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A TRANSPORTATION DECISION SUPPORT MODEL FOR RESIDENTIAL SITE SELECTION

Sharareh POUREBRAHIM
Arak University, Arak 38156-8-8349, Iran
sh_pe@yahoo.com

Mehrdad HADIPOUR
Arak University, Arak 38156-8-8349, Iran
mhadipour50@yahoo.com

Abstract
This research develops a transportation decision support model, in GIS environment using a combination of mathematical and spatial information to help in the process of residential site selection in urban transportation network. The most important conclusion is selection of interactively their site within accessible and non-polluted area. Urban transportation planning includes several economical, technical and environmental criteria. Several tasks are involved in the transportation planning phase, and important one of them is the understanding of the present statue and possible improvement and development of landuses. Information on landuse is required at different stages of planning to set the direction, goals and policy formulation of landuse plans. Spatial tools such as GIS, RS and GPS can be useful to arrange this information. Along urbanization growth, there is an increasing commercial, residential and transportation infrastructure development. This development normally involves to negative impact on the environment, one of these impacts is due to location of residential landuses in unsuitable areas, and this impact should be removed by consideration of two important infrastructure elements of urban transportation: accessibility and air quality. The use of GIS in selection process for locating a residential landuses in a suitable area will reduce the time and enhance the accuracy. This paper highlights a method.
Keywords: Urban transportation, GIS, accessibility and air quality

1. INTRODUCTION

In recent years, the application of GIS has rapidly grown in transport planning. However, most of these applications are limited to shortest path analysis, simple street mapping, and vehicle routing studies (Suxia and Xuan, 2000). For transport planning and policy evaluation, processed information is required, which is beyond the functionality of current off-the-shelf GIS. In the other hand the emergences of air quality and accessibility as major urban transport problems have been considered by many transportation experts. A review of these considerations shows several modeling studies. Various factors and performance evaluation and comparative assessment studies have also been discussed. There is a lack of full integration of potential models within the GIS environment although potential models have been extensively used by accessibility-based measures (Suxia and Xuan, 2000). Investigation of accessibility and air quality has never been considered simultaneously and their interactions have been ignored. This study has among others addressed this issue. Structure of urban transportation networks is one of the key elements in the air quality and accessibility analysis. The roadway type provided should vary according to the function of that roadway in the overall network. Work undertaken above concept over previous years has lead to the developing road hierarchy (Brindle, 2003). Air quality and accessibility should be incorporated in urban land-use development (Alpopi and Colesca, 2010). Also the improvement of accessibility is one of the criteria considered in the transportation evaluations (Gutierrez et al., 2010). With respect to importance of residential land-use, the proximity of residential zones to urban transportation network to connect other land-uses is important to enhance urban accessibility (Cura, 2003) along avoiding to air pollution. It is desirable that an urban transportation network creates friendly environments for residential landuse in the fields of air quality and accessibility. This paper presents the use of spatial methods to make a reasonable relationship between air quality and urban networks development regarding transport accessibility. During this process a good pattern has been found for detection of location of urban transportation networks and urban landuse. This paper attempts to use spatial methods for mapping and finding suitable designation of urban transportation network to support residential land-uses in urban transportation system of study area. The work is to investigate the best accessibility and air quality of residential area. The study area covers Petaling Jaya metropolitan center (MPPJ), located in the Petaling district of the state of Selangor, Malaysia. Public transportation is provided by bus companies as well as the Kuala Lumpur Putra light rail transit system, which extends slightly into PJ. It has also one access point to the national highway system – the North-South Expressway. Urban landuses of MPPJ is shown in Figure 1. It was chosen as the region has the following characteristic to fit with the developed model and environmental factors.

- Several choices of routes to access to important public facilities. The municipal itself is regarded as a metropolitan center with about 450,000 residents within 51.4 sq.km and has high number of colleges, shopping center and hotels
- Higher transportation activities
- Efforts to maintain its "garden city" concept are going on.
- Efforts on establishment of well-developed infrastructure and excellent investment opportunities
- Existence of small industrial area

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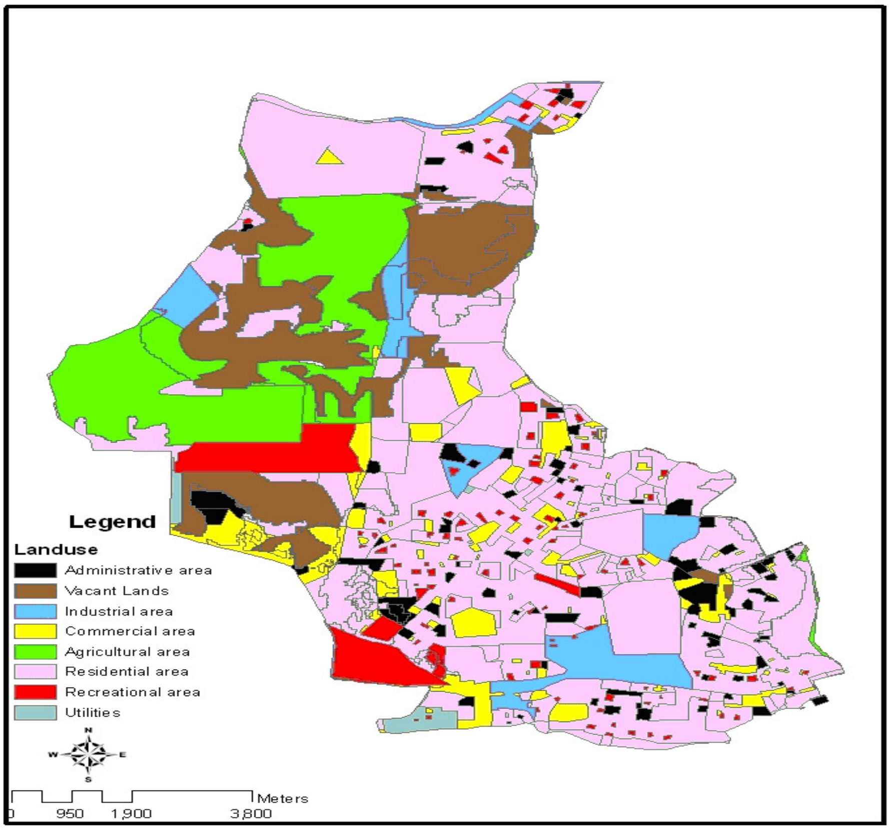

FIGURE 1 - URBAN LANDUSE MAP OF THE STUDY AREA

Spatial process, as a powerful tool for mapping, can be used to make reasonable relationships between urbanization elements (Manole et all, 2011). In the other hand air quality and urban transport accessibility are two main issues that rise in the urban transportation planning, during urban development. Different factors with different levels of influence and several degree of importance were set as criteria in these issues. Therefore, it is useful to use spatial process for mapping and analyzing importance of accessibility in the development of urban networks, due to the increase of the impact of transportation to environment particular air pollution.

2. RESEARCH APPROACH

The work undertaken includes using Geographic Information System (GIS) as visualization platform for analyzing urban planning by focusing on accessibility and air quality of residential zones.

2.1. Air Pollution Indicators in Transportation Planning

There are some elements which are emitted by vehicle transportation (Rodrigue et al., 2006). Table 1 shows the statistics of emissions of air pollution elements attributed to transportation. It shows main contribution of transportation in producing CO (particularly in urban area).

TABLE 1 - RATES OF AIR POLLUTION EMISSIONS BY TRANSPORTATION

Element	Emission (%)
Carbon monoxide	70-90
Nitrogen Oxides	45-50
HC/VOC	40-50
Lead Pb	30-40
Carbon dioxide in developed countries	30
Carbon dioxide worldwide	15
Particulates	25
CFCs	20
Sulfur dioxide	5

Source: Rodrigue et al. (2006)

Contribution of transportation in producing CO also has been emphasized by many experts. (Asatar and Nair, 2010; Haunghton et al., 2003; Meszaros et al., 2005; Chan et al., 2002). With respect to above explanation about importance of carbon monoxide in urban transportation, this element has been considered as indicator of transportation air pollution in this research.

2.2. Traffic-related Air Pollution

This research provides the understanding necessary to assess the sustainability of urban road transport in terms of exposure to traffic-related air pollution by describing combination and measurement with modeling of the movement of air, vehicles, and vehicle exhaust emissions.

Since a clear solution to the general finite line source problem is not available, it should be approximated as a series of point sources. This point source approximation significantly increases the amount of required time to run an atmospheric dispersion model for cases where there are large numbers of line sources and/or area sources. Concentration of pollutant is significantly elevated under low wind speeds (worst case scenario). This condition may be due to the fact that wind data in real world are collected at meteorological stations, which do not represent effects of moving vehicles or street canyons. These terms and conditions design a spatial-base scope for this research.

2.3. Air Pollution Models and Research Scope

Mathematical models are widely used to evaluate air quality near the roadways. Many models have been applied to describe the pollutants from roadways. These models provide theoretical estimations of air pollution levels as well as temporal and spatial variations for present, proposed and estimated conditions. The estimates are actually functioning meteorology, highway geometry, and downwind receptor location. A review of the air pollution studies shows several modeling studies in the domain of analytical modeling – deterministic mathematical, numerical and statistical models. With respect to

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mentioned scopes and elements, various model performance evaluation and comparative assessment have been discussed. Regarding the assessments the model developed by Hadipour et al. (2009) is selected to be used in this study.

2.4. Identification of Non-Polluted Area

Categorizing of non polluted areas was based on emitted transport pollution using some options such as buffering, dissolve, and union of "spatial analysis toolbox" in ArcGIS 9.1. These options are powerful tools to perform various spatial operations of all types of vector data. These processes, as shown in Figure 2, include:

i. Creating buffer zones for each road type according to determined values of Dmin (minimum Euclidean distances from each road type to avoiding air pollution).

ii. Overlaying buffer zones maps and creating a new map (Polluted Area)

iii. Generating a new map (non-polluted area) by applying unselected option on map of polluted Area - The minimum Euclidean distances from each road type to avoiding air pollution (Dmin) is calculated using following model (Hadipour et al., 2009).

$$D_{\min} = 8.68 \frac{\Delta h^{1/2} Q^{1/4}}{U^{1/4}}$$, where

Δh= plume rise of CO from exhaust of vehicles (m)

U= wind speed (m/s)

Q= Average total car emission rate (g/sec)

The results are presented in Table 2.

TABLE2 - MINIMUM EUCLIDEAN DISTANCE (TO AVOIDING AIR POLLUTION)

Road type	Dmin
Local	11.4
Collector	10.6
Sub-arterial	10.2
Arterial	9.6
Highway	7.9

Applying parameters of this model (plume rise of CO from exhaust of vehicles, wind speed and Average total car emission rate) is possible by some formulas (such as Wayson et al., 2000; Li, 1998), standards and guidelines.

During above mathematical process, some important constant values should be determined for study area, by surveying, historical data and references. For MPPJ they include:

Ts = Average exiting gas temperature from exhaust = 395° k

Vs =Average CO exiting velocity from exhaust = 0.4 m/sec

Ds =Exhaust diameter = 0.06

Average annual atmospheric temperature for MPPJ = 301° k

Average annual atmospheric pressure for MPPJ= 1000 mb

Average calculated car emission rate for one car in MPPJ = 0.17 g/100m

Lp= Grid dimension size for urban air pollution study =100m (White. R 2000)

Cm = Average one vehicle's normal space-time usage = 7.3m2

Standard Pollutant (CO) during averaging time (8-hour) =10 mg/m3 (MMWR 1997)

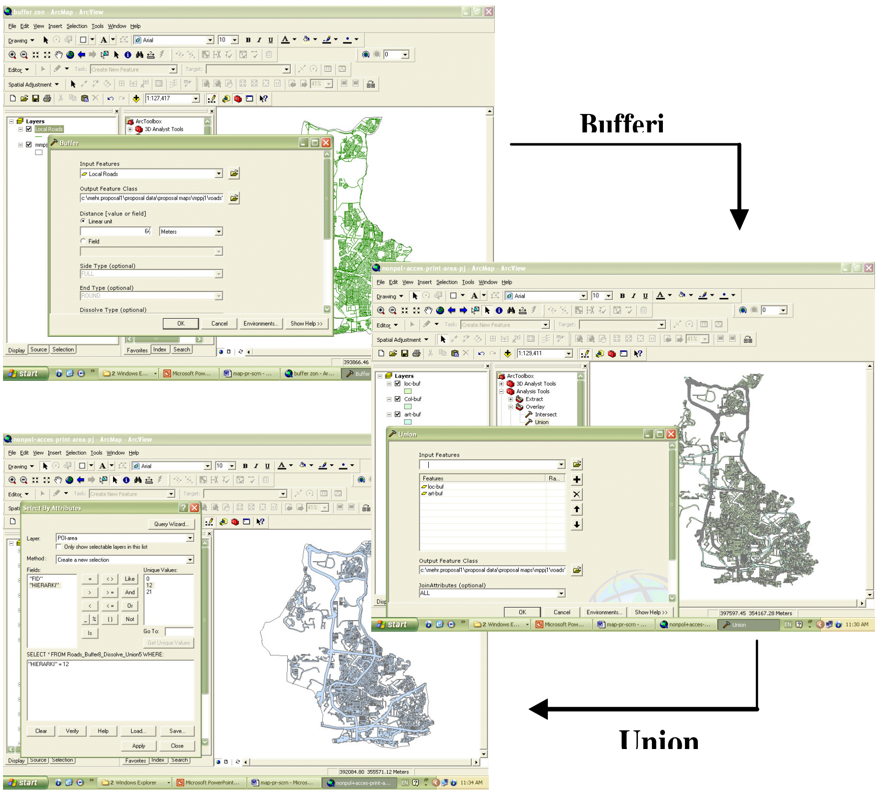

FIGURE 2 - GEO-PROCESSING STEPS TO CREATE NON-POLLUTED AREA

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The W (road width) and Vt (car speed in the origin) were determined based on Table 3 (Guideline and geometric standards on road networks, JPBD 1998).

TABLE 3 - ATTRIBUTE FOR ROAD TYPES

Road hierarchy	Average width (Carriage width)	Average speed
Local	9 m	9 m/s
Collector	11 m	11 m/s
Sub-arterial	16m	14 m/s
Arterial	20 m	17 m/s
High way	30 m	28 m/s

2.5. Functions of Accessibility

Accessibility is the core concept in this study, which is mainly drawn from literature on transportation planning, engineering, and economy. Accessibility is the potency to reach opportunities (including activities, desired goods, services and destinations). Accessibility plays an important role to determine the costs of moving people and goods between points in space. From the transportation planning point of view, accessibility is defined as a function of distance and impedance. If efficiency of transportation system is assumed perfect, distance can be defined in Euclidean shape as the shortest means of getting from point A to point B (Gimpel and Schuknecht, 2003). Accessibility and location are fundamental concepts in the spatial urban planning. In the context of this study, accessibility refers to an area where people can travel by private transportation. Residential zone in the private based transportation systems is a place where people can start their journey to other places (commercial or administrative areas); accessibility is not considered as a transportation activity only, rather it is considered an urban activity comprising of transportation links, residential, commercial and other urban landuses. Functions of accessibility are properties of passage points regarding their geographical locations. Accessibility measurement adaptation should cover major functions of the accessibility: attraction, distance, travel time, transport and cost.

2.6. Characteristics of Accessibility

The characteristics of accessibility depend on transportation and urban development policies. However, there is a general set of purposes for characterizing accessibility. It is expected enough people can access the public facility without causing much time delay. Presence of a large number of people is related to specific activities, especially commercial activities; therefore these activities can be considered as attraction criteria. Again, since it increases the overall accessibility of the area, it becomes a desired land for offices and houses.

2.7. Urban Landuse and Accessibility

Urban landuse and accessibility are often incorporated in urban development. The main concept of the landuse-transportation relationship has been analyzed by consideration of the spatial interaction (He et.al., 2011). The proximity of an urban landuse to a completed urban transportation network, connecting to other landuses and reducing the dependency on automobiles, is important to enhance urban accessibility (Cura, 2003). Geographers conceive accessibility as a measure of the spatial distribution of facilities adjusted for the desire and the ability of people to access a facility or activity (Lotfi and Koohsari, 2009). Based on general experiences commercial and administrative land uses can be considered as main destinations in urban transportation planning. The access to them (travels from home to administrative and commercial area) should be done with less travel time covering simultaneously longer distance. Hence, the accessibility to administrative and commercial area normally includes several spatial considerations. A good commercial and official destination is a station that meets good accessibility for the maximum number of residents. According to general access modes, an accessible destination should cover enough commercial and administrative surfaces (attractions), which can be accessed within acceptable time from residential areas. In a major urban transportation planning, the primary zone or walking access zone can be ignored. The access time depends on the access mode (public mode or private mode) and also depends on the road network. Cities in Malaysia, with the exception of Kuala Lumpur, do not have a mass transit system and also have little or no integration of various modes of public transport such as buses, taxis, riverboats, and passenger vans. Therefore private mode is considered as access mode (JICA, 2003).

Landuse accessibility must be taken into account to determine travel time rating, which is possible by averaging required reasonable travel time to reach common destinations by a particular mode. In general, based on definition of Victoria Transport Policy Institute (2005), a good accessibility is considered in this study as a potential path from origin to destination, within which the average access time to commercial and residential area should range between 10 and 30 minutes. It is assumed that most private users will not make a feeder-car ride more than an average of 20 minutes.

2.8. Determination of Accessible Area

To implement this step, the “Network Analyze” extension of ArcView was used. It uses the elements of transportation network database to design a suitable way. It can also develop suitable models to address transportation problems to find the best answers. Stations were selected based on the covering perimeters of administrative and commercial land uses and the reaching time was taken as 20 minutes. The process is shown in Figure 3.

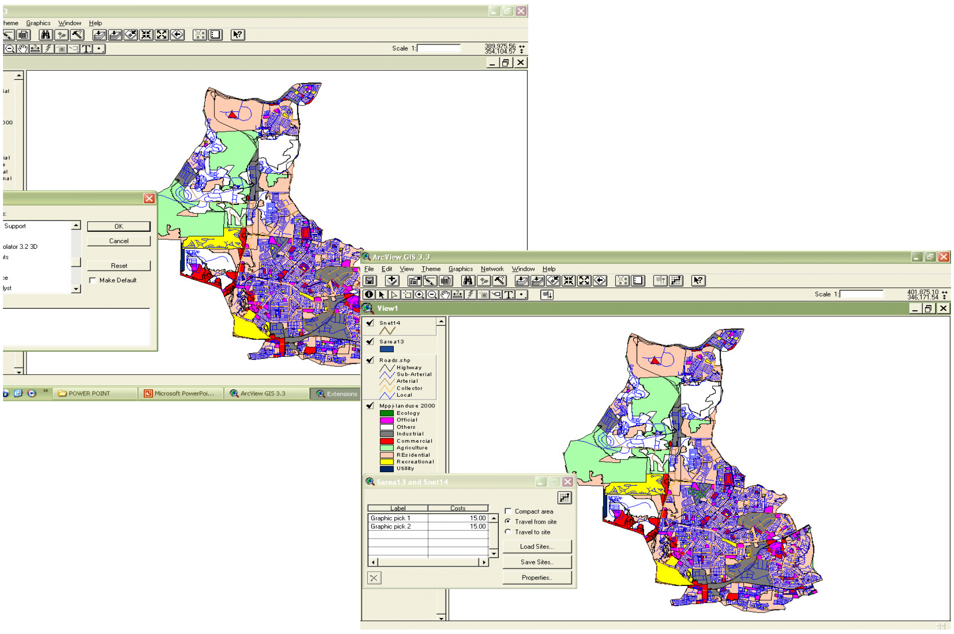

FIGURE 3 - SPATIAL PROCESS OF DETERMINING ACCESSIBLE AREA

With reference to accessibility interpretation (Figure 4), stations were selected based on the covering perimeters of administrative and commercial landuses and the reaching time were taken as 20 minutes.

Functions	**Conceptual Interpretation**	**Application of Quantitative Parameters**
Distance & Time travel to Nearest facility	Average Car speed in path	Vehicle speed based on Road types
Attraction of nearest facility	Accessible Commercial and official area	Surface area of Nearest commercial and administrative area
Traveling Comfortability	Desirable Access time	20 minutes

FIGURE 4 - QUANTITATIVE INTERPRETATION OF ACCESSIBILITY

Considerations were given to residential areas which have better accessibility from different transportation paths. The suitable locations for good accessibility were selected through a decision process covering two steps. Firstly, suitable criteria of accessibility were considered in terms of present and future demands and Environmental

Sustainability. Secondly, the suitability of each criterion from step 1 was assessed and identified using quantitative parameters.

2.9. Spatial overlaying maps for determination of adaptability:

Overlaying maps was done to find adaptability of the residential land use zone map with considerations of transportation planning (accessibility and air pollution). The option - intersect of "Analysis toolbox" of ArcGIS was used. An important and useful function of this option was utilized several times. This function uses the output of one procedure as input to another procedure. The process was done in following stages:

- Overlaying maps of Non-Polluted Area and Accessible Area to create map of Non-Polluted and Accessible Area (Figure 5)

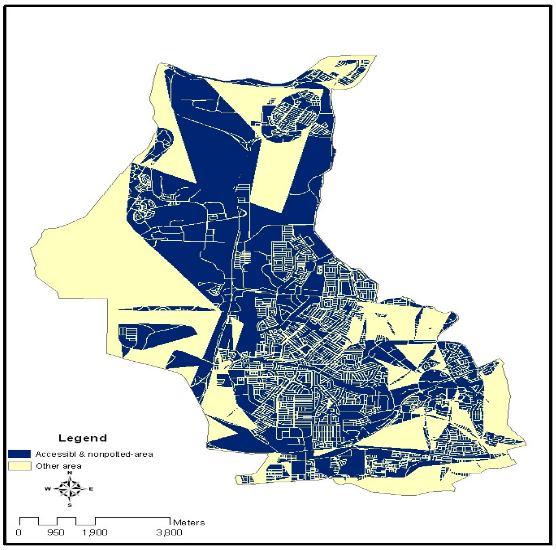

FIGURE 5 - POTENTIAL AREAS (ACCESSIBLE AND NON-POLLUTED AREA) FOR DEVELOPING RESIDENTIAL SITE

- Overlaying created map from first stage on map of Residential Area (creating map of existing suitable residential Area)

- Overlaying created map from first stage on map of Vacant Lands to create map of suitable area for developing residential landuse (Figure 6)

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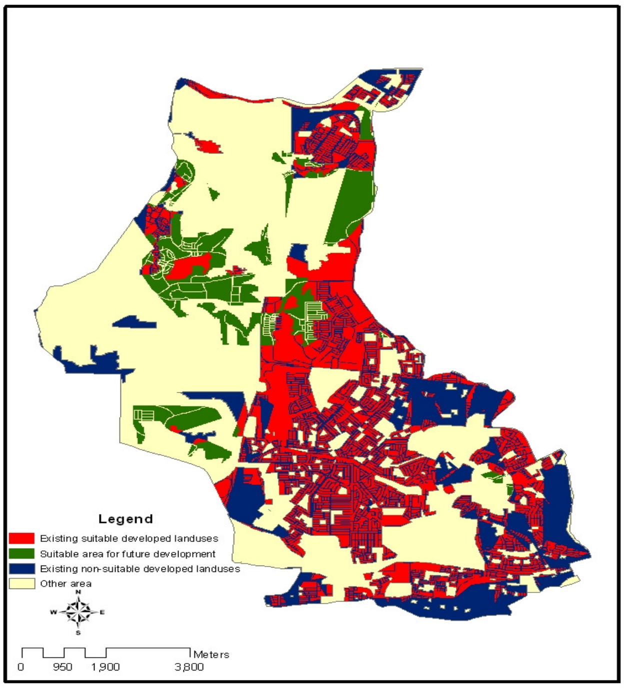

FIGURE 6 - MAP OF SUITABLE AREA FOR DEVELOPING RESIDENTIAL LANDUSE

Maps signs were also created showing which areas have all of following properties (together):

- Less concentration of transport air pollution
- More commercial and official activities
- High densities of residential development.

2.10. Statistical Calculation for Identified Area

Statistical calculation for surface areas of mapping units (polygons) were carried out on the final maps to provided clear analysis of the result. This calculation was done using the extension of "XTools" in ArcView 3.1.

The tool is a useful function to create new polygon or polygon output for calculation of area in acres or hectares, and perimeter. These calculations were based on user specifications set in the XTools defaults dialog. The geo-processing steps of this function are shown in Figure 7, and the following surfaces were calculated:

a) Current residential areas and current vacant lands,

b) Current suitable and non-suitable residential area,

c) Potential polluted and non- polluted area,

d) Accessible area,

e) Developable area for residential land use, and

f) Future possible developable area for residential land use

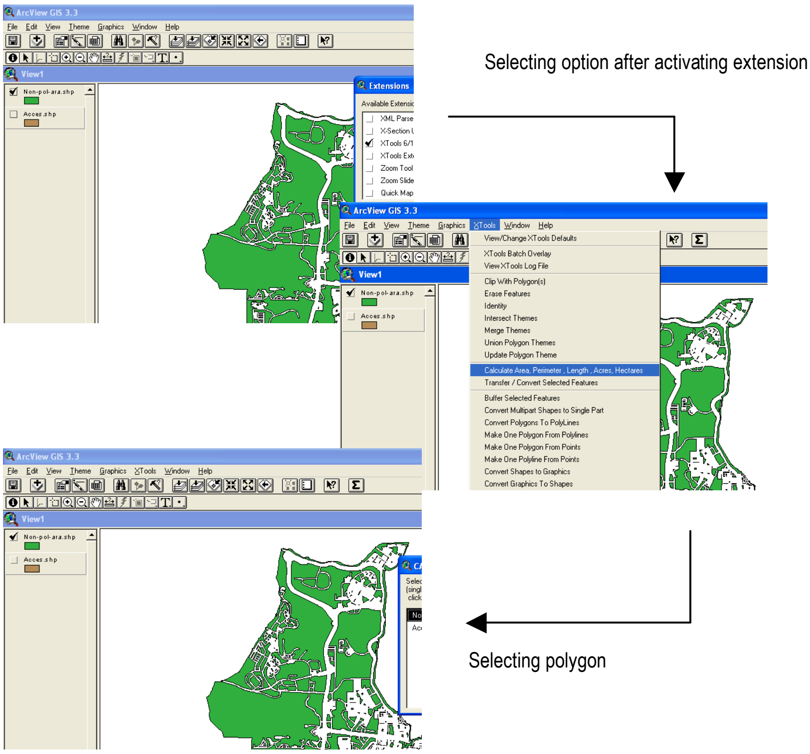

FIGURE 7 - GEO-PROCESSING STEPS TO CALCULATE SURFACE AREA

3 ANALYZING AND DECISION MAKING FRAMEWORK

The geo-spatial process was analyzed with respect to different performances of economic, social and technology. These maps can analysis by several what – if? Different alternatives arose from several scenarios and different analyses were carried out according to different levels of preferences. Scenario building revealed weaknesses which could be mitigated. There were several factors considered such as the importance of cost, physical possibility, social demands, environmental impacts, and land use locations. These differences had generated different suitable sites for development. This involved investigating and comparing the importance and value of each criterion against the impacts of changes. In other words, it was concerned with the way of development (changes) and importance of the final output. It recognized criteria selection under different points of view, perceptions and often-conflicting interests in the decision-making process. Finally it helped to analyze the various solutions or policies to generate an acceptable policy.

4. RESULTS

The results had take into consideration the two main negative and positive environmental elements in designing urban transportation networks. The suitable location for residential landuse is identified with a combined effect of these negative and positive impacts of urban transportation. Negative impacts work under the environmental guidelines to make sure that there is no air pollution danger for human health. Their effort is to make sure that residential are located with safe distance from urban road network.

In the case of positive impacts, Areas with good air quality were obtained through overlaying analysis and deselecting of effective polluted zones by road types. Based on the road types, potential polluted zones were sub-divided into five zones -potential polluted zones by collector roads, local roads, arterial roads, sub-arterial roads and highways.Applying the appropriate Dmin values indicated in Table 1, five polluted areas have been zoned and presented in maps of varying road types.

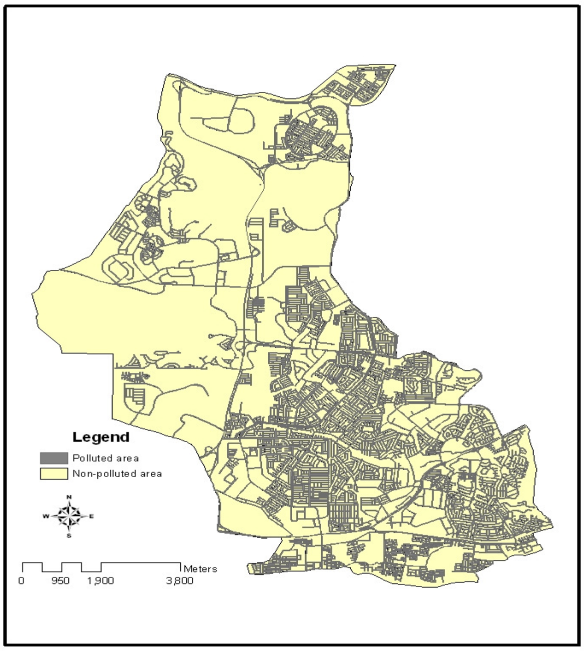

FIGURE 8 - MAP OF EFFECTIVE POLLUTED ZONE DUE URBAN TRANSPORTATION

Finally, the potential pollution zone map of MPPJ (Figure 8) was generated by overlaying all maps of potential polluted zones by road types. This map shows that 20.07 of MPPJ is potentially polluted by transportation, which is considerably high by MPPJ management standard. This map is useful in delineating non-polluted zones. By combining the maps using two major criteria - accessibility and air quality, different scenarios can be generated.

Accessibility of the residential area to official and commercial area is the most important criterion to be considered. This is because the suitable residential location should be linked with good road network as passenger can travel with ease and within the optimum time.

Though there are a lot of possible debates on the issue of accessibility criteria but as a result their effort is to make sure that residents can reach to main destinations in the optimum time. This optimum time takes into using the speed of road types, which is considered as main parameter to design urban transportation network. Area with high level of accessibility appears good for the present situation in MPPJ.

The accessibility map generated is presented in Figure 9 based on three major considerations in urban transportation. These are considering residential land-use as origin, commercial and administrative (official) landuses as destinations, and 20 minutes time as access time. The results show 66.21% of MPPJ has good accessibility; this amount with respect to distribution of landuses can be acceptable.

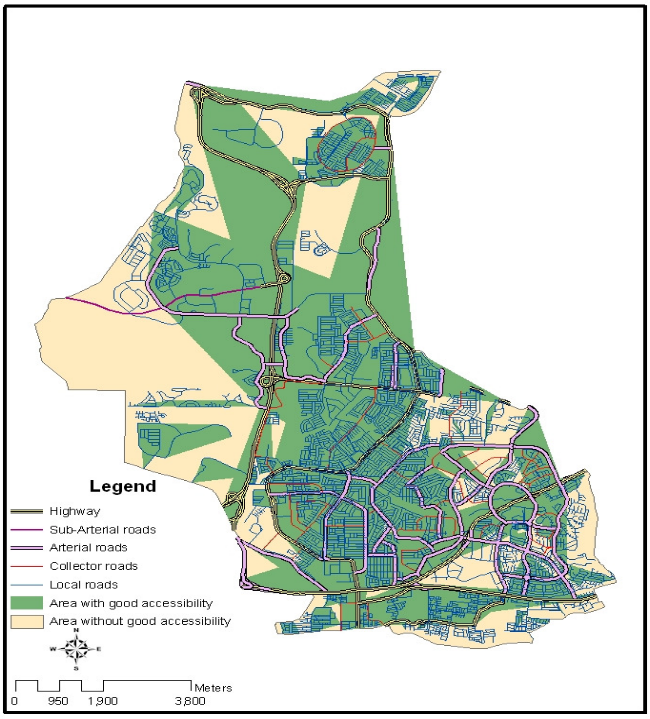

FIGURE 9 - ACCEPTABLE ACCESSIBLE ZONE AND ROAD TYPE OF MPPJ

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Developable area for residential landuse was generalized from the combination of effective non-polluted zone and accessible zone by urban transportation.

The results show 42.92% of MPPJ are not suitable locations for residential development and 57.08% of total areas are suitable for residential development. Combining map of residential area with map of potential area for developing residential land use essentially shows current suitable residential locations of MPPJ.

These locations will be considered as constant locations in all future scenarios in urban development. The resulting locations will be considered as alternative locations for possible re-urbanization in future scenarios in urban development. Current non-suitable residential locations in MPPJ were estimated as 37.99% of current residential area. It can not be ignored in future planning.

TABLE 4 - SURFACE AREA OF IDENTIFIED POLYGONS

Polygons	Surface Area (hectare)	Percentage in MPPJ
MPPJ	9807.38	100
Current Residential Area	4261.65	43.46
Current Vacant Lands	1480.63	15.10
Potential Polluted Area	1968.89	20.07
Potential Non-Polluted Area	7838.49	79.93
Accessible Area	6493.85	66.21
Developable Area for Residential Landuse	5599.38	57.08
Current Suitable Residential Area	2642.72	26.94
Current Non-Suitable Residential Area	1618.93	16.51
Future Possible Developable Area for Residential Landuse	828.93	8.44

Table 4 shows the surface coverage of identified polygons by hectares. But it does not completely show importance of transportation elements, because their spatial distributions are not represented by the tabulated values. Figure 8 shows high polluted areas are concentrated in the southern part of the MPPJ, while accessibility, as depicted in Figure 9, is limiting in the west of MPPJ. However limited accessibility in this part is not critical because of less build-ups and concentration of ecological landuse (Figure 1). In terms of development cost and possibility, more areas are available in the northern part of MPPJ, having more vacant lands. On the contrary the southern part has limited possibility for further development but planners should not ignore the wide occurrence of non-suitable residential areas. In addition these areas do not conform to environmental suitability. Both criteria and considerations for developing urban network and residential land use show similar types of spatial conditions. Vacant lands have higher preferences for development and high density areas need improvement and redevelopment.

But for improvement of current non-suitable residential landuse there are several options, which can be investigated by developing some scenarios as follows:

1. Development of residential land use and urban transportation networks in locations suggested for future residential development, removing all current non-suitable locations of residential landuse.
2. Development of residential landuse and urban transportation networks in suggested locations for future residential development, re-designation of urban networks with exchanging road types in existing non-suitable locations of residential land use.
3. Development of residential landuse and urban transportation networks in suggested locations for future residential development, re-designation of urban transportation network with reducing unnecessary roads type in current non suitable locations of residential landuse..

With respect to economical and technical possibilities, the first scenario cannot be accepted for Petaling Jaya. First part of second scenario - development in suggested locations for future developing residential land use, is acceptable. In the second part, road type was considered as a mean to alleviate urban air pollution of the study area. It was also mentioned; that the study area has an agreeable accessibility (Table 4 and Figure 9), this scenario suggests exchanging road types as solution for reducing air pollution. Most of polluted areas of the present urbanization setting are concentrated in the area with high density of local roads (Figures 8 and Figure 9).Therefore this road type may have contributed to increased urban air pollution. If this is true, transportation networks in this area should be re-designed with increasing other types as a solution. Collector and sub-arterial roads are secondary developing road types (depending on other road types), and highways cannot be built anywhere and anytime (regarding economical and technical possibility), hence the unique practical option is replacing local roads by arterial road in re-designation of transportation networks. Calculating covering accessibility and polluted area in relation to road types and road length (Hyun and Mei, 2003; Song and Sohn, 2007) shows, if some parts of local roads are replaced by arterial roads, equaling to 53% of current length of local road, current agreeable accessibility is maintained and polluted area is reduced by about 55%. Hence, scenario 2 can be confidently accepted for the study area.

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First part of Scenario 3 (development in suggested locations for future developing residential land-use) is normally acceptable. For the second part, urban transportation networks in those high pollution areas will enhance the activity of the area and will contribute to urban accessibility.

But they are associated with air pollution, hence it is expected that removal of some roads can reduce air pollution. This decision should be made by providing a short list of road alternatives with their advantages and disadvantages.

However, economical and technical possibility should be considered as well to make realistic and functional decision.With regards to the identified potential area, further preferences based on the economical and technical limitations shall also be considered. The following suggestion may help to improve urban transportation networks.

- Re-designation of transportation networks (with more replacing local roads types by arterial roads) in existing non-suitable locations of residential landuse
- Development of residential land use and urban transportation networks in suggested locations for future development of residential landuse
- Removing some unnecessary roads in existing non-suitable locations of residential land-use
- Removing a little residential land-use in existing non-suitable locations of residential land-use.

5. CONCLUSIONS

This research has successfully managed to identify and develop a scientific based method in understanding the relationship between land use and urban network location by analyzing the successful and non-successful present and future development of landuses and urban networks. The research strategy is able to support urban planners with a range of options. However, for selecting the best or most suitable sites, more comprehensive model and plan can be developed, from which choosing the sites from the alternatives will be the main purpose. Development of a spatial mathematical model based on produced noise pollution by transportation.

Implementation of method and scenarios analysis suggests that some areas can be more suitable than others for residential landuse and urban transportation network development, if performances and criteria are considered carefully. This suitability largely depends on the goals of the transportation projects, but importance of two main elements (accessibility and air quality) cannot be ignored in all of transportation projects.By development and implementation of mentioned methods in the study area, it is possible to illustrate new implementation for spatial method in urban transportation planning to explain the linkage between accessibility and air quality for better designing urban transportation network. Arrangement of number factors in relation to road type can be interpreted as a predictor of a suitable urban networks location to Illumine parallel importance of environmental and economical sectors. It can help planners to determine the potential locations for residential land-uses and urban transportation network and the possible developments and improvements for residential land-uses and urban transportation network for future sustainable urban development. The method developed under this study is not for exact site selection purpose. It may be used as a generalized spatial decision support tool to support decision making for locating residential land use and urban transportation network. It can also assist the urban planners to provide a list of alternatives with their advantages and disadvantages within the framework of transportation policies and projects. Validation of the transport planning method was performed to determine the applicability of the typical developed plan for performance assessment of urban life. The purpose of transportation planning is to identify any urbanization impacts on the transportation system and removing negative impacts. By combining environmental and transportation issues, this research has applied economic criteria to urban transportation planning, and decision-making support is provided with a new plan, which comprises state-of-the-art methods and models. This plan is devised to assess the cost-benefit of alternative solutions, which range from capacity enhancement to demand management to provide a maximum amount of mobility or accessibility at the lowest cost investment economically and environmentally.

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