International Science and Technology Journal
المجلة الدولية للعلوم والتقنية

Volume 35 العدد
Part 1 المجلد
October 2024 اكتوبر

تم استلام الورقة بتاريخ:6/ 10/2024م وتم نشرها على الموقع بتاريخ: 31/ 10/2024م

OPTIMIZING THE URBAN AREA TOWARD TACKLING ROAD ACCIDENT AND RISKS: COUNTREMEASURES FOR TRIPOLI

http://www.doi.org/10.62341/emfa2022

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Abstract

In recent years, there has been a gradual increase in the need for private vehicle ownership in Libya due to the lack and weakness of public transport infrastructure, which has led to the growth of traffic accidents, especially in Tripoli. Traffic accidents often occur as a result of driver negligence in terms of speed, hesitation, failure to give priority, using the phone while driving, and incorrectly handling turns.

Data collected from traffic accident records from the period (01/01/2015 to 31/12/2019) on 12 main roads showed the occurrence of 1827 traffic accidents. 19% of the accidents were on the airport road and the Al Shat road. Each of the selected roads had a Severity Index (SI) higher than 10.

Increasing the width of the median, pedestrian crossings, pedestrian bridges, as well as the number of lanes and traffic signs

would significantly increase road safety, by following the systematic approach stipulated by the Federal Highway Administration (FHA) which "focuses on installing countermeasures to reduce crashes at a large scale or a number of locations that share high-risk factors.

In this study, a set of countermeasures and measures will be proposed based on the CRF (Crash Reduction Factors) to reduce traffic accidents and how to apply a systematic approach for safer roads in Tripoli.

Keywords: Crash reduction factors, Road Safety, Severity Index, Road black spots, Road Accident.

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تحسين المناطق الحضرية من أجل معالجة حوادث الطرق والمخاطر: التدابير اللازمة لمواجهة ذلك في طرابلس

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الملخص

في السنوات الأخيرة هناك زيادة تدريجية في الاحتياجات لملكية المركبات الخاصة في ليبيا بسبب نقص وضعف البنية التحتية للنقل العام مما أدى إلى نمو حوادث المرور، وخاصة في طرابلس، وتحدث حوادث المرور في أغلب الأحيان نتيجة لإهمال السائق من حيث السرعة، والتردد وعدم إعطاء الأولوية، واستخدام الهاتف أثناء القيادة، والتعامل مع المنعطفات بشكل غير صحيح. في حين أظهرت نتائج تحليل الانحدار اللوجستي لبيانات السائقين والمركبات المشاركة في حوادث الطرق والمبلغ عنها في الفترة بين (2015–2019) على طريقين حضريين رئيسيين في طرابلس هما طريق المطار وطريق الشط. إن كل طريق من الطرق المختارة كان له مؤشر خطورة (SI) أعلى من 10.

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حيث أن زيادة عرض منتصف الطريق ومعابر المشاة وجسور المشاة وكذلك عدد المسارات والعلامات المرورية من شأنه أن يزيد بشكل كبير من السلامة المرورية على الطرق، وذلك من خلال إتباع النهج النظامي الذي تنص عليه الإدارة الفيدرالية للطرق السريعة (FHA) حيث "يركز على تثبيت إجراءات مضادة للحد من حوادث التصادم على نطاق واسع أو عدد من المواقع التي تشترك في عوامل عالية الخطورة

وفي هذه الدراسة سيتم اقتراح مجموعة من التدابير والإجراءات المضادة بناءً على نموذج الإبلاغ الموحد CRF للتقليل من حوادث المرور وكيفية تطبيق نهج منهجي لطرق أكثر أمانًا في طرابلس.

الكلمات المفتاحية: عوامل الحد من الحوادثCRF، السلامة على الطرق، مؤشر الخطورة، البقع السوداء على الطريق، حوادث الطرق

1. Introduction

Traffic accidents have been a serious challenge for local authorities. This study was conducted to determine the prevalence of traffic accidents and road injuries and their causes in the city of Tripoli, Libya: Data were collected from accident records at the General Directorate of Traffic and Licensing. Ministry of Interior - Tripoli.

From the period (2015-2019) it was found that road accidents ranked fourth among the leading causes of death in Libya, based on the study who evaluated the root causes of road accidents from a behavioral perspective first [1]. Using the results of this study showed the existence of two groups a survey of drivers, f behaviors; the first category assumes the important human role in road accidents, and the second category highlights the importance of urban design in terms of tremendous efficiency. In the absence of responsible behavior, urban design and regulatory system must ensure an environment that reduces accidents and their root causes.

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Another study used multiple correspondence analysis and logistic regression analysis to examine data on 1) drivers, 2) vehicles involved in accidents, and 3) traffic accidents reported between 2015 and 2019 on twelve major urban roads in Tripoli [**2**]. The results show that each of the 12 selected roads had a Severity Index (SI) above 10 and that traffic accidents occur regularly on those roads. Road accidents are commonly caused by driver negligence, including speeding, carelessness, failure to give priority, and using the phone while driving, and by improving the country's road infrastructure. The current study helps to develop countermeasures and implement a systematic approach to secure safer roads in Tripoli.
The Federal Highway Administration (FHA) stipulates that a systemic approach "is focused on installing crash reduction countermeasures over a wide range or number of sites that share a high-risk factor. Examples of risk factors could be lane width, speed, traffic volume, horizontal curvature, or traffic control devices" [3]. We have tried to understand and inform road safety as a complex issue that seeks multiple and homogeneous actions. From education to infrastructure, urban space planning must improve road safety and safe use of means of transport. Under systemic approach, we propose a set of countermeasures in order to propose an optimizing function for Tripoli city.

1.1. Crash reduction factors and countermeasures for road safety:

Improving road safety requires projects related to improving road infrastructure, signage, and urban design. For developed countries, this investment represents a basic element in sustainable development strategies, seen under the umbrella of the digital and green transition. For developing countries, improving infrastructure, and alleviating the problems that cause road insecurity is a heavy investment.

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Several works have addressed crash reduction factors. Discussing the nature of the project, the percentage of impact of these projects beside the basic conditions impacting the bias rate of their effectiveness represent a large research topic to be analyzed which will be more and more impacted by the following factors:

- Climate conditions and changes.
- Nature and quality of the data used.
- Regional and international disparities.
- Technological divides.

2. Study area:

Tripoli city is the capital of Libya with 1.68 million inhabitants, a city where the economic and social activity is very important based on large industrial, commercial but also administrative and academic sites. The city has the following main roads, see Table 1, Table 2 and Figure 1.

Figure 1 Tripoli's map July 2021 Source: Google maps October 2021

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Table1. General Information on the selected roads.

Road Name	Road Description	Road Category	Speed Limits (km/h)
Airport	From Al Quds roundabout in the city center to the intersection with the connecting Aswani Road	Motorway (M)	100
Al Shat	From the city center/ harbour to the Maitika roundabout	Expressway (E)	80

Table 2. Geometric conditions of the selected roads.

Road Name	Road Length (km)	No. of Lanes (For Each Direction)	No. of Interchanges and Big Roundabouts	No. of Ped. Bridges	Road Width (m)	Median Width (m)	No. of Traffic Signs	No. of Segments
Airport	5	3	4	1	30	2	1	3
Al Shat	9.3	3	6	0	30	1.5	2	4

3. Data and methods:

The aim of this part is to investigate the root causes of road crash in Tripoli city. We use collected daily data by roads that describes the crash; its responsible and the first concluded causes of crash, as registered by the authority.

The collection of data related to road accidents is a key element in their monitoring and explanation. In the case of Libya, the data's reliability is subject to several criticisms. Indeed, the reported data do not reflect the reality, on the one hand a part of accidents are not reported (the parties reach an amicable settlement without resorting to the authorities, even in the existence of a victim (cultural value)), on the other hand, since 2011 the country has

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been living under the effect of the tug-of-war which weakens the functions of the public authority. Apart from these considerations, the statistics announced by the WHO (World Health Organization) show how heavy the toll is. We have collected data related to road accidents in the Al Shat Road and Airport Road over the period from 01/01/2015 to 31/12/2019.
Our methodology spans a simple correspondence analysis, a logistic regression and finally an optimization function in order to propose a set of project improvement for road safety. See table 3.

Table 3.constitute our database

variables	Description
Time of the accident: The time-of-day variable was recorded into time blocks	00H-06H (12am-6am) 06H-08H (06am-8am) 08H-11H (08am-11am) 11H-14H (11am-2pm) 14H-18H (2pm-6pm) 18H-20H (6pm-8pm) 20H-00H (8pm-12am)
Gender of the driver:	F/M
Age of the driver	number
The vehicle used	Car, bus, motorcycle, Truck, Tractor, public transport
The existence of a fatality or not:	number
The existence of property damage or not:	0/1
The cause of accident speed or not:	0/1
The cause of accident inattention or not:	0/1

4. General overview about road accident and infrastructure in Tripoli's roads

The collected data stipulates that road Al Shat have a heavy toll in terms of victims and number of accidents. Maintenance and infrastructure improvement projects have been largely impacted by

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the political instability and the state of war that has dominated the landscape since 2011.
The speed explains the road accidents as follows; for AlShat Road 94.7%, for Airport Road 61.3%. There is evidence that this factor plays a common major role in road accidents in Tripoli. The means of transport involved in these accidents are mainly private cars (more than 50% on all roads), at least 20% of them have caused one fatality.

4.1 Road hot spot:

Empirical studies targeting the analysis and improvement of road safety define black spots as roads or road segments with a high accident rate [4,5,6,7,8]. Our aim is to minimize severe crashes, reducing overall crash frequency and improve safety in the network, we give priority to roads with hot spots where fatal and injuries are high. We calculate the severity index (SI), the road is considered as a hot spot area when SI is more than 10. [9].
We use the following model:

$$SI = 3F + I + \left(\frac{1}{3}\right) POD \quad (1)$$

With:
F: Fatality (number of death)
I: Injury (number of people with injury)
POD: Property only damage.

Table 4. Crash frequency and severity index

Road Name	SI
Airport	465.16
Alshat	374.80

Based on these results in table 4, we can conclude the heavy results of roads in term of crashes in Tripoli; all the roads are

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above the critical value of severity. The following elements try to investigate root causes and to propose a set of project improvement based on Tripoli's short-term budget for road safety and infrastructure maintenance. We note that Airport road, Alshat road have the high severity index, they present a priority of improvement.

4.2 Logistic regression

In this element we investigate the impact of geometric features of our roads on the SI, we use a logistic regression using the following model:

$$\mathrm{LnSI}_i = \alpha_0 + \alpha_1 \mathrm{NS}_i + \alpha_2 \mathrm{TS}_i + \alpha_3 \mathrm{SW}_i + \alpha_4 \mathrm{MW}_i + \alpha_5 \mathrm{CW}_i + \alpha_6 \mathrm{RC}_i + \alpha_7 \mathrm{NPB}_i + \alpha_8 \mathrm{NL}_i + \alpha_9 \mathrm{SL}_i + \alpha_{10} \mathrm{SPL}_i + \alpha_{11} \mathrm{NIBR}_i + \varepsilon_i \quad (2)$$

Where:

NS: No of segment, TS: Traffic sign, SW: Street width, MW: Median width, CW: Cross walk, RC: Road category, NPB: NO of ped bridges, NL: No of lanes (for each direction), SPL: Speed limits, SL: Street length, NIBR: No of interchanges and big roundabout.

4.3 Results

The estimated model is as follow:

$$\mathrm{LnSI_i} = 2.687 + 0.931\ln\mathrm{NS_i} - 0.195\mathrm{TS_i} + 2.26\ln\mathrm{SW_i} - 3.61\ln\mathrm{MW_i} - 2.15\mathrm{CW_i} - 0.125\mathrm{NPB_i} - 3.86\ln\mathrm{NL_i} - 0.06\ln\mathrm{SPL_i} + 2.89\ln\mathrm{NIBR_i} + \varepsilon_i \quad (3)$$

We can see that number of lanes for each direction is the most important geometric feature that can reduce the severity index. In fact, based on the role of speed as the most contributors in road accident in Tripoli, increasing the number of lanes will impact positively road safety. This result confirms the finding of Kononov

and al [10].Where moving from two lanes to four decreases road crashes up to 60%.
In addition, improving median width, cross walk, number of pedestrian bridges impact positively road safety and decreases the SI, by providing better mobility condition to pedestrian. We note that speed limit was econometrically insignificant in our model, besides of road category. This result confirms those of Monsere and Figliozzi [11], a reduction in pedestrian crash was observed after installing crosswalk treatments in addition of a decrease in the SI. Traffic signs have a small positive impact on road safety, this result confirms those of Michael and al [12].
These results confirm the importance of geometric factors, better infrastructure can bring important improvement, and hence Libyan authority must invest in road safety. In the following element we investigate the use of countermeasure under the constraint on road safety budget.

5. Tackling road accident in Tripoli: an optimization function

The Federal Highway Administration (FHA) stipulates that a systemic approach "*is focused on installing crash reduction countermeasures over a wide range or number of sites that share a high-risk factor. Examples of risk factors could be lane width, speed, traffic volume, horizontal curvature, or traffic control devices*".[13]
Based on the above results we propose a set of project improvement that can reduce crash. According to the road specificity we select crash reduction countermeasures for urban area from (FHA [14]-transport safety planning and Oregon Department of Transportation [15] (ODOT)), each project is associated to level of cost and a CRF. Based on the budget for road safety improvement of each road, we use an optimization function, for each road, a best combination of projects is concluded that will minimize the probability of accidents through maximization of CRF, under constraint of the set budget.

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The actual infrastructure suffers from different limits. The design of the Main Road Network it's extend, and dimensions comply with the historic development and former planning aims, but those aims were based on an underestimated development of road traffic. This explains why many of the principal roads are built in a 2+2 design (2 lanes per direction). Even today the share of 3+3 roads is still small. The significant rise in traffic has – besides congestion problems caused by capacity shortage – in many cases lead to a mechanic overstraining of the surface, so that there are now a lot of reparatory works necessary at the same time. The short- and medium-term elimination of capacity bottlenecks occurs on several places at the same time through extensions as well of nodes as of stretches of roads. Simultaneously, reparations of the road surface are carried out. There is currently extensive building construction works which sometimes obstruct traffic. Because of them, some stretches are not fully useable at times. It is likely that construction sites will lower the network's capacity even in the following years.

5.1 Objectify function:

The optimal allocation of funding can be obtained by solving the following integer programming problem:

Maximize : $\sum_i \sum_j N_i r_j X_{ij}$ (4)

Subject to: $\sum_i \sum_j c_j X_{ij} \leq B$ (5)

Where:
Ni= total number of accidents for location i
rj= crash reduction factor for project j
cj= cost of the safety improvement project j
B= total funding available for entire safety program i
Xij=1 if safety improvement project j is installed at location i, 0 otherwise.
Xij={0,1}

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In Equation 4, the objective function maximizes the CRF. Equation5 gives the constraint that the total cost of safety improvement projects to be implemented must not exceed the budget ceiling for the safety program, the proposed priorities for improvement for roads with the high SI are as follow: Table 5,6.

Table 5. Safety Treatment for Al Shat Road

Selecting Safety Treatments			Safety Treatments
Intersection Crash Reduction Factors	Signalization Countermeasures	Signal operations countermeasures	Add exclusive pedestrian
			Install pedestrian signal
			Modify signal phasing
			Provide protected left turn
			Remove flash mode (late
		Signal hardware countermeasures	Add 3-inch yellow retro
			Convert signal from
	Signs / Markings / Operational Countermeasures	Signs	Install pedestrian signing
			Install advance warning
		Pavement markings/modifications	Install pedestrian crossing
			Mark pavement with
		Regulatory	Restrict parking near
		Lighting	Improve lighting at
			Install lighting
		Operational	Install cameras to detect
			Install far-side bus stops
			Install stop signs at
Roadway Departure Crash Reduction Factors	(Barrier Countermeasures)	Barrier countermeasures	Improve guardrail
		Bridge countermeasures	Install bridge lighting
		Median countermeasures	Install median barrier
	Signs / Markings / Operational Countermeasures	Pavement	Install centerline markings
			Install edge line markings

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Table 6. Safety Treatment for Airport Road

Selecting Safety Treatments Safety Treatments			
Intersection *Crash Reduction Factors*	Signalization Countermeasures	Signal operations countermeasures	Add exclusive pedestrian phasing
			Install pedestrian signal
			Provide protected left turn phase
			Remove flash mode (late night/early morning)
		Signal hardware countermeasures	Add 3-inch yellow retro reflective sheeting to signal back plates
			Convert signal from pedestal-mounted to mast arm
		Combination signal and other countermeasures	Install left-turn lane and add turn phase
		Right-turn countermeasures	Install right-turn lane
	Geometric Countermeasures	Other geometric countermeasures	Install turn and bypass lanes
	Signs / Markings / Operational Countermeasures	Signs	Install pedestrian signing
			Install advance warning signs (positive guidance)
		Pavement markings/modifications	Install pedestrian crossing
			Install STOP bars (pedestrian crosswalk)
			Mark pavement with supplementary warning messages
		Regulatory	Permit right-turn-on red
		Lighting	Improve lighting at intersection
			Install lighting
		Operational	Increase enforcement to reduce speed

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			Install cameras to detect red-light running
			Install far-side bus stops
Roadway Departure Crash Reduction Factors	(Barrier Countermeasures)	Barrier countermeasures	Improve guardrail
		Bridge countermeasures	Install bridge lighting
			Repair bridge (steel bridge)
	Geometric Countermeasures	Geometric countermeasures	Install acceleration/ deceleration lanes
	Median Countermeasures	Median countermeasures	Re-Install median barrier
	Signs / Markings / Operational Countermeasures	Signs	Install chevron signs on horizontal curves
			Install curve advance warning signs
			Install guide signs (general)
		Markings	Install centerline markings
			Install edge line markings
Pedestrian Crash Reduction Factors	Geometric Countermeasures	Geometric countermeasures	Install pedestrian overpass/underpass
		Signs / markings / operational countermeasures	Install school zone warning signs

5.2 Results and discussion

Despite Libya's very negative road safety record, political instability has negatively impacted the implementation of a coherent road safety vision. The budget currently in place is insufficient; the results found through the optimization function suggest the limit of potential improvement and concretization of the proposed projects.

SPSS version 26.0.0 was used for the statistical analysis, the results was estimated using multilevel logistic regression analysis

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Table 7. Confirmed countermeasures.

Road	Countermeasures	Selected countermeasures		
		Variable	Value	Reduced value
AIRPORT	X1=SIGNAL OPERATIONS COUNTERMEASURES	X1	1.000000	-58.48000
	X2=SIGNAL HARDWARE COUNTERMEASURES	X2	1.000000	-63.64000
	X3=COMBINATION SIGNAL AND OTHER COUNTERMEASURES	X3	0.000000	-99.76000
	X4=Signs	X4	1.000000	-51.60000
	X5=PAVEMENT MARKINGS/MODIFICATIONS	X5	1.000000	-51.60000
	X6=REGULATORY	X6	1.000000	-51.60000
	X7=LIGHTING	X7	0.000000	-46.44000
	X8=OPERATIONAL	X8	0.000000	-27.52000
	X9=Roadway Departure Crash Reduction Factors	X9	0.000000	-60.20000
	X10=Pedestrian Crash Reduction Factors	X10	0.000000	-137.600
		Variable	Value	Reduced value
ALSHAT	X1=SIGNAL OPERATIONS COUNTERMEASURES	X1	1.000000	-51.34000
	X2=SIGNAL HARDWARE COUNTERMEASURES	X2	0.000000	-55.87000
	X3=Signs	X3	1.000000	-45.30000
	X4=PAVEMENT MARKINGS/MODIFICATIONS	X4	1.000000	- 45.30000
	X5=REGULATORY	X5	1.000000	-45.30000
	X6=LIGHTING	X6	0.000000	-20.77000
	X7=OPERATIONAL	X7	0.000000	-24.16000

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6. Conclusion

Based on WHO recommendations road safety must be viewed as a whole and coherent system, where interaction between its components must be understood, mastered and then oriented toward safer system. In this research we propose countermeasure for each hotspot area. The calculated SI suggested a high level of severity explained by high number of fatality and injuries in all the two roads of Tripoli. This first result stipulated a more complex situation since it was a common feature for the city. For the roads with the highest SI, time, age and the used vehicle were the concluded discriminated measures. Using a Logistic Regression, we have analyzed the impact of geometric features on the SI in the two roads, results confirmed the previous studies; improving median width, cross walk, number of pedestrian bridges, number of lanes in addition of traffic sign could decrease road crashes, these results confirm the importance of investing in road safety infrastructure. The optimization function developed in the last part proposes a set of countermeasures with their CRF and cost, for each road we defined project with an estimated cost. Despite the actual heavy state of road crashes, the limited fixed budget for the medium term can't confirm the proposed countermeasures and can't lead to the achievement of the UN (United Nations) agenda of 2021-2030 especially the reduction of accident by 50%.

The use of private cars must be lowered by a definition of national vision for public transport that can promote Libya's mobility and economic development. There is a prominent need to review traffic management in addition of urban design that can provide the required inclusive mobility.

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