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Spatial Response to the Consequences of Traffic Accidents on Highways in Assiut Governorate: A Study Using GIS

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Abstract:

Background: Road accidents raise significant concerns in many countries, with road safety being vital to prevent accidents and minimize losses. Swift response to accidents is an effective means of saving the injured and reducing fatality rates.

Problem: Road accidents continue to increase steadily due to various overlapping reasons. The absence of emergency services and slow local response to accidents are among the primary factors exacerbating their harmful effects on public health in Assiut.

Objectives: The study aims to assess the levels of local response to road accidents by ambulance services and hospitals operating in the governorate. This is intended to enhance the preparedness of hospitals and emergency services to address these accidents and contribute to mitigating their severity.

Methodology: Hot spot analyses were used for traffic accidents on highways to explore the temporal and spatial patterns of these points. Additionally, Network Analyst was utilized within a Geographic Information System (GIS) environment to assess the levels of local response by ambulance services and the accessibility to evacuation hospitals in the governorate.

Results: The study provided a detailed analysis of black spots for highway accidents in Assiut, focusing on the temporal and spatial trends of these accidents, as well as the accessibility and response capability of ambulance services. Additionally, a geographic analysis was presented for hospitals designated for evacuating the injured in road accidents.

Conclusion: This study serves as a model for monitoring road accidents in Assiut, offering maps of accident locations and response times. The study recommends the necessity of considering these findings and coordinating between ambulance services, hospitals, and traffic authorities to enhance response levels and health preparedness. This is aimed at saving the injured and reducing fatality rates resulting from highway accidents.

Keywords: *Traffic accidents, highways, spatial response, Assiut Governorate.*

الاستجابة المكانية لتداعيات حوادث المرور على الطرق السريعة في محافظة أسيوط دراسة باستخدام نظم المعلومات الجغرافية

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الملخص

خلفية عامة: تُشكل حوادث الطرق مصدر قلق لكثير من البلدان، وتُعد السلامة المرورية القضية الأكثر أهمية من أجل منع وقوع الحوادث وتقليل الخسائر , وتُمثل الاستجابة السريعة لتداعيات الحوادث أداة فعالة لإنقاذ المصابين، وخفض معدلات الوفيات.

مشكلة الدراسة: تتكرر حوادث الطرق بشكل متزايد نتيجة؛ لأسباب متعددة ومتشابكة, ويمثل غياب خدمات الطوارئ، وبطء الاستجابة المكانية للحوادث سببًا رئيسًا في تزايد تداعياتها الوخيمة على الصحة العامة في محافظة أسيوط.

الأهداف: تهدف الدراسة إلى تقييم مستويات الاستجابة المكانية لحوادث الطرق من قبل الإسعاف ومستشفيات الأخلاء، مما يساعد في تأهب المستشفيات وخدمات الطوارئ لهذه الحوادث والتخفيف من حدتها.

أساليب الدراسة: استخدمت الدراسة تحليلات للبقع الساخنة **(Hot spots)** لحوادث المرور على الطرق السريعة؛ بغرض استكشاف الأنماط الزمانية والمكانية لهذه النقاط، وكذلك مُحلل الشبكات في بيئة نظم المعلومات الجغرافية؛ لتقييم مستويات الاستجابة المكانية من قبل خدمات الإسعاف, وإمكانية الوصول لمستشفيات الاخلاء في المحافظة.

النتائج: قدمت الدراسة تحليلًا تفصيليًا للبقع السوداء للحوادث على الطرق السريعة بمحافظة أسيوط, وتحديداً للاتجاهات الزمانية والمكانية لتكرار الحوادث، وإمكانية وصول الاسعاف والاستجابة لها، علاوة على تقديمها تحليلًا جغرافيًا لمستشفيات إخلاء مصابي الحوادث.

الخلاصة: تعد هذه الدراسة بمثابة نموذج لمراقبة حوادث المرور على الطرق بمحافظة أسيوط في إطار ما رسمته الدراسة من خرائط لمواقع الحوادث وزمن الاستجابة لها. وتوصي الدراسة بالأخذ بعين الاعتبار لهذه النتائج، والعمل على التنسيق بين الإسعاف والمستشفيات والمرور لتحقيق مستويات استجابة وتأهب صحي عالي المستوى؛ لإنقاذ المصابين وخفض معدلات وفيات الحواث المرورية على الطرق السريعة.

الكلمات المفتاحية: حوادث المرور , الطرق السريعة، الاستجابة المكانية, محافظة أسيوط.

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I. Introduction:

In his seminal work, *The African Renaissance Project of Thabo Mbeki: Its South African Roots and Targets*, Sehlare Makgetlaneng reminds us of Mbeki's caution during the year 1979 that "… one should judge a lion by its claws rather than its roar" (2022: 4). This metaphoric expression is valid today in making sense of the political and socio-economic issues, processes and developments in the society as it was during the turbulent 1970s in South Africa (Shai & Molapo 2017).

Road Traffic Accidents (RTAs) are among the most complex issues worldwide, given their intertwined spatial and temporal dimensions. Therefore, it is essential to understand the recurrent spatial and temporal occurrence of accidents, as these incidents are not random events across space and time. Thus, a profound understanding of both the temporal and spatial dimensions of accidents simultaneously is required to achieve a comprehensive insight into the hotspots of these accidents (Le et al., 2020).

Road traffic accidents result in human losses that cannot be compensated. Globally, they pose a significant burden on public health and the economy. They are leading to death for children and youth aged 5 to 29, causing 1.9 million deaths annually, and between 20 to 50 million injuries per year, not all of which result in death but cause disability and other damages. Approximately 92% of these deaths occur in developing countries, despite the fact that the proportion of vehicles in these countries is only about 60% of the total number of vehicles worldwide. The cost of road traffic accidents in most countries is estimated to be about 3% of the gross domestic product (GDP) (WHO, 2023).

Predicting road traffic accidents and anticipating their occurrences in specific months, days, and hours, correlated with different locations and varying environmental and climatic

conditions, is one of the most important contemporary issues. Through this, it is possible to anticipate the times most prone to accidents based on these variables, thereby achieving traffic safety (Durduran, 2010). Traffic safety is considered the most important issue, as identifying areas suffering from safety deficiencies on a global scale requires preventive measures by researchers and traffic officials through the analysis of road networks and determining the risk levels of their various sectors. This is to take appropriate precautions to prevent accidents and minimize losses (Mayorga et al., 2016).

Furthermore, accurate prediction of the severity of road traffic accidents is not only beneficial for emergency responders and medical professionals in planning and responding to accidents but can also assist in policymaking decisions related to road safety and aid in preventing future accidents (Briz-Redón et al., 2019). The United Nations has included road safety as part of its Sustainable Development Goals with two objectives: first, to provide access to safe, affordable, and sustainable transportation systems for all, and second, to reduce deaths and injuries resulting from road traffic accidents worldwide by half by the year 2030.

1. Problem of the study:

The problem of the study lies in the fact that road traffic accidents pose a significant concern for developing countries and greatly impact their development process, as they occur increasingly worldwide. This is primarily attributed to the failure to develop transportation infrastructure to keep pace with the sectors of mobility and transportation (Singh et al., 2021).

In the national context, the number of road traffic accidents on highways in Egypt reached approximately 9,992 accidents in 2020, resulting in around 79,904 injuries and 6,722 fatalities

(CAPMAS, 2020). There are numerous reasons for road accidents, but human mistakes are considered the primary cause of them (WHO, 2023). For example, driving mistakes, speeding, and traffic signal violations account for about 79.7% of road traffic accidents in Egypt (CAPMAS, 2020).

Other causes include environmental factors and road conditions, mechanical factors of vehicles and their numbers, expanding road networks and national development projects, a mix of high speeds, heavy traffic alongside slower and smaller vehicles, as well as pedestrians, and ineffective enforcement of traffic laws, and the absence of emergency services (Khatun et al., 2024), or what is known as the spatial response to road traffic accidents, which is the problem from which the study emanates. That aims to assess its levels in light of the map of road traffic accidents in Assiut.

When road traffic accidents recur at a single location, it is an indicator that this location is affected by one or more factors that led to the recurrence of road traffic accidents there. However, many countries lack accurate documentation and monitoring of information about road traffic accidents and the mechanisms for dealing with their repercussions. Therefore, the absence of a geographic database for traffic statistics and the inclusion of road traffic accidents within and outside cities have made studying road traffic accidents and their spatial response challenging.

Accuracy in determining the location of a road traffic accident is key to the process of analyzing road traffic accidents and addressing their consequences. When an accident occurs at a certain place, and the traffic analyst cannot determine this location, it means wasting time, effort, and money, leaving hazardous sites unaddressed. The traffic analysis of hazardous sites becomes significantly more comprehensive when it is a

spatial analysis that aids hospitals and emergency services in preparedness for these accidents and mitigating their severity.

2. Study Area:

Assiut is one of the upper governorates of Egypt. It is bordered to the north by Minya, to the south by Sohag, to the east by the Red Sea Governorate, and to the west by the New Valley Governorate. The governorate takes on a strip-like shape, stretching 130 km along the course of the Nile River. Geographically, the governorate extends between latitudes 26°45' and 27°45' north and longitudes 30°45' and 31°45' east.

The total area of the governorate is approximately 25,926 square kilometers, accounting for 2.59% of the total area of the republic, with an inhabited area of about 1,562 square kilometers. According to the 2017 census, its population is around 4,383,289 people. Administratively, it is divided into 11 districts, 52 local units, and 235 villages (CAPMAS, 2017; Ali, 2019).

The governorate boasts a well-developed network of roads totalling approximately 3,832 kilometers in length. This includes 1,910 kilometers of regional roads, accounting for 49.8% of the total road network, and about 1,921 kilometers of internal roads, comprising 50.2% of the total roads.

These roads vary in terms of pavement condition, with approximately 2,957 kilometers of paved roads, representing 77% of the total road network in the governorate. Meanwhile, the total length of unpaved roads is 874 kilometers, accounting for 23% of the total roads in the governorate (CAPMAS, 2020) [Figure 1].

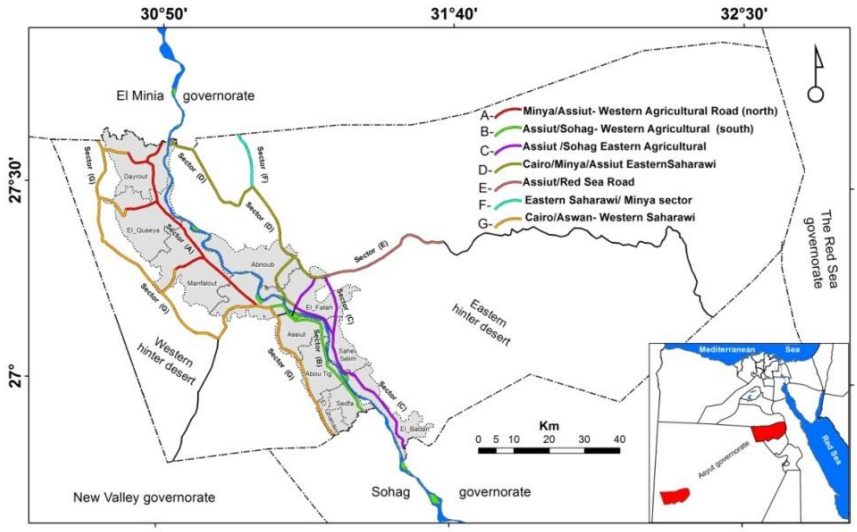

Fig. 1. Highways within Assiut Governorate, 2023

3. Literature Review:

Spatial analysis of road traffic accidents is of utmost importance, and multiple studies in different countries have investigated the spatial distribution of traffic accident risks and hotspots using various methods. One of the prominent studies in this field is the research conducted by Brian & Richard, 1998, on urban transportation problems and their solutions (a study in modern transportation geography). Another significant study is by Erdogan et al., 2008, titled "The Role of Geographic Information Systems in Assisting Traffic Accident Analysis System: A Case Study of Afyonkarahisar City."

Durduran, 2010, focuses on a decision-making system for the automatic detection of traffic accidents based on a geographic information systems platform. Additionally, the study conducted by Mohaymany et al., 2013, which addresses a method relying on geographic information systems to detect high-risk road segments using kernel density estimation. On the other hand, Yang et al., 2013, is about estimating the economic cost based on geographic

information systems for traffic accidents in St. Louis, Missouri, while the study by Osayomi & Areola, 2015, deals with the geospatial analysis of traffic accidents, injuries, and fatalities in Nigeria.

Shafabakhsh et al., 2017, address spatial analysis based on geographic information systems for urban traffic accidents, through a case study in Mashhad, Iran. Dereli and Erdogan, 2017, focus on a new model for identifying black spots of traffic accidents using spatial statistical methods supported by geographic information systems. On another note, Briz-Redón et al., 2019, deal with spatial analysis of traffic accidents near and between road intersections in a directed linear network. Additionally, Mohammed et al., 2019, provide a review of traffic accidents and related practices worldwide. On a different aspect, Le et al., 2020, tackle identifying hotspots of road traffic accidents using spatio-temporal statistical analysis techniques built on geographic information systems in Hanoi, Vietnam. Lastly, Singh et al., 2021, discuss the application of Geographic Information System (GIS) in reducing black spots of accidents and planning for a safer urban road network.

Alkhadour et al., 2021, address traffic accident detection using geographic information systems, while Mohammed et al., 2023, focus on spatio-temporal analysis based on geographic information systems for road traffic accidents to support sustainable transportation planning. On another front, Ahmed et al., 2023, examine injuries and fatalities resulting from road traffic accidents as a neglected global health issue.

Ammas, 2023, investigate spatial analysis of traffic accidents in Al Madinah using geographic information systems, whereas Aule et al., 2023, explore spatial accessibility to emergency facilities for road accident victims in the federal capital. Lastly, Infante et al., 2023, address the prediction of road traffic accidents

in Portugal using artificial intelligence, statistics, and geographic information.

Khatun et al., 2024, address the identification and analysis of black spots for accidents using geographic information systems: A study on the national highway Kushtia-Jhenaidah (N704) in Bangladesh. Meanwhile, Alhaek et al., 2024, focus on spatial pattern learning and temporal dependencies to predict the severity of traffic accidents using a deep learning approach. Most studies have demonstrated that analyzing traffic accidents using spatial solutions contributes to understanding their distribution patterns, improving response speed to accidents, and reducing associated risks, which aligns with the objectives of the current study.

II. Methodology and data collection techniques:

The study relies on data collection from the General Authority for Roads and Bridges in Assiut, the Ambulance Authority in Assiut, and the Health Information Systems Unit at the Ministry of Health. To achieve the research objectives, the study employed a descriptive analytical approach and a topical approach.

The study also employs statistical and cartographic methods to present and analyze its results, in addition to using geographic information systems (GIS) to produce and spatially analyze maps. This is to effectively analyze and illustrate the spatial variations of traffic accidents and their indicators in a detailed manner.

Additionally, the study utilized hot spot analyses to explore the spatiotemporal patterns of traffic accident hot spots on highways. Identifying these locations helps establish a priority list for addressing the risk therein and aids in developing spatial response plans by ambulance services. Furthermore, it helps determine accessibility to evacuation hospitals in the governorate. This was done using Network Analyst within the geographic information systems (GIS) environment.

III. Discussion and Results:

1. The network of highways within Assiut Governorate:

Table (1) and Figures (2, 3) indicate that the total length of highways in Assiut Governorate reached 532.62 km in 2022, distributed across seven sectors with an average of 76.09 km per sector. These seven sectors included 29 links, with an average of 18.37 km per link. Sector (H), Cairo/Aswan Western Desert, stands out as the longest highway sector in the governorate, exceeding the average by 89.41 km, and it also has the highest number of interchanges with a total of 10 interchanges. Following closely is sector (D), Minya/Assiut Eastern Desert, with a length of 87.1 km distributed across 4 interchanges, exceeding the average length of highways in the governorate by approximately 11.01 km in 2022. Sector (A), Minya/Assiut Western Agricultural, ranks third in length, surpassing the average by 8.67 km. This sector is the second largest in terms of the number of interchanges, with a total of 7 interchanges. Sector (C), Assiut/Sohag Eastern Agricultural, ranked fourth with a length of 82.36 km, exceeding the average by 6.27 km, and it comprises 4 interchanges.

Sector (B), Assiut/Sohag Western Agricultural, ranked fifth among the highway sectors in Assiut in terms of length, falling below the average by 19.19 km. This sector includes 4 interchanges. Sector (F), New Assiut/Assiut/Red Sea, came in sixth with a length of 38 km. Lastly, sector (W), Eastern Desert Road/Minya Entrance, had a length of 18 km, which is less than the average by 58.09 km.

Table (1): Division of main highway sectors in Assiut Governorate, 2023

Road/ Sector		No.	Length Km	Road/ Sector		No.	Length Km
Minya/Assiut - Western Agricultural Road (north) (A)	Assiut/ Manfalut	1	19.7	Minya/Assiut Eastern Saharawi (D)	El-Fath/Abnoub/Eastern Saharawi	16	17.8
	Manfalut/ Bani Adi	2	8.76		Assiut Al- jadeda/EL- Auamer	17	12
	Manfalut/ El Qusiya	3	21		Arab EL- Auamer/ Eastern Saharawi	18	22.7
	El Qusiya/ Dashlot	4	9		Al- hauata el- sharqia Road	19	34.6
	El-Qusiya/ Dairout	5	12	Total		(D)	87.1
	Dayrut/ Deir Mawas	6	7.6	Assiut Al- jadeda/ Assiut/Red Sea (E)		(E)	38
	Dayrut / Western Saharawi	7	6.7	Eastern Saharawi/ Minya entrance sector (F)		(F)	18
Total		(A)	84.76	Cairo/Aswan- Western Saharawi (G)	EL- Ganaim/ Drunka	20	29.5
Assiut/Sohag- Western Agricultural (south) (B)	Entrance to Assiut/ Sedfa	8	10.5		Drunka/ Assiut	21	12
	Sadfa/ Abu Tig	9	11.1		Assiut / Manqabad	22	4.8
	Abu Tig/ entrance to Assiut city	10	16.8		Manqabad/Bani Ghalib	23	18.6
	Internal road sector in Assiut city	11	18.5		Bani Ghalib/Bani Adi	24	21.3
Total		(B)	56.9		Bani Adi/ Manfalut entrance	25	7.5
Assiut /Sohag Eastern Agricultural (C)	El-Badari / Sahel Selim	12	40.6		Bani Adi/El Qusiya	26	35
	Sahel Salim/El-Fath	13	14		El Qusiya / agricultural road	27	11.5
	Sahel Selim/ Assiut Al- jadeda	14	17.5		El Qusiya/ Dashlot	28	18
	El-fath/ Assiut Al- jadeda	15	10.26		Dashlot/Dairout	29	7.3
Total		(C)	82.36	Total		(G)	165.5
Total							532.62

Source: Depending on General Authority for Roads and Bridges in Assiut, unpublished data, 2023.

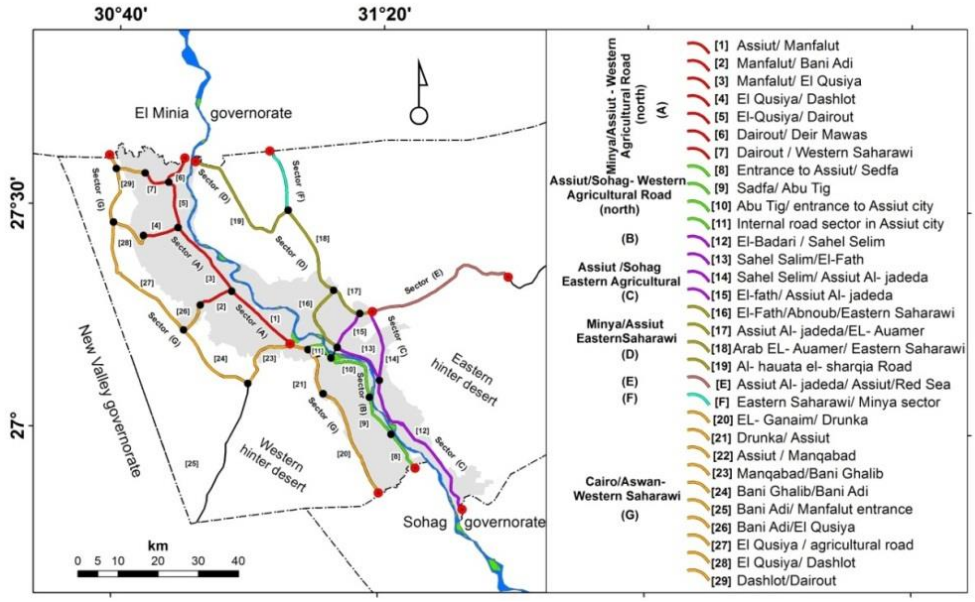

Fig. 2. Division of main highway sectors in Assiut Governorate, 2023

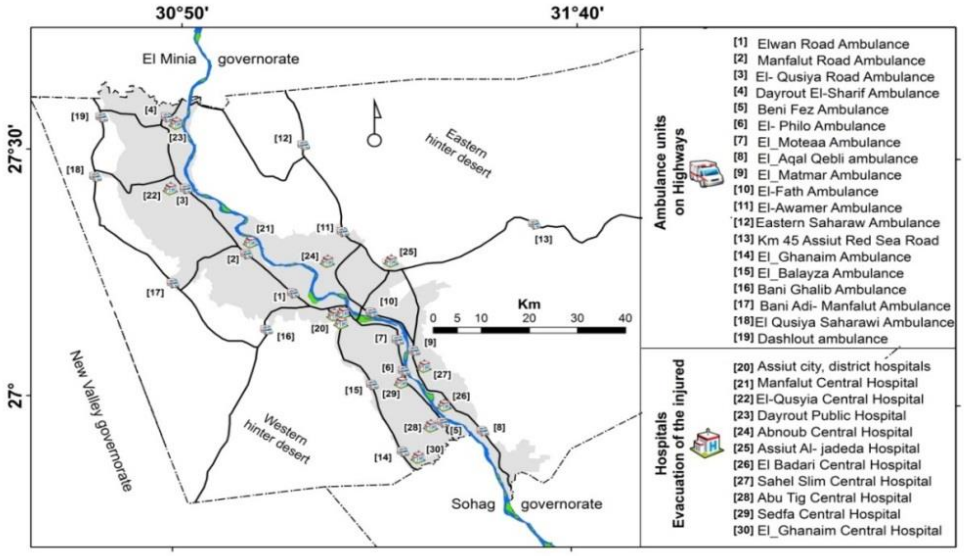

Fig. 3. locations of Ambulance and evacuation hospitals on highways in Assiut Governorate, 2023

2. Analysis of black spots for traffic accidents on highways in Assiut:

Table (2) and Figures (4, 5, 6) indicate that the total number of accidents recorded on highways in Assiut governorate during the period (2018-2022) amounted to 796 accidents, at an average of 1.99 accidents per kilometer. The highway sectors in the governorate can be classified according to this rate into the following categories:

a. **Sectors where traffic accident rates exceed the overall average in the governorate:** Sector (B), which connects Assiut to the western agricultural region of Sohag (2.48 accidents/km), sector (A), linking Minya to the western agricultural region of Assiut (2.18 accidents/km), and Sector (F), the eastern desert road/entrance to Minya (2.17 accidents/km). The higher accident rates in sectors (A) and (B) are attributed to the high residential density along these roads and the increased traffic volume associated with the daily commuting of workers to and from Assiut, the capital of the governorate. This is evident as the highest percentage of recorded traffic accidents in the governorate occurred on the link between Manfalut and Assiut in sector (A), accounting for 56.8% of the total number of accidents in this sector and 13.2% of the total number of accidents recorded on highways in the governorate during the study period. The increase in accident rates in sector (F), the eastern desert road/entrance to Minya, is attributed to the deterioration of the road surface pavement and the lack of traffic services on it.

b. **Sectors where accident rates are equal to the overall average in the governorate:** This is limited to Sector (G) Assiut/Sohag Eastern Agricultural, which recorded about 164 accidents, with a rate of 1.99 accidents per kilometer. This is primarily due to the narrow width of the road in most links of this sector.

c. **Sectors with accident rates below the overall average in the governorate:** These are represented by the sectors: (E) New Assiut /Assiut /Red Sea (1.47 accidents/km), (D) Minya/Assiut Eastern Desert (0.88 accidents/km), and finally sector (H) Cairo/Aswan Western Desert (0.81 accidents/km), all of which are desert roads far from residential areas. Regarding the number of injuries and fatalities resulting from highway accidents in Assiut Governorate during the period from 2018 to 2022, the number of injuries reached 1477 injured, at a rate of 2.77 injured per kilometer of highways, and 18.56 injured per 10 accidents. As for the number of fatalities, it reached 532 deceased, at a rate of one deceased per kilometer of highways, and 6.68 deceased per 10 accidents. Sector (A) represents the most dangerous sector among the highway sectors in the governorate, witnessing approximately 27.3% and 28.5% of the total number of injuries and fatalities, respectively. In contrast, sector (F) had the lowest recorded number of injuries at 2.6%, while sector (B) recorded the lowest number of fatalities at 10.7% of the total fatalities in highway accidents in the governorate.

Table (2): Distribution of accidents, deaths, and injuries on the main highways in Assiut Governorate during the period (2018: 2022 AD)

Sector No.		Length Km	Accidents No.	Injuries No.	Death No.	Accident/ km	Injured/ km	Deceased/ Km	Injured/ 10 Accident	Deceased/ 10 Accidents	Sector No.		Length Km	Accidents No.	Injuries No.	Death No.	Accident/ km	Injured/ km	Deceased/ Km	Injured/ 10 Accident	Deceased/ 10 Accidents
(A)	1	19.7	105	249	117	5.33	12.64	5.94	23.71	11.14	(D)	16	17.8	31	65	10	1.74	3.65	0.56	20.97	3.23
	2	8.76	13	41	7	1.48	4.68	0.8	31.54	5.38		17	١٢	١١	٣٣	٧	0.92	2.75	0.58	30	6.36
	3	21	41	62	14	1.95	2.95	0.67	15.12	3.41		18	22.7	21	52	٤٢	0.93	2.29	1.85	24.76	20
	4	9	8	22	6	0.89	2.44	0.67	27.5	7.5		19	34.6	14	36	12	0.4	1.04	0.35	25.71	8.57
	5	12	9	17	٢	0.75	1.42	0.17	18.89	2.22	(D)		87.1	77	186	71	0.88	2.14	0.82	24.16	9.22
	6	7.6	5	7	٢	0.66	0.92	0.26	14	4	(E)		38	56	102	62	1.47	2.68	1.63	18.21	11.07
	7	6.7	4	5	3	0.6	0.75	0.45	12.5	7.5	(F)		18	39	89	65	2.17	4.94	3.61	22.82	16.67
(A)		84.76	185	403	151	2.18	4.75	1.78	21.78	8.16	(G)	20	29.5	30	71	42	1.02	2.41	1.42	23.67	14
(B)	8	10.5	10	19	11	0.95	1.81	1.05	19	11		21	12	18	22	6	1.5	1.83	0.5	12.22	3.33
	9	11.1	34	76	19	3.06	6.85	1.71	22.35	5.59		22	4.8	16	21	7	3.33	4.38	1.46	13.13	4.38
	10	16.8	41	93	23	2.44	5.54	1.37	22.68	5.61		23	18.6	11	15	10	0.59	0.81	0.54	13.64	9.09
	11	18.5	56	64	4	3.03	3.46	0.22	11.43	0.71		24	21.3	5	11	6	0.23	0.52	0.28	22	12
(B)		56.9	141	252	57	2.48	4.43	1	17.87	4.04		25	7.5	10	22	14	1.33	2.93	1.87	22	14
(C)	12	40.6	59	79	46	1.45	1.95	1.13	13.39	7.8		26	35	16	27	13	0.46	0.77	0.37	16.88	8.13
	13	14	38	47	31	2.71	3.36	2.21	12.37	8.16		27	11.5	8	11	10	0.7	0.96	0.87	13.75	12.5
	14	17.5	24	34	12	1.37	1.94	0.69	14.17	5		28	18	11	19	6	0.61	1.06	0.33	17.27	5.45
	15	10.26	43	53	16	4.19	5.17	1.56	12.33	3.72		29	7.3	9	13	6	1.23	1.78	0.82	14.44	6.67
(C)		82.36	164	213	105	1.99	2.59	1.27	12.99	6.4	(G)		165.5	134	232	120	0.81	1.4	0.73	17.31	8.96
Total													532.6	796	1477	532	1.99	2.77	1	18.56	6.68

Source: Depending on Assiut Ambulance Authority, unpublished data, 2018: 2022.

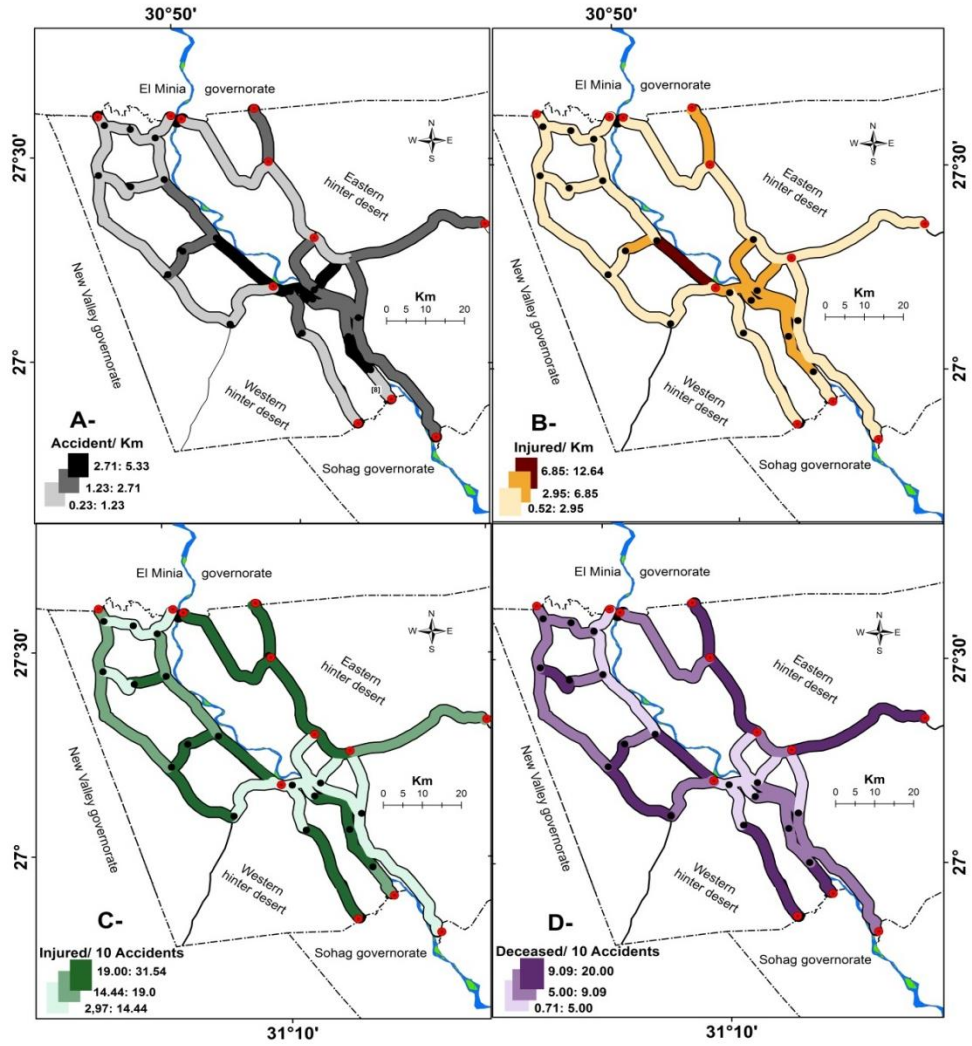

Fig 4. Indicators of severity of accidents on highways in Assiut Governorate during (2018: 2022 AD)

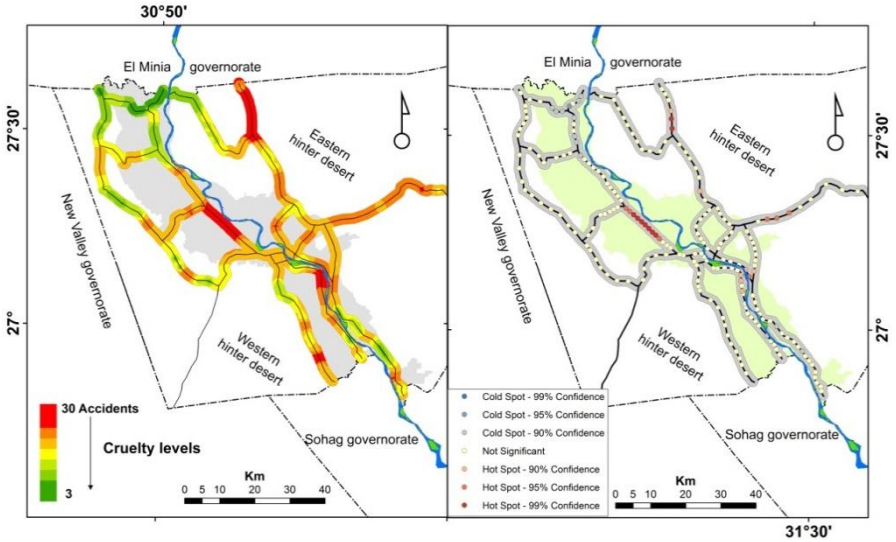

Fig. 5. Hot spot analysis of accidents on highways in Assiut Governorateduring (2018: 2022 AD)

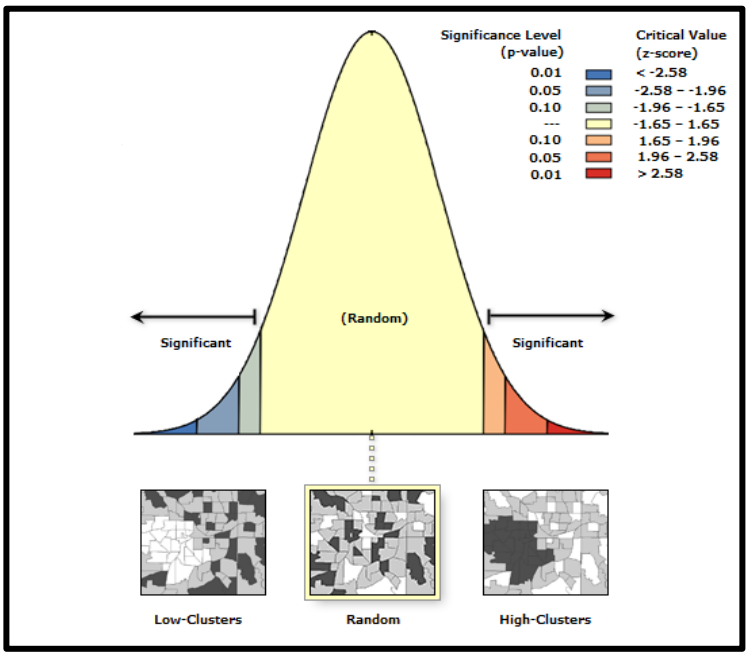

Fig. 6. Spatial Autocorrelation Report

3. Temporal-Spatial Trends of Traffic Accidents in Assiut:

From Table (3) and Figures (7, 8), it can be observed that the monthly average of accidents on highways in Assiut Governorate during the period from 2018 to 2022 was approximately 13.27 accidents per month. Sectors (A) and (C) are considered the highest sectors in terms of monthly accident rates, with 3.08 accidents per month for Sector (A) and 2.73 accidents per month for Sector (C). This can be attributed to the traffic density experienced by road links in these sectors during most months of the year.

There is a clear variation in the number of injuries from highway accidents during different months of the year for the period from 2018 to 2022. The difference between the highest recorded month for injuries (October) was 184 injuries, while the lowest (September) recorded 62 injuries, with a difference of 122 injuries, equivalent to 8.3% of the total injuries during the study period. Sector (A) tops the list of sectors in the governorate in terms of the monthly average of traffic accident injuries, with 6.72 injuries per month, followed by Sector (B) with an average of 4.2 injuries per month, then Sector (H) with an average of 3.87 injuries per month, and Sector (C) with an average of 3.55 injuries per month.

This reflects the high incidence of accidents in these four sectors, which together accounted for more than three-quarters (78.4%) of the traffic accidents recorded on highways in the governorate. In contrast, the monthly injury rates in Sectors (D), (E), and (F) are lower due to the lower incidence of traffic accidents on them, as they are further away from residential areas.

October represents the peak of traffic accident injuries on highways in the Governorate during the study period, accounting for 12.46% of the total. This coincides with the beginning of the academic year and an increase in transportation volume on the roads. Following October, November represents 11.65%, closely followed by May at 11.58%, and April at 8.94%. This increase is associated with religious occasions such as Ramadan and Eid al-Fitr, during which roads experience heavy traffic.

As for September, it represents the lowest month in terms of recorded accident injuries, accounting for 4.2% of the total injuries on highways in the governorate. This is because September is considered a month with reduced transportation volume on highways due to the prevalence of vacations during this month.

Table (3): Seasonal and monthly distribution of traffic accident injuries on main highways in Assiut Governorate during the period (2018: 2022)

Sectors	Accidents No.	No. of accidents and injuries													Monthly rate for…..	
		injuries	December	January	February	March	April	May	June	July	August	September	October	November	Total	Accidents	Injured
(A)	**185**	No	**44**	**17**	**31**	**33**	**45**	**59**	**29**	**12**	**40**	**8**	**47**	**38**	**403**	**3.08**	**6.72**
		%	**10.92**	**4.22**	**7.69**	**8.19**	**11.17**	**14.64**	**7.2**	**2.98**	**9.93**	**1.99**	**11.66**	**9.43**			
(B)	**141**	No	**17**	**21**	**9**	**24**	**20**	**35**	**11**	**21**	**11**	**14**	**31**	**38**	**252**	**2.35**	**4.2**
		%	**6.75**	**8.33**	**3.57**	**9.52**	**7.94**	**13.89**	**4.37**	**8.33**	**4.37**	**5.56**	**12.3**	**15.08**			
(C)	**164**	No	**14**	**20**	**15**	**18**	**13**	**18**	**9**	**19**	**8**	**13**	**37**	**29**	**213**	**2.73**	**3.55**
		%	**6.57**	**9.39**	**7.04**	**8.45**	**6.1**	**8.45**	**4.23**	**8.92**	**3.76**	**6.1**	**17.37**	**13.62**			
(D)	**77**	No	**14**	**18**	**11**	**15**	**20**	**10**	**14**	**12**	**15**	**13**	**24**	**20**	**186**	**1.28**	**3.1**
		%	**7.53**	**9.68**	**5.91**	**8.06**	**10.75**	**5.38**	**7.53**	**6.45**	**8.06**	**6.99**	**12.9**	**10.75**			
(E)	**56**	No	**11**	**7**	**4**	**8**	**8**	**16**	**10**	**14**	**7**	**3**	**8**	**6**	**102**	**0.93**	**1.7**
		%	**10.78**	**6.86**	**3.92**	**7.84**	**7.84**	**15.69**	**9.8**	**13.73**	**6.86**	**2.94**	**7.84**	**5.88**			
(F)	**39**	No	**8**	**5**	**7**	**6**	**9**	**8**	**8**	**5**	**10**	**3**	**11**	**9**	**89**	**0.65**	**1.48**
		%	**8.99**	**5.62**	**7.87**	**6.74**	**10.11**	**8.99**	**8.99**	**5.62**	**11.24**	**3.37**	**12.36**	**10.11**			
(G)	**134**	No	**20**	**12**	**17**	**22**	**17**	**25**	**16**	**14**	**23**	**8**	**26**	**32**	**232**	**2.23**	**3.87**
		%	**8.62**	**5.17**	**7.33**	**9.48**	**7.33**	**10.78**	**6.9**	**6.03**	**9.91**	**3.45**	**11.21**	**13.79**			
Total	**796**	No	**128**	**100**	**94**	**126**	**132**	**171**	**97**	**97**	**114**	**62**	**184**	**172**	**1477**	**13.27**	**24.62**
		%	**8.67**	**6.77**	**6.36**	**8.53**	**8.94**	**11.58**	**6.57**	**6.57**	**7.72**	**4.2**	**12.46**	**11.65**			

Source: Depending on Assiut Ambulance Authority, unpublished data, 2018: 2022

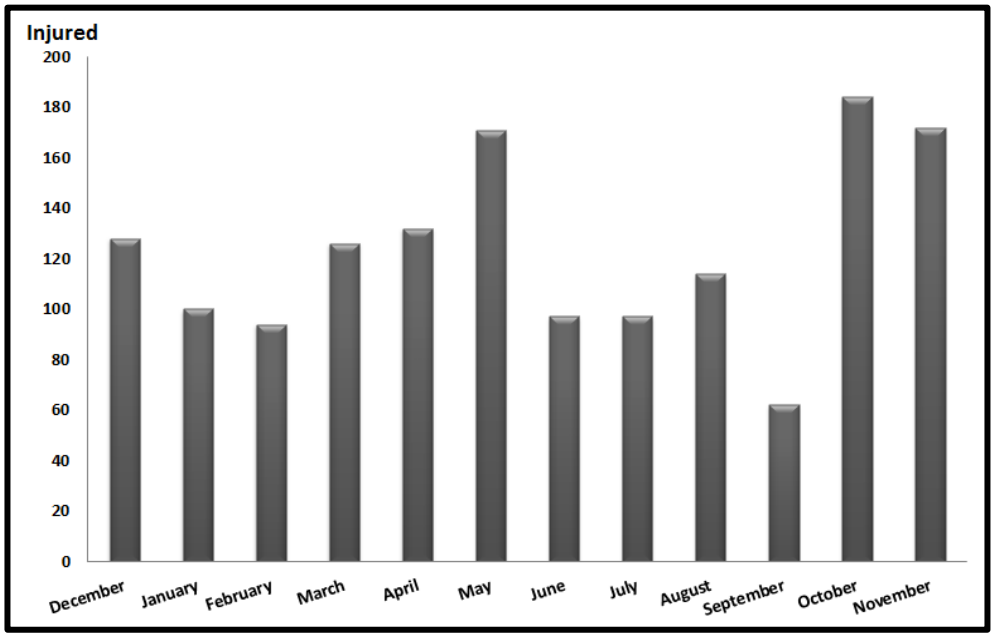

Fig. 7. Distribution of accidents and injuries on highways according to months during (2018: 2022 AD)

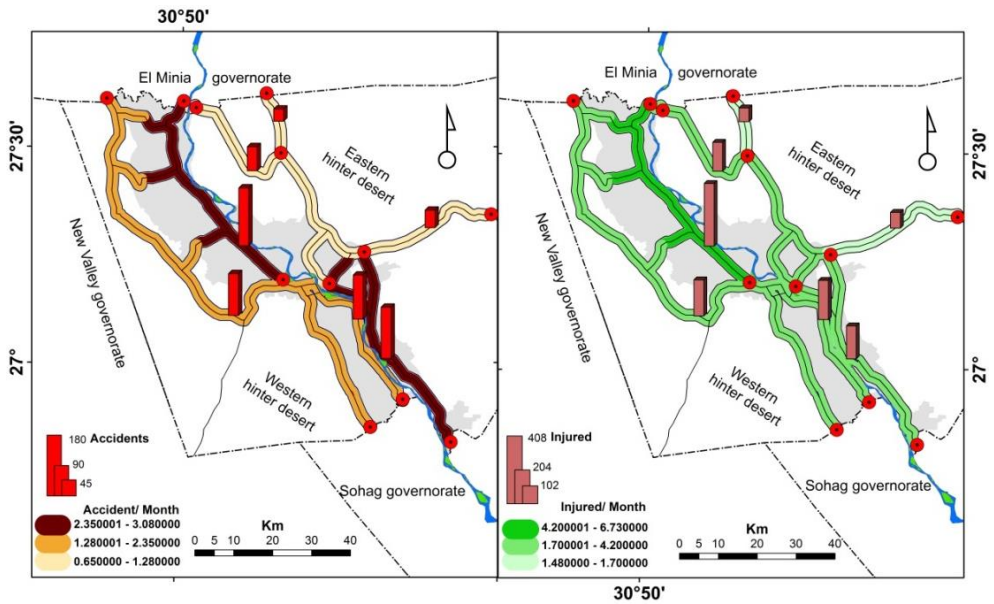

Fig. 8. Monthly rate of accidents and injuries on highways according to months during (2018: 2022 AD)

4. Analysis of ambulance response time and evacuation hospitals for road accidents in Assiut:

Table (4) and Figure (9) illustrate the variation in the response time of ambulances to accident sites on the highways in Assiut. Ambulances achieved a response time of less than 6 minutes for 571 cases, constituting 38.66% of the total reports, which is considered the ideal time for arrival on highways.

In contrast, ambulances arrived after 12 minutes for approximately 20.4% of the cases on roads that fall within the blind spot areas, far from emergency services. Ambulances arrived within a range between the ideal time and the blind spots, during a period ranging from 6 to 12 minutes for 605 cases, representing 41.96% of the cases. This time frame is considered acceptable for ambulance arrival on highways.

a. The optimal timeframe (less than 6 minutes):

Geographically, the ambulance services achieved a swift response in less than 6 minutes for over 50% of the reported incidents across the entire Sector (F), centered in Abnoub, as well as on several other roads spanning various sectors. This includes roads within Assiut district in Sector (A). Additionally, ambulance services attained responses within the optimal timeframe for over 40% of the incidents in Sector (A), encompassing Assiut and Menouf, as well as in Sector (B) centered in Abutig, and across the entirety of Sector (H), situated in Al Fath. In contrast, Sectors (H) within Manfalut and Al Qusiya districts, Sector (A) within the Al Qusiya district, and Sector (D) within the Abnoub district face challenges with ambulances arriving within the ideal timeframe. In these areas, ambulances reached less than 30% of the cases in less than 6 minutes.

b. The acceptable timeframe (6 to 12 minutes):

Ambulance services achieved arrival within the acceptable timeframe for approximately 41.96% of the cases on all highways, with responses exceeding 50% of the cases in Sector (B) within the district of Sidfa, Sector (A) within the district of Al-Qusiya, and Sector (H) in the districts of Assiut and Manfalut.

c. Blind roads (more than 12 minutes):

These are the roads that require addressing their issues and achieving faster response rates. The entire sectors (C) and (D) are among the sectors that suffer from delayed ambulance response times, where ambulances arrived for about 25% of the cases in some locations in more than 12 minutes. The roads in Badari district, due to its longitudinal extension, and the roads in the sector (D) inside Abnoub are the most in need of addressing access issues, as ambulance delays of more than 12 minutes were recorded for about 42.5% of the reports in Badari and 34.5% in Abnoub.

Concerning the accessibility from accident locations on highways to evacuation hospitals within the cities of Assiut, and as per the Ministry of Health's directive that all road accidents are to be transported to public, central, and university hospitals, it's noted that these hospitals are concentrated within cities known for traffic congestion. As a result, about 46.34% of injuries took over 20 minutes to reach hospitals. On the other hand, only around 30% of injuries arrived at hospitals in less than 10 minutes, while approximately 23.7% of cases took between 10 and 20 minutes to arrive.

Sector (A) stands out as one of the sectors of roads that achieved rapid access to hospitals, with over 44% of injuries on links in this sector reaching hospitals in less than 10 minutes. This is due to the

proximity to the University Hospital and Manfalut Central Hospital. Meanwhile, a third of the injuries (33.33%) took between 10 and 20 minutes to arrive, while 22.11% of the injuries faced difficulty in reaching hospitals and took over 20 minutes. Sectors (F), (H), and (D) face significant challenges in reaching hospitals, as 86.9% of injuries in sector (F), 82.69% in sector (H), and 66% in sector (D) took over 20 minutes to arrive.

To a lesser extent, road links in sector (C), sector (B), and sector (H) face difficulty in accessing hospitals. Approximately 48.55% of injuries in sector (C), 42.37% in sector (B), and 41.67% in sector (H) took over 20 minutes to arrive. What makes these sectors more challenging than others is that most of their links, except those belonging to Assiut and Dayrut, did not record any percentage of arrivals to hospitals within less than 10 minutes. 100% of the injuries recorded a time of arrival exceeding 10 minutes. In contrast, 100% of the injuries in sector (A) and sector (H) in the link to Dayrut did not exceed 20 minutes of arrival time.

At a detailed level, the arrival time exceeded 96.23% of injuries in sector (B) at Abu Tig link, and 94.33% of injuries at the Al-Fateh link in sector (C) exceeded 20 minutes, while only 4% of injuries took less time. Moreover, over 70% of injuries in the links of sector (D) in Abnoub and sector (H) within the Ghanayim and Al-Qusiyah districts exceeded 20 minutes to reach hospitals. These links are considered blind spots due to their distance from evacuation hospitals. Figure (9) illustrates the arrival time of ambulances, arrival at hospitals, and a map of the possibility of responding to accidents.

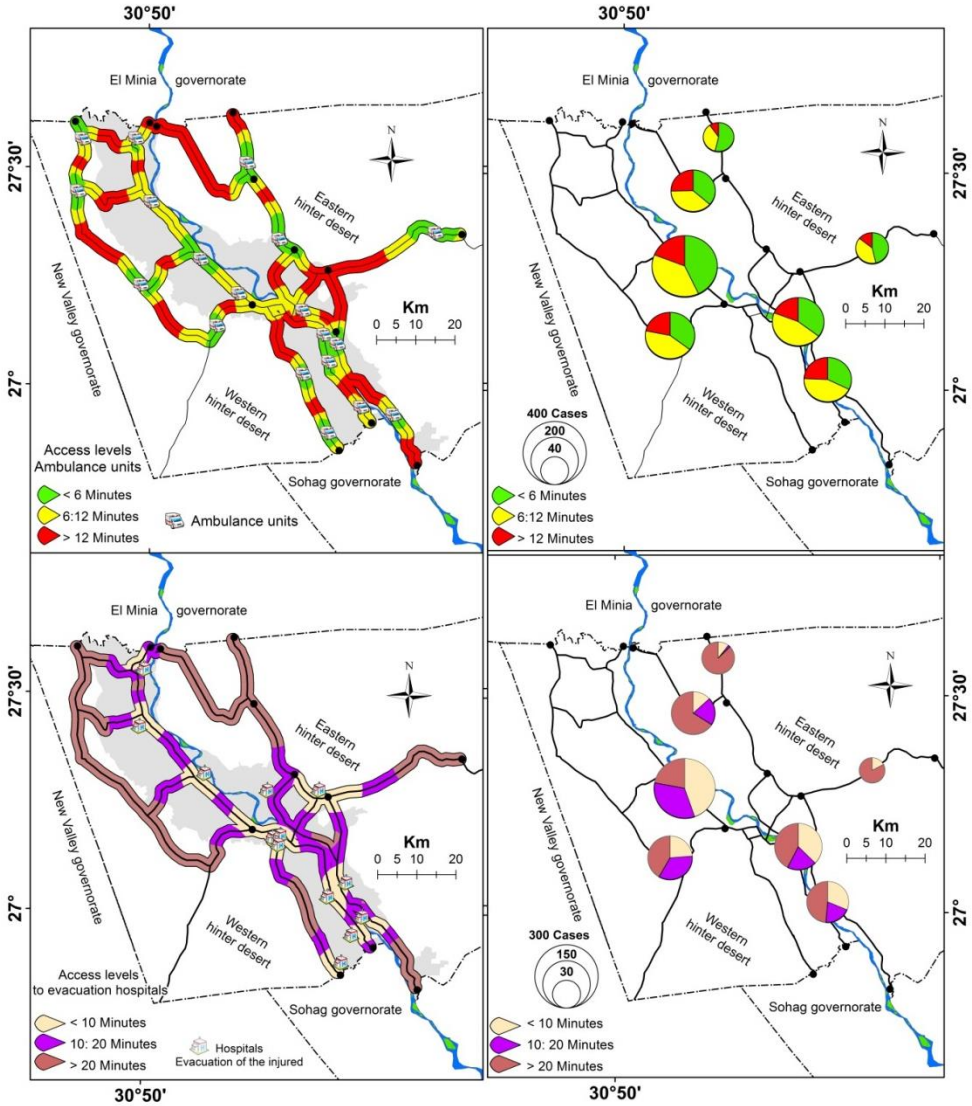

Fig. 9. Ambulance access to accident sites on highways and Accessibility to Evacuation hospitals during (2018: 2022)

Table (4): Levels of ambulance access to traffic accident sites, and access to evacuation hospitals during the period (2018: 2022 AD)

Road sectors Within Districts		Number of cases	Ambulance access time from the time of notification						Cases transported to the hospital	Access time to Hospital since the accident					
			< 6 minutes		6: ≤ 12 minutes		> 12 minutes			< 10 minutes		10: ≤ 20 minutes		> 20 minutes	
			Number	%	Number	%	Number	%		Number	%	Number	%	Number	%
(A)	Assiut	203	94	46.31	67	33	42	20.69	187	74	39.57	69	36.9	44	23.53
	Manfalut	116	52	44.83	41	35.34	23	19.83	55	30	54.55	12	21.82	13	23.64
	El-Qusiya	55	15	27.27	33	60	7	12.73	35	15	42.86	12	34.29	8	22.86
	Dairout	29	11	37.93	12	41.38	6	20.69	17	12	70.59	5	29.41	0	0
(A)		403	172	42.68	153	37.97	78	19.35	294	131	44.56	98	33.33	65	22.11
(B)	Sadfa	26	6	23.08	17	65.38	3	11.54	16	11	68.75	2	12.5	3	18.75
	Abu Tig	93	43	46.24	20	21.51	30	32.26	53	2	3.77	0	0	51	96.23
	Assiut	133	39	29.32	78	58.65	16	12.03	108	53	49.07	34	31.48	21	19.44
(B)		252	88	34.92	115	45.63	49	19.44	177	66	37.29	36	20.34	75	42.37
(C)	El-Badari	75	14	18.67	29	38.67	32	42.67	45	23	51.11	18	40	4	8.89
	Sahel Salim	56	22	39.29	27	48.21	7	12.5	41	20	48.78	7	17.07	14	34.15
	El-Fath	82	32	39.02	37	45.12	13	15.85	52	0	0	3	5.77	49	94.23
(C)		213	68	31.92	93	43.66	52	24.41	138	43	31.16	28	20.29	67	48.55
(D)	El-Fath	102	43	42.16	41	40.2	18	17.65	77	12	15.58	22	28.57	43	55.84
	Abnoub	84	24	28.57	31	36.9	29	34.52	73	8	10.96	9	12.33	56	76.71
(D)		186	67	36.02	72	38.71	47	25.27	150	20	13.33	31	20.67	99	66
(E)	El-Fath	102	47	46.08	40	39.22	15	14.71	52	9	17.31	0	0	43	82.69
(F)	Abnoub	89	48	53.93	32	35.96	9	10.11	84	9	10.71	2	2.38	73	86.9
(G)	EL- Ganaim	67	25	37.31	23	34.33	19	28.36	50	11	22	4	8	35	70
	Assiut	62	33	53.23	26	41.94	3	4.84	55	22	40	19	34.55	14	25.45
	Manfalut	57	11	19.3	30	52.63	16	28.07	27	0	0	18	66.67	9	33.33
	El-Qusiya	14	2	14.29	8	57.14	4	28.57	9	0	0	2	22.22	7	77.78
	Dairout	32	10	31.25	13	40.63	9	28.13	15	4	26.67	11	73.33	0	0
(G)		232	81	34.91	100	43.1	51	21.98	156	37	23.72	54	34.62	65	41.67
Total		1477	571	38.66	605	40.96	301	20.38	1051	315	29.97	249	23.69	487	46.34

Source: depending on Assiut Ambulance Authority, unpublished data, 2018: 2022.

5. Geographical Analysis of Evacuation of Injuries from Highway Accidents in Assiut:

Table (5) and Figure (10) show that the number of injuries transported by ambulance and received by evacuation hospitals in the governorate during the period from 2018 to 2022 amounted to approximately 1051 injuries, representing 71.2% of the total injuries from highway accidents. Meanwhile, the percentage of minor injuries transported directly from accident sites without the need to go to hospitals amounted to about 28.8% of the total injuries.

Hospitals in Assiut city took the lead in receiving cases of injuries resulting from highway accidents in the governorate, where they received nearly two-thirds (65.3%) of the total number of injuries transported to hospitals, amounting to 1051 injuries. This can be attributed to the high readiness of these hospitals, provided by qualified medical staff, modern medical equipment, emergency services, and a large bed capacity, especially in the university hospitals (El-Qasr and El-Jadeed), which alone received about one-third of the injuries transported to hospitals in the governorate. As for hospitals in other districts, they only received one-third of the number of injuries, indicating a lower level of emergency medical services in those hospitals.

Manfalut Central Hospital is considered one of the hospitals in the governorate's districts that receives a significant number of injury cases resulting from highway accidents after Assiut city hospitals, accounting for 6.2%. This is attributed to its location within Sector (A), which is considered the most dangerous,

specifically due to its proximity to black spots, such as the Assiut /Manfalut junction.

Injuries from highway accidents in Sectors (A) and (H) were distributed among hospitals in five districts as follows: Assiut (52%), Manfalut (14.5%), Al-Qusiya (8.2%), Dayrut (7.1%), and Al-Ghanayim (3.3%), along with other hospitals accounting for 14.9% due to the location of road junctions within the administrative boundaries of these five districts. As for injuries in Sector (B), they were received by hospitals in four districts: Assiut (82.5%), Sidfa (8.5%), Abu Tig, and Al-Ghanayim each with 1.7%, in addition to other hospitals accounting for 5.6%. Meanwhile, injuries in Sector (C) were distributed among hospitals in three districts: Assiut (45.5%), Al-Badrari (33.6%), Al-Sahel (20.1%), with an additional 0.8% received by other hospitals. Hospitals in Assiut and Abnub districts only received injuries (286 injuries) from accidents on the roads of Sectors (D), (E), and (F), due to the absence of a central hospital in Al-Fath district.

Table (5): Distribution of injuries according to hospitals for evacuation and reception of victims of traffic accidents on highways in Assiut Governorate during the period (2018: 2022 AD)

Road sectors Within Districts		Evacuation hospitals															Total number of injuries
		Assiut city, district hospitals				Hospitals in the other districts											
		The university	The new university	El- eman	El- Shamela	Dayrout Public Hospital	El-Qusiya Central Hospital	Manfalut Central Hospital	Abnoub Central Hospital	Sahel Slim Central Hospital	El Badari Central Hospital	Abu Tig Central Hospital	Sedfa Central Hospital	El Ghanaim Central Hospital	Other hospitals	Cases not transferred to hospitals	
(A)	Assiut	67	0	47	5	0	0	3	0	0	0	0	0	0	65	16	203
	Manfalut	15	0	0	0	0	0	40	0	0	0	0	0	0	0	61	116
	El-Qusiya	0	0	0	0	0	33	2	0	0	0	0	0	0	0	20	55
	Dairout	0	0	0	0	17	0	0	0	0	0	0	0	0	0	12	29
(A)		82	0	47	5	17	33	45	0	0	0	0	0	0	65	109	403
(B)	Sadfa	0	0	3	0	0	0	0	0	0	0	0	13	0	0	10	26
	Abu Tig	5	0	27	13	0	0	0	0	0	0	3	2	3	0	40	93
	Assiut	40	0	28	30	0	0	0	0	0	0	0	0	0	10	25	133
(B)		45	0	58	43	0	0	0	0	0	0	3	15	3	10	75	252
(C)	El-Badari	0	0	0	0	0	0	0	0	0	45	0	0	0	0	30	75
	Sahel Salim	10	0	0	2	0	0	0	0	27	0	0	0	0	2	15	56
	El-Fath	20	3	21	5	0	0	0	0	0	0	0	0	0	3	30	82
(C)		30	3	21	7	0	0	0	0	27	45	0	0	0	5	75	213
(D)	El-Fath	25	3	20	25	0	0	0	4	0	0	0	0	0	0	25	102
	Abnoub	15	18	10	5	0	0	0	25	0	0	0	0	0	0	11	84
(D)		40	21	30	30	0	0	0	29	0	0	0	0	0	0	36	186
(E)	El-Fath	30	10	10	0	0	0	0	2	0	0	0	0	0	0	50	102
(F)	Abnoub	5	8	34	27	0	0	0	10	0	0	0	0	0	0	5	89
(G)	EL- Ganaim	35	0	0	0	0	0	0	0	0	0	0	0	15	0	17	67
	Assiut	30	0	22	3	0	0	0	0	0	0	0	0	0	0	7	62
	Manfalut	0	0	5	0	0	0	20	0	0	0	0	0	0	2	30	57
	El-Qusiya	0	0	5	0	0	4	0	0	0	0	0	0	0	0	5	14
	Dairout	0	0	0	0	15	0	0	0	0	0	0	0	0	0	17	32
(G)		65	0	32	3	15	4	20	0	0	0	0	0	15	2	76	232
Total		297	42	232	115	32	37	65	41	27	45	3	15	18	82	426	1477

Source: depending on Assiut Ambulance Authority, unpublished data, 2018: 2022.

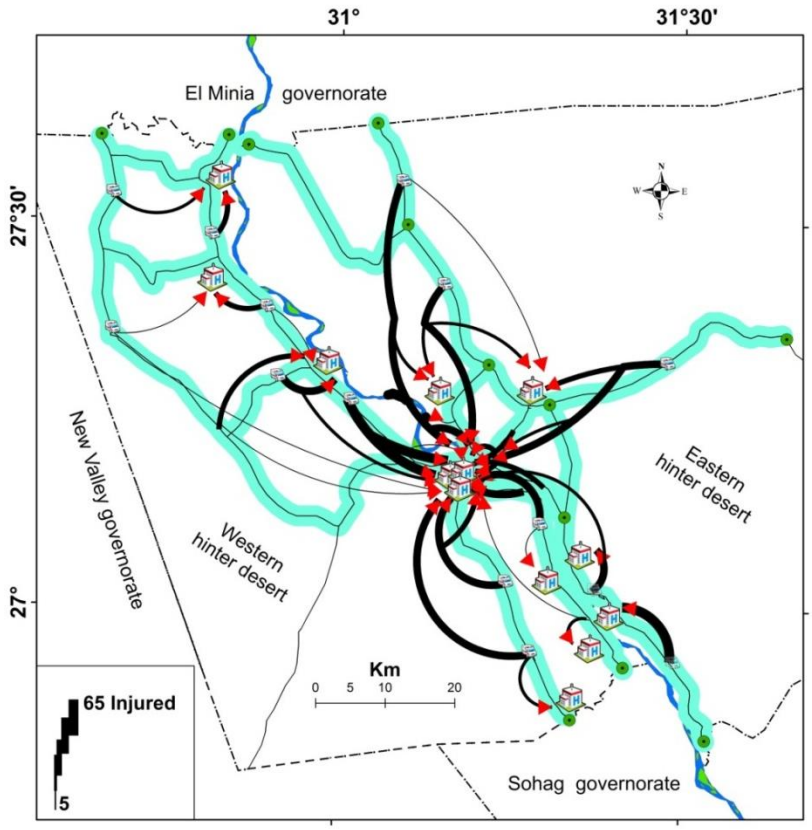

Fig. 10. Evacuating and receiving accident casualties for hospitals in Assiut Governorate during (2018: 2022)

IV. Conclusion and Recommendations:

The causes of accidents on highways, in addition to those commonly cited in most studies, include the failure of planners to resort to appropriate solutions involving the proper implementation of spatial accident monitoring tools on roads and the swift response to their consequences. Consequently, the study provided a detailed analysis of accident black spots on highways in Assiut, specifically identifying the temporal and spatial trends of accident recurrence, as well as the capacity for ambulance access and response. Furthermore, it presented a geographic analysis of hospitals designated to handle accident casualties.

To summarize, the study revealed that Assiut/Minya highway in sector (A), part of the Assiut/Minya road, is the most accident-prone area, registering the highest number of accidents, injuries, and fatalities on the highways in Assiut Governorate. Injury rates tend to increase during October, coinciding with the start of the academic year, due to increased traffic volume on the roads. Sectors (C) and (D) experience delays in ambulance arrival at accident sites, sometimes exceeding 12 minutes. The distribution of injuries reflects increased pressure on Assiut Central Hospital and the university hospital, mainly due to the inadequate emergency medical services in hospitals in other districts of the governorate.

Several recommendations can be proposed to maximize the effectiveness of this research point as follows:

- Developing a digital database illustrating hazardous areas, artificial obstacles, curves, and accident-prone zones on roads, and determining their coordinates using GPS, then linking them to a Geographic Information System (GIS) Web Application. Utilizing this database to implement a Mobile Application that signals drivers when approaching these locations, enabling them to avoid risks in black spots, which have been identified, and encouraging drivers to download this approved application from traffic authorities.
- Installing high-level screens and light signals on highways, visible from a distance, to inform drivers about road conditions, aiding in caution, speed reduction, and avoiding danger zones. Additionally, addressing deformities in the surface pavement layer of highways to reduce traffic accidents.

- Activating automatic electronic recording of speed violations by identifying the code of the violating vehicle, relying on the electronic chips recently installed in vehicles.
- Coordination between ambulance services, hospitals, and traffic authorities to achieve high levels of medical readiness, aiming to rescue victims of highway accidents in the province and reduce associated fatality rates.
- Enhancing the level of emergency medical care provided to victims of traffic accidents in the central hospitals of the province to alleviate the pressure on the university hospital.

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