Economic assessment of centralized and decentralized sewerage network systems

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Highlights

- Sewerage collection networks have been studied and compared for their capital costs.
- Three different scales of sewerage systems have been considered in this study.
- Capital investment was found to be comparable for all three scales

Introduction

As urbanization is taking place globally, it has been observed that 55% of the world’s total population resided in urban areas in 2018, and it is expected to reach 68% by 2050 (UN-DESA, 2018). Urbanization and various other factors such as population growth, industrialization, change in land-use patterns, and poor water management impose pressure on the water resources. 40% of the population is facing water scarcity already, and water stress is expected to worsen (UN, 2020). Since water is a renewable resource and an essential element for human survival on earth, it needs to be adequately managed, indicating the need for efficient wastewater management.

Wastewater management is a capital-intensive process. The system's economic viability reduces as the density of settlements becomes sparse (Hophmayer-Tokich, 2006). Decentralized wastewater management systems, on one side, are being recognized as a viable alternative to the conventional centralized systems in terms of environmental favorability and the potential of water reuse (Jung et al., 2018; Libralato et al., 2012). Simultaneously, the requirements for the cost-effectiveness of these systems need to be proved (Bakir, 2001). Most of the existing research work has been focused on analyzing the treatment part of both the centralized and decentralized sewerage systems, whereas the collection network lacks intensive research. It is noticed that in a conventional sewerage system, the collection network carries a significant economic burden with a high share in the overall capital costs (Bakir, 2001; Libralato et al., 2012). The existing research indicates that there is an opportunity to optimize the collection systems by adequate selection and sizing of its inventory (Nawrot et al., 2018).

This study aims to evaluate the economic feasibility of a decentralized sewerage system as a potential alternative to the conventional centralized sewerage system in urban areas, focusing on water reuse opportunities.

Methodology

Study Area

Ludhiana city, an industrial hub located in Punjab, India, has been selected for the case study. The city lies at 30˚35’ North and 75˚52’ East, covering an area of 159.37 sq. km with a population of 16 lakhs approximately (Census, 2011a). Three areas have been further selected in the city’s municipal limits at different scales: centralized, decentralized, and neighbourhood level, covering areas of 2754.9 ha, 363.77 ha, and 30.3 ha, respectively.

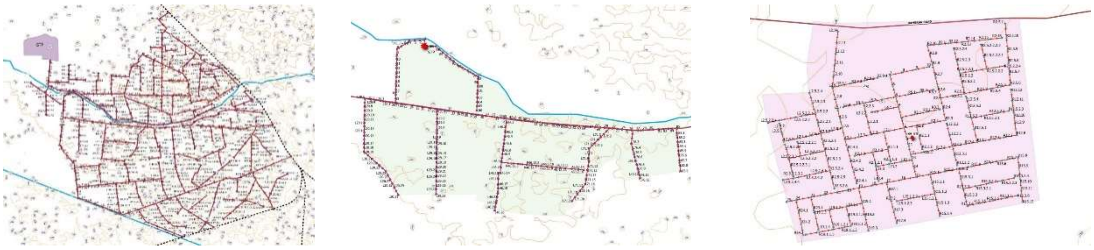

Figure 1. Sewerage network layouts; left to right: Centralized network, Decentralized network, Neighbourhood network

Sewer network design

A network of sewer pipes and manholes connected to a treatment unit was finalized in QGIS software, followed by sewer network optimization in MS Excel spreadsheets. A standard population density of 150 people/hectare and water supply of 220 LPCD was considered. Various other optimization parameters such as peak flows, flow velocity, excavation depths, sewer slopes, etc., were considered as per the CPHEEO guidelines (CPHEEO, 2012).

Table 1. Factors considered for sewer network design and optimization

Network type	Area [hectares]	Population	Wastewater generation (MLD)*	Peak factor
Centralized	2754.9	413240	72.7	2
Decentralized	363.77	54566	9.6	2.25
Neighborhood	30.3	4548	0.8	3

* Wastewater generation considered as 80% of the water supply

Capital cost calculation

The capital costs were calculated for the construction and excavation of the sewers and manholes by considering the per unit rates provided by Punjab Water Supply and Sewerage Board – Common Schedule of Rates (PWSSB, 2014). The trunk/main network costs for the centralized and decentralized networks have been calculated from the network design, followed by adding the lateral/branch network costs by the factor extrapolation method. The costs for the third type, i.e., the neighborhood network were separately calculated. All the costs were then computed for a common scale (centralized scale) for easy comparison. The treatment costs (considered cost per MLD) have also been added to the network costs to find out the total systems' costs.

Results and discussion

The network costs and the total system costs for all three systems (centralized, decentralized, and neighborhood) have been found to be comparable in this study. The network costs for a centralized network have been calculated as INR 0.467 million/ha, followed by a decentralized network with INR 0.462 million/ha, and neighborhood network cost at INR 0.409 million/ha. After adding the treatment costs, the total system cost for the centralized system was INR 0.625 million/ha, decentralized system cost was INR 0.674 million/ha, and neighborhood system cost was INR 0.673 million/ha.

The existing studies have suggested that the initial capital investments for the collection system of centralized systems are relatively higher than the decentralized systems (Libralato et al., 2012; Roux et al., 2011). The observations contradict the results from this study which does not show much significant differences in the costs of the three systems. This could be possible considering the case that the cost of sewerage systems varies significantly with the contextual characteristics such as land topography, population density, wastewater loads, etc. Despite the similar costs, the decentralized systems and neighborhood systems offer much more benefits in many other aspects such as resilience, flexibility, water reuse opportunities, etc.

The sewer pipes cost had a higher impact on the total sewer costs when compared to its excavation costs. Similarly, the manholes' construction cost came out to be higher than the manholes excavation costs. A comparison between the total sewer costs and total manholes costs, the sewer costs were found to be higher. Therefore, it can be inferred that the optimization of the sewer pipe costs according to various parameters such as the material selection, sizes, and depths, design lifespan, etc., might help in a considerable reduction of the overall costs of the collection system. When considering the optimization of total manhole costs, priority must be given to the construction of manholes, including the construction material, techniques, etc.

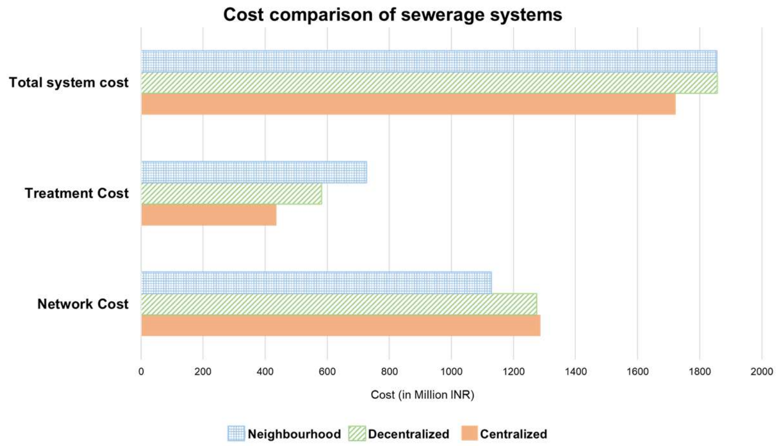

Figure 1. Cost comparison results of three systems

Conclusions and future work

In this study, an economic comparison of centralized, decentralized, and neighborhood systems has been performed for a class-I urban city in India. The capital costs have been calculated for all three systems and extrapolated to a standard scale for comparison. The results have shown that the costs of all three sewerage network systems (at different scales) are almost the same for the chosen case with a population density of 150 people/hectare and a gently sloping topography. The centralized systems may work well for developed areas with high population density and under conditions where gravity favors the flow of wastewater.

A more in-depth study can be performed as a part of the future scope by varying the contextual characteristics such as population density, topographic conditions, etc. This study is limited to the economic aspect of the assessment. Other aspects such as environment, social, governance, etc., should also be considered for a holistic analysis of these systems. The current guidelines on sewerage network design have been framed with a focus on applying centralized systems only, which should also be extended to decentralized systems for better choices.

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