Optimization of the costs of road lighting systems.

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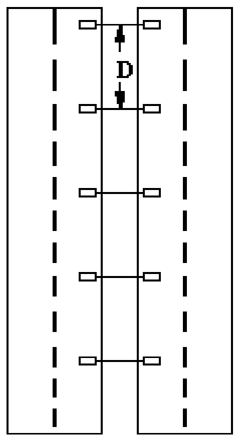
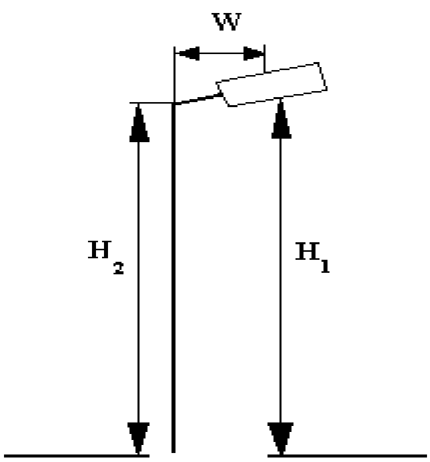
I. Introduction

Minimization of total costs of construction and exploitation of road lighting systems becomes a significant topic in Poland due to high development of road investment acticity in Poland. Many new motor- and high- ways are built in all regions. They need to be in use before 2012, because in 2012 we are host of Euro. Thus high tempo and low costs are recommended. Optimization of road lighting should include economic aspects (espenses of lighting systems) carrying on many various constrains. Optimization of lighting include a lot of tasks. In paper only most important are consider. More difficult are neglected and analyses uses a large number of simplification.





where:
H_1-height of fitting suspension
H_2-height of lighting post
W-bar length
D-distance between the post

Fig.1 Geometry of fittings

A road consists of many various elements.: roadways, sidewalks, bicycle paths, green belts, crossings etc. Lighting systems is composed of lighting fittings. Kinds and configuraton of lighting fittings achieve lighting goal. Lighting fittings have different sources, rods, posts and equipment. In paper we consider straight- road case without crossings. There are many different road lighting configuration: one-sided, two-sided opposite, two-sided alternate, on separation belt. Cross symetry of the fittings is the same as road axis. Big variety of systems is connected with various road configuration and lighting requirements. It is main task in construction to choose right one, which ensures best lighting performance to considered road. Differenation of the lighting parameters is achieved by modifying the following features: fitting types, way of their arragment, height of fitting suspension, distance between the posts, projection of the fitting above the road components, numer of fittings on single post.

II. Optimization of the road lighting costs

The optimization process consists in searching an extreme value of J(x) function, reffered to as objective function, where x is for vector of decisive variables. Decisive variables of objective function are result from many factors as, available manufacturing technologies and standard requirements. They can be continous or discrete character. Type and number of decisive variables influence on optimization method. We can distinguish two groups of decisive varibles: euality and inequality character. In the lighting system optimization task only inequality constrains are dealt. Usually method of penalty function is used. It consists in replacing the task with constrains for a constrain-free task by formulation of the objective function J(x) in modified form $J^{'}(x)$:

$$J^{/}(x)=J(x) + \sum F_P(x) \quad (1)$$

where $J^{/}(x)$-modified objective function, $\sum F_P(x)$-penalty function.

Desisive variables are distance between the fittings, post height, bar length, fitting upward inclination angle, fitting type, source type, method of fitting arrangement.

Objective function for road lighting optimization has economic character. This function is a sum of investment $J_i(x)$ and operational $J_e(x)$ costs.

$$J_i(x)=K_O+ K_Z+ K_s+ K_{OS}+K_i+ K_p \quad (2)$$

$$J_e(x)=K_e+ K_k+ K_s+ K_w+ K_d \quad (3)$$

where: $J_i(x)$-the investment part of objective function, $J_e(x)$-operational part of the objective function, K_O- the costs of lighting fittings, K_{Z-} the cost of lighting sources, K_s- the cost of the posts, K_{OS}- the cost of additional fixtures, K_i- the installation cost, K_p- cost of design, K_e- the cost of electric power, K_k- maintenance costs, K_w- the costs of periodical exchange of the sources, K_d-additional expenses (transportation,utilization of the sources and fittings).

All solutions of the optimization task, considering all adopted constrains, is reffered to as an admissible area. The form of objective function is definite beyond the admissible area. In case of the jobs of such a type the method of external penalty function may be used, in the minimization case, for the points located beyond the admissible area the value of the objective function is increased. Moreover, the penalty is different, in accordance with the amount of the transgression and number of current iteration.

The constrains of optimization process of road lighting system costs can be divided into three groups related to desisive variables, standard requirment, and the requirments imposed by investor related (esthetics, shape). The second group is related to controlling the lighting parameters(average roadway luminance, total uniformity of lumininace etc.) In consideration third group is neglected.

Some local extremes may occur during searching optimal solution to the road lighting system. Vector of decisive variables x has its constant and discrete components. To solve the problem of costs optimization of the road lightning system a nondeterministic method of genetic algorithm is used. A genetic algorithm is a search technique used in computing to find exact or approximate solutions to optimization and search problems. This method has high effectiveness in dealing with jobs. Disadvantage of method is being frequent solutions that only approximate the global one. It is necesarry to use some modifications to improve efficency of method. There are scaling of the adaption function, use of two-point crossing and use of tourment selection method with the elements of exclusivity strategy.

III. COnclusions

Optimization of a road lighting system consisting in minimization of total cost is feasible. Genetic algorithm method should be used for purpose of optimization of systems with such a objective function and different types of decisive variables and occurance of local extreme points. Some modyfication are required to improve quickness of finding an optimal solution. Decreasing costs od road lighting can rise up to 20 % in comparision with several constructions.

References

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