Decision Support Model for Water Pipes Renewal

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PROBLEMATIC

Water networks are constituted from several hydraulic components that ensure water delivery in order to satisfy consumers demand.

The Decision Support Model deals with problematic of pipes maintenance forming the network. According to hydraulic performance and budget available, water utility manager have to take the right decisions in the right time to enhance network reliability along pipes life cycle. Water networks are burden, inspection of pipes is impossible. Deterioration is noted when failure occurs. The deterioration process is described helping with statistical model.

Works on pipes represent an important investment. Decision taken must ensure that available budget is used in the right way.

It appears that optimization procedure is required. Decisions taken must involve several objectives: technical and economical. The approach is based on multiobjective optimization using Genetic Algorithm. Genetic Algorithm is linked with hydraulic simulator, Epanet2. In order to measure the impact of decisions taken on the hydraulic operation, Proposed model gives acceptable solutions according to hydraulic and economical constraints. A set of non-dominated solutions is given.

According to specific context, a solution should be preferred to others. The final decision depends on Water Utility Manager priorities.

TOOLS AND METHODOLOGY

Decision support model is based on two principals steps:

First step

It concerns selection of pipes candidates to renewal. We assume that water utility disposes of data related to pipes. In fact, the selection procedure takes into account variables linked with pipe structure and its environment: length, diameter, previous failure, installation date, soil occupation, traffic level. Also hydraulic importance of each pipe is considered in analysis. We need hydraulic characteristics of pipes: roughness, demand, pressure required.

According to available data, we use Proportional Hazard Model (PHM) to describe pipe deterioration process. PHM takes into account cited variables on the structural deterioration of pipe. It is described helping with Genetic Algorithm.

Second Step

At this level, implementation of Modified Genetic Algorithm (MGA) is done. Before implementation, we define design variables of the considered problem as the required alternatives to enhance hydraulic reliability of network. We consider three possible works on pipes: to repair if break occurs, to replace with same works on pipes: to repair if break occurs, to replace with same hydraulic and reliability of network. We consider three possible works alternatives described before. According to Hydraulic Algorithms, solutions are codes helping with hydraulic indexes and prediction failures in order to identify critical pipes to be renewed. Using hydraulic simulation, Optimization algorithm and hydraulic simulation, Optimization algorithm helps with genetic approach helping with genetic approach.

TOOL AND METHODOLOGY

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APPLICATION

Model was applied to water network contained 5 tanks, 3 pumps, 450 pipes and 325 consumer nodes. About consumers we have 2 plants, a swimming pool, retirement hotel and houses. Peak demand is noted between 07:00 PM and 09:00 PM. As shown in Figure 3, during this period, we observe pressure deficiencies on 66 nodes (pressure less than 20 m, nodes in red).

Figure 3. Water network studied

According to hydraulic deficiencies observed and available data about pipe characteristics, we apply the first step of optimization model. Using hydraulic indexes and survey function according to PHM Model, we select pipes candidates to renewal. 40 pipes are selected among 450. The next step consists of implementing Modified genetic algorithm. We consider a set of 50 initial possible solutions. Each solution is codes using string of 40 codes taking into account three works alternatives described before. Hydraulic performance and maintenance cost are assessed for each proposed solution. We assume that solution must ensure minimum pressure of 20 m and maximum pressure of 50 m. Budget constraint is not specified.

Figure 4. Feasible and non dominated solutions

MGA gives a set of feasible solutions, with 4 non-dominated solutions forming Pareto Front (discontinue red line, Figure 4). The solutions proposed are resumed in Table 1.

Table 1. Non-dominated solutions

<table>
<thead>
<tr>
<th>Minimum Pressure (Meter)</th>
<th>Economical objective function (Euros)</th>
<th>Budget Assessing (Euros)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.53</td>
<td>164 161 06</td>
<td>706 108</td>
</tr>
<tr>
<td>20.43</td>
<td>206 005 64</td>
<td>813 609</td>
</tr>
<tr>
<td>20.24</td>
<td>2194 435</td>
<td>863 151</td>
</tr>
<tr>
<td>20.00</td>
<td>2312 295</td>
<td>722 884</td>
</tr>
</tbody>
</table>

It's appears that solutions are sensitive to the pressure level and budget assessing. Hydraulic performance doesn't depend on budget available, but on sequence of work on pipes. The final decision depends on the priorities of the water utility manager. According to the solutions proposed, enhancing pressure level may be ensured with minimum budget.

CONCLUSIONS

According to available data, Model developed assessed hydraulic indexes and prediction failures in order to identify critical pipes to be renewed. Using multiobjective approach helping with genetic algorithm and hydraulic simulation, Optimization model proposes a set of non-dominated solutions according to objectives and constraints involved.

Depending on budget available and desired pressure level, a solution could be selected. Final decision depends on context and water utilities priorities.

Figure 1. Decision support model

Figure 2. Definition of policy according to three works alternatives