SELECTION OF OPTIMAL LAYOUT FOR SEWERAGE NETWORK USING DYNAMIC PROGRAMMING

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ABSTRACT

The sewerage system must be properly and skilfully planned and designed, so as to remove the entire sewage effectively and efficiently from the houses, and up to the point of disposal. The sole aim of providing a sewerage system is to transport all nodal flows through a set of links connected in the form of a tree (drainage system) to the pre-decided sink node. Thus, the sink node is known as receiving node. This paper pertains to the application of dynamic programming for the optimal design of a given sewerage system by using layout generation algorithm. Using this algorithm, all constraints of the sewer layout problems are systematically handled and the optimal layout can be selected by applying this simple algorithm.

Keywords: Algorithm, Dynamic programming, Layout, Optimization, Sewerage systems

I. INTRODUCTION

The optimal design of a sewerage system for a given system outlet involves two aspects: (1) generation of alternate layouts; and (2) the optimal design of the selected layout. The alternate layouts at a stage can be generated using the feasible connections at a node. The evaluation of cost of these generated network options can be done using any of the well-established methods for the optimal design of a network. Thus, these two aspects together constitute the total problem of layout optimization. Therefore, dynamic programming or its variations can be used for both the aspects of the sewerage system.

The selection of an optimal layout for a given sewerage system is a complex task. Therefore, to select an optimal layout is to generate all the feasible layouts, and evaluate cost of each layout. This will eventually lead to the global optimal solution. However, for large sewerage network it is impractical to investigate every feasible layout. In this paper, an algorithm was used for generating layout in a simplest and easiest manner. The process of generating layout using this algorithm has been explained considering a 18-node sewerage system and the results obtained have been presented.

II. COST FUNCTIONS

In order to evaluate the cost structure of each layout, certain parameters of the sewerage system should be known. The parameters such as length of each sewer links and flow at each nodal point, except receiving node, should be known to evaluate the cost of each layout. The cost of layout is evaluated using following formula can be written as (Liebman, J. C. 1967):

$$C = K\, L \sqrt{Q} \qquad (1)$$

Where, K = Cost parameter, monetary unit;

L = Length of sewer link, m;

Q= Discharge flowing in sewer link, m^3/s.

III. LAYOUT GENERATION CONSTRAINTS

While generating a feasible layout from a base layout the following basic constraints need to be met (Haghighi, 2013):

1. No cycle is accepted. The layout is therefore, a tree.
2. All manholes must be involved in the tree.
3. There is an outlet (root) in the system toward which the spanning tree must be directed.
4. Several sewers can flow into a manhole. However, except for the root node, exactly one sewer leaves from every non-root manhole in the direction of the root.

IV. LAYOUT GENERATION PROCESS

1. Determine the minimum spanning tree (shortest path layout) from the base layout. The basic steps to determine the minimum spanning tree are as follows:

i. Choose the edge e_1 (sewer link) from the base layout from the initial node *i.e.* (node 1) such that it is as small as possible.

ii. Similarly, from each node except sink node choose the minimum length of sewer link and generate the minimum spanning tree from the base layout of sewerage system.

2. Take the minimum spanning tree as initial layout for Trial I.
3. The dynamic programming requires a problem to be converted into a number of distinct stages. It can be easily divided into N_n-1 number of distinct stages *i.e.* the number of stages is equal to number of links, where, N_n = Number of Nodes.
4. From the initial layout, generate all the feasible layouts at Stage $a_{1.}$
5. Evaluate the cost of each layout at Stage $a_{1.}$
6. Select the three layouts of least cost from Stage $a_{1.}$ Such layout becomes the input layout for the next Stage a_1+1.
7. This process is repeated till all the stages are over.
8. At the final stage, number of feasible layout options are generated. Select the three layouts of least cost from the final stage.
9. Such layout becomes the input layout for Trial II.
10. Repeat the same procedure as followed for Trial I.
11. The layout having minimum cost at the stage N_n-1 is eventually the optimal layout for the given sewerage system.

This is the simple and straight forward method that can be used to confirm that the solution sought is a better solution.

V. ILLUSTRATIVE DESIGN EXAMPLE

The 18-node sewerage system is considered as the design example. The data such as length (m) of each sewer links is shown in Fig. 1 and nodal flows q_i (m^3/s) is given in Table 1.

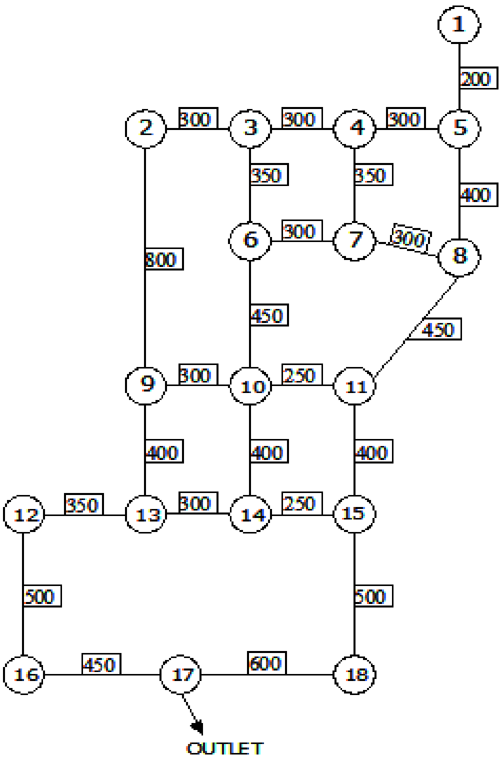


Fig. 1: 18-Node sewerage system

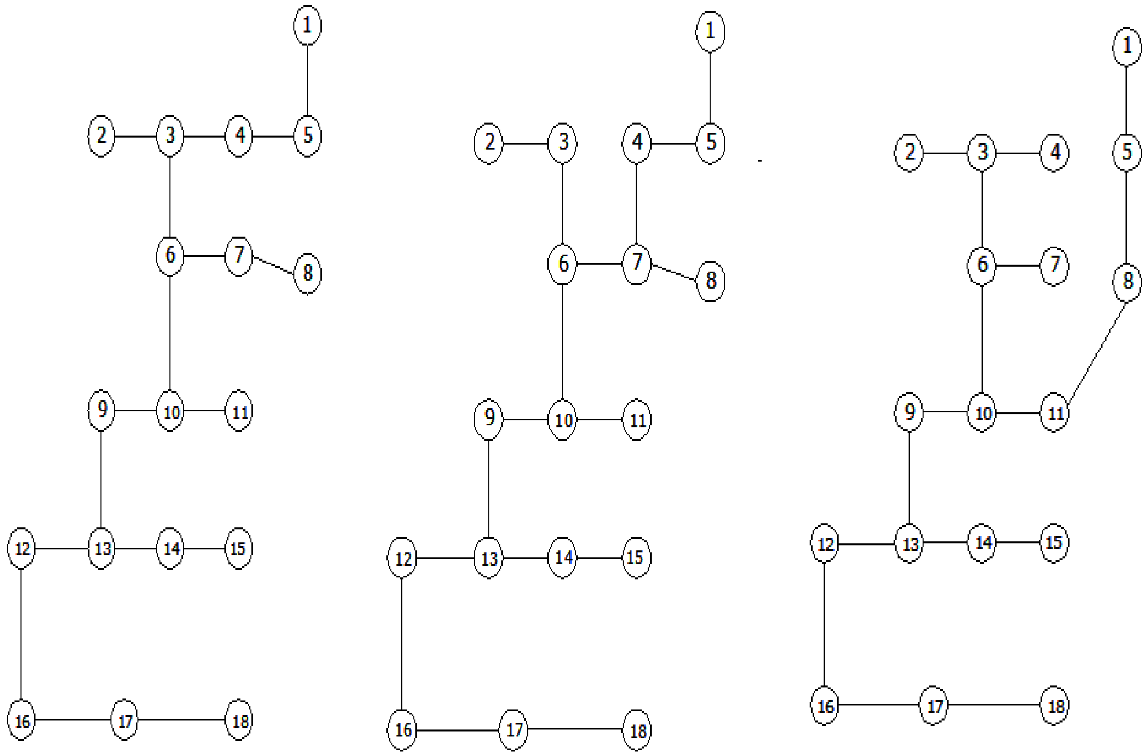
Table 1: Nodal flows for 18-node sewerage system

Nodes	q_i	Nodes	q_i
1	0.005	10	0.006
2	0.007	11	0.005
3	0.007	12	0.008
4	0.005	13	0.006
5	0.006	14	0.005
6	0.008	15	0.007
7	0.005	16	0.008
8	0.006	17	Outlet
9	0.007	18	0.009

VI. RESULTS AND DISCUSSIONS

While generating the layout for a large sewerage system, it becomes very difficult to generate the total number of feasible layouts. Therefore, a large sewerage system has been solved by converting the problem into no. of distinct stages by taking minimum two numbers of Trials. The given sewerage system has been solved by generating three random layouts as initial layouts instead of generating minimum spanning layout. After solving the problem, the competitive layouts for the given sewerage system has been obtained in Trial III. But after solving the problem by taking minimum spanning layout as initial layout, the competitive layouts were obtained in Trial II for the same given sewerage system. The optimal layout selected at the stage *Nn*-1 obtained in the last trial is eventually the optimal layout for the given sewerage system. After three trials, it was observed that the layout cost decreased by 3.40% in Trial II with respect to Trial I, and 2.14% of layout cost decreased in Trial III with respect to Trial II.

During the investigation of feasible layout, three layouts were found to be very competitive is shown in Fig. 2. The least cost of all the selected layouts with stages which are obtained in Trials I, II and III which is shown in Fig. 3. From Fig. 3, it can be observed that as the number of trial increases, the cost of layout decreases with stages *i.e* from Stage 2 onwards, the cost of layout remains constant for Trial III. Variation in cost range of selected layout with stage for Trial 3 is shown in Fig. 4. It also shows that from Stage 2 to 17, the variation in the cost range remains constant, so there is no need to go for further trials.



a: Layout I (1026.52) b: Layout II (1031.47) c: Layout III (1033.37)

Fig. 2: Three most competitive layouts for the 18-node sewerage system

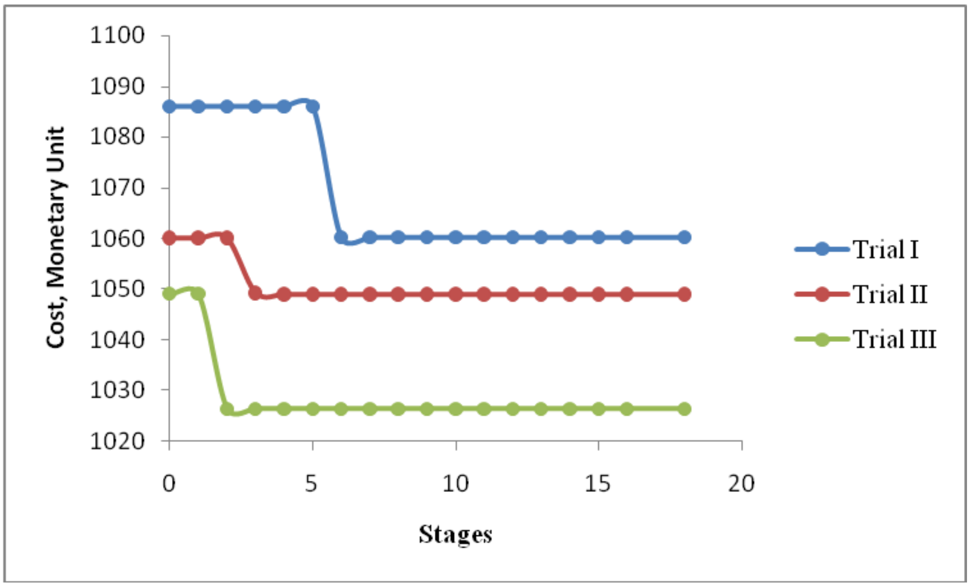


Fig. 3: Variation in cost of least cost layout with stages for 3 Trials

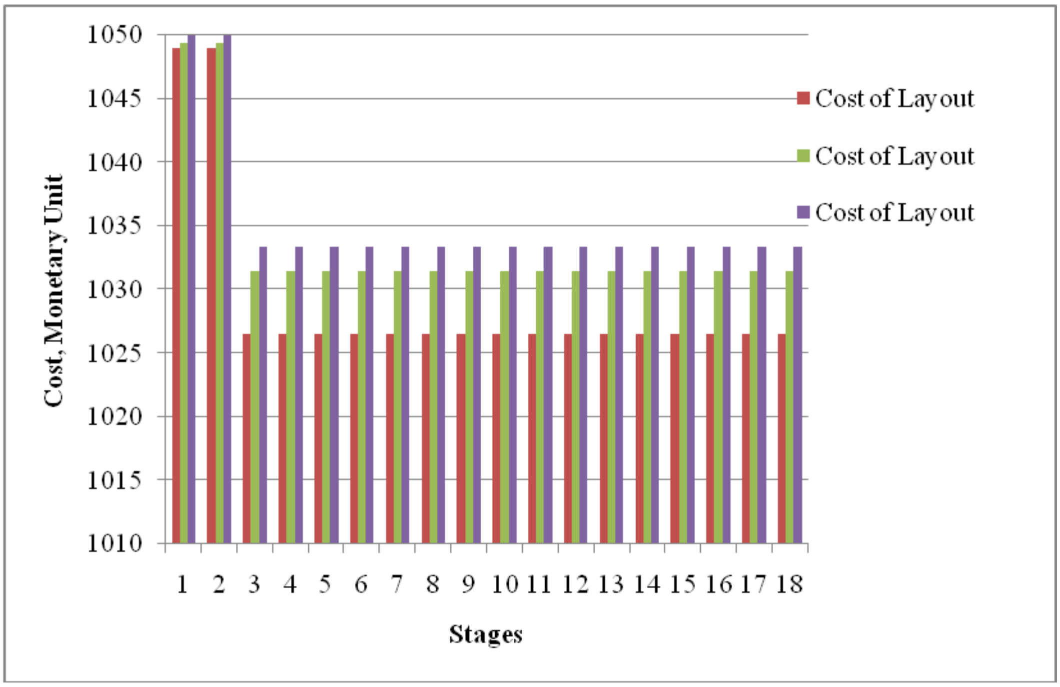


Fig. 4: Variation in cost range of selected layout with stage for Trial III

VII. CONCLUSIONS

Following conclusions can be drawn from the present study:

1. The proposed method does not require any assumption to start the process of layout generation.
2. For solving complex problems, a simple, but efficient procedure has been developed to generate main layout from the shortest path connecting each node in the network to the final outlet.
3. For solving the large sewerage network problem, always take minimum spanning tree (shortest path layout) as initial layout, so as to get the competitive layout in less number of trials.
4. The optimal layout, in terms of least-cost, was found to be most significant contributor.
5. Specification of the sewer lines (links) connecting the manhole, the flows at nodal point, sewer lengths and a final outlet are sufficient to generate optimal layouts.
6. The method is very simple and easy to understand and is based on the principle of dynamic programming.

REFERENCES

[1] Liebman, J. C. (1967), "A heuristic aid for the design of sewer networks", Journal of the sanitary engineering division, 93(4), 81–90.

[2] Haghighi, A. (2013), "Loop-by-loop cutting algorithm to generate layouts for urban drainage systems", Journal of water resources planning and management, 139(6), 2013, pp. 693–703.

[3] Argaman, yerachmiel, shamir, U., and spivak, E. (1973), "Design of optimal sewerage systems", Journal of the environmental engineering division, 99(5), 703–16.

[4] Navin, P. K., and Matur, Y. P. (2015), "Application of graph theory for optimal sewer layout generation", Discovery, 40(183), 151-157.