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Route Network Analysis in Khartoum City

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ABSTRACT - Road network has been viewed as a major dynamic force in influencing quality of life and shaping cities all over the globe. Sudan as developing country is witnessing growth in transport and infrastructure such as roads and bridges. Big cities such as Khartoum suffer from congestions of traffic. Nevertheless, finding correct route in the required time is a difficult problem for many drivers especially in emergency cases. The lack of adequate information to find the shortest route to the nearest service, together with the lack of tools to extract such information and presents it when needed. The purpose of the paper is to introduce a proposal to produce digital route guided maps and hence deploy digital spatially enabled location-based computer program to be downloaded in laptop and mobile as a platform to improve services in case of emergencies such as accidents. This had been done by utilizing the capabilities of GIS in network analysis and visualization to enhance decision making in route selection to the nearest hospital by mapping the services area based on travel time.

Keywords: *Route, Network Analysis, GIS, Shortest road, services area.*

المستخلص – شبكة الطرق ينظر إليها فى جميع أنحاء العالم على أنها قوة ديناميكية كبيرة في التأثير على نوعية الحياة وشكل المدن. السودان كدولة نامية تشهد نمواً فى المواصلات والبنى التحتية مثل الطرق والكبارى ورغماً عن ذلك فإن المدن الكبيرة مثل الخرطوم تعانى من الإزدحام المرورى. إن تحديد المسار الصحيح فى الزمن المطلوب تعتبر مشكلة صعبة للعديد من السائقين خصوصاً فى حالات الطوارئ .عدم وجود المعلومات الكافية للعثور على أقصر الطرق إلى أقرب خدمة لا يمكن تحديدها بسبب عدم وجود أداة تستخلص هذه المعلومات وتعرضها عند الحاجة. الغرض من هذه الورقة هو إقتراح توفير خرائط رقمية إرشادية للمسارات، ومن ثم إطلاق موقع خدمات مكانية رقمية تستند إلى برنامج حاسوبى يمكن تحميله على أجهزة الحاسوب المحمول و الهاتف النقال لتحسين الخدمات في حالات الطوارئ مثل الحوادث. هذا وقد تم عمل ذلك بإستخدام قدرات نظم المعلومات الجغرافية فى تحليل الشبكات والعرض لتحسين إتخاذ القرار في تحديد المسار إلى أقرب مستشفى برسم خرائط منطقة الخدمات إعتمادًا على زمن الوصول.

INTRODUCTION

Khartoum as capital of Sudan has the highest concentration of economic activities so it has experienced rapid urbanization in the form of growing mega cities and a high percentage of population living in urban areas [3] .Khartoum state has an estimated population of 5,274,321 (5th Sudan Population and Housing census – 2008). Due to an increase of population, social development and scattered residential area around Khartoum state traffic jam and accidents has become a normal scene in Khartoum. The problem of congestion in Khartoum city center illustrated and explained [6]. Drivers and transport operators go through rigor in finding their ways to their destination even if they have to pass through longer routes. Finding the shortest route through a

road network is crucial for emergency. The time consider critical factor for ambulances or car to locate the nearest hospital in case of accidents.

GIS provides both the individual and organization with increased knowledge and understanding of spatial data[2]. On the other hand, networks give the means for the movement of people, the flow of resources and energy and the communication of information [5]. Analysis of these networks improves the movement of people, goods, services and the flow of resources. Network analysis in GIS provides good decision support for users interested in finding the nearest facility.

In Malaysia, the transportation authorities focused on determining the optimal route between two or more destinations based on specific travel expense [1]. Those expenses of travel would be based on the length of time or distance required traveling from origin to any destination point by visiting certain location point.

This paper used GIS as effective tool in applying network analysis for Khartoum city center. In addition it provides helpful application for finding the most efficient travel route, generating travel directions, finding the closest facility and mapping service areas based on travel time

MATERIALS AND METHODS

Study area:

Khartoum is the capital of Sudan and the Khartoum state. It is located at the point where the White Nile meets the Blue Nile. The conjunction of the two Niles (where Khartoum is located) is known as "The Mogran". The capital Khartoum contains three metropolitan cities i.e. Khartoum, Khartoum North and Omdurman linked by bridges; they all together form Khartoum State [3]. Khartoum is located between latitudes 15°26′ N and 15°45′ N and longitudes 32° 25′ E and 32°40′ E at an average reduced level 380.000 meters above mean sea level as shown in Figure 1.

The data:

The study involved fieldwork in which the hospital locations were visited and their geographic coordinates picked using hand held GPS (Garmin navigator) 3 meters accuracy. Attribute data and the directions of the one way roads/streets were obtained from the General Management of Traffic, Ministry of Interior. The image of study area was obtained from Google Earth.

METHODS

The process of geo-referencing and digitizing roads to the study area were performed. Thematic layers including streets, building and hospital were created. Road layer was classified according to road category like main road, secondary road and highway. Database was constructed for the query of attribute included road name, maximum design speed, direction of roads as revealed in (Table 1). Lengths had been calculated in the field shape length and travel times had been calculated in the field FT_MINUTES in the attribute Table I.

ANALYSIS

A key component of ArcGIS 9.3 Spatial Analyst has the ability to perform queries. The query functionality gives the analyst the ability to leverage existing data and to make more informed decisions [4].

The key to network representation is to represent nodes, arcs and network topology efficiently. Once the nodes, arcs, and network topology are efficiently represented, other data and information associated with nodes, arcs, stops and turns can be represented as attributes either associated with nodes or arcs**.**

When a geometric network is created, ArcGIS 9.3 also creates a corresponding logical network, which is used to represent and model connectivity relationships between features.

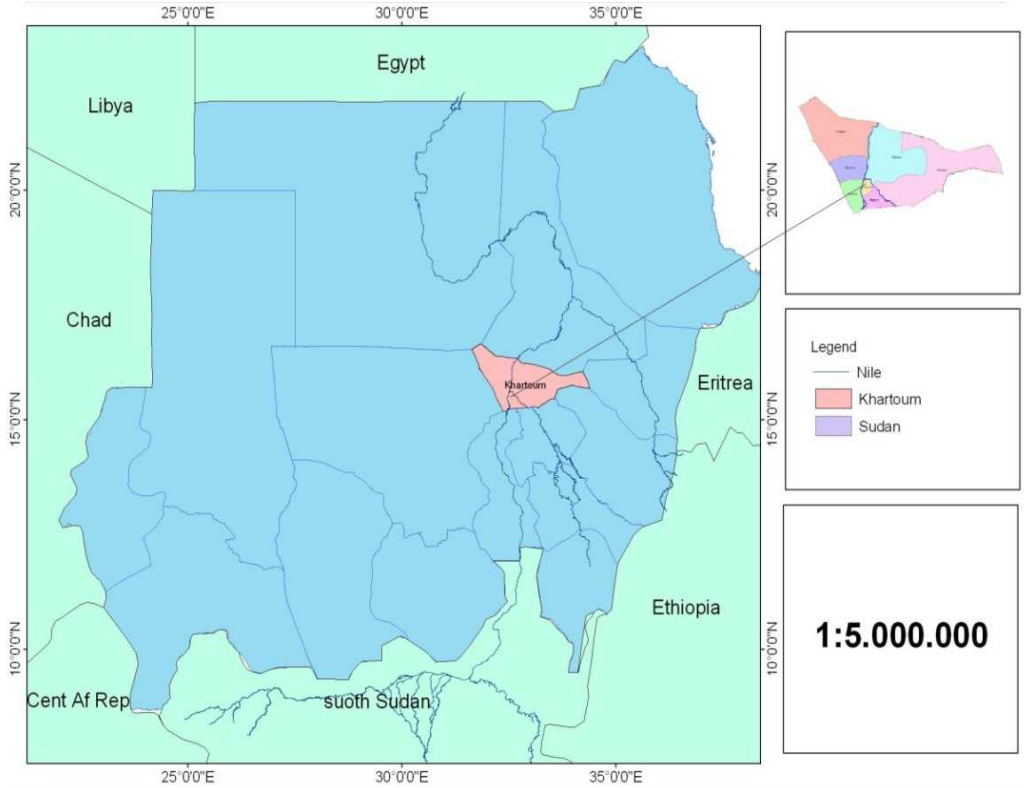

Figure 1: Location map of Khartoum state

Table I: Data used for route network analysis.

*	Name	Oneway	TF_MINUTES	METTER	MAX_SPEED	ROADTYPE	FT_MINUTES	Shape_Length
1	Nile		8.031	6.693	50	1	8.031	6692.618097
2	Algamaa	FT	8.01	6.675	50	1	8.01	6675.090399
3	Algamhoorya	FT	6.873	5.728	50	1	6.873	5727.848851
4	Altabya		6.833	5.694	50	1	6.833	5694.244072
5	Alsaid Abd Arahman	FT	3.135	2.613	50	1	3.135	2595.842633
6	Altabya		1.171	0.976	50	2	1.171	976.067677
7	Osman Digna	FT	1.35	1.125	50	2	1.35	1125.324788
8	Almak Nimir		2.112	1.76	50	1	2.112	1759.979674
9	Algasr		2.103	1.753	50	1	2.103	1752.718304
10	Altayar Izz Edeen Ganoob	FT	0.865	0.721	50	2	0.865	643.170972
11	Alhurrya	FT	1.803	1.502	50	1	1.803	1486.344597
12	Alshaheed Dafalla		1.345	1.121	50	1	1.345	1110.155877
13	Tirhaga	FT	0.93	0.775	50	2	0.93	754.102121
14	Kobri Algoat Almoslaha		0.757	0.631	50	2	0.757	630.648877
15	Salih Basha Almak		1.789	1.491	50	1	1.789	1475.90637
16	Ali Abd Alateef	FT	1.622	1.351	50	2	1.622	1345.598182
17	Atbara	FT	0.788	0.656	50	2	0.788	662.021927
18	Alnigoomi	FT	1.214	1.012	50	2	1.214	1011.614652
19	Sinkat	FT	0.769	0.641	50	2	0.769	640.57238
20	Abd ALLAH Alnoor		1.595	1.33	50	1	1.595	1329.530474
21	ALtigane Elmahi	FT	1.826	1.522	50	2	1.826	1522.028356
22	SOLAIMAN KISHA	FT	1.06	0.883	50	2	1.06	882.959776
23	Mostafa Abo Elala	FT	0.737	0.614	50	2	0.737	613.865301
24	Albaladia2		3.493	2.911	50	1	3.493	2911.079957
25	Abd Elmonim Mohmmed		0.355	0.296	50	1	0.355	296.184083
26	Abd Elmonim Mohmmed	FT	1.452	1.21	50	1	1.452	1149.475761
27	ELshareef ELhindi	FT	1.683	1.402	50	2	1.683	1402.213155
28	Elbaladia	FT	2.733	2.277	50	1	2.733	2282.3186
29	ALtyar Morad	FT	1.006	0.839	50	2	1.006	838.680266
30	Korsheed basha	FT	0.721	0.601	50	2	0.721	377.905442

The logical network is the connectivity graph used for route analysis. The logical network allows quickly discovering and modeling the connectivity relationships between connected edges and junctions in a geometric network during editing and analysis. This allows for fast network tracing and facilitates the generation of on-the-fly connectivity while editing. When edges and junctions are edited or updated in the geometric network the corresponding logical network is automatically updated and maintained as well. In this paper network data set was created and topology was conducted to ensure model validation and connectivity relationships.

The network analysis:

A path between two vertices that minimizes a pre-defined metric such as the total number of steps, total distance or time, is called a shortest path. Determination of shortest paths is often described as shortest path analysis [8].

To determine the best way one needs at a minimum an origin and a destination. The problem of identifying the shortest path along a road network is a fundamental problem in network analysis, ranging from route guidance in a navigation system to solving spatial allocation problems [9].

Similarly, if any where any sort of case like accident, heart-attack etc are happened, user can find the shortest route to reach to the desired hospital based on travel time.

Mapping the services area based on time

Identify those hospitals that can be reached within a specified time and then buffer them to show services zones.

RESULTS

A route Network dataset was generated as shown in Figure 2. A very important use of GIS software is to query shortest route. One can find several routes from one stoppage to another stoppage as shown in Figure 3 and Table II.

When some of the routes are blocked due to any reasons (Accident) GIS must show and lead different possible shortest routes [9], as revealed in Figure 4 and Table III. The analysis involved identifying the closest facility from a location, tracing the best route to the facility and step-by-step directions along the identified route as in Figure5 and Figure IV.

If arrival in 1- 3 minutes to service area, the analysis displays different zones where every zone has a definite time, Shown in Figure 6. For instance, the 1 - 3minutes service area for a facility includes all the streets that can be reached within 1 - 3 minutes from that facility and then bound the roads by a polygon Figure 6. The blue color area illustrates the reachable area within 1 minute. The green color area in Figure 6 illustrates the reachable area within 2 minutes. The red color area illustrates the reachable area within 3 minutes. Unselected area is reachable in more than three minutes.

CONCLUSIONS

An appropriate network had been constructed. Details of road information like one way streets and speed limits were required and had been involved in database tables. Network analysis needs special consideration to provide the prospective results like the shortest route or closest facility. Network analysis relies on the attribute table and lines to produce meaningful results. The process cannot produce a meaningful route without knowing about one-way streets. There is also the issue of topology is a vital step before analysis. After data collection, interring, digitizing the study area, performing the network analysis provides successful results in shortest route, services area and nearest facilities. In GIS, networks are used for more than just finding shortest routes. It provides successful result in nearest facilities and services area based on travel time. It demonstrates how GIS application could lead to improve decision making.

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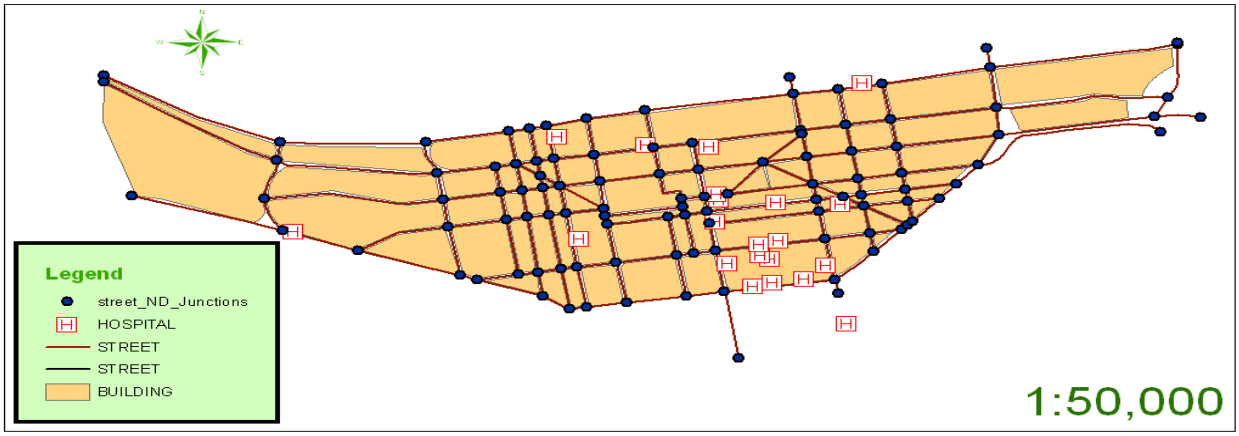

Figure 2: Route network dataset.

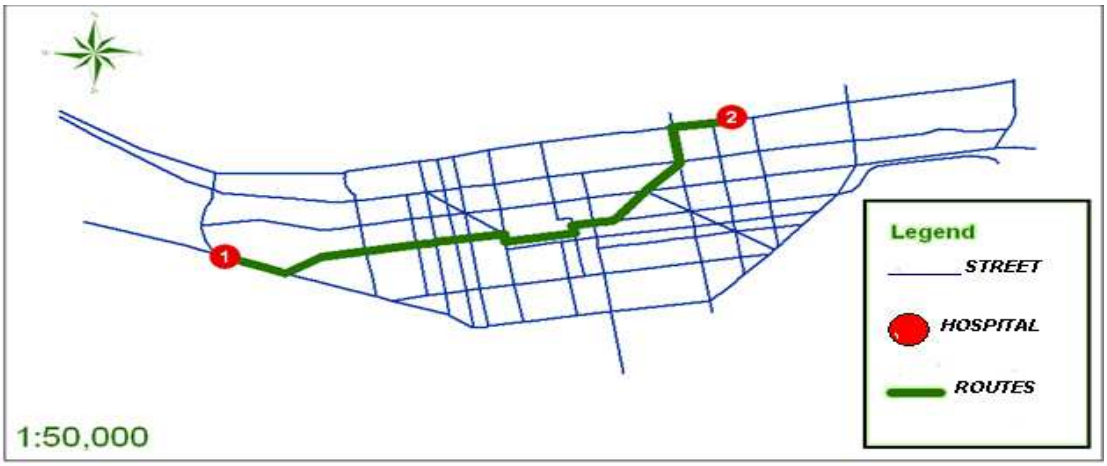

Figure 3: Paths between two locations.

Table II: Route directions.

[-]	Route: Graphic Pick 10 - Graphic Pick 11	5.5 km	7 min	
1:	Start at Graphic Pick 10			Map
2:	Go west on Nile toward Altabya	0.3 km	< 1 min	Map
3:	Turn left on Altabya	1.5 km	2 min	Map
4:	Bear right on Alsaid Abd Arahman	2.6 km	3 min	Map
5:	Bear right on Altabya	0.8 km	< 1 min	Map
6:	Make sharp right on Elbaladia	0.4 km	< 1 min	Map
7:	Finish at Graphic Pick 11, on the right			Map
	Total time: 7 min Total distance: 5.5 km			

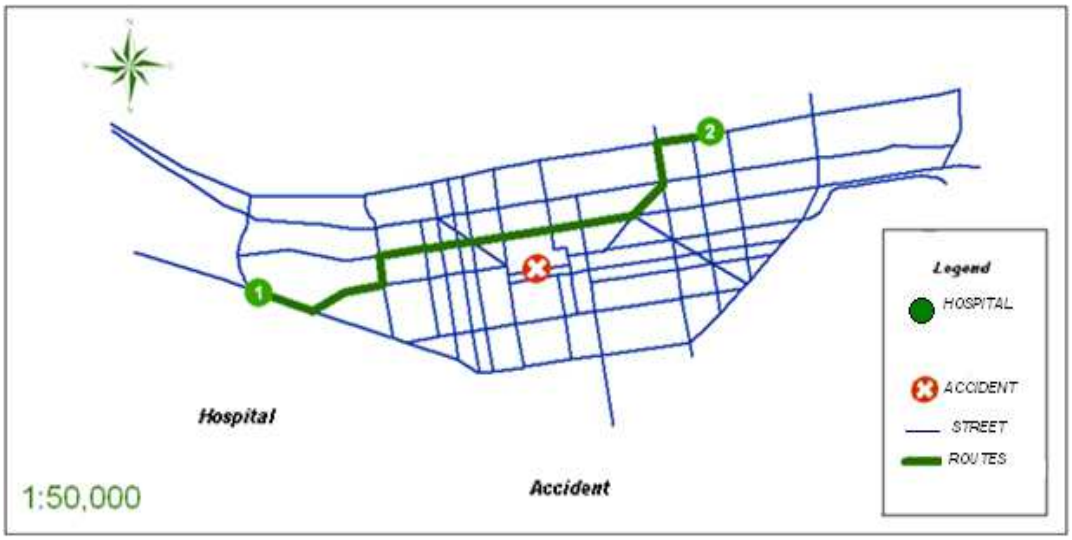

Figure 4: Paths between two locations at barrier.

Table III: Route directions at barrier.

Route: Graphic Pick 1 - Graphic Pick 2	4.3 km	5 min	
1: Start at Graphic Pick 1			Map
2: Go east on Altabya toward Elbaladia	0.4 km	< 1 min	Map
3: Turn left on Elbaladia	0.6 km	< 1 min	Map
4: Turn left on Alshaheed Dafalla	0.2 km	< 1 min	Map
5: Turn right on Algamhoorya	2 km	2 min	Map
6: Bear left on Atbara	0.3 km	< 1 min	Map
7: Turn left on Almak Nimir	0.3 km	< 1 min	Map
8: Turn right on Nile	0.4 km	< 1 min	Map
9: Finish at Graphic Pick 2, on the left			Map
Total time: 5 min Total distance: 4.3 km			

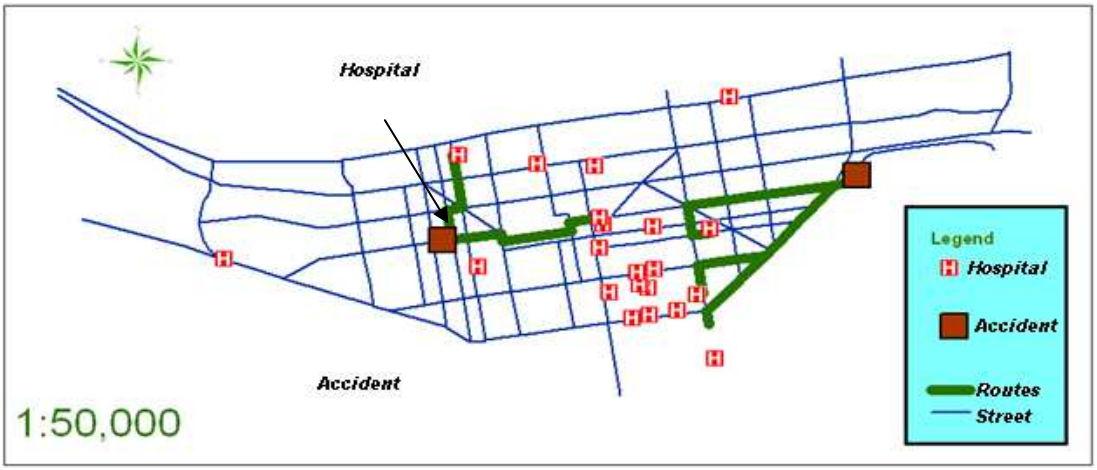

Figure 5: Closest facilities.

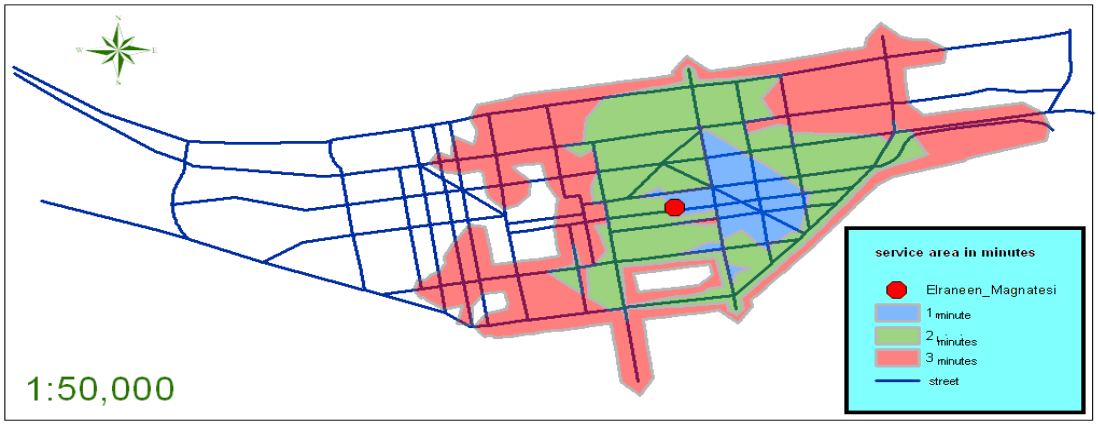

Figure 6: Service area based on travel time.

Table IV: Directions (closest facility).

[−]	**Route: Graphic Pick 1 - Location 3**		0.8 km	< 1 min	
	1:	Start at Graphic Pick 1			Map
	2:	Go east on Elbaladia toward Salih Basha Almak	< 0.1 km	< 1 min	Map
	3:	Turn left on Salih Basha Almak	0.2 km	< 1 min	Map
	4:	Turn right on Algamhoorya	0.1 km	< 1 min	Map
		Total time: < 1 min Total distance: 0.8 km			
1 min	[+]	Route: Graphic Pick 1 - Location 18			1.2 km
2 min	[+]	Route: Graphic Pick 1 - Location 15			1.2 km
2 min	[−]	Route: Graphic Pick 2 - Location 4			1.6 km
	Map	1:	Start at Graphic Pick 2		
< 1 min	Map	2:	Go southwest on Albaladia2 toward Altabya		0.2 km
< 1 min	Map	3:	Bear left on Altabya		0.7 km
< 1 min	Map	4:	At fork keep left on Altabya		0.6 km
< 1 min	Map	5:	Turn left on Almak Nimir		0.1 km
	Map	6:	Finish at Location 4		
			Total time: 2 min Total distance: 1.6 km		
2 min	[+]	**Route: Graphic Pick 2 - Location 17**			1.6 km
2 min	[+]	**Route: Graphic Pick 2 - Location 11**			1.6 km