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MEASURING THE RELATIVE IMPORTANCE OF APPLYING ENGINEERING SOLUTIONS TO URBAN TRAFFIC INTERSECTIONS: A PLANNING PERSPECTIVE

Summary. This research is an attempt to compare engineering solutions for traffic intersections from a planning viewpoint. In this research, various solutions have been discussed for traffic intersections (traffic light, roundabout, underpass and overpass). The research highlighted the importance of each of these solutions in urban environments and clarified all variables related to the pros, cons, costs, capacity and environmental compatibility of each of these solutions with the surrounding urban environment. Weights were developed for all these variables, then correlation was determined using the linear regression method.

The analysis of statistical results shows that the creation of underpasses often achieves most of the designated goals when compared to other solutions, despite some technical difficulties and high construction costs.

Keywords: transportation planning; traffic intersections; traffic light; roundabout; underpass; overpass; linear regression.

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1. INTRODUCTION

The urban transport network is congested with vehicles, especially at intersections. There are many points of conflict between cars at these intersections, and the number of conflict points varies depending on the type of intersections and how they are resolved; see Figure 1 [1].

Roads sometimes share the same area at intersections. All drivers, when they reach intersections, must select an alternative direction to proceed. Intersections may be classified as either separated with ramps or slopes (interchanges) or non-separated.

When traffic volumes are high, structural interchanges are usually implemented, which provide different levels of traffic crossflow without interruption, to reduce delay and conflict points at intersections [1].

The increase in population and vehicles and the expansion of urbanized cities, such as the city of Baghdad, have led to a greater impacts on road networks and intersections, which have resulted in the creation of crowded lanes of vehicles at these intersections.

This research studies a general problem concerning Baghdad City, which has recently constructed seven overpasses and one underpass at the city's intersections [2] in order to solve traffic congestion. However, these intersections have not functioned properly.

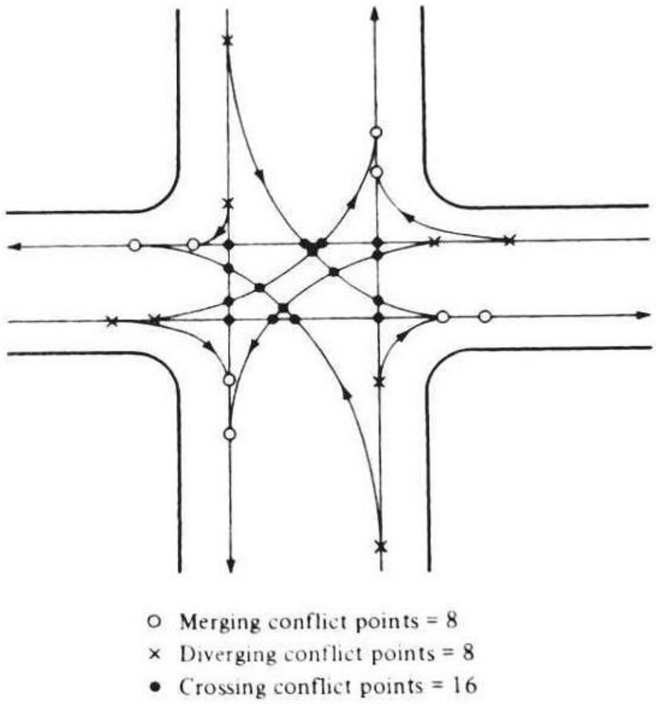

Fig. 1. Conflict points at four-approach non-signalized intersection [1]

2. TRAFFIC INTERSECTION SOLUTIONS

To reduce traffic delays and crashes at intersections and to improve the capacity of roads and streets, many types of traffic control systems are used.

A traffic light is one of the most effective traffic controlling methods at intersections. This kind of solution can be used to eliminate many conflicts at the intersections because the traffic streams are assigned at different times in the intersection [1].

The traditional traffic light solutions have many advantages for the city in terms of the low cost of construction and maintenance, being easy and quick to construct, flexibility in potential replacement by other solutions, and spatial suitability of different areas. Adding some improvements to traffic lights enables traffic to flow quickly, easily and safely and increase their importance [3-6].

To monitor the characteristic and volume of traffic in order to give priority to congested tracks and public transport, sensors are added to traffic signal systems, which adapt traffic lights in order to dynamically adjust to various situations, such as time of day and specific traffic conditions [3-5]. The use of these smart traffic signals has increased the efficiency of these systems, especially in areas with irregular traffic [3]. The green wave is one of the improvements made to the traffic signal in order to achieve continuity in the traffic flow and reduce the overall duration of stops at intersections [7,8].

When traffic lights are unable to regulate movement at intersections, roundabouts may be constructed to help solve a number of major and minor road problems encountered by traditional intersections [9]. The decision-making process of creating a roundabout is a planning more than an engineering process. Based on the existence of traffic problems at several intersections in an urban area, it is necessary to study volumes, patterns of traffic and adequate space availability [10], as well as consider the central island radius and the level of the whole intersection with access roads when using roundabouts [11].

Roundabouts decrease vehicle-pedestrian and vehicle-vehicle collision points at intersections, which helps reduce the number of accidents. In the US, studies found a dramatic drop in accidents by 29% and injured persons by 81% when roundabouts were installed at uncontrolled intersections [9,12,17].

In some instances, setting up roundabouts is not feasible for several reasons, such as a lack of space especially in historical and highly developed areas, when the land‘s nature does not fit with roundabouts, or in areas where there is the overlap of high traffic volumes with pedestrians and bicycles. Thus, transport planners and engineers are resorting to alternative solutions, such as overpasses and underpasses (interchanges) [13].

The overpass and underpass are considered appropriate planning alternatives when the traffic volume at intersections and roundabouts increases [14,20].

It is clear that the main reason for the hesitancy to create an overpass or underpass is cost. But, in the future, these structures will positively impact the city economy by providing greater accessibility [15,18].

Underpasses are usually costlier than overpasses when only considering the construction factors. But it may be argued that the additional costs incurred during construction do not outweigh the benefit that the underpass will provide by utilizing structures above it. Reconstructing an intersection to grade-separate left turns requires an extension of the intersection footprint. This means introducing an additional right of way and adding some supplementary costs to the project, as well as creating impacts, especially in terms of the city plan [15]; see Figure 2.

Fig. 2. Boston‘s Big Dig, which provided Boston with “a new highway system that has made zipping beneath Boston and Boston Harbor more easy” [16]

3. METHODS

For the purpose of comparing a range of traffic solutions for urban intersections (traffic lights, roundabouts, overpasses and underpasses) in an urban environment, it is necessary to establish a set of variables (Xs) representing the strengths and weaknesses that should be considered when addressing issues at intersections.

These variables are related to the location of intersections in the urban environment, the type of land used, the cost of land, construction cost and other factors. Based on the experience of a group of transport experts (academics and technicians), weights have been put in place to represent the relationship between the solutions for intersections and the variables (Xs). These weights varied between 1 and 10, with 10 representing the highest positive value, while 1 represents the lowest negative value between loads.

The relative importance of achieving each of these variables (Xs) in the city was determined by the same weights (1-10); see Table 1.

The application of the linear regression method to this data demonstrated a correlation between the relative importance of the comparison variables (Xs), in relation to the intersection solutions.

It was found that many factors affect the selection of one of these solutions at an intersection of the city, which can aid transport planners and decision-makers in determining the fundamental features of the future intersection before developing plans. Additionally, any intersection in the city can be tested for the purpose of determining the appropriate solution for it, depending on the relative importance of its own conditions.

Table 1

Weights of study variables Xs and their importance Y

Preference variables	Importance	Traffic light	Roundabout	Underpass	Overpass
X1 Traffic regulation	8	5	4	10	9
X2 Decrease waiting time	8	2	5	10	10
X3 Reduce fuel consumption and pollution	8	2	4	10	9
X4 Reduce police efforts	6	7	5	9	9
X5 Minimize accidents	10	5	4	9	7
X6 Reduce traffic downtime	8	2	6	10	10
X7 Remove direct vehicle collisions	7	5	2	9	9
X8 Sustain urban mobility	7	5	6	7	6
X9 Preservation of urban spaces	8	6	8	10	1
X10 Property costs	6	7	4	10	1
X11 Land development	7	5	3	10	1
X12 Average lifespan	6	7	8	10	8
X13 Malfunctions and delays	5	3	9	7	10
X14 Expansion requirements	8	7	5	10	1
X15 Suitable for high traffic	8	1	2	10	10
X16 Construction between traffic lights	5	8	2	6	6
X17 Duration of construction	2	10	9	1	2
X18 Design and implementation difficulties	1	9	9	2	4
X19 Construction and operating costs	4	9	10	1	3
X20 Maintenance cost	4	8	8	1	2
X21 Ability to discharge vehicles	8	3	5	10	10
X22 Environmental impacts	8	6	5	10	1
X23 Impact on city scenery	8	6	6	10	3
X24 Interference with pedestrians	7	5	1	10	7
X25 Suitable for historical areas	8	10	4	10	1
X26 Suitable for irregular traffic flow	8	9	2	10	10
X27 Suitable with slopes	6	5	1	9	8
X28 Suitable for high cycling users	7	6	1	10	6
X29 Resilience	6	8	9	1	1

4. RESULTS AND DISCUSSION

4.1. Hypothesis

The application of the regression method is based on the data in Table 1. In the case of estimating the selection of H_0 , there is no significant regression and the dependent variable is not correlated with the independent variables. In the case of H_1 , there is a significant regression and correlation between the dependent variable and independent variables.

4.2. Discussion of the model

The regression test results showed strong correlation between the underpass solution and the relative importance of the preference among different types of solutions.

The correlation ratio was (0.8), which is a strong correlation, with a significant percentage of (0.000), which is statistically significant. The underpasses represented more suitable solutions for most urban areas, which are not visible, not consuming the city‘s land, and are providing a high capacity for traffic volumes. There is no correlation between the overpasses and the relative importance of selecting the types of solutions that recorded a weak correlation (0.253), at (0.093), which is non-significant value. The overpasses have a negative impact on the urban environment and the city‘s scenery. In addition to the high construction cost, limited urban resilience and incompatibility with historical areas, overpasses also consume large areas of the city‘s land.

The type of the proposed solution (traffic lights and roundabouts) was inversely correlated with the preference variables. This indicates that these types of traditional solutions have become less important and more burdensome to the city, because it represents conflict points of traffic, congestion and low capacity for growing traffic volumes.

4.3. Best solution

Solutions with low correlation have been excluded. The underpasses solution was proven in the data set to be the best model due to its high correlation and significance. The correlation-squared value (R^2) was 0.64, while the adjusted R-squared value was (0.63) and the value of the standard deviations, which were interpreted as independent variables of 64% from the dependent variable, was (1.2); see Table 2.

Table 2

Model summary (b): approved solution

Model	R	R-squared	Adjusted R-squared	Std. error
1	.800(a)	.641	.627	1.20372

a Predictors: (constant), underpass
b Dependent variable: importance

Table 3 shows the result of the (ANOVA) test, where the F-value was 48.109 with a significant value of 0.000. Therefore, we accept the alternative hypothesis, that is, there is a relationship between dependent and independent variables; and, from the preference of coefficients for the regression equation (see Table 4), it is clear which factors are affecting the model, while the regression equation is as follows:

$$y = 2.827 + 0.474\text{Underpass} \tag{1}$$

Table 3

Relationship between dependent and independent variables: ANOVA (b)

Model	Sum of squares	df	Mean square	F	Sig.
1 Regression	69.706	1	69.706	48.109	.000(a)
Residual	39.121	27	1.449		
Total	108.828	28			

a Predictors: (constant), underpass
b Dependent variable: importance

Table 4

Coefficients for regression equation

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.	Correlations		
	B	Std. error	Beta			Zero-order	Partial	Part
1 (constant)	2.827	.591		4.785	.000			
Underpass	.474	.068	.800	6.936	.000	.800	.800	.800

Dependent variable: importance

5. CONCLUSIONS

There is a set of characteristics that makes the overpass alternative more preferable. These characteristics relate to traffic safety, sustainability of the urban environment and preservation of the city‘s land, as characterized by paucity, especially in historical areas. Issues such as technical difficulties, duration of construction and costs related to construction, management, and maintenance did not have much impact on this alternative.

According to the study, the relative importance of factors, such as urban resilience, was not so important, due to the fact that the questionnaire was issued to people working in a relatively stable environment against natural disasters. Factors such as traffic congestion, inefficiency of public transport and high traffic accidents increased the relative importance of variables related to those factors.

The availability of some financial allocations related to the construction of road projects (costs factors) did not make these factors difficult obstacles in the opinion of the identified sample. Therefore, applying this model to different environments requires different data relating to those areas.

It is not logical to transform all the city intersections into underpasses, but this method should be seriously considered. Instead of constructing several overpasses within urban areas such as Baghdad, it is preferable to establish underpasses wherever possible to reduce the urban deformity caused by concrete structures. As for traditional solutions to traffic intersections, traffic lights and roundabouts are still practical and low-cost options in urban areas with less traffic density. The conventional solutions have been inversely correlated with the relative importance of the preference variables, showing a strong individual relationship with some variables such as cost, duration of construction and technical difficulties related to development. These are vital but not at the expense of safety and the regulation of traffic in mega-cities where it is difficult to solve intersections by conventional means.

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