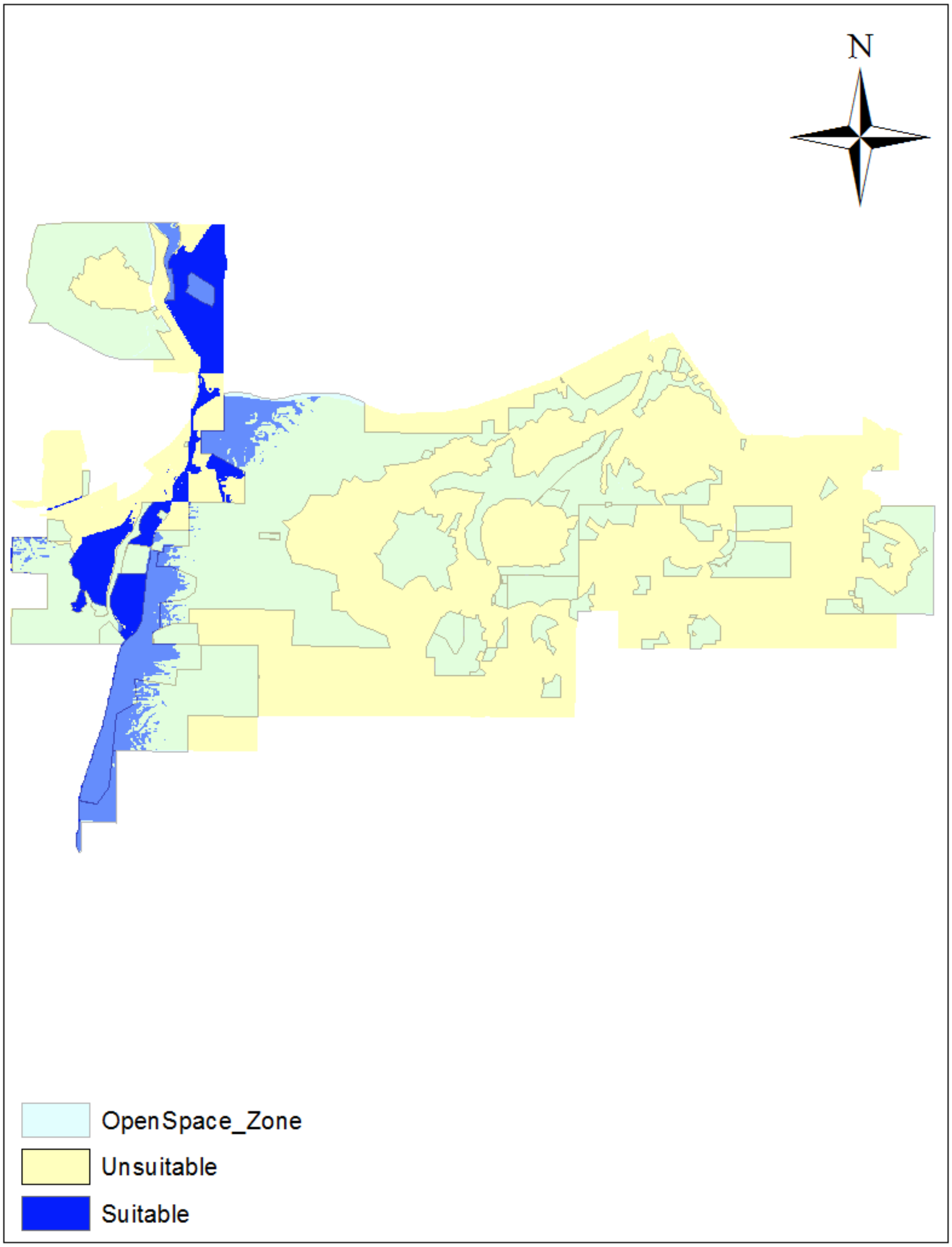

Figure 16 - Suitable Areas Using WLC Method with Top 15 Percent

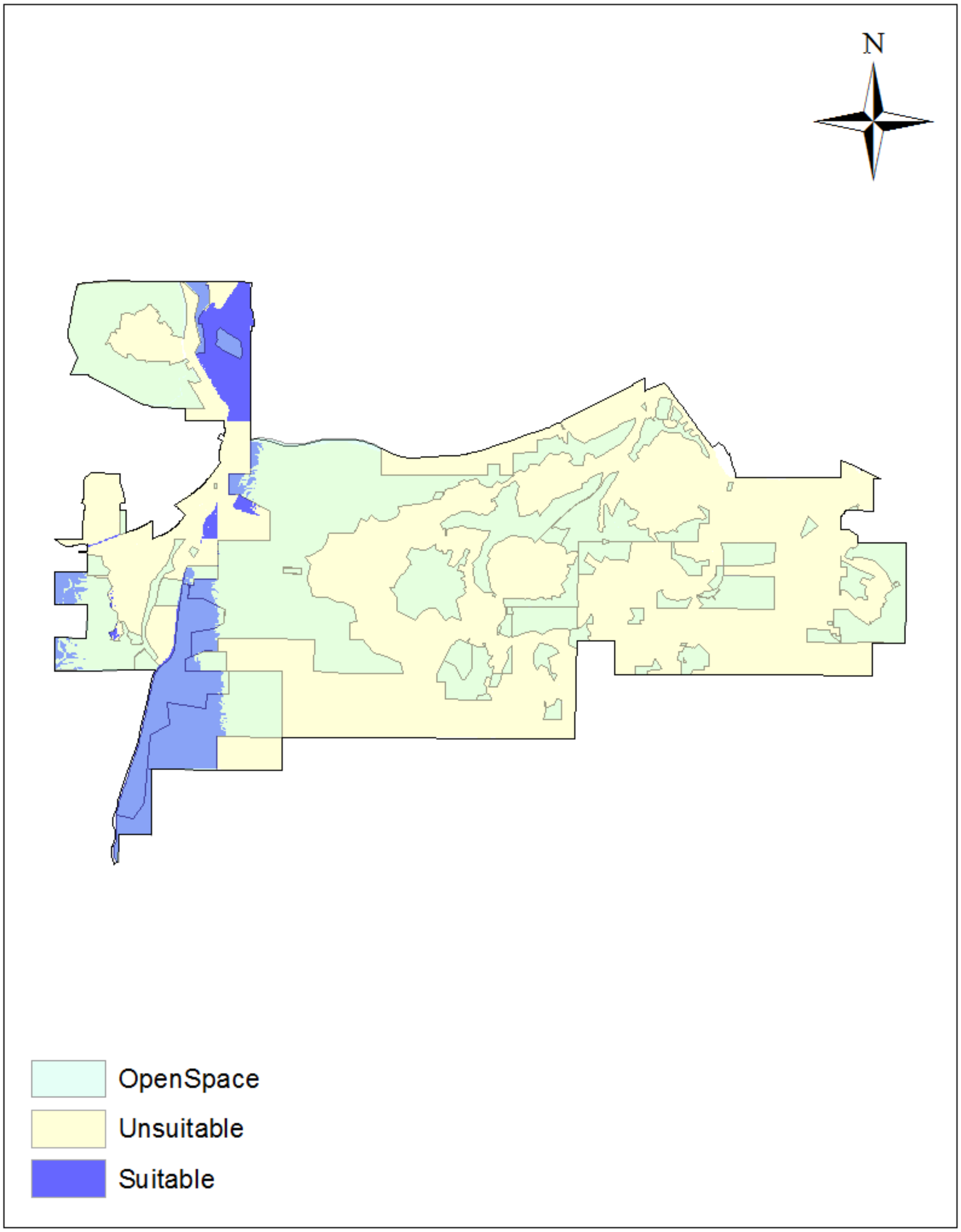

Figure 17 - Suitable Areas Using TOPSIS Method with Top 15 Percent

6.0 – CONCLUSION

Overcrowded classrooms in Calabasas High School have increased the necessity of a new high school in the city of Calabasas. The focus of this study has been to locate an optimal site to build a new high school. Siting the most suitable area for a school location is a complicated procedure involving the evaluation of several factors. In this process, choosing criteria is very important. The criteria used in this study were selected based on their relevance to the study area. Six criteria were identified for this purpose which in order of importance were: distance from the existing high school, population under 18 years-old, land use, proximity to major roads, slope and proximity to restaurants.

In this study, input data required for the analysis are generated from National Elevation Dataset (NED), Digital Elevation Model (DEM), Aerial Photos from Landsat 7, 2003 for Los Angeles County, City of Calabasas General Plan, North American Industry Classification System (NAICS), Los Angeles County GIS Data Portal and United States Department of Transportation.

Using GIS for site selection is an economical and practical way as they have capabilities of producing useful, and high quality maps. Multicriteria decision analysis is also a powerful tool in siting decision in the area by supplying consistent ranking and weighting to the potential area. In this study, GIS-based multicriteria decision analysis techniques have been employed to evaluate the criteria to identify suitable area for the new campus. The weights of the criteria are determined by using

WLC method, and the score of alternatives are calculated by TOPSIS method for the purpose of evaluating and selecting the best suitable location effectively. WLC is a very helpful method for evaluating complex multicriteria problem. Furthermore, WLC used pairwise comparison method for determining the weights of criteria. TOPSIS is one of the most popular method and can easily implemented for ranking the alternatives, because of the consideration of distance to positive ideal solution and negative ideal solution. The combination of WLC and TOPSIS methods provides an efficient location selection process for specified purposes. This model requires more effort and time to implement, but the results are sensitive and effective compared to applying each method along.

The output maps illustrate the city from unsuitable to the most suitable areas. The result of this study determines that the most suitable area for the new high school is the area located on the west side of the city and stretching north to south, somewhere in the vicinity of A.E. Wright Middle School, perhaps along Las Virgenes road. There are a number of large, undeveloped parcels in this region, several of them would make ideal locations, if zoning considerations can be overcome.

For the future study, the problem can be viewed from different points by using different techniques, such as other multicriteria evaluation methods like Simple Additive Weighting (SAW) or Analytic Hierarchy Process (AHP). Additionally by changing the weights of criteria, the change in the rank of alternatives can be observed.

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APPENDIX A

Step I - Pairwise Comparison Matrix generation.

Column1	Column2	Column3	Column4	Column5	Column6	Column7
	1	***2***	***3***	***4***	***5***	***6***
Distance to Existing High School ***(1)***	1	2	3	4	5	6
Population U18 ***(2)***	1/2	1	2	3	4	5
Land Use ***(3)***	1/3	1/2	1	2	3	4
Proximity to Major Roads ***(4)***	1/4	1/3	1/2	1	2	3
Slope ***(5)***	1/5	1/4	1/3	1/2	1	2
Proximity to Fast Food ***(6)***	1/6	1/5	1/4	1/3	1/2	1
Total	***2.449***	***4.283***	***7.083***	***10.833***	***15.500***	***21.000***

Step II - Normalization of Pairwise Comparison Matrix.

Column1	Column2	Column3	Column4	Column5	Column6	Column7
Criterion	***1***	***2***	***3***	***4***	***5***	***6***
Distance to Existing High School ***(1)***	0.408	0.467	0.424	0.369	0.322	0.286
Population U18 ***(2)***	0.204	0.233	0.282	0.277	0.258	0.238
Land Use ***(3)***	0.136	0.117	0.141	0.185	0.194	0.190
Proximity to Major Roads ***(4)***	0.102	0.078	0.071	0.092	0.129	0.143
Slope ***(5)***	0.082	0.058	0.047	0.046	0.065	0.095
Proximity to Fast Food ***(6)***	0.068	0.047	0.035	0.031	0.032	0.048
Total	***1.000***	***1.000***	***1.000***	***1.000***	***1.000***	***1.000***

Step III - Sum of Normalized Score Divided by the Number of Criteria.

Criterion	Weight
Distance to Existing High School	0.379
Population U18	0.249
Land Use	0.161
Proximity to Major Roads	0.103
Slope	0.065
Proximity to Fast Food	0.043
Total	***1.000***

Step IV - Computation Process for Estimation of the Consistency

Column1	Column2	Column3	Column4	Column5	Column6	Column7	Column8
Criterion	***1***	***2***	***3***	***4***	***5***	***6***	***Step III***
Distance to Existing High School ***(1)***	0.379(1) 0.379	0.249(2) 0.498	0.161(3) 0.483	0.103(4) 0.412	0.065(5) 0.325	0.043(6) 0.258	6.214
Population U18 ***(2)***	0.379(0.500) 0.189	0.249(1) 0.249	0.161(2) 0.322	0.103(3) 0.309	0.065(4) 0.26	0.043(5) 0.215	6.2
Land Use ***(3)***	0.379(0.333) 0.126	0.249(0.500) 0.124	0.161(1) 0.161	0.103(2) 0.206	0.065(3) 0.195	0.043(4) 0.172	6.112
Proximity to Major Roads ***(4)***	0.379(0.250) 0.095	0.249(0.333) 0.083	0.161(0.500) 0.081	0.103(1) 0.103	0.065(2) 0.13	0.043(3) 0.129	6.029
Slope ***(5)***	0.379(0.200) 0.076	0.249(0.250) 0.062	0.161(0.333) 0.053	0.103(0.500) 0.051	0.065(1) 0.065	0.043(2) 0.086	6.046
Proximity to Fast Food ***(6)***	0.379(0.166) 0.063	0.249(0.200) 0.050	0.161(0.250) 0.040	0.103(0.333) 0.034	0.065(0.500) 0.032	0.043(1) 0.043	6.093

APPENDIX B

17.16.030 Voter approval required for redesignation of open space for non-open space use

A.

Voter approval required as follows:

1.

No amendment to the General Plan or any specific plan that would redesignate for non-open space use of any property in the city designated OS-R or OS-RP by the Land Use Map of the Calabasas General Plan, adopted on December 10, 2008 by Resolution Number 2008-1159 shall be effective for any purpose until that amendment has been approved by two-thirds of the voters of the city casting votes on the question. Prior to the placement of such amendment on the ballot, the city shall follow the procedures required by local, state, and federal law, including the California Environmental Quality Act, Public Resources Code Sections 21000 et seq. f. Such an amendment may take effect only upon two-thirds approval of those casting votes on the question.

2.

No amendment to the General Plan or any specific plan that would redesignate for non-open space use any property in the city designated PF-R by the Land Use Map of the Calabasas General Plan, adopted on December 10, 2008 by Resolution Number 2008-1159 shall be effective for any purpose without compliance with the applicable requirements of California law related to the protection of park lands, including Government Code Sections 25550.7, 37111, 37111.1, 38440 through 38462, 38501 through 38510 and Public Resources Code Sections 5400 et seq. If any future amendment of these sections reduce or eliminate requirements for a supermajority council vote or for a vote of the city's electorate, then such supermajority council vote or vote of the electorate shall continue to be required for the redesignation for non-open space use of property in the city designated PF-R.

B. Subsection (A) of this section shall not apply to:

1. Amendments determined by the council, on the advice of the city attorney, to be necessary to avoid an unconstitutional taking of private property or otherwise required by law;

2. Reorganization, renumbering or updating elements of the General Plan in accordance with state law, provided that such actions do not reduce the property designated OS-R, OS-RP, and PF-R; or

3. Amendments which facilitate any of the following land uses: uses permitted in the PF land use district; uses in support of open space uses such as bus shelters, parking facilities, and comfort stations; and public utility facilities (e.g., antennae and pipelines).

C. Any land designated OS-R, OS-RP or PF-R* after July 20, 2005 shall become subject to the requirements of this section upon such designation.

D. This section shall be of no further force and effect on and after November 8, 2030, unless it is sooner readopted, repealed or amended by the voters of the city.

(Ord. No. 2010-265, § 3, 1-27-2010)

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*: OS-R: Open Space Recreational, OS-RP: Open Space- Resource Protection, PF-R: Public Facilities- Recreational