A GIS for Routing of Oversized and Hazardous Material Carrying Vehicles

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Abstract

The objective of this paper is to document the development of an automatic procedure for routing of industrial freight vehicles such as oversized vehicle and hazardous material carrying vehicles on congested urban transport networks in Geographical Information System (GIS). The use of a network routing procedure within a GIS environment is one of the distinctive features of the proposed work. The study area selected for the present work is Greater Mumbai. As a first step of the work, complete GIS database is prepared in GIS-T software: TransCAD. Two modules namely oversized vehicle routing module and hazardous material carrying vehicle routing module were developed by using the script language (source code) of TransCAD. The objective of the first module is to develop an automatic procedure for routing a oversized vehicle by considering the width of road, type of road, vertical clearance restrictions under flyovers and adequacy of bridges as constraints. The objective of the second module is to find a path having less human exposure along the route. For this purpose two types of buffers are created for each and every link-one is a buffer of severe intensity and second one is of less intensity. The module will find the path having minimum human exposure along the severe buffer area. Finally, these modules are attached to the GIS map so that user can run these modules by selecting the origin and destination nodes with a click of a mouse button and gets the best path satisfying all requirements as output.

Keywords: Geographical Information Systems, Routing of Oversized vehicle, Routing of hazardous material carrying vehicle, TransCAD.

1. Introduction

The Road Transport Officers (RTO'S) has the responsibility of issuing permits for oversize and overweight vehicles using the urban highways. Some of these vehicles transport super heavy loads in excess of 90,000 kg and with more physical dimensions. Figure 1.1 shows a vehicle that is representative of the type of vehicles for which routes need to be generated. The process for finding feasible routes consists of (1) the establishment of a tentative route with adequate width and height clearances; (2) a manual identification of all the bridges along the route; (4) Checking of each bridge to evaluate the adequacy of its structure; and (5) identification of an alternative route when at least one requirement is not satisfied (Roberto et. al, 1999).

Hazardous materials (hazmat) comprise explosives, flammables, oxidizing substances, poisonous gases, and radioactive materials. By definition, they can be extremely harmful to environment and to human health, since exposure to their toxic ingredients may cause injury or death to plants, animals, and humans (Karkazis, 1995).

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Figure 2.1 A over sized and over weight vehicle

Their negative effects are an apparently inevitable consequence of industrial processes dictated by the life style of a modern society. It follows that transporting these materials, often in populated or environmentally sensitive areas, is also inevitable. Reducing the potential negative impacts of transporting hazmat is an important task faced by communities, governments, hazmat producers and shippers. Routing hazmat wisely and designing safer networks for doing so are powerful means to achieve this end. A fundamental requirement of route design and assignment is to minimize the risk imposed by shipments traversing each link in a network (Jianjun, 2000). The procedure for finding the route consists of (1) Create buffers of specified widths (based on the type of chemical) for severe and less intense areas to all links. (2).Generate all available paths between origin and destination and find the total population coming in the buffer area by overlay. (3). Select the path which is having minimum population exposure. (4). Show the total population coming in each buffer (Mark et. al, 1998).

Considering the complexities in developing, updating, managing and processing of the transport network data, there is an urgent need to adopt new concepts of information technology in design and development of information system for efficient transportation network management. One of the software tools which satisfy the requirement is Geographical Information System (GIS). GIS provides the hub technology for planning, deploying, operating, and optimizing transportation systems. The use of GIS is increasing day by day. This increase is due to cheaper and faster data collection tools and the availability of high-quality commercial data sets. Transportation professionals can use GIS to integrate mapping analysis into decision support for network planning and analysis, vehicle tracking and routing, asset management, inventory tracking, route planning and analysis, and everything in between. After observing the advantages of GIS, the modules are developed in GIS environment (Mark, 1993).

To make the modules more realistic, Greater Mumbai was selected as the study area for present analysis. To develop the routing procedures for the study area, we have to build a GIS map along with network database. After completing map and database in GIS, modules were developed and attached. These modules are written in GIS developers Kit (GISDK) code and attached to the database using GIS-T software TransCAD. There are three ways to develop

applications in GISDK such as Add-ins, Custom application and server applications. For the present work, modules are coded as Add-ins in GISDK. These are known as the resource files. Then the resource files are installed and complied in the GISDK custom application environment so that any layman can also use these facilities with minor introduction. On running the above developed macros, the macros will prompt the user to enter the required details through dialog boxes and gives the result.

2. STUDY AREA AND GIS DATABASE PREPARATION

Study area

Greater Mumbai was selected as study area for present work. It includes geographical limits of Greater Mumbai (Up to Dahisar in the North, Mulund in the North-East and Airoli and Vashi in the East). The study area lies between 72E and 78E longitudes.

Zoning System

The zoning scheme for this study has been designed using 227 electoral wards of Greater Mumbai (refer Figure 2.2). Till now 88 Census sections have been used as zoning scheme since 1961 in all previous studies. The present study is designed with the help of 227 electoral wards, as the zones are very big and not homogenous in previous studies.

Network layer

The network built at 1 in 10,000 scales was obtained from a GIS company named Mappls. All major and minor roads which are having width more than 5 mts are considered for the analysis (refer Figure 2.3).

2.1 Preparation of GIS database

To perform routing analysis in GIS, different layers like zones, network layers with appropriate attributes are required. Present section describes the procedure involved in preparing GIS database.

Zonal layer and its attributes

The election commission of India has adopted 227 electoral wards in Greater Mumbai. But the census of India adopted 88 census sections. The zonal areas of these 88 census sections are very large. In all major projects conducted in the study area are with these 88 census sections. For the present study 227 zonal system is adopted by minimizing the area of each zone. Finding the exact population exposure in the buffer area is not possible, as the data regarding the exact building foot prints is not available. So, the population coming into the specified buffer is calculated by assuming the population in the zone is uniformly distributed. To minimize the error which is going to come by this approximation is minimized by dividing the area into smaller zones as shown in Figure 2.2.

Transport Network

The road layer in digital format has been obtained from GIS Company Mappls. This layer was made with poly lines without following the link, node and chain concepts. The complete layer with 9200 links and 5200 nodes was digitized over the Mappls layer in TransCAD by using map-

editing tool. The road network inventory carried out during the MMS identified 19 link types of road links. All these link types were appropriately recorded while coding the road network and preparing link list for basic network of study area. The widths of links are calculated based on these link types. The ID's of link types are given in Table 2.1 While digitizing the road layer, node layer is developed automatically. Network attribute Table prepared in TransCAD is shown in Figure 2.4

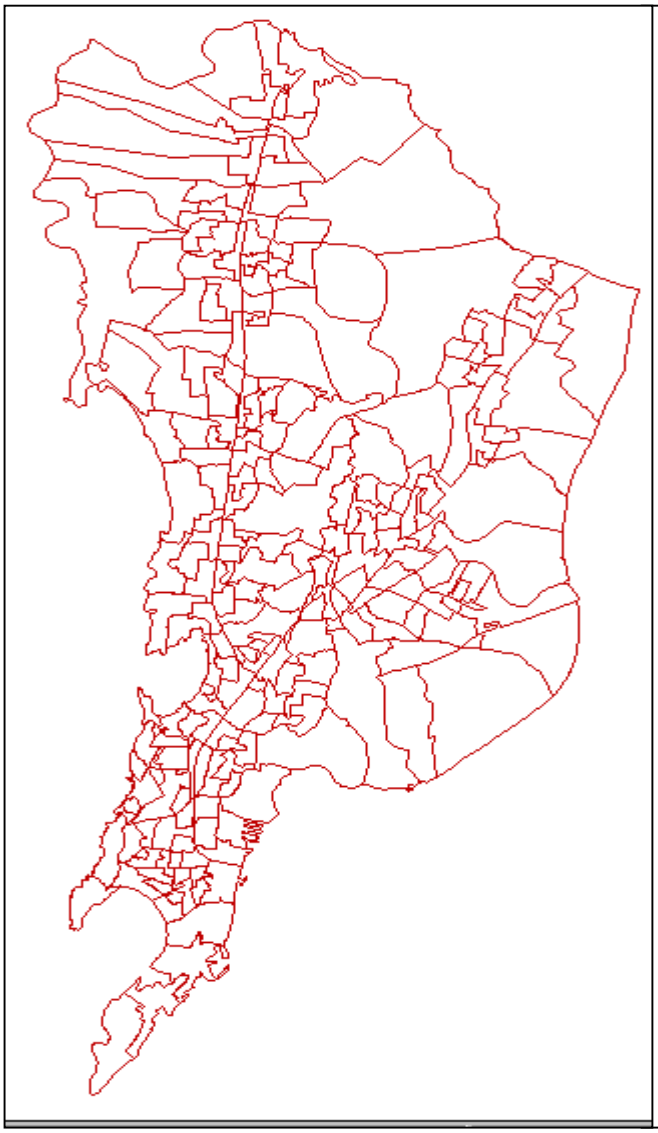
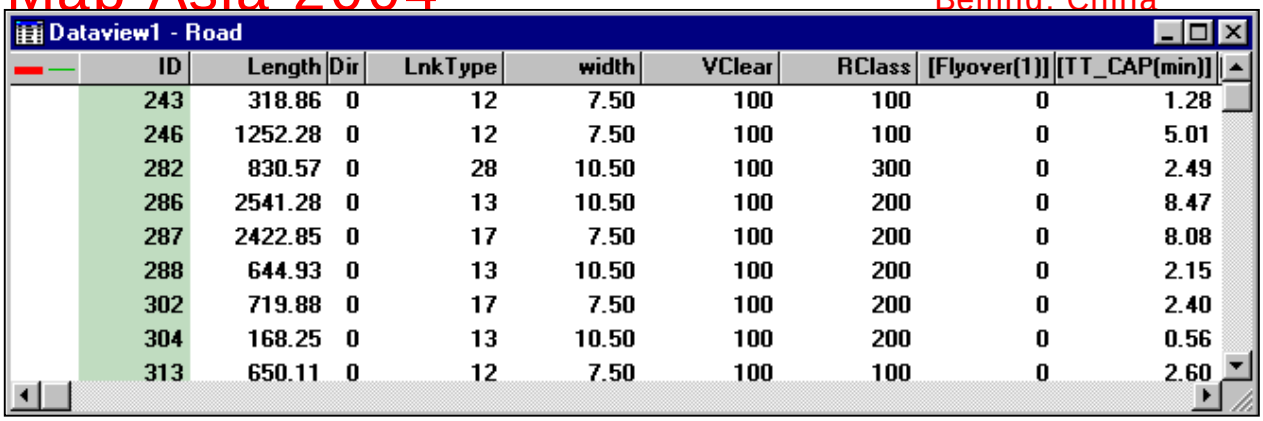


Figure 2.2 Zonal Layer

Figure 2.3 Network Layer



Dataview1 - Road

ID	Length	Dir	LnkType	width	VClear	RClass	[Flyover(1)]	[TT_CAP(min)]
243	318.86	0	12	7.50	100	100	0	1.28
246	1252.28	0	12	7.50	100	100	0	5.01
282	830.57	0	28	10.50	100	300	0	2.49
286	2541.28	0	13	10.50	100	200	0	8.47
287	2422.85	0	17	7.50	100	200	0	8.08
288	644.93	0	13	10.50	100	200	0	2.15
302	719.88	0	17	7.50	100	200	0	2.40
304	168.25	0	13	10.50	100	200	0	0.56
313	650.11	0	12	7.50	100	100	0	2.60

Figure 2.4 Network Attribute Table

Table 2.1 Different Types of Links in the Network

Link type	No. of lanes	Divided/ Un divided	Oneway/ twoway
1	One Lane	Undivided	One-way
2	Two Lane	Undivided	One-way
3	Three Lane	Undivided	One-way
4	Four Lane	Undivided	One-way
5	Five Lane	Undivided	One-way
6	Six Lane	Undivided	One-way
7	Three Lane	Divided	One-way
8	Four Lane	Divided	One-way
9	Six Lane	Divided	One-way
10	One Lane	Undivided	Two-way
11	Two Lane	Undivided	Two-way
12	Three Lane	Undivided	Two-way
13	Four Lane	Undivided	Two-way
14	Five Lane	Undivided	Two-way
15	Six Lane	Undivided	Two-way
16	Three Lane	Divided	Two-way
17	Four Lane	Divided	Two-way
18	Six Lane	Divided	Two-way
19	Eight Lane	Divided	Two-way

3. Oversized Vehicle Routing Module

The objective of this module is to develop a procedure for routing of oversized vehicles by considering width of vehicle, type of road that is to be avoided and height as inputs and giving

a graphical output depicting the path to be followed by the vehicle on the network. The main emphasis of this module is to provide a best route for an overweight and oversized vehicle in a heavily congested and fully constrained network like Greater Mumbai. The procedure automatically identifies all links on a specified route and evaluates the adequacy of the links for vertical and horizontal clearance requirements of a given vehicle. The process for finding feasible routes consists of:

1. The establishment of a tentative route with adequate width and height clearances.
2. Identification of all the bridges along the route for vertical clearance.
3. Check whether width constraint is satisfied or not.
4. Check for type of road.
5. Identification of an alternative route when at least one requirement is not satisfied.
6. Finally select the shortest path satisfying all requirements.

The procedure adopted for present module was clearly explained in Figure 3.1. The details link attribute table created in TransCAD was shown in Table 3.1.

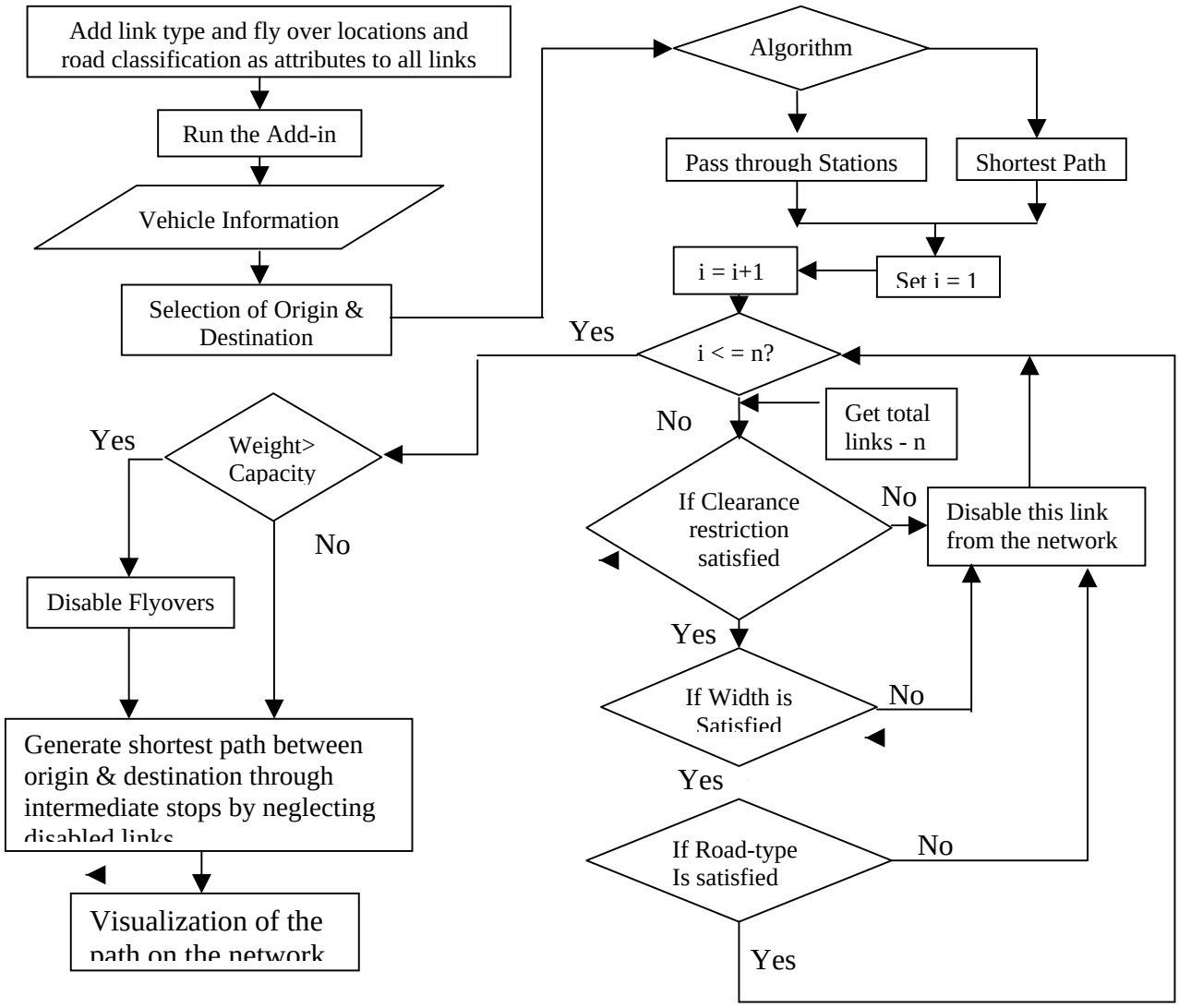


Figure 3.1 Flow Chart of Oversized Vehicle Routing Module

Table 3.1 Link Attribute Table

Link Attribute	Description	Attribute Values
Length	Length of the road link	Generated by TransCAD
Flyover(1)	Flyover identification	1-links going under flyover 2- links going over flyover 0- no flyover
RClass	Road class	300 – Major arterials 200 - Minor arterial 100 - Streets
Width	width	Calculated based on Link characteristics table
Vclear	Vertical clearance	6m – links going under flyovers 90m – links going over flyovers 100m- links not connected with flyover

3.1 Results

When ever the user runs this module, it will open a dialog box containing blank spaces to enter the details of the vehicle like height, width and weather weight is more than bridge capacity or not etc. After entering these values, it will show the messages indicating the details entered. Then it will prompt the user to select his origin and destination with a click of a mouse and immediately it will generate the path satisfying all the requirements. If there is no path satisfying the requirements, a message was given by indicating the same. The final results are shown in Figure 3.2 and 3.3. In Figure 3.2 the programme was asked to give a path across a flyover. It generated a path as shown by satisfying all the requirements. In Figure 3.3 a path between Thane and Sewri was asked for a 5 m width vehicle having problems with weight and clearances. The path generated by programme was logical as it is avoiding enroute bridges and minor routes.

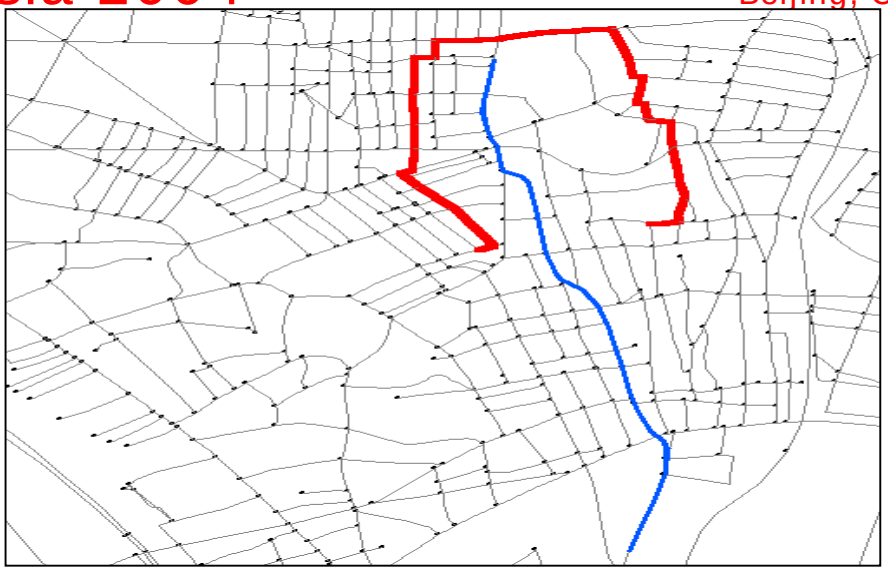


Figure 3.2 Results of Oversized Vehicle Routing Module

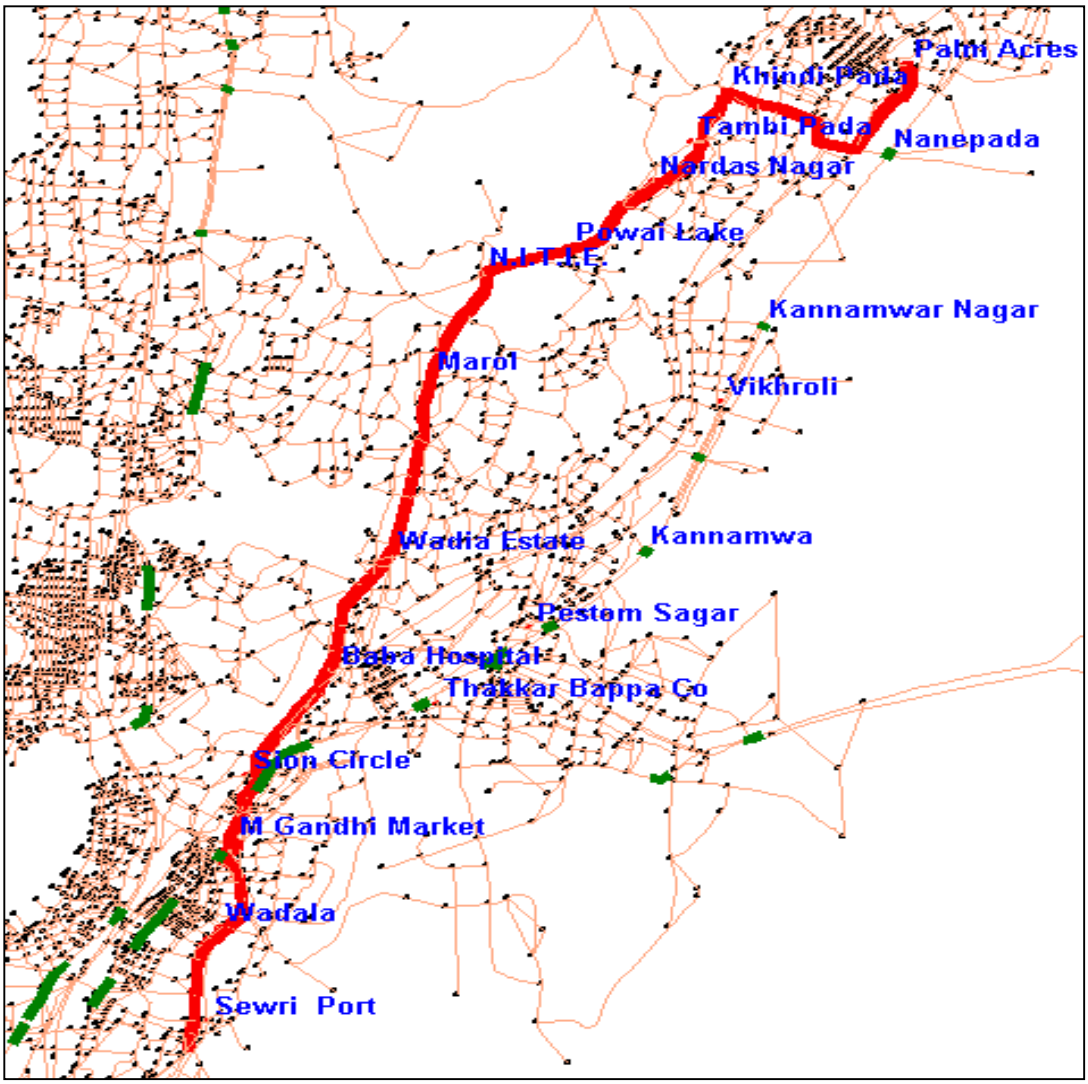


Figure 3.3 Results of Oversized Vehicle Routing Module

4. Hazardous Material Shipment Module

The main emphasis of this module is to provide a route for the vehicle which is carrying hazardous or radioactive material. While routing such type of vehicles, we have to consider the possible risk of any spills occurring from these vehicles. If any accident/spills occur from these vehicles, it will cause lot of damage to human life as well as properties. Such occurrences cannot be avoided, but we can minimize the damage by allowing those vehicles on a path, which has minimum population exposure along it in a selected band width. The damage to property along the road side could be minimized by not allowing the vehicle to pass through an area with valuable property lying along the path. Detailed data with building foot prints is not available at present to calculate exact amount of population coming into the buffer area, so it is assumed that the population is distributed evenly in the zone. The procedure for finding the route consists of 1) Create buffers of specified width to all links. 2) Generate all available paths between origin and destination and find the total population coming in the buffer area. 3) Calculate the total population coming into the buffer area by overlay analysis. 4) Select the path which is having minimum population exposure.

The main problem for this module is creation of buffer for the links. TransCAD will create buffers but there is a problem of double counting at all end points, now we will discuss about what is double counting, why it occurs, and how to rectify it. Figure 4.1 shows how TransCAD will create buffer for each link. At each end point the buffer is counted twice if we use the buffers created by the TransCAD, while calculating total population along the selected path, as shown in the figure. To rectify this problem, we have to remove half node buffer for each end point. This is best explained with the help of a diagram in Figure 4.1. A separate module was written and is attached to the original module to perform this process. The following algorithm will discus in brief about how to make correction and do analysis. This algorithm is shown in the form of flow chart in Figure 4.2

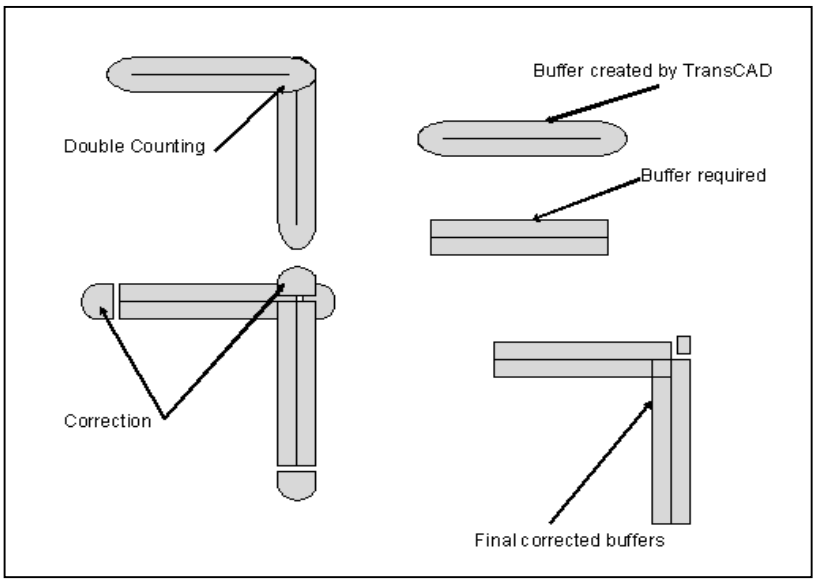


Figure 4.1 Buffer correction

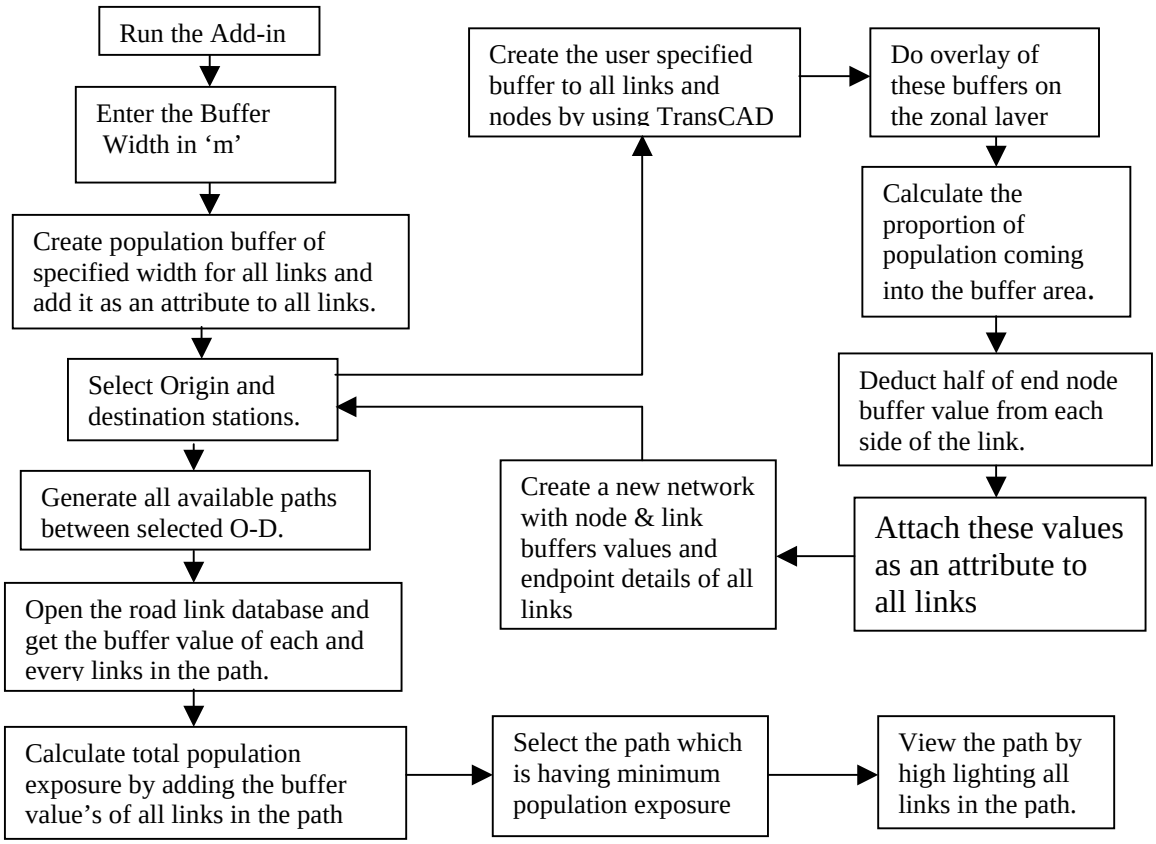


Figure 4.2 Flowchart of Hazardous vehicle routing module

4.1 Results

When ever the user runs the module, it will prompt to give the severe and less severe buffer values based on the type of chemical carried by the vehicle. Then the user will get an option to select any origin and destination. The module will generate the path having less human exposure compared to other paths. Along with the path it will give the total population coming in the specified buffer also. The results of this module were shown in Figure 4.3. Even though there are several shortest paths between origin and destination, it generated the path going through un developed area.

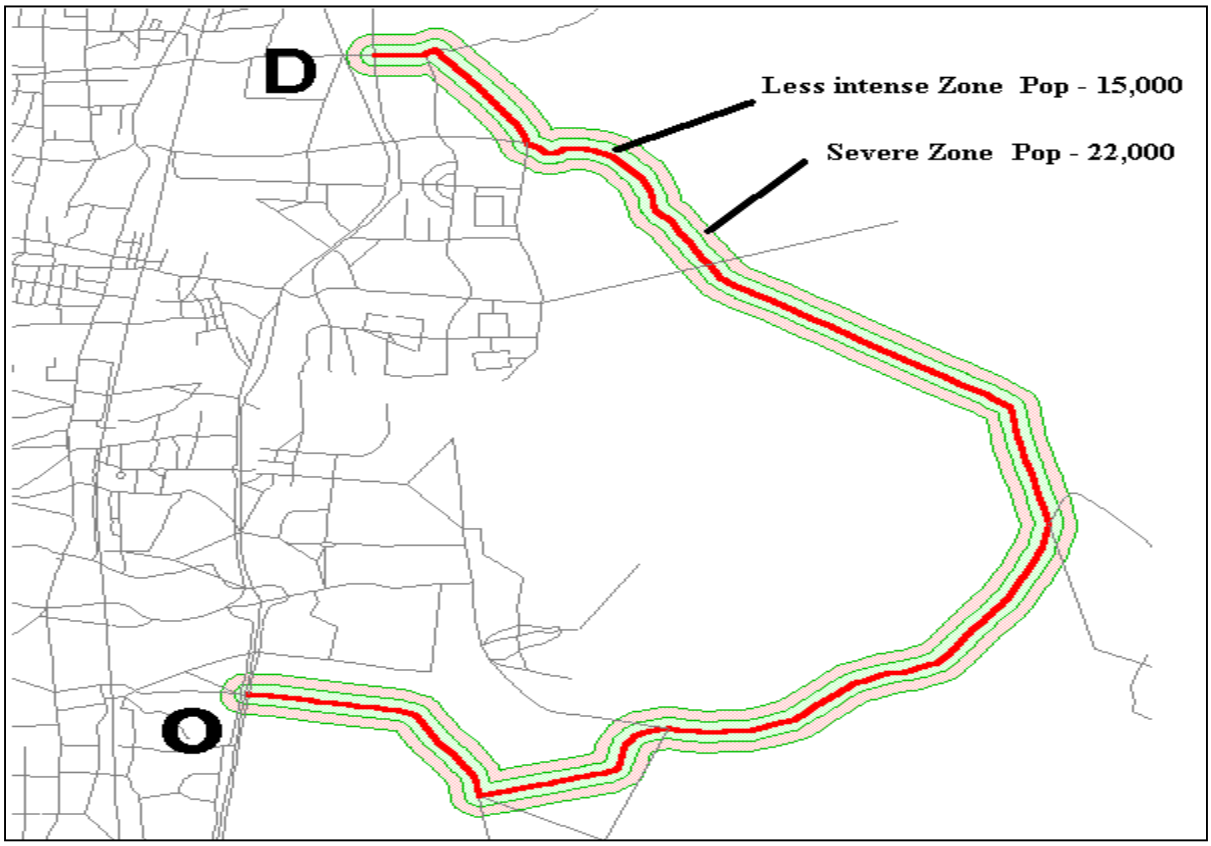


Figure 4.3 Results Hazardous Material Shipment Module

5. Summary and conclusions

In major metropolitan areas, goods traffic need special attention for safe movement. Several measures are carried out to regulate and control their movements by manual methods. The scientific study carried out to update the road conditions and understanding the ability to accommodate the vehicles with specific constraints viz. over size, hazardous material carrying is an useful example in the area of disaster management. This paper discussed the implementation of an automatic procedure for the routing of overweight, oversized vehicles and hazardous material carrying vehicles using GIS based network routing procedure. Finally these modules are attached to the study area in GIS platform using script language of TransCAD. It is found that they are working properly so that any end user can use them to solve real time problems.

6. References

1. Jianjun Zhang, John Hudson, Erhan Erkut. (2000), “Using GIS to assess the risks of harzardous materials transport in networks” European Journal of Operational Research , 121,pp 316-329.

2. Karkazis, J., Boffey, T.B. (1995), "Optimal location of routes for vehicles transporting hazardous materials ", *European Journal of Operational Research 86*, (1995) 201-215.
3. Mark, Abkowitz., Paul, Der-Ming, Chen., And Mark, Lepofsky. (1998), "Use of geographic Information Systems in Managing Hazardous Materials Shipments", *Transportation Research Record* 1261, TRB, National Research Council, Washington D. C.,35-43.
4. Mark, Lepofsky., Mark, Abkowitz., and Paul, Cheng. (1993), " Transportation hazard analysis in integrated GIS environment", *Journal of Transportation engineering*, ASCE, 119(2), 239-254.
5. Roberto, Osegueda., Alberto, Garcia-Diaz., Suleiman, Ashur., Octavio, Melchor., Sung-Ho, Chang., Cesar, Carrasco., and Ahmet, Kuyumcu. (1999), "GIS-based network routing procedures for overweight and oversized vehicles", *Journal of Transportation Engineering*, ASCE, 125(4), 324-331.