Techno-Economical Evaluation of Accidents' Preventing Measures and Remedial Measures in Intersections on Existing Rural Two-Lane Highways.

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Abstract

The objective of this paper is the techno-economical evaluation of accidents' preventing measures and remedial measures in intersections on existing rural two-lane highways. The main target is the optimization between the cost of the treatment measures and the provided road safety in intersections with high traffic volume. As a result, case studies were conducted, through which special diagrams were produced to assess the hazard level of variation of each parameter. The impact of each treatment in provided road safety was correlated with the installation cost and the traffic volume of the intersection, in order to find in every case, the optimal solution. Finally, the results of the road safety that every critical treatment provides as a result of the FM17 software were compared with predicted crashes in these road segments, with use of the IHSDM software.

Keywords: *Techno-Economical Evaluation, Risk Ranking Software, Hazard Level Methodology, Intersection Remedial Measures, Accident Prediction*

1. Introduction

Upgrading the level of the provided road safety as well as reducing the impact of road accidents is a main priority for the global community. In this context, international research has focused on upgrading passive vehicle safety systems, the influence of human-dependent parameters such as mobile phone use, alcohol consumption, non-helmet motorcyclists, etc., as well as improvement of existing and new road infrastructure, taking into consideration the increased level of the provided road safety.

Geometric design of new road infrastructures, as well as roadside equipment (safety barriers, road lighting poles, etc.), are constantly upgraded, offering users comfort and safety when driving. However, there has been no corresponding effort to upgrade the existing road network, as the possibility of remedial measures is often limited, and in many cases the cost of implementation is particularly high.

In this context, this paper aims at evaluating remedial measures that can be applied at At-Grade intersections in order to prioritize treatment measures according to the impact in the provided

road safety in combination with the financial cost of implementation. Through this investigation, useful tools are available to help designers and Project Leaders choose the interventions that have the greatest road safety impact at the lowest possible cost while rejecting those that do not offer substantial upgrade in relation to their cost of implementation.

In the international literature, corresponding surveys have been recorded, the majority of which came from "Case Studies" evaluation. In the case studies the recorded accidents before and after the implementation of the remedial measures were considered. Such investigations have been presented by FHWA (1, 2, 3), by the State of Kentucky (4, 5) and by further research in international (6) and Greek level (7-9). However, it is noted that the present research is innovating as the evaluation was based on the correlation of results obtained from several appropriate software applications, such as the FM17 software developed by the scientific team of the Department of Transportation Planning and Engineering of NTUA (10-13), as well as the Interactive Highway Safety Design Module (IHSDM) software, which evaluates the hazard level of a road section based on quantitative criteria.

In practice, the usefulness of this research lies in the fact that reliable guidance is given to the Researchers to make the right choice of the interventions to be implemented at the Intersection, knowing in advance the improvement rate to be achieved in the provided level of road safety combined with the cost which will be required. Consequently, this research helps researchers to prioritize treatments according to the techno-economical footprint, as well as the Authorities to use the funds in interventions that will have the best possible result at the lowest possible cost.

2. General Principles for Design of At-Grade Intersections

At-Grade Intersections are critical points of the road network where a high number of accidents occurs. For this reason, particular emphasis should be placed on their geometric design, as well as the correct positioning of the horizontal and vertical signage and the adequacy of road lighting. Taking into consideration that the already existing intersections in many cases do not meet the above requirements, it is crucial to carry out the necessary treatments in order to comply with the modern instructions. In this context, the following remedial measures were examined in the present study, firstly regarding the improvement they bring to the provided level of road safety and secondly by taking into consideration the financial cost of their implementation. Briefly examined:

1. Placement of vertical signage
2. Construction of dividing island in the minor road
3. Construction of a separate left-turn lane
4. Construction of a separate right-turn lane
5. Changing the crossing angle between the roads at the intersection point
6. Improvement / placement of road lighting

Initially for actions 2, 3, 4 and 5, typical drawings were made to calculate the cost of implementation, while for actions 1 and 6 the cost of implementation was obtained per item

(per signpost or per road lighting pole). For example, Figure 1 shows the typical drawings that were used to calculate the cost of left-turn lane construction.
Two alternative scenarios were examined in the four remedial measures for which typical drawings have been created, the first of which shows the minimum interventions required to achieve the desired geometry (Figure 1a), while the second the maximum ones (Figure 1b).

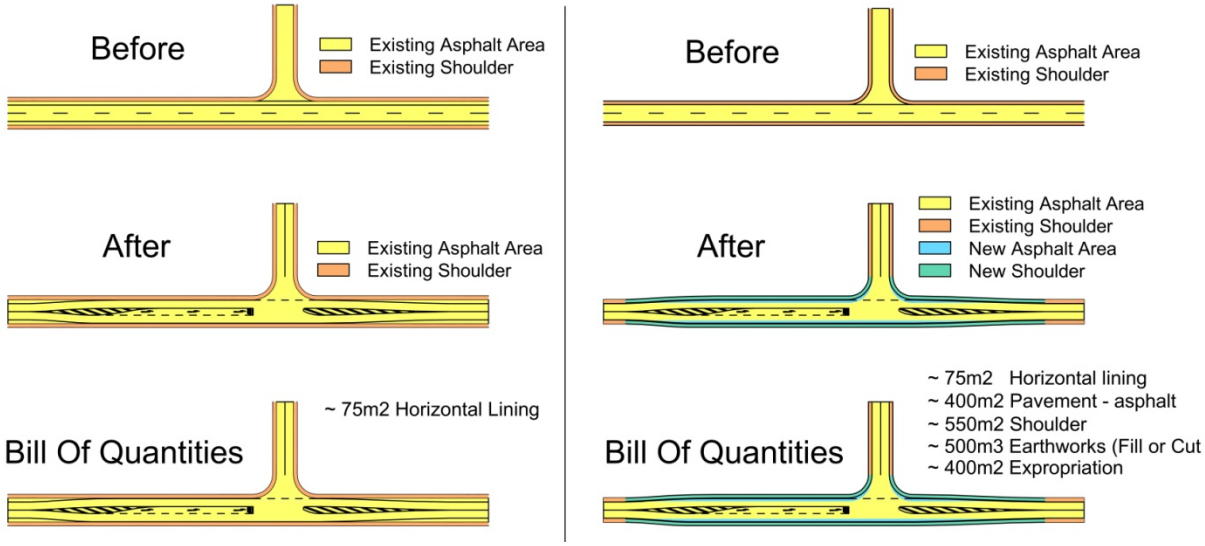

Figure 1a *– Lower Modifications* ***Figure 1b*** *- Higher Modifications*

Figure 1: *Typical drawings that were used to calculate the cost of left-turn lane.*

Based on the typical drawings that were created, the cost of each action was calculated, as presented in Table 1.

Table 1: *Cost of measures evaluated.*

Remedial Measure		**Cost (€)**	
		Lowest	**Highest**
Construction of triangular or dividing island		2.000	5.000
Construction of left-turn lane		700	22.000
Construction of right-turn lane		150	10.000
Improvement of Intersection Angle	From 30° to 72°	15.000	
	From 30° to 90°	18.000	
	From 60° to 72°	8.000	
	From 60° to 90°	15.000	
Placement of road lighting		37.500	67.500
Placement of vertical sign posts		100	1.400

3. *Techno-economical evaluation of remedial measures*

For each of the treatments described above, the improvement achieved in the provided level of road safety through FM17 software was examined in relation to the estimated cost of the treatment. This process was carried out through the evaluation of six (6) sections of the rural road network in the district of Florina prefecture, about 50 km long with a plethora and variety of at-grade intersections. With the help of the FM17 software, the score of the existing intersection was correlated with the score they would have had when specific treatments were implemented, or a combination of them.

As a result of this investigation, for each examined intersection, specific diagrams were obtained, showing the correlation between cost and rating differentiation. Some of these diagrams are shown in Figure 2.

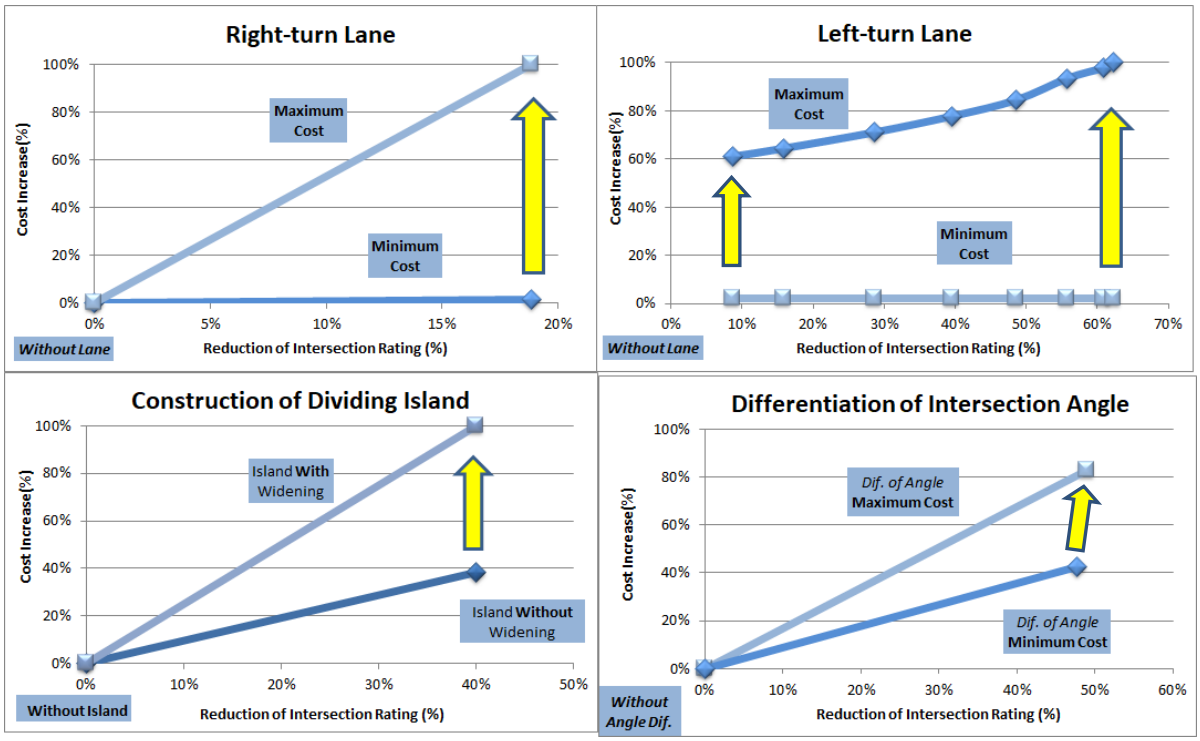

Figure 2: *Charts of cost differentiation and road safety improvement due to various treatments.*

Finally, correlation diagrams of economic costs and road safety improvement for variety of at-grade intersections were created. The results were grouped in order to obtain the average of the improvement achieved by each remedial measure. The range of the improvement scores identified for each intervention is summarized in Table 2, along with the minimum and maximum cost of each measure.

Table 2: *Intervention cost and road safety improvement achieved.*

Remedial Measure		Cost (€)		Road Safety Improvement
		Lowest	Highest	
Construction of triangular or dividing island		2.000	5.000	40%
Construction of left-turn lane		700	22.000	9% ~ 62%
Construction of right-turn lane		150	10.000	19%
Improvement of Intersection Angle	From 30° to 72°	15.000		70% ~ 73%
	From 30° to 90°	18.000		71% ~ 75%
	From 60° to 72°	8.000		40% ~ 42%
	From 60° to 90°	15.000		40% ~ 43%
Placement of road lighting		37.500	67.500	15% ~ 38%
Placement of vertical sign posts		100	1.400	8% ~ 52%

The results presented in Table 2 were plotted on the diagram shown in Figure 3 to correlate the improvement achieved in the level of provided road safety with the costs of interventions. The aim is, through this diagram of techno-economical evaluation, to give researchers the choice of a direct view of the effectiveness of each remedial measure. In this context, the diagram was divided into the following four areas:

- Area of highly efficient interventions
- Area of medium-efficient interventions
- Area of low-efficient interventions and
- Area of inefficient interventions

In addition to the 6 interventions described above, two combinations of interventions were additionally plotted in figure 3:

- Placement of vertical signage in combination with the construction dividing island in the minor road (low cost interventions) and
- Construction of left-turn lane combined with construction of right-turn lane (medium cost interventions)

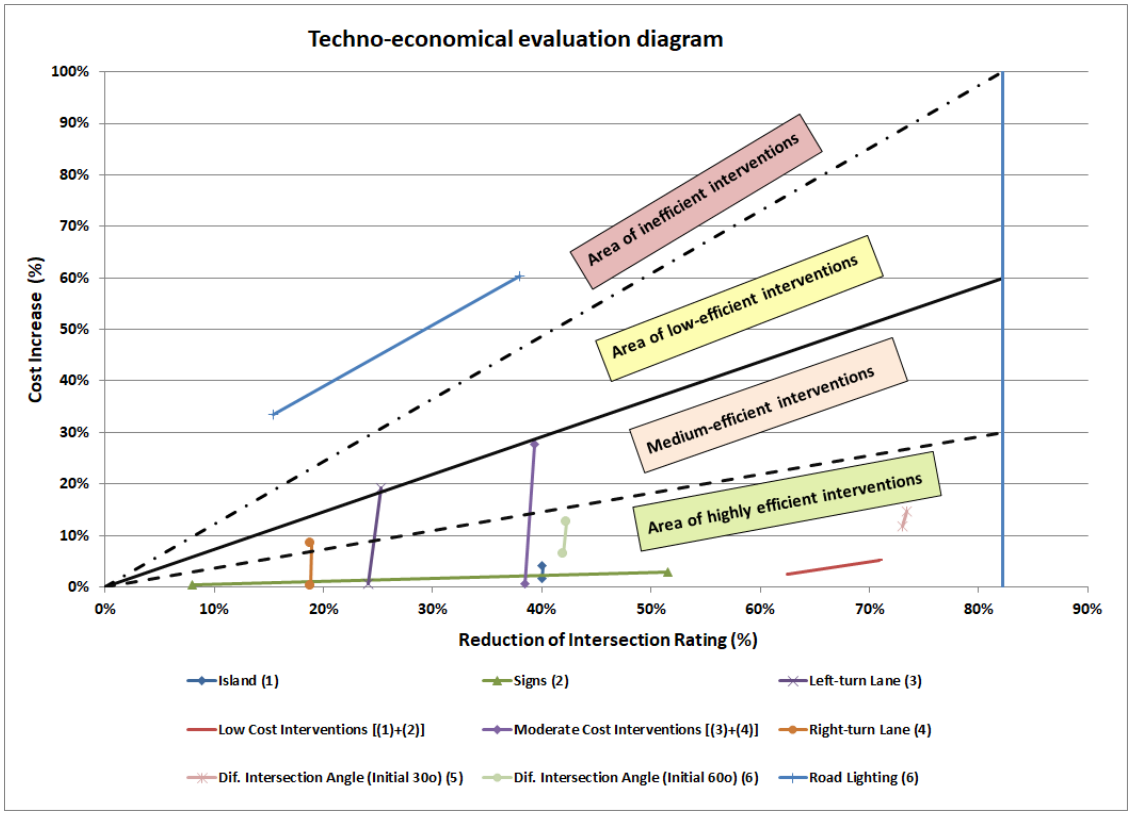

Figure 3: *Techno-economical evaluation diagram.*

The conclusions extracted from Figure 3 show that:

- The installation of signs, the construction of dividing island in the minor road, as well as the improvement of the very small angle of cross roads at the intersection point regarding the minor road (60º and 30º) despite the high cost of the intervention, were included in the very efficient measures.
- The modestly efficient measures include the construction of the right-turn and left-turn lane. Under the conditions of low construction costs, these measures appear to be highly efficient and
- Improvement of road lighting appears to be an inefficient measure.

4. *Correlation of FM17 Software with IHSDM Software*

In order to strengthen the results presented in Figure 3, an attempt was made to correlate the results of the FM17 and IHSDM software, in order to exploit the results of the IHSDM software. For this purpose, the data from the six road sections of Florina prefecture were exploited. In the first stage was investigated the existence of a correlation between the total rating of intersections, as it results from the FM17 software, and the expected number of accidents in these sections over a period of six years (2019-2024), as derived from the IHSDM software. The correlation of the results is shown in the diagram of Figure 4.

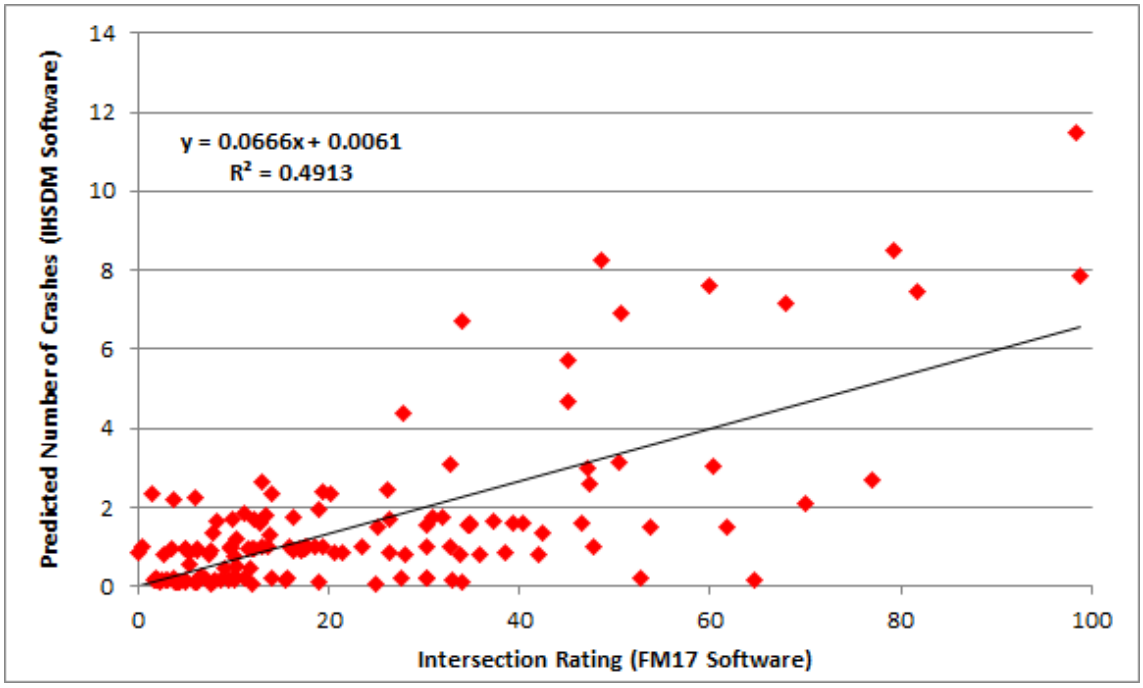

Figure 4: *Correlation diagram of rating (FM17 Software) and predicted number of accidents (IHSDM Software).*

Because, as shown in Figure 4, there was no strong correlation between the two software packages, it was chosen not to exploit the results of the IHSDM software in the present study. Nevertheless, the trend of the correlation line between the results of the two software seems rational and should be reconsidered by broader statistical analysis and greater road sections.

5. *Conclusions*

Based on the analysis made in the present study and the results as obtained and described in the figures and tables presented, the following conclusions are drawn:

- Countermeasures relating to the application of vertical signage as well as the construction of a dividing island in the minor road are ranked in the area of highly efficient interventions, which means that they have a particularly low cost compared to the road safety improvement they achieve.

- On the other hand, the left-turn and / or right-turn lane intervention has in some cases a very positive impact, while in other cases the cost of implementation is particularly high, which makes this measure techno-economically inefficient.
- The measure of improving the intersection angle has a particularly high implementation cost but achieves a remarkable upgrade to the level of provided road safety. For this reason, it is ranked in the areas of moderate or very efficient interventions in the techno-economical diagram.
- The implementation of road lighting in at-grade intersections is a measure that is particularly expensive and does not bring a significant improvement in the level of provided road safety. For this reason, the implementation of this measure is considered to be inefficient.
- Finally, it should be noted that the correlation between the results obtained through the FM17 software and the IHSDM software did not appear strong and requires further investigation.

6. Subject for Further Research

Objectives for further research could be the following:

- Evaluation of the pavement condition and its influence on road safety. Parameters of the pavement that could be the objective of further research are the existing friction coefficient between tires and pavement, road smoothness and condition of the pavement (cracks, deformations, pits, etc.).
- Evaluation of parameters related to night driving, such as the reflectivity of the signs, the adequacy of reflective elements on safety barriers, delimiters, road lighting, etc.
- Comparative evaluation of interventions applied in more road sections and intersections.
- It would be useful to evaluate, through the method used in the present research, road sections outside Greece in order to compare the results of the evaluation with what Greece appears to present.
- It would be important to correlate the effectiveness of the interventions as it results from the current research with recorded road accidents before and after their implementation in at-grade intersections located in Greece.
- The attempt to make greater use of the IHSDM software in order to obtain a satisfactory correlation with the results obtained through the FM17 software and then to correlate the results with the techno-economical evaluation presented in this research.

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