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DESIGN OF OPTIMAL LAYOUT OF SEWERAGE NETWORK

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Abstract : *The sewerage system must be properly and skillfully planned and designed, so as to remove the entire sewage effectively and efficiently from the houses, and up to the point of disposal. The aim of providing a sewerage system is to transport all nodal flows through a set of links connected in the form of a tree 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 method. Using this method, all constrains of the sewer layout problems are systematically handle and the optimal layout can be easily selected by applying this method.*

Keywords*: *Layout, Optimization, Sewerage System, Dynamic Programming, MS-Excel.

I. INTRODUCTION

The optimal design of a sewerage system includes two aspects : (1) determining the optimal layout of the sewage system; and (2) the optimal design of a given sewer layout. Alternate in-phase layouts can be generated using appropriate connections at the node. Cost evaluation of these generated network options can be done using any of the well-established methods for optimal network design. The simplest and easiest method of choosing the optimal layout is to generate all feasible layouts and evaluate the cost of each layout. However, the number of possible layouts is extremely large and as such it is impractical to use such exhaustive search algorithms. Due to the complexity of the problem, only one of the two sub-problems of the overall problem was usually given due attention. Therefore, this method can be used for the aspects of the sewerage system.
The selection of an optimal layout foe a given sewerage system is a complex task. So, to select a optimal layout to generate a feasible layouts, and evaluate cost of each layout. This will lead the global optimal solution. In this paper, and algorithm was used to generate the layout in simplest and easier manner. The process of generating layout using this algorithm has been explained considering a 6-node sewerage system and the result obtained have been presented.

II. COST FUNCTION

In order to evaluate the cost structure of each layout, certain parameters of the sewerage system should be known. The parameters like length of each pipe and flow at each nodal, expect receiving node, should be known to evaluate the cost of each layout. The cost of each layout is evaluated using the following formula which is written as (Libmen, J. C. 1967):

$$C = K\,L\,\sqrt{Q}$$

Where, K = Cost parameter,
L = Length of pipe, m;
Q = Discharge at nodal, m^3/s.

III. LAYOUT GENERATION CONSTRAINS

When generating a feasible layout from a basic layout, the following basic constraints must be met (Haghighi, 2013):
1. No cycle is accepted. So the layout is a tree;
2. All hatches must be plugged into the tree;
3. There is an outlet (root) in the system to which the skeleton must point; and

4. Several sewers can flow into the shaft. With the exception of the root node, however, each non-root shaft leaves exactly one sewer 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 en (sewer link from the base layout from the initial node i.e. (node 1) such that it is as small as possible; and it.

   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

1. Take the minimum spanning tree or assumed layout as initial layout for Trial I;
2. From the initial layout, generate all the feasible layouts at Stage an

   i. When the layout is generated, it is observed that, sometimes there are two to three links which are possible from one node, in such cases, generate all the feasible option from such node one by one.
3. In order to select the optimal option at stage at, it is essential to determine the cost of each layout option at stage al;
4. From all the feasible option which is generated at stage al, the three layout options whose cost is least is selected as the optimal layout at the Stage al. Such layout becomes the input layout for the next Stage at 1;
5. This process is repeated till all the stages are over;
6. At the final stage, a large number of feasible layout options is generated. Select the three layouts having lesser cost at the final stage;
7. The selected three layouts become the input layouts for Trial 11;
8. Repeat the same procedure as followed for Trial I; and
9. The layout having minimum cost at the stage N,-I is eventually the optimal layout for the given sewerage system.

   This is the simple method that can be used to confirm that the solution is selected is better solution.

V. ILLUSTRATIVE DESIGN EXAMPLE

The 6-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 the nodal flows q_i (m^3/s) is given in Table 1.

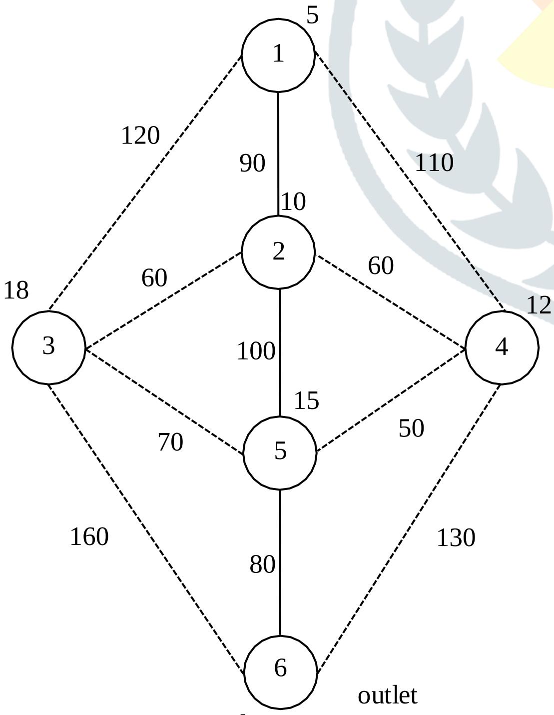


Figure 1: 6-Node sewerage system

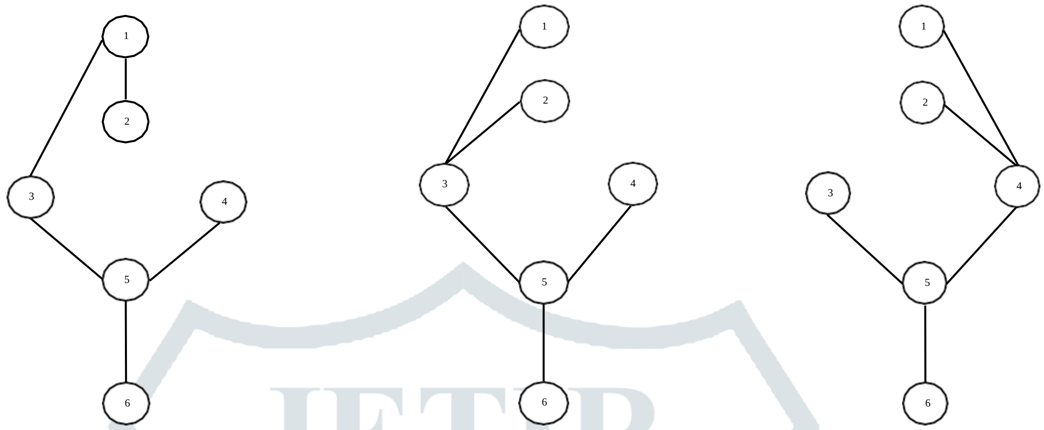
Table 1. Nodal flow for 6-node sewerage system

NODES	FLOW
1	5
2	10
3	18
4	12
5	15

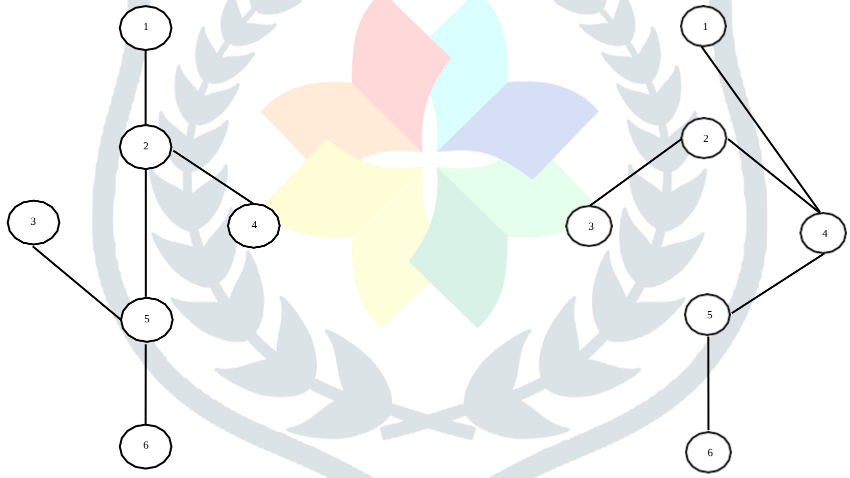
VI. RESULT AND DISCUSSION

While generating the layout of the given sewerage system, The total number of feasible layout were found to be 221. However, it becomes very difficult to generate the total number of feasible layout for a very large sewerage system. In order to reduce this problem, minimum two number of trials should be taken. From each Stage, five layout layouts should be selected having least cost. While solving the problem, the optimal layout was found in trial II, there is no need of trial III. Therefore, the optimal layout was selected at the final stage in Trial II is eventually the optimal layout for the given sewerage system. After solving the problem by taking minimum spanning layout as initial layout, the competitive layouts were obtained for the given sewerage system.

During this investigation of feasible layout, five layout were found to be very competitive is shown in Fig. 2. The least cost of all the selected layout with stages which are obtained are shown in Fig. 2. From fig it is observed that the number of trials increases, the cost of layout decreases. Variation in cost range of selected layout is shown in Fig. 3. The total number of feasible layout from the given sewerage system and their respective cost as shown in Table 2.



a: Layout I (3387093 Rs) b: Layout II (3553319 Rs.) c: Layout III (3529264 Rs.)



d: Layout IV (3838878 Rs.) e: Layout V (3831013 Rs.)

Fig 2 : Five most Competitive Layout for the 6-Node Sewerage System

Table 2. Total Cost of Layout

Layout	Pipe	K	Length M	Flow, m^3s	Cost, Rs.	Total Cost Rs.
1	1-2	3612	90	5	727003.61	3387093
	1-3	3612	120	5	969201.304	
	3-5	3612	70	2	357569.757	
	4-5	3612	50	12	625616.752	
	5-6	3612	80	6	707804.556	
2	1-2	3612	120	5	969201.304	3553319
	1-3	3612	60	10	685328.815	
	3-5	3612	70	5	565367.427	
	4-5	3612	50	12	625616.752	
	5-6	3612	80	6	707804.556	
3	1-2	3612	120	5	888434.539	3529264
	2-3	3612	60	10	685328.815	
	3-5	3612	70	5	565367.427	
	4-5	3612	50	12	625616.752	
	5-6	3612	80	7	764516.299	
4	1-4	3612	110	5	969201.304	3838878
	2-4	3612	60	10	685328.815	
	2-5	3612	70	18	1072709.27	
	4-5	3612	50	5	403833.877	
	5-6	3612	80	6	707804.556	
5	1-3	3612	120	5	969201.304	3831013
	2-3	3612	60	10	685328.815	
	2-5	3612	100	10	1142214.69	
	4-5	3612	50	12	625616.752	
	5-6	3612	80	2	408651.151	

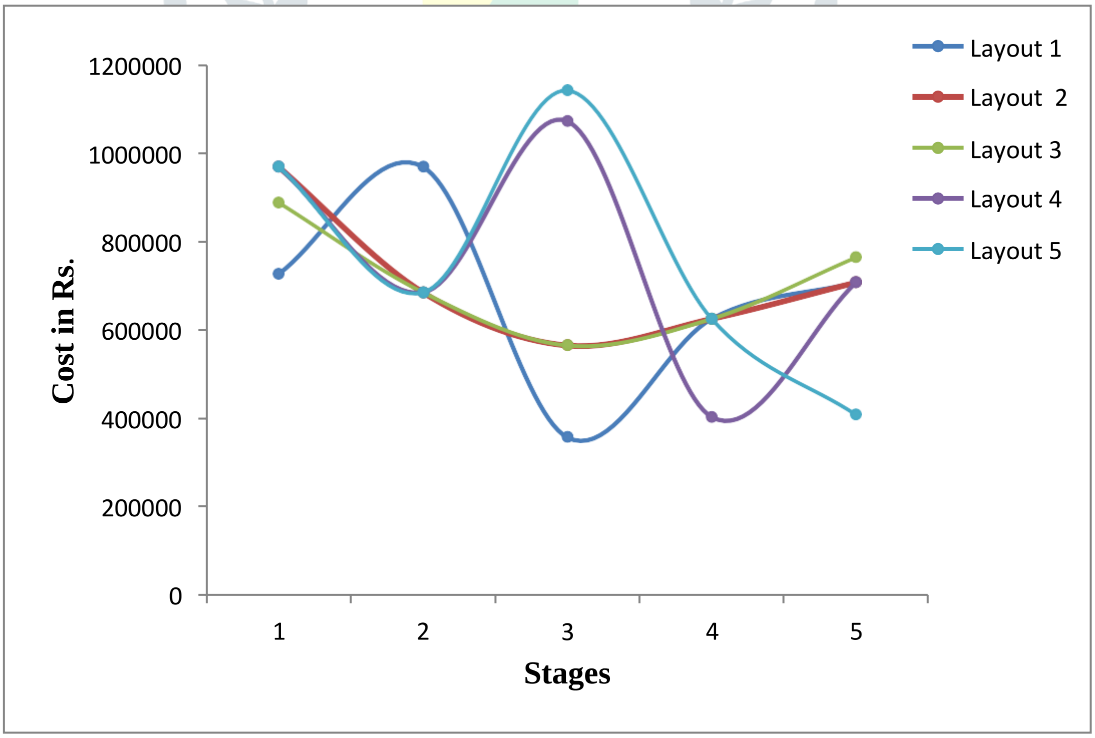


Fig. 3 : Variation in Cost of Layout with Stages for 5 Layout.

VII. COMPARISION OF LAYOUT

The variation in the cost after comparing by Libmen-1967, Minimum Length, Minimum Spanning Tree is shown in Fig. 4.

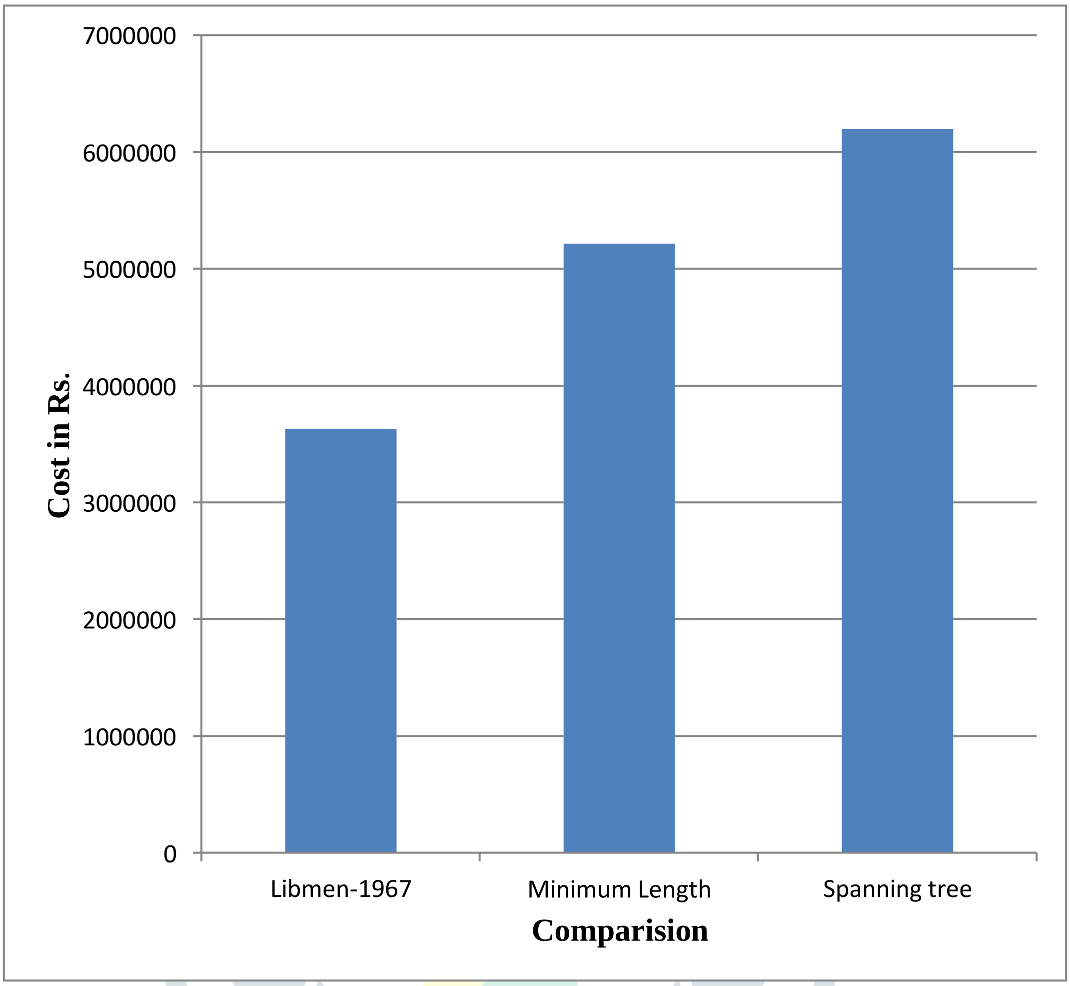


Figure 4 : Variation in Cost of Layouts

VIII. CONCLUSIONS

Following conclusion 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 efficiently 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 flow at nodal point, sewer lengths and a final outlet are sufficient to generate optimal layout.
6. The method is very simple and easy to understand and is based on the principle of dynamic programming.
7. The cost of Libmen-1967 layout is found to be 41.45% more than minimum spanning tree of IDE.
8. The cost of minimum length of layout is found to be 15.81% less than minimum spanning tree of IDE.

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