Chapter 54
A Sensitivity Analysis of Critical Genetic Algorithm Parameters: Highway Alignment Optimization Case Study

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ABSTRACT

Genetic Algorithms (GAs) have been applied in many complex combinatorial optimization problems and have been proven to yield reasonably good solutions due to their ability of searching in continuous spaces and avoiding local optima. However, one issue in GA application that needs to be carefully explored is to examine sensitivity of critical parameters that may affect the quality of solutions. The key critical GA parameters affecting solution quality include the number of genetic operators, the number of encoded decision variables, the parameter for selective pressure, and the parameter for non-uniform mutation. The effect of these parameters on solution quality is particularly significant for complex problems of combinatorial nature. In this paper the authors test the sensitivity of critical GA parameters in optimizing 3-dimensional highway alignments which has been proven to be a complex combinatorial optimization problem for which an exact solution is not possible warranting the application of heuristics procedures, such as GAs. If GAs are applied properly, similar optimal solutions should be expected at each replication. The authors perform several example studies in order to arrive at a general set of conclusions regarding the sensitivity of critical GA parameters on solution quality. The first study shows that the optimal solutions obtained for a range of scenarios consisting of different combinations of the critical parameters are quite close. The second study shows that different optimal solutions are obtained when the number of encoded decision variables is changed.

DOI: 10.4018/978-1-4666-8473-7.ch054

INTRODUCTION

Optimizing highway alignments (Jong & Schonfeld 2003; Jha, Schonfeld, Jong, & Kim, 2006) involves selection of the best alignment among many alternatives based on specified objectives while satisfying various design and operational constraints. Since there are numerous factors (such as topography, right-of-way, environmental and socio-economic characteristics, to name a few) that influence location of highway alignments, a comprehensive formulation of the objective function and selection of a good search algorithm is highly desirable. Our previous efforts (see Table 1) have been largely devoted to:

1. Objective function development;
2. Genetic algorithm development for search and optimization; and
3. Studying problems with different characteristics that represent real-world scenarios.

Recently, we have also investigated bi-level and multi-objective approaches to the highway alignment problem (Kang, Yang, Schonfeld, & Jha, 2010; Maji & Jha 2009). Many details of the highway alignment optimization problem, such as impact of the topography on alignment selection has been skipped here since those can be found in previously published works. A brief reference of previously published works by our research team in the field of highway alignment optimization is shown in Table 1.

Three types of models have been developed for optimizing highway alignments (Jha et al., 2006; Jong & Schonfeld, 2003):

1. Models for horizontal alignment optimization,
2. Models for vertical alignment optimization, and
3. Models for simultaneously optimizing horizontal and vertical alignments.

Table 1. Summary contribution in previously published papers related to HAO

Article	Summary Contribution
1. Preliminary highway design with genetic algorithms and geographic information systems by *Jong et al., (2000).*	This paper provides the basic overview of 3-dimensional highway alignment optimization with the aid of a Geographic Information System and Genetic Algorithms.
2. Geographic Information system-based analysis of right-of-way cost for highway optimization by *Jha & Schonfeld (2000).*	In this paper a comprehensive formulation of right-of-way is provided for optimizing highway alignments.
3. Criteria-based decision support system for selecting highway alignments by *Jha (2003).*	This paper shows how a decision support system can be developed to screen and save a set of optimal highway alignments subject to user-specified criteria.
4. Tradeoffs between initial and maintenance costs of highways in cross-slopes by *Jha & Schonfeld (2003).*	This paper considers the maintenance and life-cycle costs in optimizing highway alignments.
5. An evolutionary model for simultaneously optimizing three-dimensional highway alignments by Jong and Schonfeld (2003).	This paper provides a comprehensive overview of the genetic algorithms applied for optimizing highway alignments.
6. Intersection modeling for highway alignment optimization by *Kim, Jha, Lovell, & Schonfeld (2004).*	This paper provides a local optimization approach for intersections in the overall scheme of highway alignment optimization.
7. A Highway alignment optimization model using geographic information systems by *Jha & Schonfeld (2004).*	This paper provides a comprehensive overview and extensive sensitivity analysis of geographic information system application in optimizing highway alignments.
8. Improving the computational efficiency of highway alignment optimization models through a stepwise genetic algorithms approach by *Kim et al., (2005).*	In this paper a stepwise genetic algorithm is proposed to improve the computational efficiency of highway alignment optimization models.
9. Highway route optimization based on accessibility, proximity, and land-use changes by *Jha & Kim (2006).*	In this paper a trade-off analysis is proposed to investigate the relative weights of utilities and disutilities associated with highway construction.

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