

An Assessment of Authorized Car Wash Site Suitability Using a GIS-Based Modeling in Khartoum City, Sudan

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Abstract

The goal of this study is to assess the ability of existing car washing stations in Khartoum City using an ArcMap suitability modeling tool. **Methods:** In Khartoum, an increasing number of vehicle wash stations were opened every day. The main criteria are street, the slope, the hospitals, the police station, and the school, which have been used to build a model of suitability based on weight overlay in ArcGIS 10.4. The findings revealed two evaluation tendencies. One tendency involves business centers that are located on main roads but are adjacent to residential areas, while another involves business centers that have rezoned residential plots without consideration for ideal site requirements for the environment. There are locations that would be appropriate for vehicle wash centers, according to the final suitability map. On a scale of 1 to 5, less than 30% of the study area is considered suitable for a new car wash regarding class 5. On the other hand, significant areas are available for car wash development in the second value of suitability 4, but as second-ranked suitability. The assessment was accomplished by comparing the final suitability map of car washing centers to the layers which represented them.

Keywords

Car Wash Centers, Suitability Analysis, Suitability Modeling, Criteria

1. Introduction

Car wash is defined as a facility used to clean the exterior [1]. Internationally, there is a great intention about the urban utilities mainly where these can be located. The utilities and services of car washing in urban centers should be located away from residents. Car wash selection is of a special type from an envi-

ronmental point of view. Car wash issue introduces in many related topics concern car wash types, car wash and location, car wash and income, car wash characterization, car wash modernization, car wash system market, car wash industry, car wash plans car wash accessibility and car wash self-service and many others. The visibility of the car wash centers to be higher efficiency should not establish randomly, instead, they must be followed standards that offer appropriate location suitability. The pre-construction procedures include the authorized assessment of the surrounding landscape and stating the environmental impact assessment for most adverse impacts expected in the future. An important point to be defined is that; the type of car wash used in this paper is not high-tech car wash type. There are two types of car wash in the study area; manual and machine washing services. The machine car washing characterizes by its building place that satisfied some official procedures. As far as the recent, modern car wash is concerned, there is a recognizable transformation in thinking about car wash equipment, investment, and impacts that will be expected.

Carwash service looks easy, but without environmental impact assessment, some environmental complications can occur after operation. Often society has been slow to recognize the link between individual behaviors and practices. One of these practices is residential car washing [2]. The car wash service can operate safely if it locates at a proper place. The proper place is that considers all key criteria for establishing such utility. Generated wastewater may contain specific pollutants (metals, detergents, hydrocarbons, etc.) that disturb the quality of surroundings. As the home car washing was declined in the developed countries [3], the vehicle noise and movement must not interfere with family housing, hospitals, schools and other installation activities. The night lighting at the facility as recommended, must not disturb the surrounding area [4], and Discharge Standard Approach was effectively enforced in industries including car wash effluents discharged from vehicle wash facilities [5]. Suitability modeling and site selection are the most important guidelines in justifying spatial optimal solutions. The optimum car wash site selection will definitely be cost-saving on capital strategy and operators. Based on the historical strategic plan formulated for different facilities, the authority of Khartoum city is faced with a real problem concerns new car wash establishment. Finding suitable and appropriate space for the construction of a new facility is not easy; instead rezoning the residential plot is an unsuitable solution. Evaluating existing car wash centers based on standard criteria gives good views about the current conditions that do not appear in optimal suitability.

The size of the car wash center is not the same; it differs based on the rezoned space. The average area is range from 50 - 75 m² and has a rectangular shape in most cases. The significant observation during the field survey over the city's main streets is the cheap hand car washing that has grown up on main streets, parks, and institutions, often practice by uneducated younger. The hand car washers have no authorized permission to practice this service in open spaces and streets and highly compete with the car washing authorized stations. As far as

car washing customer's attitudes are concerned and based on observation and citizens' interviews, approximately about 70% are washing their cars at home and/or street in Khartoum City.

In planning for car washing center location, the critical prerequisite that should be included besides the site suitability modeling is the environmental and social impact assessment (ESIA). This will be strengthening the final decision about where to locate proper car wash centers of less adverse impact.

2. Previous Studies

The progressive intention about car washing worldwide expanded through the collaboration of the International Car washing Association [6]. It reflects that washing a vehicle is a universal activity. Companies and private business sector are interesting in establishing guidelines for their car wash activities. The hand car washing that is being practiced on the side of the road, petrol stations, disused forecourts, former public car parks, and in supermarket car parking yards [7]. Car washing emerged also as a degree in business management about business plan for xyz hand car wash in Filind [8]. One of the innovative challenges in the area of car wash safety is the Clewer initiative and the Santa Maeta Group. The initiative is to quantify via application the protected workers in the sector of the hand car washes [9]. With the emergence of COVI-19, some recent studies showed new standards for responsibility of car washed in cities. The minimum sector specific COVID-19 workplace safety standards identified are: Distancing protocol, Hygiene protocols, and staffing [10].

Many researchers have studied the issue of car wash impacts upon the environment. They focused on the effluent and run-off from vehicle washing and cleaning activities that can damage the environment and contaminate the surroundings [11] [12] [13] [14] [15]. Also, the critical issue studied intensively is the wastewater generated by washing car including contaminants that are highly identified as the car wash environmental impacts, which may affect the surroundings [16] [17] [18] [19]. The International Car Wash Association (ICA) identified water reclamation in professional car washes as a critical concept since the 1990s. Reclamation is one conservation tool available to performed car wash operators. In the area of car wash criteria, there are many institutional projects about central vehicle wash facilities manual that aimed to provide a comprehensive reference source for planning and designing a central vehicle wash facility (CVWF), and decentralized, net zero wash facility [20]. Reclamation has attracted more attention in the past several years from regulators and manufacturers as a means of water conservation and quality control [21]. Paper concerns water saving in domestic car washing was published as the writers categorized the cars into five classes (small, medium, large, people carrier, and large 4 × 4) cars [22]. In 2018, the Home of Commons Environmental Audit Committee has finished the tenth report of series 2017-2019 about hand car washes. The report included many topics, such as the growth of hand car washes in the UK defined

as unregulated business [23].

3. Problem Identification

In recent urbanism perspectives, the planners and decision-makers ask a considerable question: where to locate a new car wash center that suits our environment and does not harm the social setup? Accepting this question, the problem is that car wash centers are the most important service activities in Khartoum Town increasing progressively in recent times, and the demand for more will be planned, but how will be located? Most of the current car wash centers seem to be lacking some sort of optimal locations criteria. So, in terms of geographical perspective, there is a problem that needs to be studied. In addition, the progressive increase of car populations has motivated new business investors to invest in the car washing services in Khartoum City. The site selection for this utility has been a challenging issue as no land can be specified for this kind of facility.

The most critical issue is the conflict between investors who owned a piece of land that did not suit the car wash business, and his insistence to have authorized permission to do that. Khartoum city land use planning is quite confused, and space adjustments are the problem of the study area. There is no master plan that identified free zoning for future expansion of specific land uses. Consequently, the city has an increasing daily car that needs some kind of car services. Where to locate the optimal car wash centers is the top of the recent urbanization issue in Khartoum. The hand car washers practice car washing everywhere in streets, surrounding institutions and at recreational areas.

4. Study Area

Khartoum locality consists of 8 administrative units located at the confluence of the White Nile and the Blue Nile, between longitudes 32°27'18" - 32°40'35" degree East, and latitudes 15°11'58" and 15°38'26" degree North (**Figure 1**). Khartoum is a growing city that welcomes more daily thousands of new incomers. The car population also is progressively growing during the last 20 years, while related facilities such as car washing do not. There are 27 authorized car wash centers to serve more than 25,000 cars in Khartoum east administrative unit located with less accessible sites [24]. The majority of these centers have license without pre environmental impact assessment procedures. The sample streets selected for this study are traversed the area from south to north and some from east to west as shown in **Table 1**.

5. Methodology

The main methodological plan for this paper concerns car wash suitability site selection is a GIS-based application. **Figure 2** is a schematic diagram that presents systematically the key elements of the methodology that consists of the methods and procedures of data used as well as methods and procedures of data analysis. The schematic diagram also shows the post-analysis outputs and final interpretation in consequential order.

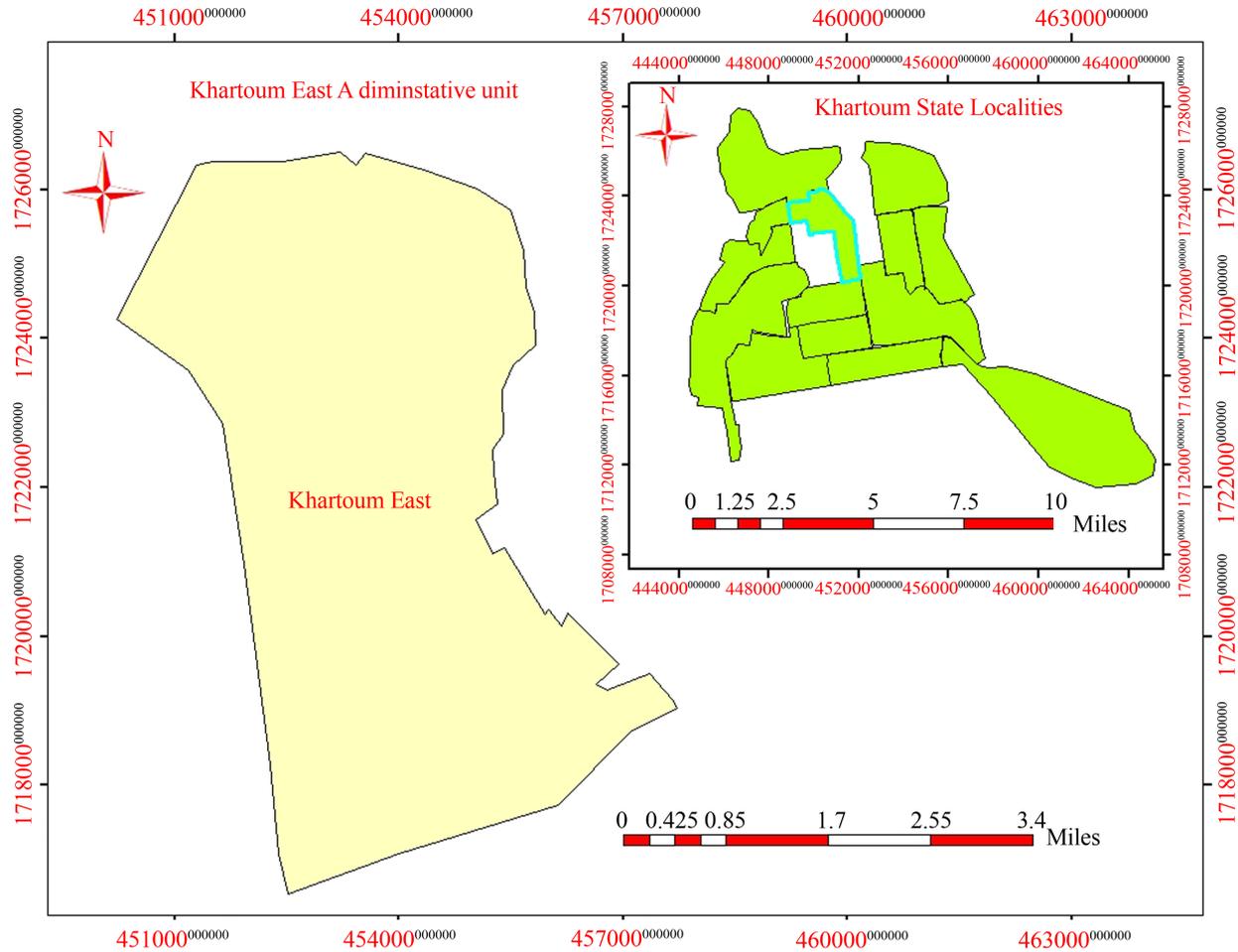


Figure 1. Location of the Study Area—Khartoum-Sudan. Source: Based on ArcGIS analysis.

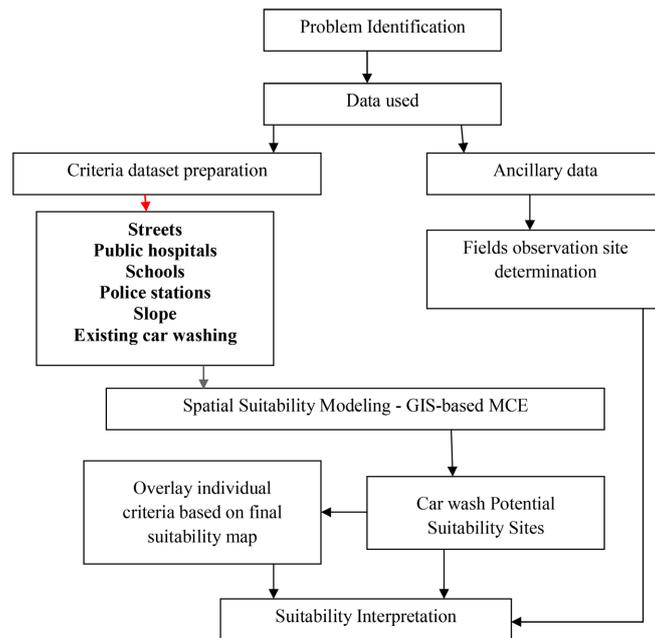


Figure 2. Methodological framework schematic diagram

Table 1. Car wash center locations by street type.

Street	No	street Type	Street	No	Street Type
Almarad	1	Main street	Al-Mashtal south	2	Secondary
Ibed Khatim	6	Main street	Al-Mashtal north	1	Secondary
Al-Seteen	4	Main street	Africa	2	Main street
Mohamed Sharif	1	Secondary	Al-Shargi	1	Secondary
Amtedad Nasser	2	Secondary	Al-Salma	2	Main street
Omak	1	Main street	Mokhtar street	2	Secondary
Al-Riyad west	1	Secondary	Al-Amarat	1	Secondary

Source: Field survey (2020).

5.1. Preparing Dataset

All data were prepared and analyzed with Arc map 10.4 spatial tools. Four layers have been created based on Khartoum base maps for the public hospital, police stations, schools, and soils. The slope was derived from DEM (30 m) resolution, while the existing car wash center locations layer was created using GPS field survey. The final modeling suitability of the car wash sites is mapped based on these dataset criteria. Each layer in the dataset involves certain weight that defined its importance for the problem under consideration. The five criteria used in this paper were selected based on the data sources' availability.

5.2. Methods of Data Processing

The methodological framework used to evaluate the location of the car wash is based on multi-criteria measurements. A suitable site is a function of the combination of the criteria that were weighted according to their importance. The benefits of using GIS providers and factors used in determining business locations for the facility have a considerable space in pieces of literature. There are relationships between business site selection, location analysis, and GIS [25]. The criteria were ranked from most to lesser important showings their weight percentages. As applied in many studies the criteria's weights have more or less favorable on the final decision [26]. Tools from Arc GIS spatial analyst extensions were combined in the analysis. The steps for creating suitability modeling are; first to create a new toolbox; create a new model within the toolbox; deriving prepared dataset; reclassifying datasets; weighting and combining datasets; selecting overall optimal locations; and interpreting the appropriate site with validating using overlay analysis.

5.2.1. Criteria Used Explanations

The criteria that achieve the goal of this study were determined with different weights, according to the importance of each criterion in terms of the effect associated with the proximity of the distance. More explanation about the weighting process criteria is coming in the sequential order presented by number 5-2-3.

The most appropriate criteria determine the suitability of establishing car wash centers can be briefly explained in the following points:

- **Existing car wash centers:** It is of high significance in car wash businesses to consider the existing facilities. This criterion should be involved for its spatial services allocation and from a competitive perspective keeping the appropriate distance from the existing car wash center. In urban, it is recommended that the location of a new car wash not be within a mile of any other car wash in its optimal view. This criterion is governed by the urban land use master plan that does not apply in the study area.
- **Slope:** It is an important physical criterion involved in most site selection projects due to its impacts upon the area's drainage system. The general fact is that even slight variations in slope can influence site drainage pattern.
- **The main streets:** The location of a car wash should be located near the main streets. Flow of traffic that secure vast comfortable, attract people to choice the center. The recommended distance from the main street is 200 meters; the nearer is better. Main streets associated with the transportation route are the first to be considered when thinking to locate car wash business facility. Narrow streets are not capable of promoting car wash centers and not attracted by customers.
- **Hospital and school sectors:** Clean, and safe hospital and school proximity are important to all public service planners. It's a matter of a distance criterion from car washing activities. In modern site selection modeling, hospital and school safety locations have been greatly recommended. When car wash centers located within the vicinity of a hospital or school, the wastewater generated together with the nuisance have kind of environmental disturbances.
- **The police Stations:** The relationship between the car washing station and nearby police station emerges from the security needs surrounding the business utility. Police station location across the urban vicinities was considered as a protective expected risk. For this purpose and reason, it was formulated as one of the criteria that have its importance weight in the final score of the suitability model.

5.2.2. Reclassifying Processing

The pre-weighted overlay process is to use reclassify the tool for transforming dataset layers to suitability scale. The data set prepared for model inputs should be reclassified. Each layer was reclassified into five classes. One indicates least suitably, while five assigns the high suitability as shown in **Table 2**.

5.2.3. Weighting and Combine Criteria

There are several methods of processing weighting analysis. Multi-criteria analysis in molding suitability is applied and recommended to be most appropriate by many researchers. The weighted overlay tool is the process of weighting the different dataset within the car wash model. Different weights have been assigned

Table 2. Criteria reclassification values important ranking.

Value range	Ranks	Value range	Ranks	Value range	Ranks
Existing Carwash Centers		Hospitals		Roads	
0 - 356	1	0 - 618	1	0 - 265	5
356 - 713	2	618 - 1236	2	265 - 530	4
713 - 1070	3	1236 - 1855	3	530 - 796	3
1070 - 1427	4	1855 - 2473	4	796 - 1061	2
1427 - 1783	5	2473 - 3092	5	1061 - 1326	1
Police Stations		Schools		slope	
0 - 783	5	0 - 356	1	0 - 0.4373	1
783 - 1566	4	356 - 713	2	0.4373 - 0.5614	2
1566 - 2349	3	713 - 1070	3	0.5614 - 0.9987	5
2349 - 3132	2	1070 - 1427	4	0.9987 - 2.5392	4
3132 - 3915	1	1427 - 1783	5	2.5392 - 7.9658	3

Source: Based on arc map 10.4 reclassify process.

to the criteria for final suitability sites. Each criterion (layer) is classified into five classes given weight values ranging from one to five. For the weighting overlay process, 100 percentages have been distributed not equally for the five criteria depending on their effectiveness on the car wash site selection. Overlay analysis is a common method for creating a suitability model, which involves using GIS techniques and software as recommended by ESRI.

The process of weighting site selection criteria comes through five steps, which are; defining criteria creating raster dataset to be used in the analysis, reclassifying the created raster dataset, giving weight for each criterion based on its importance for car washing site suitability, and overlying the output with each of the criteria used. **Figure 3** presents the flow chart showing multi-criteria spatial modeling using weighted overlay in consequential and logical procedures. The main procedure of this method is to find the weighted overlay of the elected ratings for each criterion. Suitability site selection needs to estimate weights for criteria that must balance weights total 100% (**Figure 4**).

6. Results and Discussion

From the suitability map, a specific location to establish carwash centers is assigned for the functional needs based on the key factors used. Carwash centers rezoned location is the spatial problem we seek to analyze and assess its misleading management standard. Based on the goal of this paper, the researcher tried to achieve that the carwash centers' location should be assessed with the orientation of the master plan and authority guidelines. This part includes three main analytical and discussion aspects.

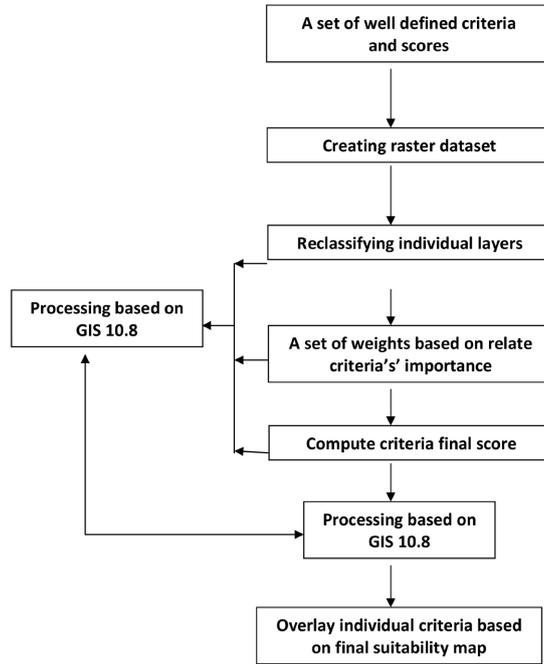


Figure 3. Weighting site selection criteria process.

Raster	Influence	Field	Scale value
Reclassified_car wash	27	1	1
		2	2
		3	3
		4	4
		5	5
Reclassified_Hospital	17	1	1
		2	2
		3	3
		4	4
		5	5
Reclassified_Road	30	1	1
		2	2
		3	3
		4	4
		5	5
Reclassified_Police_stat	4	1	1
		2	2
		3	3
		4	4
		5	5
Reclassified_School	10	1	1
		2	2
		3	3
		4	4
		5	5
Reclassified_Slope	12	1	1
		2	2
		3	3
		4	4
		5	5
Sum of influence	100	Set equal influence	

Figure 4. GIS-based overall weighted overlay percentages.

6.1. Existing Carwash Assessment

90% of the existing car wash centers are previously planned as residential development. The current rezoned centers for business investment are surrounded by homes. The current facility is half simple mechanized and half hand finish washing. Vehicles would wait at streets having a limited parking area as there aren't defined drive-through lanes. The only one level of services is washing the exterior and interior parts of cars. The customer pays directly for the service after operation had been done. The majority of the existing carwash centers in the study area are established in the main streets. In fact, rezoned places are located among residential areas, though some are on the main streets. 18 of the existing sites are located in the main streets, and nine are located in secondary streets. Based on the field observation, **Table 3** gives an assessment of the existing car wash centers depending on the international and regional recent applied criteria. More than 85% of the existing car wash centers shouldn't have been established in the right places lacking certain environmental and social site selection requirements.

6.2. Analyzing Suitability Based Criteria

Today, the carwash facility has developed into a complete car care center with a

Table 3. Overall assessment of the existing car wash centers.

criteria	standard	Overall assessment		
		Satisfied	Not satisfied	To some extend
Property and location viable for	An express exterior	×	✓	×
	Full service	×	×	✓
	Flex service	×	×	✓
Landscape attractive	Always clean	×	×	✓
	Space available	×	✓	×
	Building uniqueness	×	✓	×
	Site is customer friendly	×	×	✓
Design specifications	Suitable place	×	×	✓
	Gig turns	×	✓	×
	Good entrance	×	✓	×
	Nice wide lanes	×	✓	×
	Spacious queen areas	×	✓	×
	Building height	×	×	✓
	It is a distinctive site	×	×	✓
	It is secure safe place	×	✓	×

Source: Based on the field survey (December-2019).

wide range of modern car washers. It is convenient and takes less time than self-serve washing [27]. Perfect selected criteria help to locate the car wash centers that maintain safety and healthy environment. Location analysis is crucial part of the suitability process and should be carefully undertaken at the top of the proposed procedures.

The coming analysis concerns the overlay of the existing car wash centers (**Figure 5(a)**) and other criteria used for the general assessment. The following are the brief interpretation of each criterion used.

6.2.1. Suitability Analysis to the Main Street

Urban main streets are vital locations of citizen's life. Where characteristics of frequent parking and high pedestrian values are realized the car wash center has an attractive business benefit. The specific criterion is that vehicle washing centers prefer to be on the main streets. In the study area there are 17 centers (65%) are located on the main streets (Sixty Street, Obaid Khatim, and Africa), while there are pillars (34%) located on the secondary streets between Sixty Street, Obaid Khatim and Airport Street. The majority of car wash centers in the study area are located with some modifications in the main streets. This positive orientation gives new attractive attitudes and raises the competition in car wash business though they are neighboring residential areas (**Figure 5(b)**).

6.2.2. Suitability Analysis to Hospital Locations

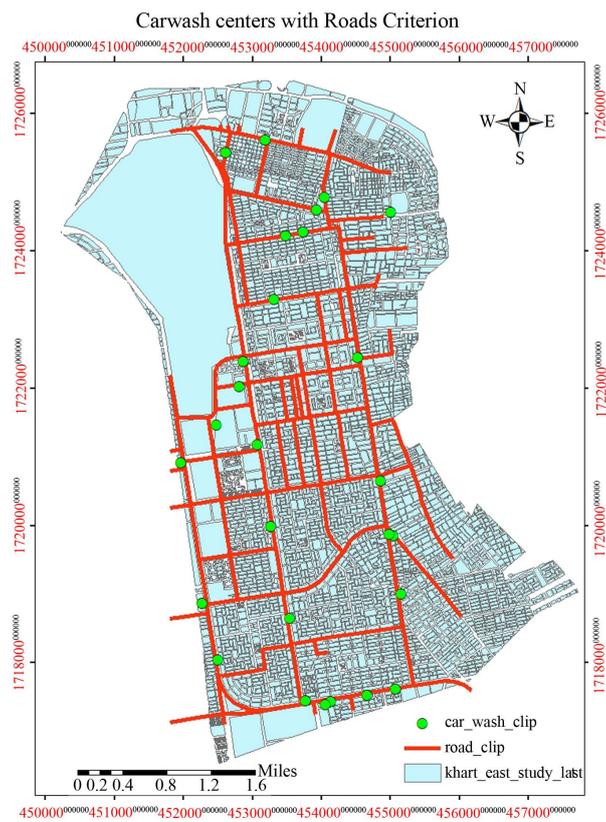
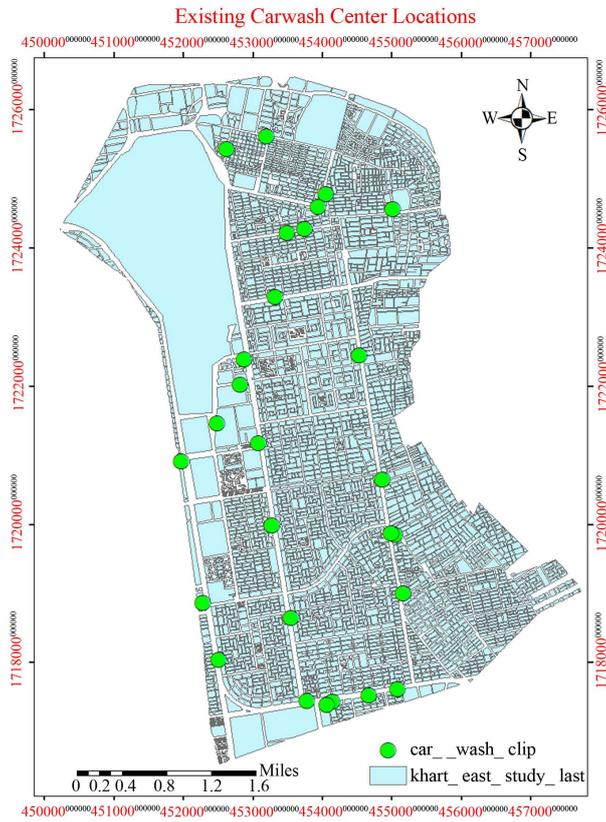
To reclassify scale used to transform the distance from the hospital onto a common scale of 1 to 5. The standard is that the far away from the hospital to carwash centers, the better, because being close to car wash may expose to noise and air pollution that has adverse impacts. When analyzing the distance between government hospitals in the study area and vehicle washing centers, there are four hospitals located next to carwash centers, with distances varying from 150 to 500 meters, especially those located on the main streets. The other 24 public hospitals, more or less are located at a reasonable distance from the existing carwash centers (**Figure 5(c)**).

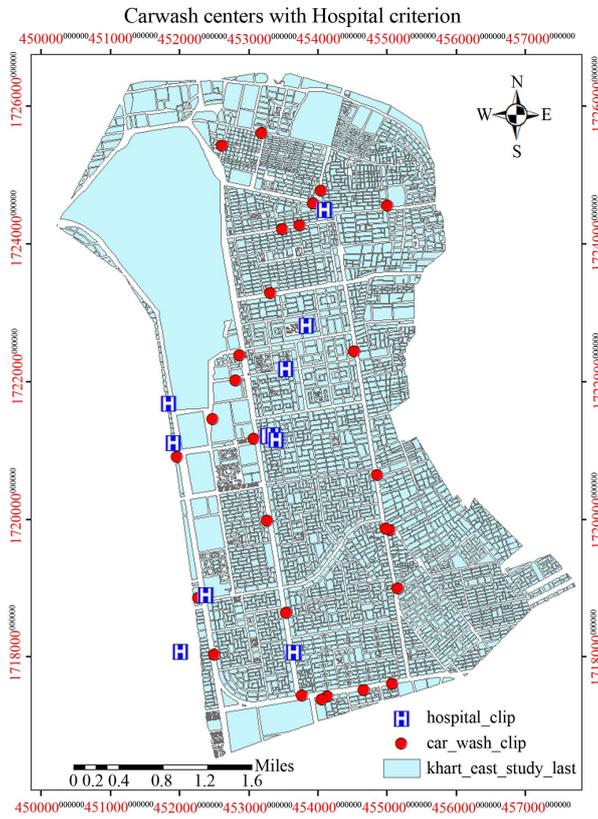
6.2.3. Suitability Analysis to Police Stations

The relationship between the locations of the police station and the locations of the car washing centers in the city indicated that the number of police stations is limited. Of the five stations, there are four, which are located on the main streets and at suitable distances from the car washing centers, except one that is located at sixty street (**Figure 5(d)**).

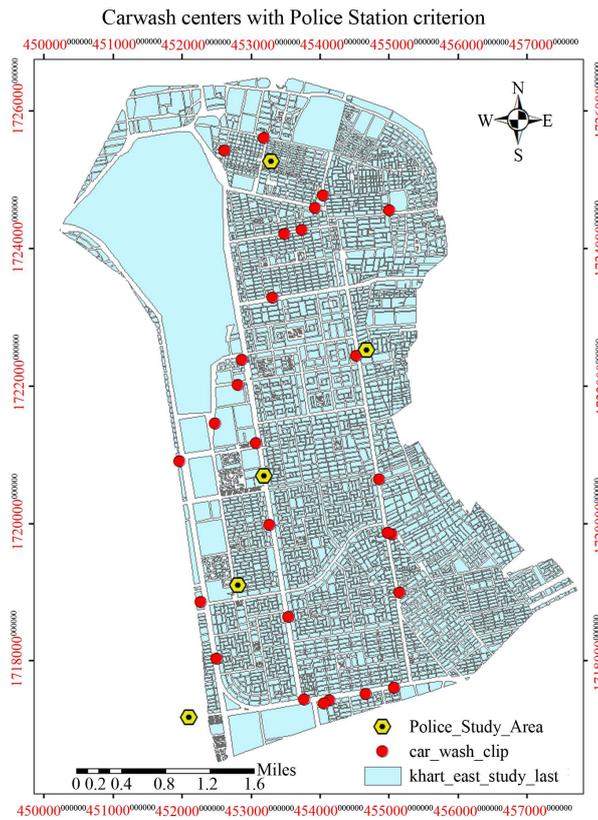
6.2.4. Suitability Analysis to School Locations

The school locations overlay with the carwash centers map showed that the proximity to schools is optimal. A standard of the distance from the car washing center is achieved because the schools are already planned to be located inside neighborhoods far from the main streets as an important criterion when implementing sites for primary schools, especially for the purpose of safety (**Figure 5(f)**).

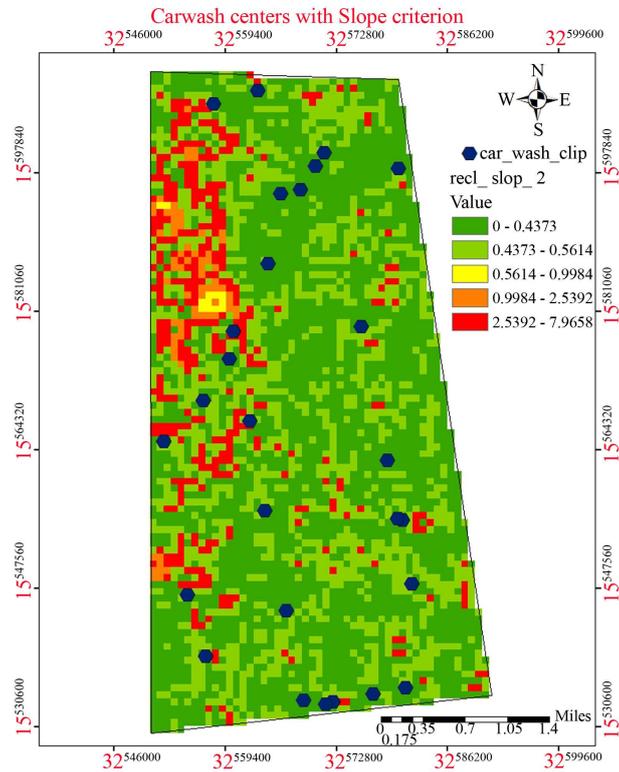




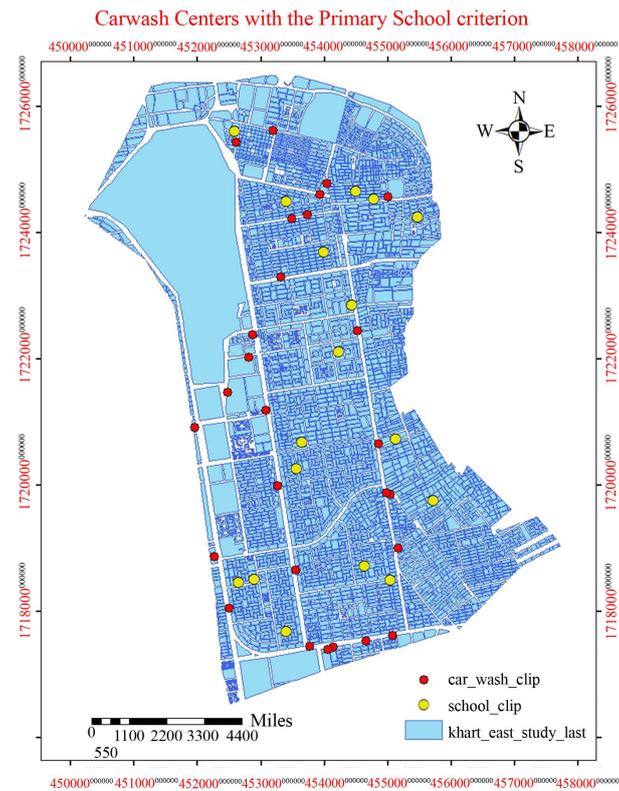
(c)



(d)



(e)



(f)

Figure 5. (a)-(d): Suitability-based criteria analysis; (e) and (f): Suitability-based criteria analysis. Source: Based on ArcGIS analysis.

6.2.5. Suitability Analysis to Slope Property

To display the land slope of the area, slope scale values representing five classes were created having weights based on their importance. Slope layer presented in **Figure 5(e)** derived from the DEM data are showed a scale from 1 (red) to 5 (green). This has a weight 12% proportional to other criteria used. All existing car wash sites in the study area are relatively flat landscapes.

6.3. Final Suitability Analyses

The overlay analysis combines the weights of the criteria used as dataset into a final indicative layer. So, based on this final layer, we can specify the most suitable areas, which are identified by three classes (high, medium and least suitable) for establishing car wash centers.

6.3.1. Suitability Modeling for Car Wash Site Selection

As we seek an optimal site of car wash center, the integration of spatial modeling and Arc GIS is implemented. Suitability model is a model that weights locations relative to each other based on given criteria. Inputs data are the main criteria, while the tools used are Euclidean distance for the hospital, police stations and schools. Weight overlay tool was linked all the reclassified layers with their different weights.

In its sequential order, the methodology ends by creating suitability model schemata (**Figure 6**). In this process, all created dataset layers combined into a single ranked map of potential spaces suitable for establishing carwash centers. Each layer has a suitability scale of 1 to 5, with 5 being the most suitable. So, the model for this problem was constructed based on these dataset criteria. Carwash suitability analysis concerns site selection as a multi-operation needs a proper methodology to finalize its optimality.

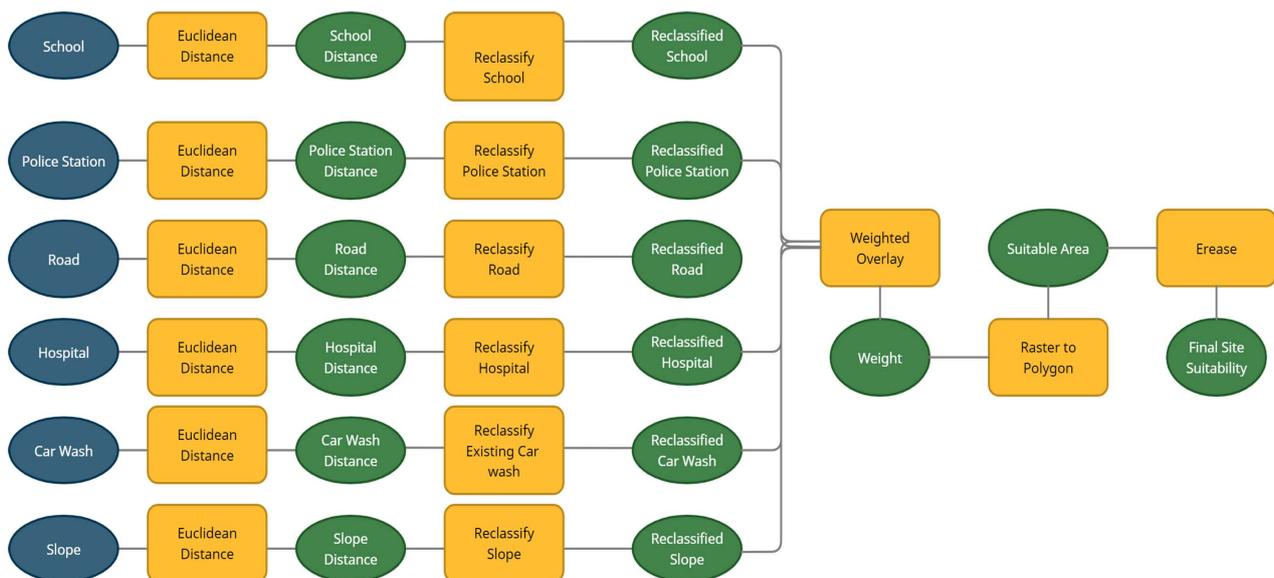


Figure 6. Structural model for car wash suitability analysis. Source: Based on ArcGIS analysis.

6.3.2. Final Car Wash Location Suitability Map

There are sequential steps that the suitability model builder should be satisfied when implementing weighted overlay in Arc Map 10.4 environments. For this study, a model weighted overlay was used different criteria having different scale values of importance. Before processing weighted overlay, each criterion was reclassified into a common preference scale used as mentioned before. As the study applied a simple car wash suitability model, the input weights showed their influence in creating the final map. Weights defined for the existing carwash centers, public hospitals, roads, police stations, slopes, and schools are 27%, 17%, 20%, 4%, 12%, and 10% respectively.

The final suitability map showed the vast space that assigned a suitability value of 4 with fewer areas assigned the optimal suitability value 5 (Figure 7). The

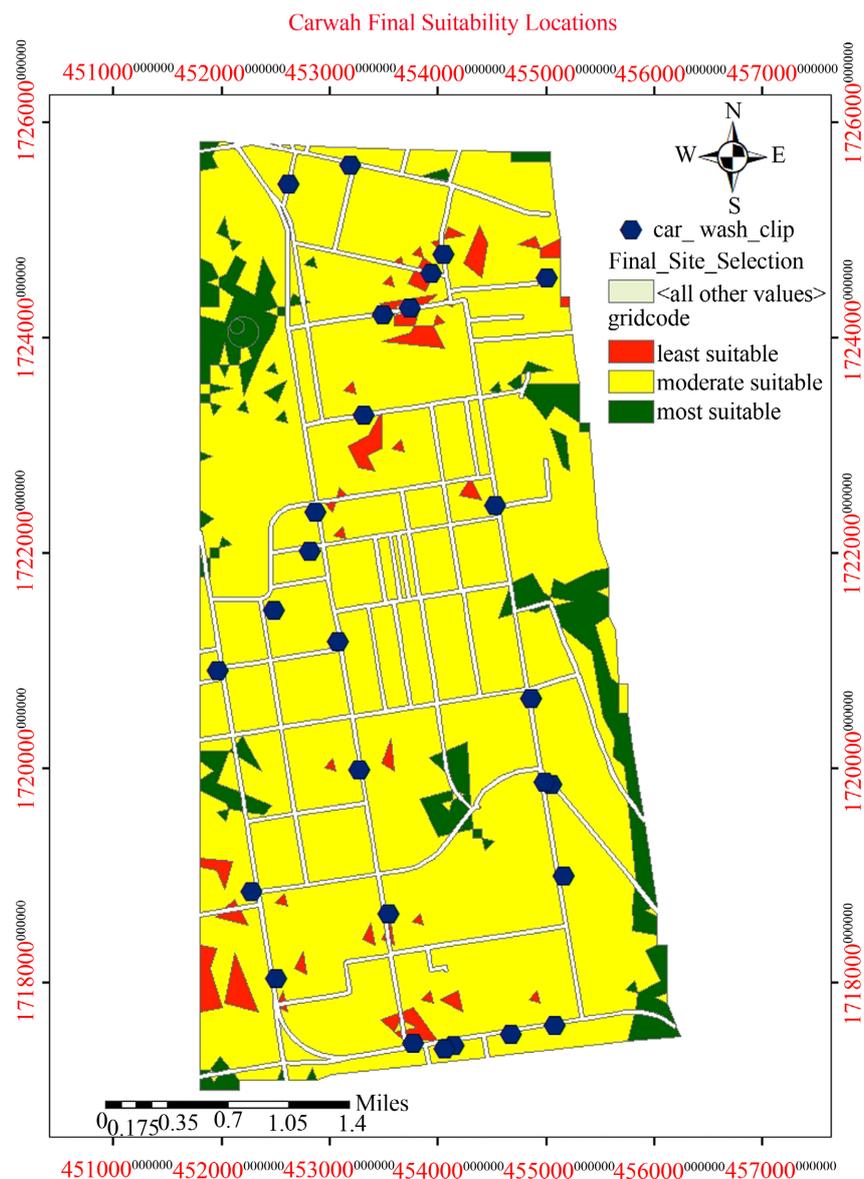


Figure 7. The final suitability map. Source: based on arc GIS analysis.

suitability space assigned of value 4 is the second-order suitability in its significance also accepted.

7. Conclusion

The suitability site selections for car washing were assessed and weighted overlay using five selection criteria to realize a potential decision is recommended. Site suitability modeling provides an effective guideline to remark all sites with the regarded standards in finding the optimal locations. The space analysis indicated that the only option for installing car wash center is to rezone the already developed land-use patterns. So, the shifting from housing purpose to car wash service is the typical problem in the city of Khartoum. This can be evaluated as no qualified location identified based on the master plan over the Khartoum State. The size of the car wash center governs by the availability of the space and its land-use patterns surroundings. Rezoned space is not recommended for establishing car wash service as it will not satisfy the spatial requirements for all related operations that cope with the modern system requirements. In fact, the carwash site selection is a matter of integrated groups of criteria. Due to data limitations, this paper implemented some of the main criteria recommended for modeling carwash suitability. Therefore, the researcher may not fully use criteria to judge that the car wash suitability site is hundred percent proper. Thus, the new trend in the field of urban facilities is to use a method that has high spatial analysis capabilities, the most important and effective is the Geographic Information System (GIS). The researcher recommends that special attention should be focused on Khartoum's urban services that are most considerable for its environment and modernization. Such attention presents today's challenge in Khartoum's urban environment, including car wash location, and all other public services.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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