# TOWARDS THE IMPLEMENTATION OF INTELLIGENT OPTIMIZATION SYSTEMS FOR PROCESS MANAGEMENT IN PAVEMENT REHABILITATION

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## 1. BACKGROUND

Pavement rehabilitation comprises a very time sensitive and complex set of operations. Not only does this type of construction typically rely on very expensive heavy mechanical equipment, as it also usually involves closing lanes that will inevitably cause delays to users. Even though there is an increasing interest in completing these rehabilitation interventions with the lowest cost and durations, the planning of this process is currently mostly based on the designer's experience. While optimization tools have already been used in the planning phase of projects to manage resources and constructive processes in other fields, such as in earthworks and bridge construction [1,2], there has been a lack of development regarding the optimization of road pavement constructive processes, especially in the context of rehabilitation of highways. Actually, the few attempts that address optimization in this context attempt to tackle the high complexity of the problem by adopting pre-defined sets of materials, crew formations, and work conditions [3] in order to simplify the mathematical representation of reality, ultimately meaning that the resulting systems are neither capable of guaranteeing the optimality of solutions, nor susceptible to generalization. Thus, this work focused on developing an optimization system based on an evolutionary multi-objective approach, capable of supporting decision making in asphalt pavements rehabilitation planning. On the one hand, it tackles an identified research gap regarding the study of the viability and gain of the implementation of multi-objective optimization in planning of pavement rehabilitation. On the other hand, a more practical contribution is related to the development of a system capable of supporting decision making in the planning of pavement rehabilitation interventions from the designer's viewpoint, thus focusing on multi-objective minimization of both time and cost simultaneously.

## 2. OPTIMIZATION SYSTEM

Making a parallelism to the manufacturing industry, asphalt pavements rehabilitation can be depicted as a series of production lines based on resources (heavy mechanical equipment) that execute a set of tasks (such as milling, transportation, paving and compaction) in a specific sequential order throughout different work fronts (lanes) until a certain parameter is reached. In this case, the critical task that determines the speed at which the whole process progresses is the paving task. Therefore, pavers are allocated to work fronts supported by the corresponding production line (i.e., remaining support equipment, such as trucks and rollers), which has the objective of paving a certain volume of bituminous mixture. Hence, in the proposed system, the allocation of equipment is carried out in two stages. The first stage corresponds to the allocation of the critical task of production lines, corresponding to paving teams, by means of a multi-objective genetic algorithm, namely the NSGA-II. The second stage consists of the allocation of the available equipment throughout the remaining tasks that support paving, by means of linear programming focusing on minimizing the operational cost while guaranteeing that the productivity of the paving team does not get compromised. In short, the optimization system (depicted in Figure 1) relies on the interactions between the genetic algorithm and the fitness function. While the NSGA-II generates the population of solutions in every generation, the fitness function keeps the solutions feasible and calculates the objectives values for each solution. Each solution is composed of a sequence of integer genes $g_j^i$ that denotes the paving front to which the $j_{th}$ paver is allocated in the $i_{th}$ construction phase. Each gene corresponds to the sequential positioning of a paver throughout the construction duration. The fitness function, which will ultimately assess the quality of a solution in terms of cost and time, is executed for each solution and includes two processes: the verification and repair process, and the solution quality assessment process. On the one hand, the verification and repair process examines the feasibility of solutions. On the other hand, the solution quality assessment process includes the LP models and aims to distribute the remaining equipment to active fronts, leading to the determination of the total costs and duration.

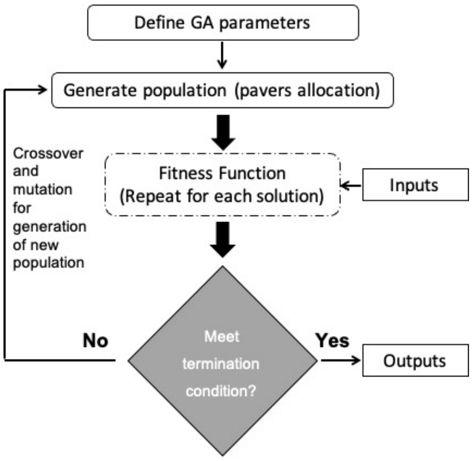


**Figure 1.** Simplified optimization system workflow

## 3. RESULTS AND CONCLUSIONS

The capabilities of the system were validated and tested in a real motorway rehabilitation project. Several scenarios were analyzed based on the case study in order to showcase the potential of the system to support decision making in real-world conditions, as well as its generalization capabilities which allow it to be applied in any pavement rehabilitation project. The obtained results were enough to back up the original decision to allocate the pavers in the real context of the construction as one of the optimal alternatives. However, with the quantities and types of equipment available to develop this project, it was not possible to find a solution that outperformed the originally adopted, i.e., an equipment allocation solution that was cheaper and faster at the same time. Nevertheless, it was also possible to find other equally optimal solutions, that would either be slightly less expensive but would take longer, or one solution which was faster but more expensive. Having more than one optimal solution to choose from provides decision makers with a broad view of the options, as well as a higher flexibility, since according to their own criteria they are able to choose the fittest option to complete the project in any condition, i.e., depending on different budgets or deadlines.

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