

COST- EFFICIENCY ENGINEERING MEASURES OF LOW COST IN SPAIN

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SUMMARY

The aim of the present abstract, is to evaluate the efficiency and economic profitability, attending exclusively to criteria of road safety, of the low cost performances of the programs of road safety that are being developing annually by the General Directorate of Roads.

For it, more than 3.800 works have been studied, quantifying the reduction of accidents rate reached after its getting into force, its relation cost - benefit and its time of amortization. The methodology used for its determination has taken into account the variation of the traffic experienced after the above mentioned accomplishments as well as that not any other performance had been carried out at least during a period of time of one year, so that in this way to attribute the reduction of accidents rate to a sole work. Also, the statistical importance of the results has been analyzed by means of the test of the chi-squared (χ^2).

As for the obtained results, it is necessary to highlight that in the sections affected by the set of performances developed into the programs of road safety, the risk of accidents rate has diminished in 38 % and fatal accident in 34 %, recovering the investment realized in 2,5 years. Within these programs, the improvements of vertical-horizontal signings are the most efficient measures since they reduce the risk of fatality in 39 % and are amortized in less than 2,5 months (relation benefit - cost 6,5). The treatments of margins reduce the risk of fatality 84 %. The lighting, external borders, the local improvements of tracing and the treatments of road safety of the road surface diminish the index of dangerousness and fatality more than 50 % and 62 %, respectively. Finally, the treatments of ditches have reduced the fatality risk 31 %

More prominent conclusions are: 1) to reduce the accidents rate it is necessary to invest in roads. But the levels can be improved without carrying out very expensive performances. 2) The development of specific programs of road safety, independent from those of maintenance and construction, it is highly effective and profitable.

These programs, which include performances of low cost, constitute a very good strategy to follow concerning the road safety relative to the infrastructure. The success rests on the measures adopted are very located and designed after a detailed study on the safety lacks in the road.

1. COST- EFFICIENCY ENGINEERING MEASURES OF LOW COST IN SPAIN

1.1 INTRODUCTION

The important problem that the lost of human lives suppose for a Country in road-accidents, have stirred up a social-political demand set to improve the Safety driving level.

All countries are involved, especially underdeveloped ones, in large projects of infrastructures and adaptation from old network to the new network imposed by the economic activity and the social pressure.

But the investing eagerness in new infrastructures is braked sharply in period of economic crisis, where the budgetary restriction make it possible to optimise the assignment of the resources in the way that the level in road safety keep on improving as the social demand do not cease. For it, if it would be possible to get trusted foresights concerning a decrease in traffic accidents of the adopted measure, it would be possible to select the most efficient and cost-benefit ones.

There are few publications and committees however, that address the subject of a possible decrease in accidents through infrastructure measures in terms of the adopted actuation. But, in which measure the concrete programmes or works carried out on infrastructure are instrumental for the improvement in Road Safety?, which of them are the most efficient ones and which of them the most cost-effective ones in Road Safety?. To answer these questions is not an easy task, since the interaction is frequent among different performances spatially and in the period of its execution, besides the changes experienced on the road behaviour of the users.

Nevertheless, to know the answer to these questions is especially important, for it allows optimising the assignment of the available resources and, in addition, it constitutes one more argument at the moment of justifying the request of major budgetary endowment to improve the safety levels in the roads.

In this paper, we try to give response to these questions on the basis of the experience accumulated in this field by the General Directorate for Roads of the Spanish National Road Administration by means of the development of the specific Programs of Road Safety that, with an investment of approximately 100 million Euros per year, include performances relative to the infrastructure designed to improve dangerous or potentially troubled situations for the traffic.

The prominent reduction of accidentally experienced together with the number of performances carried out and the period of sufficient time from its getting into force of the performances, have allowed to realize a rigorous and statistically significant analysis of the efficiency and economic profitability of the executed measures.

This way, in this presentation we explain the methodology followed in the evaluation of the efficiency - profitability of the different measures carried out, in general, of low cost, and the obtained results.

2. METHODOLOGY

2.1. EVALUATION OF EFFECTIVENESS

Next, the main methodological principles in this analysis will be itemised: reliability of the sample analysed, right assignation of the variation of accidents in a determined work, appraisal of the traffic variation in the analysis of the reduction of accidents for the affected section roads, contrast of the reliability of results and influence of other factors in the accidents variation.

2.1.1. Reliability of the sample analysed

The number of performances necessary to analyze for every type of measure must be sufficient in order that the results that are obtained could be considered to be representative.

As data information it has been considered more than 3.800 performances in the Spanish Network Roads and getting into force in 5 years.

2.1.2. Right imputations of the reduction of accidents according the measure adopted

This stage is very important to get satisfactory and coherent results. We can't forget that the objective of this analysis is to determine what is the effectiveness to reduce accidents of each kind of measure. If in the same section have been made some works of different kind in the same year, it be hard to know what is the reduction obtained from each measure.

Therefore, to assure the right assignation of the experimented variation of accidents in a determined performance, it has been demanded that at least in a period of a year-time no other procedure had been carried out in the same affected section.

For which it has been necessary to accomplish a previous selection by overlap "physical" understanding by physical overlap the fact that works having in part or as a whole in common the section of road, independently of which one had been carried out. Nevertheless, those works physical overlapped but have at least one year after and before his execution have been taken for the analysis, because it's possible to ascribe the reduction to the work.

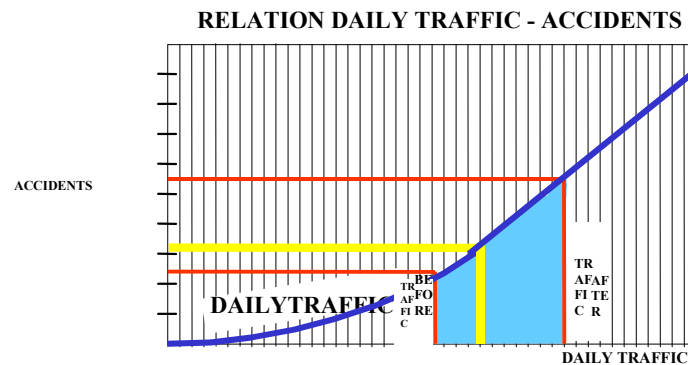
This action guarantee the rigorousness of the study and its conclusions. The resulting works from this process of purification have been fair enough representatives, as they concern to almost 5.000 km, that to say, to the 20% of the network approximately.

2.1.3. Reduction of accidents in terms of traffic

The evaluation of the efficiency of a performance of improvement of the road safety starts with a comparison of the number of accidents observed in a period of time of equal duration before and after the execution of the same one. But it is not the same thing to reduce 10 accidents in a section in which 1000 vehicles / day circulate that in other section with 100.000 vehicles / day.

To calculate the reduction of accidents it was necessary to bear in mind the level variation of the exposure, represented by the traffic volume (v-km), since it increases annually, in general. Wherefore, the analysis starts from the hypothesis that if we don't make anything

in a road, the safety rates¹ stay even, other wise we assumed that the number of accidents would be the same although grow up or down the traffic volume.



According to this standards it was evaluated the effectiveness of different measures, quantifying the reached accident reduction.

2.1.4. Reliability of the obtained results

It is also necessary to make a valuation of the obtained results, that is to say, to check through statistic techniques if the results are or not significant.

On the other hand, it is known that the theoretical distribution that better fit to the frequency of accidents is the Poisson's distribution. On the strength of this, it has been determined the trusting level of the obtained results through the statistic test of the χ^2 and in general, they have turned out to be "sufficiently trustworthy or statistically significant. Nevertheless, it is necessary to outline that the statistical relevancy has been something minor for the fatal accidents as consequence of the existence of a minor sample (frequency of fatal accidents).

2.1.5. Influence of other factors apart from the road in the accident variation

Lastly, one must bear in mind that in the reduction achieved in those sections where works have been carried out on infrastructure, also contribute to it the general improvements experienced along that years in the points of road education, drivers training, improving or renewing of the motor-vehicle park, surveillance and control, etc.

For that, it is necessary to determine in some way the influence of other factors apart from roads factor (human and vehicle) in the reduction of accidents.

With this purpose, it was identified those sections where no works on infrastructure were made in the same years and following a similar methodology, it was quantified the reduction of accidents achieved in a 7%. Obviously this reduction can be attributed to a set of measures before mentioned, all of them different from the road.

So, supposing that these factors (different from the road) have participated in the same way in the sections where measures on infrastructure were taken, the differential between the total reduction achieved (calculated according to paragraph 2.1.3) and the 7%, would be the real decrease of accidents ascribed solely to the improvement carried out in roads

¹ Safety Rates: Injury accidents rate = number of injury accidents per 100 million vehicles-km driven
 Fatality rate = number of fatalities per 100 million vehicles-km driven

2.2. ECONOMIC PROFITABILITY

Equally, a study were made on the economic profitability gazing solely the total toss, that is to say, accounting exclusively the benefits arisen from the reduction of victims without quantifying other aspects as the capacity improvement, mobility, fuel saving, reduction of driving time, etc. The assessment of accidents taken in the study have been of 175.00€ for the mortal victim, 20.000€ for the critical injured and 360€ for the slight injured. Logically, the evaluation adopted in this type of studies is fundamental for the future profitability of the analyses actions. In this way, it is to be point out that the medium cost contemplated in the countries of the European Union for the mortal victim is 4 times higher than in Spain, which made the obtained results not to be compared or extrapolated with other countries.

Made this exception, the accidents rates have been obtained avoided by unit of investment (600.000 €), as well as the relation benefit / cost and the period of recovery of the realized investment.

3. RESULTS

Firstly, it is necessary to say that the measures including in road safety programmes, in arise from a previous analysis of accidents together with a work "in situ", analysing the possible lack in road safety. They deal with adopted measures normally in short sections quite localised and after a thorough study, therefore the effectiveness achieved is excellent but without generalise for any situation. So, for the set of section affected (845 km) the works included in road safety programmes have achieved to reduce the accident with victims and the mortal accidents to a half (a 50% and 45% respectively). So, the road safety programmes prove to be the most effectiveness ones, the ones that allow better reductions of accidents with less investment. About 7 accidents with victims (7,25) and practically 1 mortal (0,8) have been avoided for each 600.000€ invested, which give way to a period of amortisation of all programme less than 2,5 years. It is self-evident the importance of these programmes in the improvement of road safety; even more in a crisis epoch, where the budgetary cut-outs make them to have higher importance for the safety levels must be supported and improved with a less economic availability.

Let's see next the results obtained in the affected sections distinguishing by type of performance that is detailed in the attached table. 10 performances have been studied, as follows:

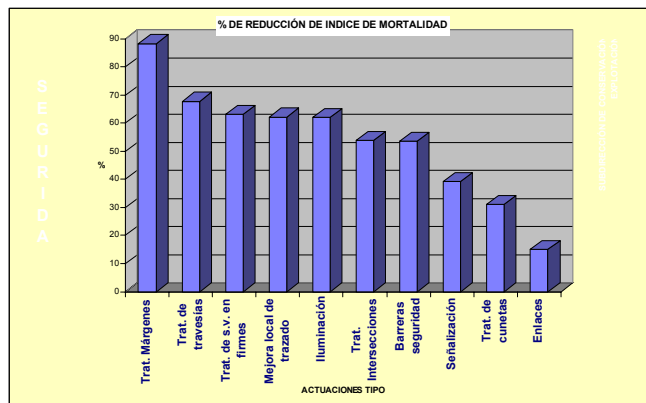
- First, it must be underlined the high profitability of signing improvements. (Installation of new vertical signs, directional panels in curves, traffic guidance - mark, guidance, delineators -, etc.). Its high efficiency together with its low cost make that in a few months are amortized. This way, with an average cost of these performances of 4026,78 €/km, the risk that an accident happened in the above mentioned sections diminished 18 % (confidence level for the percentile 95 - χ_{95} - of 81 %) and that of fatal accidents 39 %. The relation benefit/cost obtained have been a 6,5% (the higher in all performances taken), whereupon in just 2 months the initial investment have been recovered.

TIPO DE ACTUACIÓN	Índice de Peligrosidad			Índice de Mortalidad			RECUPERACIÓN INVERSIÓN (años)
	antes	después	reducc.	antes	después	reducc.	
Iluminación	34,9	9	74%	3,2	1,2	62%	8,6
Tratamientos de travestias	82,0	43,8	47%	5,3	1,7	68%	2,4
Mejora local de trazado	27,7	13,9	50%	3,7	1,4	62%	15,9
Tratamientos de s.v. en firmes	42,5	22,4	47%	13,0	4,8	63%	0,7
Enlances	52,6	30,8	41%	6,7	5,7	15%	80,8
Tratamientos Márgenes	34,2	20,1	41%	12,9	1,5	88%	2,3
Tratamientos Intersecciones	43,6	32,2	26%	7,8	3,6	54%	10,2
Señalización	61,6	50,8	18%	9,7	5,9	39%	0,2
Barreras seguridad	10,0	9,5	5%	1,1	0,5	54%	1,7
Tratamientos de cunetas	26,7	30,6	-15%	6,0	4,1	31%	1,1

- In the treated stretches with illumination, mainly in the urban area, with an average length of 2,4 km, the risk of accident has been reduced a 74% and the fatality risk in a 62% (Level of relevancy $-\chi_{95}$ - superior to 81 %). This means a reduction of 4 accidents per each 600.000€, with an end result of 8,5 years amortisation. Nevertheless, it is necessary to emphasize that these results correspond to the set of the diurnal and night accidentally.

- So much in the treated stretches with cross town roads treatments, local improvements of alignment, as well as with special treatments in pavement the injury accidents and the risk level have been reduced to a half in the treated sections, whereas the fatal accidents and the risk of fatality have diminished in more than 62 % (Level of relevancy $-\chi_{95}$ - superior to 95 % except in the fatal accidents of the improvements of tracing where the risk is 52 %). On the other hand, the economic profitability, still being a discharge in all the cases, it differs more depending from a type or other.

This way, the special treatments of the road surface (non-slipping pavements, slurrys, bituminous grouts, porous pavements..) with an average cost of 24.000 €/km are amortized in only 8 months.



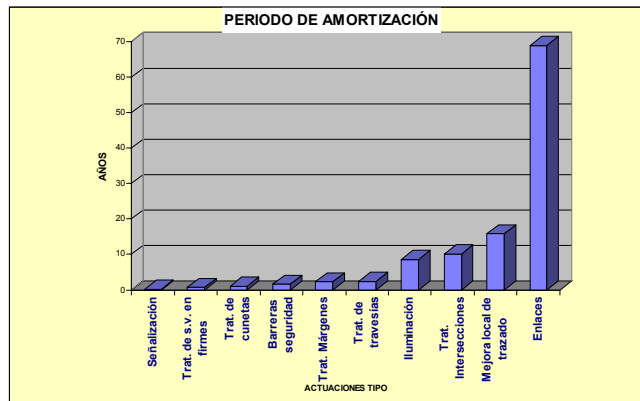
The cross town sections treatments (construction of sidewalks, installation of bridge-rails, improvements of the road surface, installation of pedestrian crossings, illumination, ...), with average cost of 114.000 €/Km, have been amortized in slightly less than 2 years and a half (29 months).

The local improvements of tracing (rectification of curves and / or the gradient), with an average cost for km from 240.404,84€, are achieved to amortize in approximately 16 years.

- By means of the treatment of the external borders (lateral freeings, elimination of obstacles..., etc) the accidents have been reduced (when increased the visibility) and, fundamentally, the gravity and consequences of the same ones, having diminished, in the affected sections, the risk of fatality 88 % (percentile 95 $-\chi_{95}$ - of 78 %) and that of dangerousness of 41 % ($-\chi_{95}$ - = 98 %). The period of recovery of the investment has been of something more than 2 years (2,3). Therefore, it is a question of the most effective and profitable measurements to diminish the consequences of the accidents for runs out of the road.

- Another type of highly effective performance in the reduction of the gravity of the accidents and very profitable economically it is the installation of safety fences. This way,

while in the sections treated the risk of having an accident diminished only 5 %, the fatality risk did it in a 54 %.



- The performances of treatment of ditches (protection, covering, smoothed of banks, construction of safety ditches, etc.) suppose also a very effective measurement to diminish the gravity of the accidents. In spite of having increased the index of dangerousness a 15 % in the sections with these performances, the fatality risk has diminished in 31 %. The average period of return of the investment obtained for this type of measurements has been one year.

- Also performances of treatment of intersections have been studied consisting of small local improvements and conditionings (channelling draft - by means of construction or painted islets, traffic guidance-, construction of tapers, rails for changing speed, central waiting rails, ...). In them, the accident risk has diminished in 26 % and the fatality risk in 54 %. The period of amortization for these performances has been 10 years. On the other hand, the substitution of intersections by links in highways, in spite of having reduced the dangerousness in 41 % ($\chi_{95} = 99$ %) in general, they are not economically justify exclusively for safety criteria, since the high cost - approximately 1.200.000 €-, make that its period of amortization is much more extensive.

4. CONCLUSIONS

Next, we introduce the most important conclusions that come from the results previously exposed:

1.-The specific programs of safety road, independent from those of maintenance and construction, are highly effective and profitable and constitute a very good strategy to continuing concerning safety road relative to the infrastructure. The construction of highways and motorway supposes an important improvement in the safety road, specially in the risk of fatality, but in view of its high cost.

2.- These programs include performances relative to the infrastructure, in general of small cost, designed to eliminate dangerous or potentially troubled situations for the traffic. This is the strategy followed in the last years in Spain by the General Directorate for Roads with excellent results, avoiding annually more than about 7 injured, practically, 1 fatal accident for every 600.000 Euros invested in the programs of road safety.

3.-The success of the developed measures rests on that are adopted in sections very located after a detailed study of the safety lacks. This way, in those sections where treatments of external borders have been implemented, the risk of fatality has diminished 88 % and where illumination measures have been applied, the risk of having an accident diminished 74 % and the risk of fatality 62 %. But, no doubt, the most efficient measure of all is the traffic and marking sign since it presents a relation benefit - cost of 6,5, which supposes that in a few months is amortized.

4.-Therefore, to reduce the risk it is necessary to invest in roads. But the levels of accidents can be improved without need to realize very expensive performances.

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