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Article

Evaluation and Improvement of Urban Unsignalized Intersection Safety: A Case Study of Latakia City, Syria

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Abstract

This paper assesses and compares the state of safety on traffic at major urban and unmarked traffic intersections in Latakia City, Syria. This paper is to shed light on the international safety foundations, the level of their application in the chosen local intersections, and to offer the concrete engineering and operational solutions to the traffic safety improvement and the level of congestion reduction, with references to the idea of the sustainable solutions such as solar- powered traffic lights. The approach consisted of embracing the existing safety standards, including the ones of the MUTCD, and conducting an in-depth field research in Latakia. Some major safety gaps were as follows: the absence of adequate sign maintenance, insufficient pedestrian amenities and inoperative electrical in-frastructure, which are some of the contributing factors to key operational and safety risks at major crossroads. Among the recommendations, there should be prompt signage repairs, enhancement of infrastructure (pedestrian tunnels, ramps), and introduction of solar-powered traffic control systems.

Keywords: urban intersection safety; unsignalized junctions; traffic control; pedestrian safety; solar-powered signals; MUTCD standards; Latakia Syria; sustainable transportation

1. Introduction

Intersections are generally known as one of the most dangerous components of the city road system as they bring together moving forces of motor vehicles and pedestrians, cyclists and micromobility users, which have opposing directions. Empirical evidence indicates that a significant percentage of serious and fatal accidents involve intersections, and unsignalized or incompetent intersections present exceptionally dangerous areas to pedestrians and other at-risk users of roads [13]. The current findings of data-driven research of unsignalized crossings have shown that the infrastructure features (e.g., the type of crosswalk, its visibility, approach speed, and the presence of traffic control devices) have a significant impact on the frequency and severity of pedestrian crashes [4,5]. It is widely reviewed that measures like Time-to-Collision (TTC) and Post-Encroachment Time (PET) are useful in the quantification of risks of interaction in heterogeneous city

traffic scenarios [67]. Recent implementations of SSMs with machine learning prove that increased speed, reduced visual range and unequal priority management largely increase collision risk at unsignalized junctions [9,10]. The studies of varying cities in the world have shown that complicated geometry, lack of pedestrian infrastructure (crosswalks, refuge islands, signals), and low visibility are the key factors that significantly contribute to the probability and the severity of pedestrian and vehicle collisions [113]. Studies on non-signaled crosswalks also indicate that unless there is a high enforcement and an improved infrastructure, the safety of pedestrians is very much influenced by the fact that drivers yield and approach speeds [4,12]. Crash-based analyses and systematic reviews of literature confirm that the modern roundabouts greatly minimize se- vere crashes in cases where they were planned with the correct roundabout geometry and speed control [3,7]. The other studies suggest safety indices and ranking processes to combine geometric, operations and conflict-based indices to determine high-risk crossing or roundabouts that might need special interventions [7,14]. In more recent years, the move to focus on sustainable and intelligent safety solutions has been made, including sensor-based warning systems, intelligent crosswalks, and in-built digital safety systems. Research indicates that the systems enhance detection, visibility and general safety of susceptible road users in sophisticated urban settlements [13,14,15]. Poor maintenance, irregular power supply, and unofficial road use habits are common in these settings and intersections are in effect unsignalized junctions, which are seldom discussed in the literature [2,11]. This is a particularly sensitive gap in rapid and unregulated development of the Middle Eastern urban centres. An example of this challenge has been the Latakia City, Syria. Latakia, being a significant commercial and seaside urban centre, has been characterized by significant population explosion and motorization at the same time with deteriorating infrastructure, lack of functioning traffic lights, and deteriorating pedestrian facilities. These problems indicate a broader inconsistency between international standards of best-practice (e.g. MUTCD principles) and local on-ground reality. It is upon this background that the current paper seeks to assess and enhance the safety of large city, mostly uncontrolled intersections in Latakia based on recent research findings and the International safety standards. The research aims at achieving these three goals: To compile the major global safety essentials of an urban unsignalized intersection basing on current research works and worldwide design standards. To determine and examine the current safety shortcomings on the chosen intersections in Latakia with special attention to pedestrian infrastructure, signage, geometry, and operational control. To suggest context-specific, sustainable engineering countermeasures such as maintenance measures, geometric redesign measures, and electricity-independent traffic control measures to mitigate the threat of crashes and enhance mobility. This study offers a contribution to the small literature on unsignalized intersection safety through the combination of finely detailed field-observation and the state-of-the-art intersection-safety research in the resource-bound yet highly dynamic urban settings.

2. Materials and Methods

The study employed a structured methodology consisting of the following stages.

2.1. Data Collection

This stage involved compiling both theoretical and empirical data:

- **Literature Review:** Reviewing international safety standards, including the MUTCD (The Manual on Uniform Traffic Control Devices for Streets and Highways). The MUTCD is referenced as a key information source for field reviews, providing minimum standards for the installation and maintenance of traffic control devices. Compliance

with MUTCD standards regarding signage andmm pavement markings (Traffic Delineation) is considered essential for a safer transportation system.

- **Field Study:** Conducting on-site surveys and assessments of selected high-volume intersections in Latakia City.

2.2. Evaluation and Solution Formulation

The subsequent stages focused on analysis and proposal generation:

- **Arrangement and Evaluation of Results:** Analyzing the identified local problems against established safety criteria.
- **Proposal of Solutions:** Developing a set of proposed solutions drawn from successful strategies used globally to improve the safety of unsignalized intersections.

2.3. Safety Countermeasure Evaluation

The last phase explains the necessity of monitoring after the implementation. The effectiveness of the safety solutions installed is very important to consider. The period of data collection in this level must be a minimum of one year and the ideal three years are favorable. The necessary information is the existence of complaints publicly, police records, observations of the maintenance crew, and, most significantly, the pre- and after-implementation crash data.

3. Results

The results are presented in two parts: a review of the generalized safety solutions and the specific findings from the Latakia case study.

3.1. General Safety Solutions (Engineering Countermeasures)

The following strategies, aimed at improving unsignalized intersection safety, were reviewed:

Table 1. Engineering Countermeasures for Unsignalized Intersections.

Countermeasure	Description
Improved Intersection Visibility	Providing advanced intersection warning signs.
Enhanced Stop Sign Maintenance	Regular replacement of damaged signs and improved stop sign maintenance.
Supplemental Signage	Installing additional stop signs mounted overhead on theroadway.
Warning Devices	Installing Transverse Rumble Strips to provide an au- dible/tactile warning, and flashing beacons at stop- controlled intersections.
Geometric Improvements	Installing separator islands on the minor road
Lane Management	Providing right-turn lanes, shoulder turning lanes at T- intersections, and left-turn lanes (potentially using direc- tional islands).
Lighting and Intersection Type	Enhancing intersection visibility through improved lighting and creating Roundabouts.

3.2. Latakia Case Study:

Identified Deficiencies and Proposed Solutions

The field study revealed several critical safety and operational failures across key junctions:

3.2.1. Yemen Square Roundabout (Dawar Sahat al-Yemen)

Pedestrian Hazard: The existing pedestrian underpasses are neglected (lack of lighting, debris, poor maintenance). Consequently, pedestrians prefer chaotic, at-grade street crossing, increasing collision risk.

Figure 1. Yemen Square Roundabout showing neglected pedestrian infrastructure.

Proposed Solution*:* Immediate refurbishment, lighting, and cleaning of the underpass to restore its intended function.

Signage Degradation: Traffic signs are damaged or outdated. An example is a "No Left Turn" sign needing renewal. Furthermore, an incorrect diamond-shaped yellow warning sign (used internationally for hazards) is improperly displayed to signify a school zone near the bridge end; it must be replaced with the standard triangular school warning sign. Proposed Solution: Regular maintenance and replacement of damaged signs, and correction of improperly coded warning signs.

3.2.2. Al-Zaytoun Suburb and Al-Idkhar Project Intersection

Figure 2. Al-Zaytoun and Al-Idkhar intersection lacking traffic control.

Unregulated High-Volume Intersection: This high-volume junction connecting several branches lacks any form of traffic control (no signs, no pedestrian crossings). Pedestrian sidewalks are also in disrepair. Future Congestion Risk: Construction of residential buildings and a commercial center nearby is projected to severely increase congestion, yet no multi-story parking garage was planned, exacerbating illegal parking.

Cause of Current Congestion: Previous attempts to manage traffic by converting Al-Sabee' Min Naysan and Al-Idkhar streets from two-way to one-way traffic led to significant bottlenecks. Proposed Solution: Revert the street flow to the original two-way directions to ease pressure. Design a small roundabout and strictly enforce a ban on random parking.

3.2.3. Al-Hamma¯m Square Intersection (Dawar Al-Hamma¯m)

Poor Regulation: This is a major gateway to city suburbs with high traffic and pedestrian volumes, yet it is completely unregulated (no signals, no directional islands). It suffers from encroachment by unauthorized buildings and continuous random parking.

Figure 3. Al-Hamma¯m Square showing unregulated traffic conditions.

Proposed Solution: Installation of traffic signs, maintenance of sidewalks, and prohibition of random parking.

3.2.4. Besna¯da Intersection

Figure 4. Besna¯da intersection near Ibrahim Mahfoud School.

School Zone Danger: One arm of this high-volume intersection is adjacent to a school (Ibrahim Mah- foud School). Despite high traffic and pedestrian flow, there are no school warning signs or designated pedestrian crossings.

Solutions: Installation of "Attention: School" signs and crosswalks. Placement of traffic police during peak hours is also recommended.

Radical Geometric Need: The intersection near Mar Rasha Church has a badly damaged central island and has no alternate route.

Proposed Solution: The sole radical solution proposed is road widening through the demolition of adjacent buildings, followed by the installation of a small roundabout to accommodate the heavy traffic volumes.

3.2.5. Traffic Signals and Sustainability

Figure 5. Proposed solar-powered traffic signal system.

Signal Failure: The majority of existing signalized intersections are non-operational due to permanent

electrical outages. This increases conflicts and traffic obstruction.

Solution: Solar Power: The implementation of Solar-Powered Traffic Signals is proposed as an innovative and environmentally friendly solution. These systems ensure continuous operation, smooth function in darkness and winter, and require minimal maintenance (rust-resistant steel structure).

3. Discussion

The analysis notes that the weakness of safety in Latakia is because of both old infrastructure and absence of constant maintenance and modern traffic control measures. The lack of operationality of the traffic signals because of electrical outages is a significant weakness in the operation that reduces the regulated intersec- tions to an uncontrolled conflict area. The dependency on Solar Traffic Signal solution is an important and viable move towards the realization of a sustained control, which is in line with the world trends on the use of alternative energy. The omnipresent pedestrian problems (bridges in bad condition, underpasses in poor condition, and the absence of ramps to allow handicapped access (e.g. Al-Zira'a Roundabout) suggest an inability to implement a Complete Streets plan. Moreover, improper landscaping (trees outgrowing and obstructing passage of sight at the Tishreen Suburb) has a direct negative impact on safety, especially of such susceptible users as schoolchildren. The solutions suggested in the case study are of low cost and short term solutions (signage renewal, cleaning of the tunnel, etc.) and high cost and high impact geometric redesigns (road widening at Besna da and roundabout in- stallation). The methodology justifies the systematic approach, where the issues are not only resolved

when the crashes arise but are also predicted on the basis of further land use (Al-Zaytoun commercial cen- ter).

5. Conclusions

This study was able to extrapolate the overall intersection safety requirements on to the particular and problematic issues in the Latakia City. These facts are good evidence of the immediate necessity of a complete safety remodeling that would include, both, the technological modernization (solar signals) and strict funding of the simple infrastructure (signs, tunnels, sidewalks). The Latakia City can become a place where the risk of collision is much less, the congestion decreases, and the quality of life of all road users is improved with the help of the proposed solutions, particularly the ones that would address pedestrian safety and the continuity of the traffic control.

6. Patents

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