A VECTOR-RASTER GIS APPROACH FOR SELECTING SUITABLE BUS STOP LOCATIONS ALONG URBAN TRANSIT LINE

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ABSTRACT
The Raster data modeling is combined with the traditional vector representation in the present GIS study. The suitability of screen pixel level to model the surrounding environment of bus stop location is thought to best suits the problem at hand. After selecting locations of bus stop in the vector mode of operation, the raster mode is switched on and several layers of data representation describing the environment of the society where the transit line is serving were developed. A pixel addition scenario is adopted between the developed raster layers and thus a suitability map was produced. A comparison between the previously done vector mode bus stop locations and the newly raster suitability map is conducted and finally a recommended scenario is presented to adjust the unsuitable location of bus stop.

KEY WORDS: GIS, Vector vs Raster, Screen Pixel, Suitability Constraints, Pixel Addition, Suitability Map.

1. INTRODUCTION
GIS representation is a main aspect of a GIS research, it refers to the ways in which geographic space and entities are structured in the analytical framework of a particular study. GIS represents the real world in either one of two spatial models which are object-based data models and field-based data models. An object-based data models treats geographic space as populated by discrete and identifiable objects. On the other hand, a field-based data model treats geographic space as populated by real-world features that vary continuously over space. These two approaches are referred to as vector GIS [i.e., features are represented as points, lines and/or polygon] and raster GIS [i.e., features are represented as continuous grid of pixels].

GIS in Transportation studies have employed both vector and raster data to represent the relevant geographic data. Some transportation problems tend to fit better with type of GIS data model than the other. For example, network analysis based on the graph theory typically represents a network as a set of nodes interconnected with a set of links. Vector GIS therefore are better for such transportation network representations. On the other hand, surface analysis represents the land topography as a set of continuous pixels, where their values varying over
space representing the land level at each pixel's location. Raster GIS therefore are better for such transportation network representation. In short, one critical component of GIS in Transportation field is how we can represent data related to transportation in the GIS environment in order to facilitate and integrate the needs of various transportation applications.

2- SCOPE OF THE CURRENT STUDY

The purpose of the current study is to develop a Vector - Raster GIS Model capable of selecting and checking the suitability of bus stop locations along any transit system operating within a city. Therefore, the scope of the present research can be outlined in the following points:

1 - Develop an initially vector model capable of allocating the bus stop locations taking into consideration the appropriate spacing according to the different district types where the transit line passes through.

2 - Adopting a complementary raster modeling scenario capable of zooming in and reflecting the urban environment surrounding the previously selected stop locations.

3 - Building up all the necessary raster layers required by the previously listed point 4 - Building up the so-called Suitability Map which represents the needed tool for the examining process to finally decide on the stop location suitability.

3- INITIAL VECTOR REPRESENTATION OF BUS STOP LOCATIONS ALONG ITS ROUTE

The previously developed digitized road network of the city of Alexandria by the authors [1] is used where a major roadway is chosen as a model for the transit bus route as shown in figure [1]. The selected bus route has a total length of 9.80 km and passes through three districts with different development types. The first district is a central business district followed by an urban district and finally a suburban district as shown in the figure.

The bus stops spacing is the distance between individual stops, which is normally based on the type and population density of the adjacent land uses. Further, more urban regions have established standards for the spacing of the transit stops [2] & [3], which is primarily determined based on the goals that are frequently subdivided by the surrounding development type, such as residential areas, commercial or central business districts (CBD), as indicated in [4] & [5].

In order to allocate the bus stops according to the spacing criterion, a built - in GIS tool is programmed to automate such process, as an Arc View script named "bus stops allocator" is programmed using Avenue Language to build a GIS tool capable for allocating the bus stops according to the spacing standards indicated in the TCRP guidelines [6]. But at first a sort of data preparation must be followed as indicated in the following two steps:

1 - The bus route should be subdivided into segments at every change in the underlying district development type, in this example the imaginary bus route was divided into three segment with a first segment length of 3.63 Km which passes through the CBD, followed by a second with a length of 2.93 Km which passes through the urban district and finally a third segment with a length of 3.25 Km which passes through the suburban district as shown in figure [1].
Fig. 1. The Selected Bus Route Is Subdivided Into Three Segments With Different Development Types In Vector Mode.

2 – In the bus route attributes Table, a new field labeled "District Type" should be added in which the type of the district that the bus route segment passes, is entered as one of the following types [CBD, Urban, Sub Urban or Rural] as shown in the following table.

Table 1. Bus Routes Attributes Table.

<table>
<thead>
<tr>
<th>Shape</th>
<th>Segment Name</th>
<th>Segment Length</th>
<th>District Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>PolyLine</td>
<td>Segment #1</td>
<td>3.63</td>
<td>CBD</td>
</tr>
<tr>
<td>PolyLine</td>
<td>Segment #2</td>
<td>2.93</td>
<td>Urban</td>
</tr>
<tr>
<td>PolyLine</td>
<td>Segment #3</td>
<td>3.25</td>
<td>Sub Urban</td>
</tr>
</tbody>
</table>

After the achievement of the two previous preparatory steps, the built-in GIS tool named "Bus stops allocator" is run in order to allocate the bus stops along the selected transit route, the following flowchart shows the algorithm at which the script is working.
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Fig. 2. Flowchart Showing The Algorithm Of The Bus Stops Allocator Script.

Figure [3] shows the bus route after allocating the bus stops on it using the bus stop allocator. A total number of 45 bus stops were allocated as follows: 21 bus stops were allocated on the first segment [CBD] with a typical stop spacing equal to 180 m, 13 bus stops were allocated on the second segment [Urban] with a typical stop spacing equals to 230 m, and finally 11 bus stops were allocated on the third segment [Suburban] with a typical stop spacing equals to 300 m.
4- ADOPTED RASTER APPROACH TO CHECK THE SUITABILITY OF BUS STOP LOCATIONS

In fact, the current stage of research can be viewed as a part of ongoing research where the GIS concept is applied to various related problems of interest to our research program [7] & [8]. However, the bus stops are placed [so far] regarding only the stop spacing criterion, but the final decision on selecting a bus stop location is constrained by several critical spatial restrictions which require on-site evaluation. The most critical factors in bus stop placements are safety and avoidance of conflicts between the bus stop location and both the road network and the land use system that would otherwise impede the traffic flow.

Using the benefits of the spatial analysis GIS functions, a raster GIS approach is invented regarding various spatial restrictions that represent constraints to the bus stop placement. The idea behind the approach is that all the ground surface is considered suitable for placing a bus stop except those locations which are constrained by a spatial constraint, as they are either not safe or impede bus, car, or pedestrian flows. Raster data representation is selected for modeling this approach, as the ground surface is considered a continuous data type.

Three spatial constraints were modeled for presenting the idea, knowing that any other spatial constraint to the bus stop location can be treated with the same technique. The three modeled spatial constraints are bus routes, roads intersections and area prohibiting the existence of a bus stop. Each of the spatial constraints is modeled in a separate raster data theme which is subdivided into a number of pixels representing the ground surface. A value of 1 or 0 is assigned as an attribute to each pixel showing either its location is suitable for
A vector-raster GIS approach for selecting suitable bus stop locations along urban transit line.

placing a bus stop or not, as a value of 1 is assigned to pixel if its location is proper for placing a bus stop otherwise the pixel is assigned a value of 0.

4.1. Raster theme modeling Route Path Constraint
A bus stop has to be located on the bus route, a raster data model is constructed using the Arc View spatial Analyst in which it models the locations of the bus routes on the ground surface. Where each pixel on the raster that lies on a bus route is assigned a value of 1, otherwise the pixel is assigned a value of 0 as shown in figure [4].

![Image](image.png)

Fig.4. A Raster Theme Modeling The Locations Of The Bus Route On The Ground Surface.

4.2. Raster theme Modeling Roads Intersections (nodes) Constraint
A bus stop location affects the flow and movement of the other vehicles and pedestrians. A well located bus stop can allow passengers to board and alight without the bus significantly impeding or delaying adjacent traffic. As the bus stop has not to be located at roads intersections and to avoid conflicts with the traffic passing the intersection, a raster data theme is constructed using the Arc View Spatial Analyst in which it models the locations of roads intersections on the ground surface. Where each pixel that lies within an assumed circular buffer of 10 m radius from an intersection is assigned a value of 0, else the pixel is assigned a value of 1 as shown in figure [5].
4.3 Raster theme Modeling Area Prohibiting Existence of a Bus Stop Constraint
Placing a bus stop is not always allowed in any place which is on a bus route and far enough from roads intersections. There are many locations which prohibit the existence of a bus stop, a raster data theme is constructed using the Arc View Spatial Analyst in which it models seven imaginary spots at which a bus stop can not be located. Where each pixel that lies within any of the seven spots is assigned a value of 0, else the pixel is assigned a value of 1 as shown in figure [6].

5- Building a Final GIS Raster Suitability Map
After constructing the raster data themes representing various constraints to a bus stop placement and regarding each constraint separately. The Arc View Spatial analyst map calculator is used to add the pixel values of the three constructed raster themes to result in a resultant raster theme having pixels values ranging from 0 up to 3 as indicated in table [2].
Table 2. Pixel Values Description For The Resultant Raster Theme.

<table>
<thead>
<tr>
<th>Pixel Value on the Resultant Raster Theme</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>The pixel location didn’t achieve any constraint (not suitable for bus stop placement)</td>
</tr>
<tr>
<td>1</td>
<td>The pixel location achieved only one constraint (not suitable for bus stop placement)</td>
</tr>
<tr>
<td>2</td>
<td>The pixel location achieved two constraints (not suitable for bus stop placement)</td>
</tr>
<tr>
<td>3</td>
<td>The pixel location achieved all the constraints (suitable for bus stop placement)</td>
</tr>
</tbody>
</table>

After that a suitability map is constructed using the Arc View Spatial Analyst query tool, by searching on the resultant raster theme for pixels that achieve all the constraints (with pixel value equals to 3). The result is then, a new raster theme which represents suitable places for locating a bus stop, which are located on a bus route, far enough from roads intersections and on places that allow the existence of a bus stop as indicated in figure [7].

![Raster Suitability Map](image)

Fig.7. A Raster Suitability Map Showing All The Locations With Pixel Values Equals To 3.

6- APPLICATION ON HOW THE SUITABILITY OF THE BUS STOP LOCATIONS CAN BE CHECKED.

A GIS analysis is performed to portray the relation between the bus stop locations and both the road network and the land use system as, the constructed suitability map is overlain by the theme containing the previously allocated 45 bus stops to show whether the places of the allocated bus stops are suitable for a bus placement or not. A bus stop which lies on a pixel not achieving all the discussed constraints is indicated by a red square, on the other hand, a
bus stop which lies on a pixel representing a suitable place for a bus stop placement is indicated with a green star, as shown in figure [8].

![Map of bus stops and suitable locations](image)

**Legend**
- ★ Bus Stops in Suitable Places
- CBD
- ■ Bus Stops in Unsuitable Places
- Urban
- □ Sub Urban

**Fig. 8. The Suitability Map Overlain by the Allocated Bus Stops.**

The previous overlay analysis shows that 21 bus stops were located in suitable places and the other 24 bus stops were located on unsuitable places. Further, the bus stop spacing between all the stops is considered within range.

## 7. REALLOCATING THE UNSUITABLY BUS STOPS

An Arc View Script named “unsuitably located bus stops reallocator” is programmed using Avenue language to develop a tool capable for reallocating the bus stops which are placed on unsuitable places to the nearest suitable ones, that's in order to minimize altering the bus stops spacing. The following flowchart shows the algorithm by which the script is working.
Fig. 9. Flowchart Showing The Algorithm Of The Unsuitably Located Bus Stops Reallocator Script.

The following figure (10) shows the bus route after reallocating the bus stops on it using the unsuitably located bus stops reallocator, a total number of 24 stops were reallocated and placed on spatially suitable locations.
After running the script, 24 unsuitable bus stop locations were reallocated to end up with 45 bus stops which are all located in suitable places.

8. Concluding Remarks
Several GIS themes are developed in an attempt to tackle the bus stop selection problems along transit line route.
Initially, a vector-based approach is developed to select the locations only considering the spacing factor. Then a more comprehensive, complementary raster approach is developed considering the nature and the surrounding environment for the selected bus stops. Three different raster themes are introduced considering actual path of the transit line, area of the network intersections and possible area restricting the existence of bus stops. An overlap scenario is presented among all developed raster layers to end up with the suitability map. This map is used together with the initially located bus stops to examine the position of each stops along the transit bus line.

9. FUTURE WORK
The pixel addition scenario introduced in the current study makes the present approach an open-ended type of analysis.
Therefore, possible addition of raster layers not considered in the current stage of research is quite clear. In the meantime a weighting scenario can be extended where a pixel can be assigned a positive or negative value according to the newly introduced attributes which could describe the surrounding environment more thoroughly.
REFERENCES


