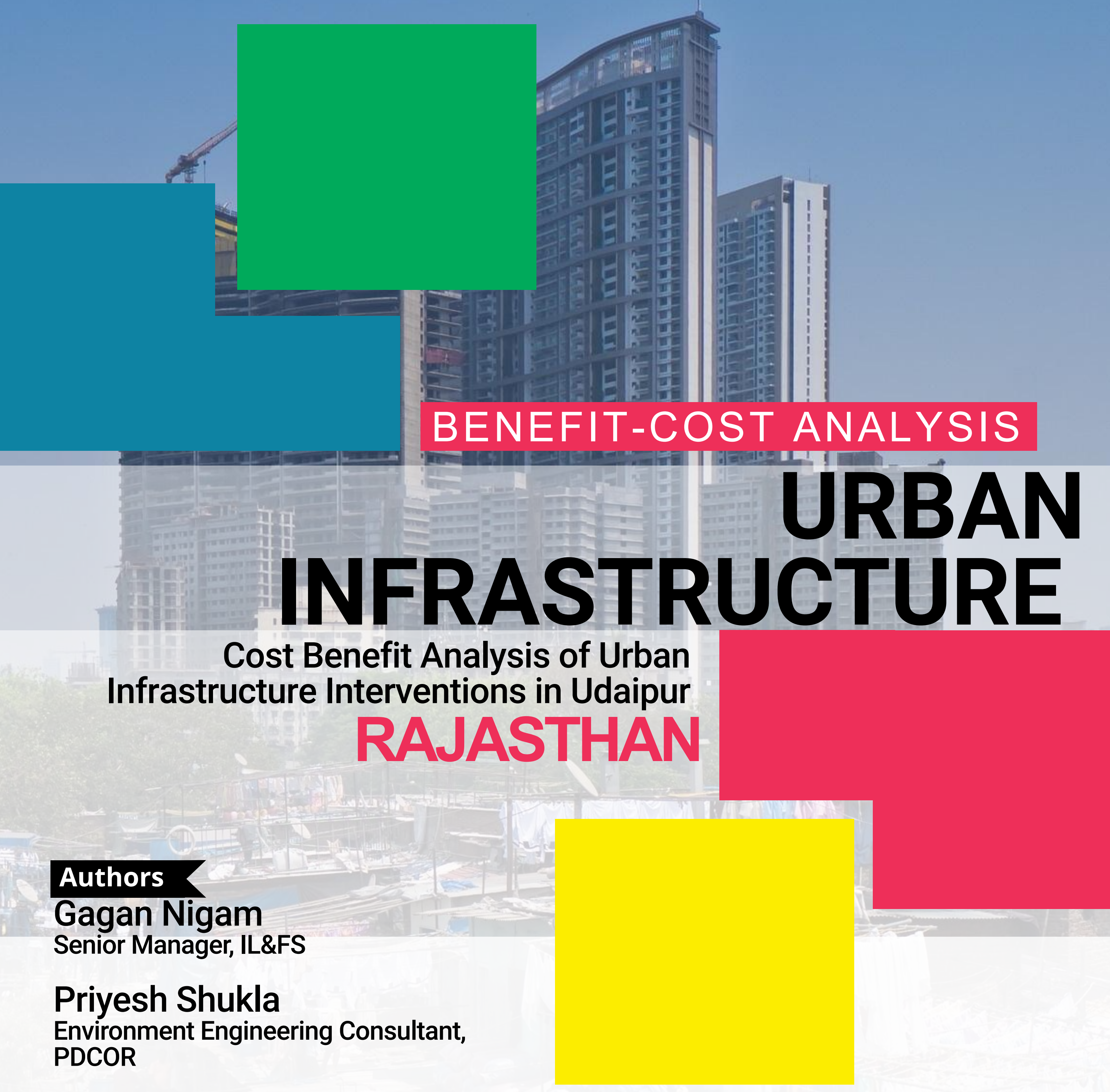

BENEFIT-COST ANALYSIS

URBAN INFRASTRUCTURE

Cost Benefit Analysis of Urban Infrastructure Interventions in Udaipur

RAJASTHAN

Authors

Gagan Nigam
Senior Manager, IL&FS

Priyesh Shukla
Environment Engineering Consultant, PDCOR

Manish Gupta
Vice President, PDCOR

RAJASTHAN PRIORITIES — AN INDIA CONSENSUS PRIORITIZATION PROJECT

INDIA CONSENSUS — A TATA TRUSTS & COPENHAGEN CONSENSUS CENTER PARTNERSHIP

This work has been produced as a part of the Rajasthan Priorities project under the larger, India Consensus project.

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TATA TRUSTS

Cost Benefit Analysis of Urban Infrastructure Interventions in Udaipur

Rajasthan Priorities
An Indian Consensus Prioritization Project

Gagan Nigam[1], Priyesh Shukla[2], Manish Gupta[3]

[1]*Senior Manager, IL&FS*

[2] *Environment Engineering Consultant, PDCOR*

[3]*Vice President, PDCOR*

IL&FS Academy of Applied Development

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Abbreviations

AMRUT	Atal Mission for Rejuvenation and Urban Transformation
BCR	Benefit to Cost Ratio
CAGR	Compounded Annual Growth Rate
CBA	Cost Benefit Analysis
CDP	City Development Plan
DALY	Disability Adjusted Life Year
DLC	District Level Committee
GDDP	Gross District Domestic Product
HPEC	High Powered Expert Committee
IEISL	IL&FS Environmental Infrastructure & Services Ltd.
IIHS	Indian Institute of Human Settlements
ILO	International Labor Organization
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
Lpcd	Liters per Capita per Day
MDPE	Medium-density polyethylene
MSW	Municipal Solid Waste
NPV	Net Present Value
NRW	Non Revenue Water
O&M	Operations and Maintenance
OECD	Organisation for Economic Co-operation and Development
PCIC	Per Capita Investment Cost
PHED	Public Health Engineering Department
RDF	Refuse Derived Fuel
RUIDP	Rajasthan Urban Infrastructure Development Project
SWM	Solid Waste Management
UIDDSSMT	Urban Infrastructure Development Scheme for Small and Medium Towns
UIT	Urban Improvement Trust
UMC	Udaipur Municipal Corporation
WHO	World Health Organization
WSS	Water Supply and Sanitation

Academic Abstract

India has been on a trajectory of accelerated urban growth and is now poised to more than double its urban population during the next 20 years (Weitz, Ravi Kumar and Raman, 2016). However, the pace of urbanization does not match the delivery of services in cities, leading to environmental pollution and deteriorating public health. Further, demographic changes are expected to result in an increase in the number of people in the working age group with high expectations of a better future.

As an important destination for tourism, the West Indian city of Udaipur witnesses significant international tourist footfall. Udaipur's population is expected to rise to about 1 million by 2043, making the delivery of urban development services that affect health and hygiene crucial for future growth. Provisions for 24x7 supply of piped water, sewerage and treatment networks, and solid waste management are, therefore, critical for continued growth and prosperity of the city.

This paper conducts a cost-benefit analysis (CBA) of three urban interventions aimed at providing: 24x7 piped water supply, 100 percent coverage for sewage and waste water treatment, and 100 percent management of solid waste (collection, transportation and treatment). At 5% discount rate, the benefit cost ratio (BCR) is highest for the intervention to ensure 24x7 piped water supply, followed by that for solid waste management. The BCR is lowest for the sewage network and treatment intervention, though all three interventions are feasible, the paper finds. This means that all three services are economically attractive, though the interventions for piped water supply and solid waste management are significantly more attractive. A sensitivity analysis was conducted to evaluate the impact of several variables on the overall feasibility of the interventions.

Policy Abstract

The Problem

India is urbanizing rapidly. The number of metropolitan cities in India with a population of 1 million and above has increased from 35 in 2001 to 50 in 2011 and will further rise to 87 by 2031. It is expected that the urban population of approximately 400 million (in 2010) will double by 2050 . As a result, all cities will witness increased demand for urban services such as piped water supply, sewage and waste water treatment, and solid waste management (Mckinsey, 2010). The current levels of these services are low, as can be inferred from Table 8.

As the largest Indian state in terms of area, Rajasthan has a population of 69 million people with an urbanization ratio of 25%, less than the national average of 28%. The state also has the lowest availability of water and the least reliable supply in the country with only 162 of its 222 towns receiving water every day (World Bank, 2012). The availability of water varies largely from daily to once every three days. Only 23 towns have a service level above 100 Lpcd. Moreover, the state's water supply infrastructure is ageing and is badly in need of upgrades and revamping. It is projected that by 2045, Rajasthan will face a demand-supply gap of 3,037 MLD in both groundwater and surface water. . The Rajasthan State Water Policy envisions 24x7 piped water supply with 100 percent coverage and cost recovery by 2025. It also seeks to "encourage private initiative in water sector".

On the sewerage and waste water treatment front, it is to be noted that only 24% households have access to closed drainage in the state. Besides, as few as 11 cities have access to partial sewerage (World Bank, 2012). Rajasthan lags in municipal solid waste management too, as no city from the state has managed to make it to the list of top 150 cities as per Swachh Survekshan 2017, the country's Swachh Bharat Abhiyan survey.

In the past, funding sources for investment in the water and sanitation sectors have come through public health and engineering department (PHED), Rajasthan urban infrastructure development project (RUIDP), Jawaharlal Nehru national urban renewal mission (JNNURM), urban infrastructure development scheme for small and medium towns (UIDSSMT), Swachh Bharat Abhiyaan, and Atal mission for rejuvenation and urban transformation (AMRUT).

Udaipur is a tourist destination that has witnessed increased international tourist footfall in recent times. Its current population is approximately 0.5 million and is expected to rise to about 1 million by 2043. As the city's population and economic activity continue to grow, the demand for utility- and environment-based services have also gone up. Ensuring high-quality urban services (24x7 piped water, 100 percent sewage and waste water treatment, and 100 percent solid waste management), therefore, becomes imperative for future growth.

As much as almost 80% of Udaipur is covered by the piped water network. However, more than half of approximately 78,000 connections are old, dilapidated and need replacement, as per the City Development Plan (2041). The existing connections are of galvanized iron (GI) pipes that are old and have points of contamination. More than 60% of the pumping station infrastructure needs replacement as pumps are running below desired levels of optimum efficiency. Leakages and losses in the system need to be addressed as well. The O&M cost recovery by PHED is only 29%. Water is supplied at an interval of two days. The population left out of the coverage network is supplied water through alternative sources (CRISIL, 2014) – a mix of standposts and hand pumps installed at various localities in Udaipur. A project under UIDSSMT that was implemented before 2010 to strengthen distribution and enhance network coverage is expected to cater to the requirements till 2021. A proposal for another project catering to the period up to 2041 was prepared by Udaipur's PHED for the rehabilitation, augmentation and operation of the water supply and sewerage system in the city through a PPP project. In the absence of any intervention, the PHED may face a challenge to supply water to the uncovered and incremental population and may have to use alternative sources of supply such as tankers. Leakages and losses may continue and affect supply intermittently.

Over 50% of the population in Udaipur is yet to be connected to the sewerage network and treatment infrastructure. As a result, a significant share of waste water generated in Udaipur flows in to pollute the Ahar river (CRISIL, 2014) which is now akin to an open drain. This has resulted in loss of aquatic life due to low levels of dissolved oxygen and severe groundwater contamination. A foul stench emanates from the water body all along its 21-km stretch. This is likely to affect a large portion of Udaipur's residents who live in Ahar's catchment. Acting on the issue, the city's lake conservation committee had in 2009 launched a successful pilot project for cleaning up the water body using green bridge technology.

Though Udaipur generates approximately 120 MT of municipal solid waste every day (Udaipur Municipal Corporation and Janaagraha Centre for Citizenship & Democracy, 2017), the city lacks facilities for waste segregation, processing and treatment. The entire bulk of the waste collected is dumped in an open non-sanitary landfill located approximately 15 km from the city. Udaipur has been ranked 310 among 434 cities for sanitation, as per *Swachh Survekshan 2017*. An investment plan to improve solid waste collection, segregation and secondary storage, transportation, and treatment was proposed before 2010 but the DPR was not prepared due to lack of technical knowhow (CRISIL, 2014). Going forward, the size of and public inconvenience caused due to the landfill will grow significantly and huge investment may be required for its remediation, in the absence of any intervention.

Intervention 1: 24x7 supply of piped water

Overview

Old networks, irregular supplies and low pressure are some of the most common issues in water supply faced by the residents of Udaipur. This intervention intends to provide 24x7 piped water supply to ensure 100% coverage of all households, with significant improvement in the service quality. The intervention shall benefit more than 1 million residents during the implementation period.

The implementation may be carried out through Public Health and Engineering Department (PHED), Rajasthan. Alternatively, the PHED can implement the same through Public Private Partnership. No such network replacement exercise has been done in the recent past. The intervention will yield revenues based on published tariffs that are periodically (typically once a year) revised.

Implementation Considerations

Timelines: The project life is assumed to be 25 years. It shall start in the year 2019 and continue through till 2043. The entire capex is planned in the first year. In the subsequent years, additional capex for the incremental population will be incurred.

Risks: Sensitivities against which the intervention results (BCR and NPV) were tested are common risks such as capex and opex overrun, under-recovery in revenues, and uncertain variables such as relative risk of piped water supply over unimproved supply and social costs of disruption.

Success measures: The intervention can be declared successful when the entire population (including incremental population every year) gets round-the-clock (24x7) water supply throughout the year, and network leakages are plugged. Consequently, there would be greater willing ness to pay dues, resulting in full recovery of costs incurred.

Quality of information: The quality of most of the data for the 24x7 piped water supply intervention is strong as it is taken from sources such as the high powered expert committee (HPEC) report, Udaipur City Development Plan, annual report of Udaipur Municipal Corporation, published government tariffs, WHO's *Global Burden of Diseases* report, and various meta studies. This has been supported with site visits to meet the experts and validate data.

Costs and Benefits

Costs

The net present value of the total cost of the intervention to ensure 24x7 piped water supply at 5% discount rate is approximately Rs. 23 billion. This comprises direct costs – capex, opex and cost of water supply through tankers (in year 1), and indirect costs – social costs of traffic disruption and delay due to construction. The breakup of costs is presented in Table 1.

Table 1: Summary of costs for Intervention 1

Direct costs (in Rs. billion)	
Capex	5.9
Opex	14.1
Tanker cost	0.1
Indirect costs (in Rs. billion)	
Social cost of disruption	3.0
Total	**23**

Note: All values are at 5% discount rate

Benefits

The net present value of the total benefits of Intervention 1 at 5% discount rate is approximately Rs. 53 billion. The benefits comprise direct benefits – revenues accrued through the tariffs, salvage value and cost of alternate water supply, and indirect benefits – consumer surplus from water supply services. The breakup of benefits is depicted in Table 2.

Table 2: Summary of benefits for Intervention 1

Direct benefits (in Rs. billion)	
Revenue	3.7
Salvage value	1.5
Tanker cost avoided	6.9
Indirect benefits (in Rs. billion)	
Consumer surplus from water supply services	40.6
Total	**53**

Note: All values have 5% discount rate

Intervention 2: 100 percent sewage and waste water treatment

Overview

Presently, more than half of Udaipur is not covered by the sewerage network. Intervention 2 aims to ensure 100% coverage of the city's sewerage network and provisions for waste water treatment. The intervention shall benefit more than 1 million residents of Udaipur during the implementation period. This would also help maintain the cleanliness of the Ahar river, which is currently polluted by the sewage that flows into it. The implementation may be carried out through the Udaipur Municipal Corporation (UMC) or PPP mechanisms.

Implementation Considerations

Timeline: The project life is assumed to be 25 years. It shall start in the year 2019 and continue through till 2043. The entire capex is planned in the first year. In the subsequent years, additional capex for incremental population will be required.

Risks: Sensitivities against which the intervention results (BCR and NPV) were tested are common risks such as capex and opex overrun, under-recovery in revenues, and uncertain variables such as relative risk of sewerage and social costs of disruption.

Success measures: The intervention can be declared successful once the entire (100%) population (including the incremental population every year) is covered by the sewerage network and treatment infrastructure. The Ahar shall be free of sewage and there would be significant reduction in the number of water-borne diseases as well.

Quality of information: The quality of most of the data for 100 percent sewerage network and treatment intervention is strong as it is taken from high quality sources such as high-powered expert committee (HPEC) report, Udaipur City Development Plan, annual report of Udaipur Municipal Corporation, published governmen. tariffs, Center for Science and Environment, global burden of diseases and various meta studies. This was supported with site visit to meet the experts and validate data.

Costs and Benefits

Costs

The net present value of the total cost of Intervention 2 is approximately Rs. 13 billion. The cost comprises direct costs – capex and opex, and indirect costs – social cost of traffic disruption and delay due to construction. The breakup of costs is shown in Table 3.

Table 3: Summary of costs for Intervention 2

Direct costs (In Rs. billion)	
Capex	2.9
Opex	8.6
Indirect costs (In Rs. billion)	
Social cost of disruption	1.4
Total	**13**

Note: All values are at 5% discount rate

Benefits

The net present value of the total benefits for Intervention 2 is approximately Rs. 15 billion. The benefits comprise direct benefits – revenues accrued through the tariffs, salvage value of the project, cost avoided for cleaning river and indirect benefits – avoided disability adjusted life years (DALYs). The breakup of benefits is shown in Table 4.

Table 4: Summary of benefits for Intervention 2

Direct benefits (In Rs. billion)	
Sewerage revenue	0.1
Salvage value	0.6
Indirect benefits (In Rs. billion)	
River cleaning cost avoided	0.1
DALY	14
Total	**15**

Note: All values are at 5% discount rate

Intervention 3: 100 percent solid waste management

Overview

The city of Udaipur generates approximately 120 tons per day (TPD) of municipal solid waste (MSW). Door-to-door collection services cover only approximately 20%; moreover, segregation and processing are not carried out. The entire bulk of MSW generated is dumped in the Titri landfill, located about 15 km away from the city. This intervention targets 100% collection, transportation, and management of of solid waste with minimum landfill use (as per MSW Rules 2016). This shall benefit more than 1 million residents of Udaipur during the intervention period. The initiative may be undertaken by the Udaipur municipal corporation directly or in a PPP mode.

Processing of MSW results in the creation of some recycled products that have market value, while the rest still needs to be landfilled:

1. Approximately 30% of input waste can be converted to compost (from the experience of IL&FS Environment, which operates multiple compost manufacturing plants across India, including 300 TPD in Rajasthan).
2. Approximately 30% of input waste can be converted to refuse-derived fuel (RDF) (as per MSW breakup provided in the UMC annual report).

Implementation Considerations

Timeline: The project life is assumed to be 25 years. It shall start in the year 2019 and continue through till 2043. The capex is planned to be 100% in the first year. In the subsequent years, additional capex for the incremental population is required.

Risks: Sensitivities against which the intervention results (BCR and NPV) were tested are capex and opex overrun, under-recovery in revenues through sale of RDF and compost, and uncertain variables such as willingness to pay (WTP) for SWM services. The only critically-sensitive parameter was WTP.

Success measures: The intervention can be declared successful once the entire population (including the one that adds every year) gains access to 100% collection, transportation and processing of solid waste. Minimum landfilling is required after segregation, composting and RDF generation, and UMC is able to generate revenues through sale of compost and RDF. In addition, there would be significant saving in space on account of reduced land requirement for landfilling in Udaipur.

Quality of information: The quality of most of the data considered is strong as it is taken from high-quality sources such as high-powered expert committee (HPEC) report, Udaipur City Development Plan, Annual report of Udaipur Municipal Corporation, Global burden of diseases and various meta studies. In the absence of any reliable government source on price of RDF and compost, data was taken from sources available through IL&FS Environment and other waste management companies. This was supported by site visits to Udaipur in January 2018 where UMC officials were interviewed and the 'Titri' landfill was also visited.

Costs and Benefits

Costs

The net present value of the total cost of for this intervention is about Rs 5 billion. This comprises direct costs – capex and opex. The collection and transportation infrastructure will need to be replaced multiple times during the project life given that the life of vehicles in this application is on an average about 8 years. The breakup of costs is shown in Table 5.

Table 5: Summary of costs for Intervention 3

Direct costs (in Rs. billion)	
Capex	0.6
Opex	4.0
Total	**4.6**

Note: All values are at 5% discount rate

Benefits

The net present value of the total benefits of Intervention 3 is about Rs 9 billion. This comprises direct benefits – revenues accrued through the sale of compost and RDF, salvage value of the project, savings in land value due to the intervention, and indirect benefits – landfill closure cost avoided and willingness to pay for improved waste management. The breakup of benefits is shown in the Table 6.

Table 6: Summary of benefits for Intervention 3

Direct benefits (in Rs. billion)	
Compost and RDF sales	0.5
Salvage value of the project	0.1
Saving in land value due to intervention	1.6
Indirect benefits (in Rs. billion)	
Landfill closure cost avoided	0.9
Willingness to pay for improved MSW management	6.1
Total	**9.1**

Note: All values are at 5% discounting

BCR Table

Summary of BCR calculations is presented in Table 7.

Table 7: Summary table

Interventions	Benefit (in Rs. bn)	Cost (in Rs. bn)	BCR	Quality of Evidence
24x7 piped water supply	53	23	2.27	Strong
100 percent coverage for sewerage and waste water treatment	15	13	1.15	Strong
100 percent solid waste management	9	5	1.97	Strong

Note: All figures assume a 5% discount rate

At 5% discounting, all three interventions are economically feasible. However, the intervention to provide piped water supply 24x7 emerged as the most attractive intervention with highest BCR, followed by the intervention for 100% solid waste management and 100% coverage of sewerage and waste water treatment.

1. Introduction

India's rapid urbanization

India has been on a trajectory of accelerated urban growth and is now poised to more than double its urban population during the next 20 years (Weitz, Kumar and Raman, 2016). However, delivery of urban services could not match the pace of urbanization, leading to environmental pollution and deteriorating public health. The current service levels are low relative to the needs of urban households (HPEC, 2010), as can be seen in Table 8.

Table 8: Service delivery levels of urban services in India

Water service delivery	*Urban population coverage by individual connections/ standposts* • 64% in India, vis-à-vis 91% in China, 86% in South Africa, and 80% in Brazil. *Duration of water supply* • India (1 - 6 hours), vis-à-vis Brazil and China (24 hours) and Vietnam (22 hours) *Faulty infrastructure and losses* • 70% leakages are due to conncection pipes and malfunctioning of water meters • Non-revenue water (NRW): India – 50%, Singapore – 5%
Urban Sewerage and Sanitation	• 4861 out of 5161 cities/towns don't have even partial sewerage network • Treated sewage: India (21%) vis-à-vis South Africa (57%) • Of the 79 sewage treatment plants under state ownership reviewed in 2007, 46 were operating under very poor conditions
Solid waste management	• Primary collection 38% • Segregation of recyclables 33% • Processing 9% • Disposal 1%

Source: HPEC, 2010

Rajasthan lags significantly in urban services provisioning. As far as water supply is concerned, only 23 towns have a service level above 100 Lpcd. The water supply infrastructure is ageing and is badly in need of restoration and revamping. It is projected that by 2045, Rajasthan will face a demand-supply gap of 3,037 MLD in both groundwater and surface water. . The

Rajasthan State Water Policy envisions 24x7 piped water supply with 100% coverage and cost recovery by 2025. It further seeks to "encourage private initiative in water sector."

On the sewerage front, only 24% households have access to closed drainage. As few as 11 cities have access to partial sewerage (World Bank, 2012). Rajasthan has a long way to go as far as solid waste management is concerned. Not a single city in the state managed to make it to the list of top 150 cities ranked on the basis of cleanliess and sanitation, as per the *Swachh Survekshan 2017* - the Swachh Bharat Abhiyan survey. Fast tracking investments in sanitation in Rajasthan can potentially yield savings to the economy by increasing productivity of human resources and building human capital (EPW, 1994).

Udaipur is one of the oldest cities in India and is known as the city of lakes, strategically surrounded by the Aravalli hills. It s the fifth largest district in terms of total population and holds the eighth position in terms of urban population in the state. Udaipur accounts for 74% of the district's total urban population. The city falls under the Class 1C, as per the city classification system based on population, i.e. city with population between 1 lakh and 5 lakh (HPEC, 2010).

Table 9: Udaipur population trend

Year	Population	Decadal Growth
1971	161278	-
1981	232583	44.2%
1991	308571	32.7%
2001	389438	26.2%
2011	488019	15.8%

Source: CRISIL, 2014

The population and household trend is presented in Table 9 and Table 10. Udaipur has experienced a two-fold increase in its population over the last three-and-a-half decades. However, the household size has reduced marginally by 0.2 points over the past decade. Population CAGR is calculated with the help of population base of 2011 and projected population for 2041. Household CAGR is calculated based on the household size of 2001 and 2011.

Table 10: Udaipur household trend

Year	Household size
2001	4.96
2011	4.76

Source: CRISIL, 2014

Udaipur has a diversified economic base comprising tourism, education, administration and trade, and commerce and industrial sectors. It accounts for 9% of the state's industrial output (CRISIL, 2014) with the trade and hospitality sectors followed by the manufacturing sector as the largest contributors to GSDP.

Udaipur houses 18,127 industrial units in eight industrial areas, as on 31 March, 2013. Udaipur Phosphates and Fertilizers, Secure Meters, Hindustan Zinc Ltd. and Rajasthan Petro Synthetic are some of the major units. There are 14,678 commercial establishments in the city, as of 2011 (including shops and workshops).

Udaipur Municipal Corporation (UMC), Urban Improvement Trust (UIT) and Public Health Engineering Department (PHED) are responsible for the provision of basic infrastructure facilities in the city. UMC serves an area of 64 sq km after the city's expansion and is divided into 55 wards. UMC is responsible for providing sewerage and sanitation, SWM, streetlights, roads, housing, and basic services in slum areas within UMC jurisdictions. PHED is responsible for planning, designing, construction, operation, and maintenance of the water supply system.

As per the Rajasthan Municipal Act, provisioning for sewerage services in the city is the responsibility of the UMC and UIT in their respective jurisdictions. PHED provides new sewerage connections in the city and collects sewerage charge along with the water supply bills.

The major sources of water supply in Udaipur are groundwater as well as surface water. With approximately 80% coverage and 78,000 connections, water is currently supplied at an interval of two days. Due to undulating topography of the city, there are many low-pressure points affecting the water supply pressure at the consumer end. Further, many consumer connection pipes are old and are sources of potential contamination and leakages.

Last available data on service level indicators is depicted in Table 11.

Table 11: Water supply coverage in Udaipur

Indicator	Data (2014)
Total no. of households	1.1 lakh
Coverage of water supply connections	79%
Per capita water availability at consumer end	124 Lpcd
Cost recovery	29%

Source: CRISIL, 2014

The key issues identified with respect to piped water supply under the Udaipur City Development plan (Ministry of Urban Development) are as follows:

- Insufficient water resources resulting in groundwater extraction and depletion (70MLD against demand of 80MLD).
- Old water supply infrastructure, resulting in water leakages and sudden breakdowns.
- Duration of water supply, low pressure, and uneven distribution of resources (at 2 – 3-day intervals)
- Low cost recovery (29% cost recovery)

The total underground sewerage network in the city is 23.5 km. Approximately 35% of the population under UMC is directly connected to the sewerage network (UMC, FY17). As per a detailed project report made under Amrut II in 2017, existing trunk sewer lines are not sufficient to bear the heavy load of sewage in Udaipur.

In the absence of connection to the sewer lines, the waste water flows into the Ahar river, affecting the ecological balance by depleting aquatic life and creating inconvenience for the population living in the catchment of the river flow. Since the river merges into one of the city's lakes, which is a source of water for Udaipur, the river needs to be cleaned. A successful pilot was done in 2009 using green bridge technology.

The generation of MSW in Udaipur is pegged at 120 MT per day (Udaipur Municipal Corporation and Janaagraha Centre for Citizenship & Democracy, 2017). There are no proper facilities for waste segregation and processing. The efficiency of door-to-door collection is only 20% (Udaipur Municipal Corporation and Janaagraha Centre for Citizenship & Democracy, 2017) The bulk of the waste collected is dumped in the open Titri landfill, approximately 15 km away from the city. With inadequate waste treatment and disposal facilities, Udaipur doesn't levy user charges for SWM services. The cost for remediation of landfill-related issues would be huge, and is estimated to be about Rs 2.5 billion, as the average life of a landfill is 25 years (Mahadevia and Wolfe, 2008).

Primary collection of solid waste is done through door-to-door services, public waste bins and street sweeping. Udaipur was ranked at 310 in the all-India Swachh Bharat survey on cleanliness and sanitation.

Key issues on solid waste management highlighted by Udaipur's City Development Plan are:

- Inadequate coverage of door-to-door waste collection facilities.
- Absence of waste segregation and processing, and scientific disposal facilities.
- UMC doesn't have a separate department for SWM services.
- Lack of financial and institutional resources.

Improved solid waste management can also result in substantial improvement in the cleanliness of the city and lead to significant savings in space required for landfilling. It would also help avoid the cost required for landfill remediation.

The aim of this study is to evaluate three urban interventions using an economic framework of cost benefit analysis (CBA) to evaluate the following:

- 24x7 piped water supply to all households
- 100 percent sewage and waste water treatment
- 100 percent solid waste management

Specifically, CBA is employed to assess the suitability of the selected intervention strategies from the perspective of the society. This study investigates the following key research questions:

(i) What is the relevance of the three interventions to Udaipur?

(ii) What are the costs of these interventions?

(iii) What are the socio-economic, health, and environmental benefits of the interventions?

(iv) How do these interventions compare on cost and benefit through estimation of BCR – Benefit Cost Ratio?

This paper provides an opportunity for policymakers to consider alternatives and investment decisions by understanding the relative cost benefits of the three interventions. Given the vital nature of all three services, the results from the study should not be treated as recommendations to reject or defer investments in any of the three areas. Further, the results indicate BCR of greater than one in all three interventions, thereby supporting the case to invest in all the three. Under budget constraints, the results can be used to prioritize investments in conjunction with implementation considerations.

1.1 Theory

This study has adopted the CBA approach to evaluate the potential socio-economic impact of different interventions. This approach is widely used to evaluate and compare various programs in policy discussions around the world. In this approach, incremental benefits are compared with the cost of the investment to determine if the benefits exceed the costs. BCR is measured as ratio of discounted present value of interventions benefits to the discounted present value of interventions costs expressed as:

$$BCR = \frac{\sum_{t=1}^{n} \frac{(B_t)}{(1+r)^t}}{\sum_{t=1}^{n} \frac{(C_t)}{(1+r)^t}}$$

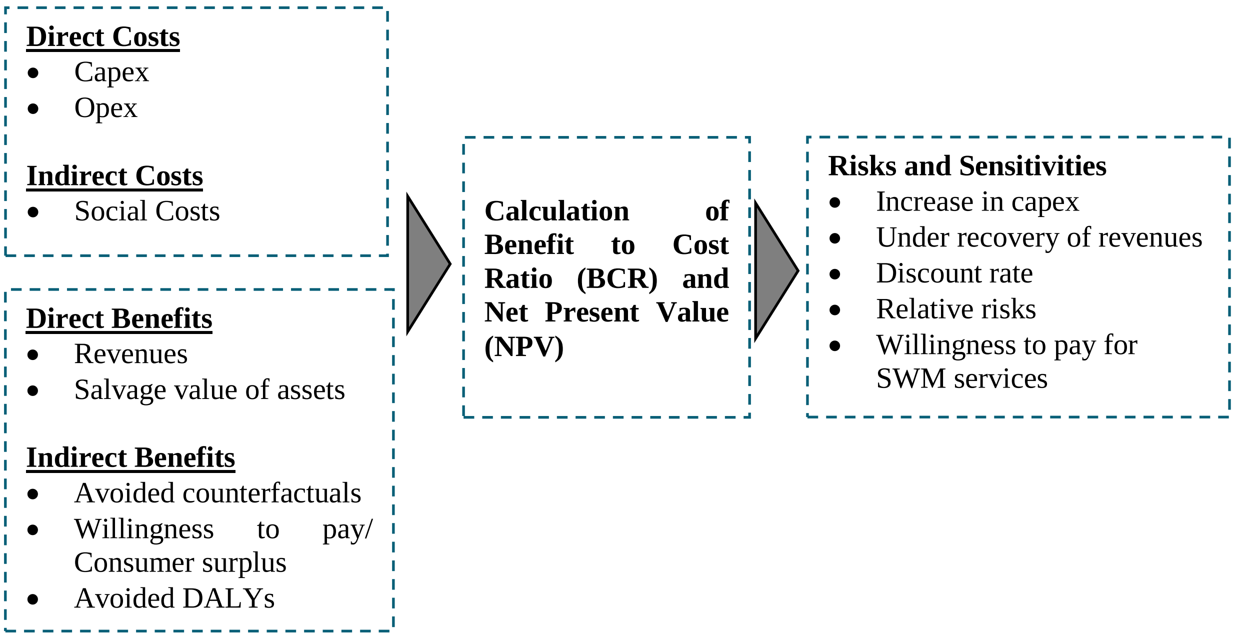
Here, B, C, r and t denote benefit, cost, discount rate and time frame of the project (t = 1,..., n), respectively. The discount rate was used to calculate net present value for costs and benefits.

A BCR greater than 1 indicates that benefits exceed the cost of investment i.e. the program generates net benefits and a BCR less than 1 implies the costs of undertaking the program exceed the benefits generated by it. BCRs enable policymakers to compare and rank alternative policy interventions to prioritize among potential intervention strategies.

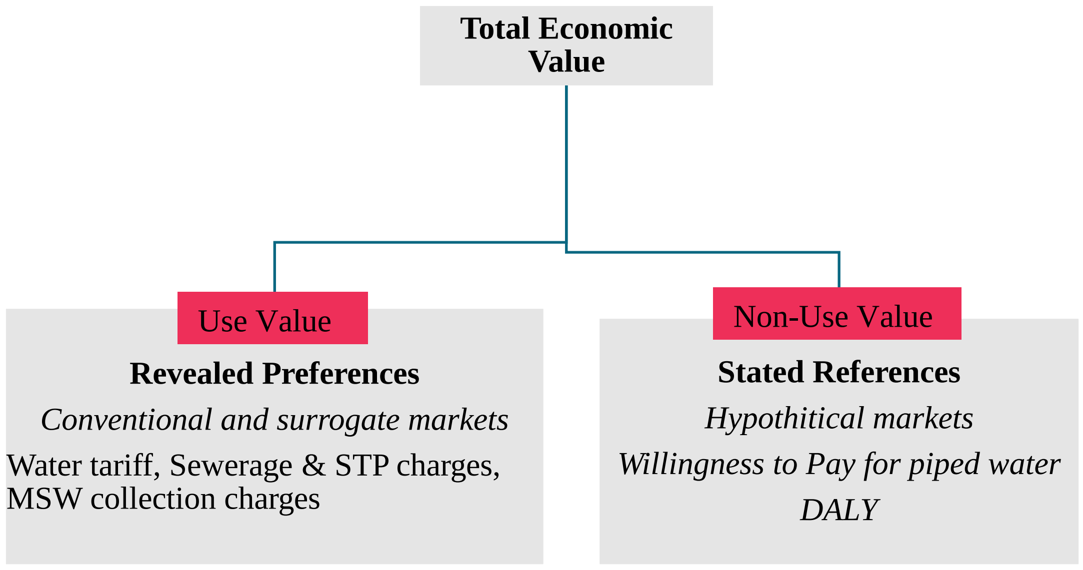
CBA Methodology

The present study captures both direct and indirect costs and benefits accrued due to implementation of the interventions.

For the base case scenario, the discount rate is assumed to be 5%. Any project is subject to various types of risks during the life cycle of the project. Key risk factors have been identified and sensitivity analysis was performed on the outputs. The below figure summarizes the approach.



This research uses the CBA methodology through computing BCR and NPV to measure and quantify the value of the potential intervention strategies. However, the study does not compute any IRR for evaluating the capital investments, considering the methodological flaws of IRR. The study uses 'Total Economic Value' for estimating different types of benefits. Additionally, both use and non-use values are considered to calculate the benefits. The typology of monetary valuation method used in this study is explained in the figure below:



Source: (Pearce and Howarth, 2000)

2. 24x7 piped water supply

2.1 Description of intervention

The intervention for 24x7 piped water supply shall ensure the following standards and benefits:

- Water to be supplied 24 hours a day
- 100% individual piped water supply for all households
- Increase in the average residual pressure in consumer water taps

These are as per benchmarks provided in the HPEC recommendations.

2.2 Literature Review

The economic benefits of piped water supply are well-documented in multiple studies. A cost benefit study on water and sanitation shows that in developing countries, the return on a US$1 investment was in the range US$5 to US$46, depending on the intervention. For the least-developed regions, every US$1 invested to meet the combined water supply and sanitation lead to a return of at least US$5 (Hutton, Haller, and Bartram, 2007). OECD estimates that that Millennium Development Goals (MDGs) for water and sanitation would generate benefits of US$84 billion per year with a benefit to cost ratio of 7 to 1 . A meta study on willingness to pay for improved water for 41 different countries (including India) between 1986 and 2013 shows the WTP ranges in value from $0.02 to over $154, with an average (median) value of $19 ($10.50) (Van Houtven, Pattanayak, Usmani and Yang, 2017).

Cities and towns in India are visibly deficient in the quality of services they provide, even to the existing population. Current service levels are low in relation to the needs of urban households (HPEC, 2010), as can be seen in Table 1. Living standards and business operations are negatively impacted by India's inability to provide and sustain universal access to basic urban services. In 35 municipal corporations, the average underspending on capital investments necessary to meet minimum standards of services is 76% . Intervention-specific studies have been carried out to highlight their importance and challenges.

It is estimated that inadequate sanitation costs India Rs. 2.4 trillion a year and the national cumulative sanitation market has the potential of Rs. 6.87 trillion (US$152 billion) over the 2007-2020 period (World Bank, 2011). In addition to economic benefits accrued to citizens, there is ample evidence to show the positive health impacts of access to piped water and sanitation. Meta studies results show inadequate provisions for water and sanitation are associated with considerable risks of diarrheal disease and that there are notable differences in illness reduction according to the type of improved water and sanitation intervention implemented (Pruss-Usten et al 2015, following Wolf et al 2014).

Only 49% of households in the country have access to piped water supply within their premises (IIHS, 2014). Average supply is 75 Lpcd, as opposed to the norm of 135 Lpcd (Wankhade , 2014). Typically, water utilities in India supply standpipes and taps in poorer areas and, when necessary, supplement this with tanker supplies (IRG, 2004).

Water supply systems require operation at constant pressure. Where there is intermittent supply, the constant changes in pressure as water is pumped into the system and then drawn down cause rapid deterioration to joints which then leak. This not only results in high water losses but also in deposition of pollutants in the pipes that are sucked in through the leaking joints. At best, these pollutants are mud and soil, and at worst sewage. The effect is that even if water is adequately treated at the plant, the water coming out of the tap is not potable (IRG, 2004).

As cited by the ICRIER working paper, the negative health and economic impacts of falling groundwater quality tend to be concentrated in poor urban areas where residents frequently lack access to piped water supply and sewage systems . Fast tracking investments in water supply and sewerage can potentially yield savings by increasing productivity and savings on health expenditure (Working group for 12th five year plan).

2.3 Data

Data on costs and benefits of interventions have been sourced from secondary sources. Additionally, a site visit was conducted in the third week of January 2018 to Udaipur to validate the data and primary results. Assumptions can be classified in two sets – generic and intervention specific. Following are the set of generic assumptions, common across interventions:

Population and Household Size: The population and household related information as well as forecast are sourced from the City Development Plan made for Udaipur by CRISIL Infrastructure Advisory as part of a joint partnership program between the ministry of urban development and the World Bank.

Project life: The period of all three urban interventions has been considered to be 25 years with investment being made in 2019. Benefits accrue over the lifetime of the interventions.

Capex and Opex: Capex and Opex information has been sourced from the high-powered expert committee (HPEC) report put out by the ministry of urban development (ICRIER, 2011) for class 1C cities. Since the data pertains to 2009, the authors have escalated it to 2017 prices using inflation data for the respective years (WPI for Capex and CPI for Opex). To estimate the value of capex and opex from 2019 onwards, the items are divided into two components - labor and capital. A labor component of 20% and 50% each are considered for capex and opex, respectively, as per own assumption. The labor component for both capex and opex have increased at the real wage growth rate, provided by Copenhagen Consensus. However, the capital component is considered constant over time. Further, cost of land acquisition is not accounted for in the analysis, considering the government shall provide land at almost nil value for such interventions that have wider social and economic benefits.

Social cost of disruption: The assumption for social cost is sourced from the report by National Research Council of Canada (Rahman, Vanier and Newton, 2005). The main items taken into account include delays and diversions to road traffic and disruption of local economic activity. While it is assumed that social costs can go up to 400% of construction cost, for the purpose of water and sewerage interventions, 78% is the average recommended by the NRCC report, which has been assumed in the first year itself, as entire capex is assumed to be incurred in the first year itself.

Following are the set of assumptions specific to Intervention 1:

Current coverage: The current piped supply coverage is considered to be 79% (CRISIL, 2014), as presented in Table 11. The remaining 21% population is assumed to be receiving water through alternative sources (tanker supply). As much as 80% of existing connections are to be replaced, as recommended in the HPEC report.

Investment in existing population: Per capita investment cost (PCIC) or capex for water supply is categorized into four categories: water production, 24x7 distribution extension, 24x7 replacement / upgrade and opex. While water production is assumed on the entire population, the distribution extension is towards the population currently not covered by piped water supply and it is assumed that 80% of existing connections shall be replaced.

Investment in incremental population: Capex on the incremental population is considered to be 100% of original distribution extension capex, as it's assumed that pipelines will be laid mainly in the city's peripheral areas, where new houses are expected to come up.

Opex has been calculated for the entire population.

Avoided cost of water supply through alternative source: To estimate the foregone cost (or benefit) for alternative source of water supply (tanker water) in the absence of piped water supply, a conservative approach is adopted using minimum water needed for survival as per World Health Organization (WHO, 2010).

Escalation in water tariffs: All water-related tariffs are escalated at a y-o-y rate of 10%, as per the revised tariff schedule for water supply put out by the Public Health Engineering

Department of Rajasthan (PHED, 2017) till 2017. Subsequently, the tariffs have been increased as per the real wage growth reflecting increased willingness to pay.

Counterfactual revenues: Counterfactual water revenues have been excluded from the total revenues getting accrued subsequent to interventions. Counterfactual revenue has been escalated with the CAGR for past 6 years.

Salvage value: Salvage value of assets at the end of project life has been included in the analysis. A depreciation rate of 3% is used based on the ministry of drinking water and sanitation's guidelines . A reducing balance method been used to estimate the salvage value of the asset at the end of the project life.

Consumer surplus for 24x7 water supply: Consumer surplus for improved water access in terms of US$ gained for Rajasthan is sourced from meta-analysis (Van Houtiven, Pattanayak, Usmani, Yang, 2017) and converted to INR using the INR/US dollar purchasing power parity conversion value from OECD. Further, the future value of willingness to pay for improved water access is estimated by escalating the value as per the real income growth of Rajasthan. Finally, the water revenue for UMC due to the piped water supply intervention is reduced from the corresponding year's willingness to pay number to arrive at the consumer surplus value.

Disability adjusted life years (DALYs) avoided: Burden of disease data relevant to water and sanitation has been sourced from meta studies to assess the health impact of drinking water, and data from the *Global Burden of Diseases* report relevant to Rajasthan. The relevant data is used to calculate death (Years of Life Lost or YLLs) and morbidity (Years Lost to Disease or YLDs), and finally the Value of avoided (Disability Adjusted Life Year) DALY's was arrived at different discount rates.

The assumptions and sources for the data points have been summarized in Table 12.

Table 12: Data-related assumptions for Intervention 1

Parameter	Assumption	Source
Generic		
Population (2011)	488019	
Population growth rate	1.9%	
Household size (2011)	4.7	
Household size growth rate	(0.4)%	
Project life	25 years	Own assumption
Specific for Intervention 1		
Current coverage	80%	
Replacement of existing connections	80%	
Per Capita Capex for incremental population	100%	Assumption
Per day water supply	135 Lpcd	
Minimum water needed for survival	20 Lpcd	
Costs Assumptions		
Capex per capita (Water Production)	Rs. 1,404	
Capex per capita (24x7 Distribution Extension)	Rs. 4,520	
Capex per capita (24x7 Replacement/ Upgradation)	Rs. 3,855	
Labour: Capital split in capex	20:80	Own assumption
Labour: Capital split in opex	50:50	Own assumption
Escalation in labour component in capex & opex	As per Rajasthan real wage growth	CC
Escalation in capital component in capex & opex	NIL real increase	
Opex	Rs. 491	
Cost of alternative water source (tanker)	Rs. 350	Government tender
Social cost of disruption (taken only for first year)	78%	NRCC report
Benefit Considerations		
Revenue from water charges	As per slabs	
Revenue from general charges	As per slabs	
Revenue from New connection charges	As per slabs	
Avoided cost of alternative supply	Rs. 350	Govt. tender for tanker
Tariff escalation till 2017	Tariff schedule	
Tariff escalation post 2017	Raj. real wage growth	CC
Depreciation rate for salvage value of asset	3%	Ministry of DW&S
Consumer Surplus	Calculated	Meta-Analysis, OECD
DALY's avoided	Calculated	Global burden of diseases

2.4 Calculation of Costs and Benefits

2.4.1 Cost elements

Total capital investment and opex requirement has been derived through the product of per capita investment cost (PCIC) with the city population. Key cost items (also captured in Table 12) are:

- Capex for production: Considered for the entire population
- Capex for distribution *extension* network: Considered for uncovered (20%) and incremental population
- Capex for distribution replacement and upgradation cost: Considered for 80% of the already-connected population. As much as 79% of the total population of Udaipur is already connected to piped water supply.
- Opex: Entire population
- Tanker supply: Cost assumed for the uncovered population in the first year.
- Social cost of disruption: Considered only for the construction phase

The costs are summarized in Table 13.

Table 13: Costs of intervention to provide 27x7 piped water supply

Direct costs (in Rs. billion)	
Capex	5.9
Opex	14.1
Tanker cost	0.1
Indirect costs (in Rs. billion)	
Social cost of disruption	3.0
Total	**23**

2.4.2 Benefit elements

Benefit elements (also captured inTable 12 are as follows:

- Water revenues: Summation of water charges, general charges and new connection charges as per tariff schedule – net of counterfactual revenues.
- Tanker water supply avoided to unconnected and incremental population: Considered from the second year onwards, after implementation of the intervention. Water

distributed through tanker supply is assumed to be treated and potable in the base case.

- Salvage value of the asset at the end of life of the project
- Willingness to pay for water supply
- Avoided Disability Adjusted Life Year (DALY).
- Water distributed through tanker supply assumed to be treated and potable.

The benefits are summarized in Table 14.

Table 14: Benefits of intervention to provide 24x7 piped water supply

Direct benefits (in Rs. billion)	
Revenue	3.7
Salvage value	1.5
Indirect benefits (in Rs. billion)	
Tanker cost avoided	6.9
Consumer surplus for water supply	40.6
Avoided DALYs	0
Total	**53**

2.5 Assessment of Quality of Evidence

Data on benefits and costs of interventions has been sourced from secondary sources – published papers and a few unpublished documents. Research papers, reports, and other documents relating to the key domains of this research and with particular reference to Udaipur have been considered. Relevant documents have been analyzed to review estimated costs and benefits of the interventions. Further, most of the data points were validated in discussion with sector experts. The data sources are summarized in Table 12. Most of the assumptions and data points are sourced from strong sources, which makes them high-quality inputs for the cost benefit analysis.

2.6 Sensitivity Analysis

All projects are exposed to various types of risks during the life cycle. Specifically, large infrastructure projects are exposed to high risks during the development phase (Mckinsey, 2013). Cost overruns, delays, failed procurement and unavailability of financing are common. Hence, sensitivity analysis has been conducted to assess the potential impact of uncertain variables. This will provide policymakers with an idea of the relative degree of uncertainty surrounding the interventions.

Several variables were tested in order to arrive at the key sensitivities towards BCR and NPV of the intervention to provide 24x7 piped water supply – increase in capex (10% and 30%), increase in opex (10% and 30%), under-recovery in revenues (10% and 25%), quality improvement - high-quality piped water supply over basic piped water and unimproved sources , increase/ decrease in social cost, and no tariff escalation. Significant sensitivities are summarized in Table 15.

Table 15: Risks and sensitivities for 24x7 piped water supply

Scenarios	NPV of Net Benefit (in Rs. bn)	BCR	Significance
Base case: *Relative risk of piped water (0.77) – Basic piped water over unimproved sources*	*30*	*2.27*	
Relative risk of piped water (0.21) – High-quality piped water over unimproved sources	60	3.60	Significant upside
Social cost at 200% (Base case: 78%)	28	2.07	Significant downside

Note: All figures assume a 5% discount rate

Round-the-clock piped water supply emerges as a safe intervention against the adverse sensitivities of variables such as capex, opex and tariffs. This is primarily due to the significant benefits contributed mainly by consumer surplus. The only parameters to which the intervention BCR responds significantly are considerations for relative risks and substantial increase in social costs.

3. 100 percent sewage and waste water treatment

3.1 Description of intervention

Intervention 2 shall achieve the following sewerage standards in Udaipur:

- Underground sewerage system with complete coverage

- 100% collection and treatment of waste water
- Better service revenue for local municipality
- Reduction in river pollution and water-borne diseases

3.2 Literature Review

Waste water is both an asset and a problem in an urbanizing world (Drechsel et al., 2015a; UN-Water, 2015). Presently, an estimated 80% of global waste water is being discharged untreated into the world's waterways. This affects the biological diversity of aquatic ecosystems and disrupts the fundamental web of our life support systems, on which a wide range of sectors from urban development to food production and industry depend (Hernández-Sancho, Lamizana-Diallo, Mateo-Sagasta and Qadir, 2015).

Lack of sanitation contributes to about 10% of the global disease burden, causing mainly diarrheal diseases (Mara et al., 2010). A global cost benefit study on water and sanitation interventions shows the return on a US$1 investment is in the range of US$5 to US$46 in developing countries, depending on the intervention. For least-developed regions, every US$1 invested to meet the combined water supply and sanitation requirements lead to a return of at least US$5 (Hutton, Haller and Bartram 2007). OECD estimates that that Millennium Development Goals (MDGs) for water and sanitation would generate benefits of US$84 billion per year with a benefit to cost ratio of 7 to 1 (OECD, 2011).

Current service levels in sewage and waste water treatment in India are low, in relation to the needs of urban households (HPEC, 2010), as can be inferred from Table 8. About 70% of urban sewage is left untreated. As per the draft National Policy on Faecal Sludge and Septage Management, only 33% urban households are connected or yet to be connected to the municipal sewer system (MoUHA, 2017). People are mainly dependent on conventional individual septic tanks for waste water management. It is estimated that about 29% of India's population uses septic tanks (USAID, 2010).

Dumping of city sewage and garbage into the water bodies in Udaipur is leading to waidespread pollution (EPW, 1994). As per a study by Udaipur Municipal Corporation, water resources in the city are polluted due to the direct disposal of sewage into surface drains or surface water bodies. Groundwater contamination is essentially due to absence of septic tanks in the city, leakages and overflowing of sewerage pipelines, mixing of water and sewerage due to faulty lines.

The investment requirement for urban sanitation during 2013-2032 has been estimated to be Rs. 8,440 billion; which includes capital, O&M and support costs (World Bank, 2016).

3.3 Data

Data on costs and benefits of interventions was sourced from secondary sources – published papers and a few unpublished documents. Additionally, a site visit was conducted in the third week of January 2018 to Udaipur to validate the data and primary results.

The exhaustive data set for the intervention to ensure 100% sewage and waste water treatment is presented in Table 16. Following are the set of assumptions that are specific to Intervention 2:

Coverage: About 35% of Udaipur's total population is currently connected to the sewerage network for waste water treatment.

Investment in uncovered population: The remaining population is assumed to be connected in the first year of the intervention, wherein 100% capex is planned to be incurred.

Investment in incremental population: The incremental capex (to serve incremental population) from the second year two is considered to be 100% of the original network capex, as it is assumed that the laying of new connections to the sewerage network will mainly happen in the peripheral areas as the city's population expands.

Avoided cost of cleaning the river: It is assumed that Rs. 5 lakh per MLD is required to clean the river, along with Rs 5 lakh of annual maintenance.

Table 16: Data-related assumptions for intervention to provide for 100% sewage and waste water treatment

Parameter	Assumption	Source
Generic		
Population (2011)	488019	
Population growth rate	1.9%	
Household size (2011)	4.7	
Household size growth rate	(0.4)%	
Project life	25 years	Own assumption
Intervention specific		
Current population accessing sewerage network and treatment	35%	
Per Capita Capex for incremental population	100%	Assumption
Costs Assumptions		
Capex per capita (Network)	Rs. 2,338	
Capex per capita (Treatment)	Rs. 1,073	
Labour: Capital split in capex	20:80	Own assumption
Labour: Capital split in opex	50:50	Own assumption
Escalation in labour component in capex & opex	As per Raj. Real wage growth	CC
Escalation in capital component in capex & opex	NIL real increase	
Opex per capita	Rs. 290	
Social cost in the first year	78% of capex	NRCC report, 2005
Benefit Consideration		
Revenue from Sewerage Tax	20% of water charges	PHED Tariff Schedule, 2017
Revenue from STP charges	13% of water charges	PHED Tariff Schedule
Yearly escalation of tariff	Real wage growth of Raj.	CC
Avoided capex towards river cleaning	INR 5L per MLD	CSE & site visit
Avoided opex per year for river cleaning	INR 3L per year	CSE & site visit
Depreciation for calculating Salvage Value	4%	Ministry of DWS
DALY's avoided	Calculated	Global burden of diseases

3.4 Calculation of Costs and Benefits

3.4.1 Calculation of costs

Key cost items are presented in Table 18. They include:

- Total capital investment and opex requirement: derived by multiplying per capita investment cost (PCIC) with the city population. Key cost items include:
    - Capex for network
    - Capex for treatment
    - Opex

  The cost of land acquisition is not considered in this analysis, considering the government shall provide land almost at nil value for such interventions that have wider social and economic benefits.

- Coverage: About 35% of the population
- Social cost of disruption

Table 17: Costs towards 100 percent sewerage network and treatment

Direct costs (in Rs. billion)	
Capex	2.9
Opex	8.6
Indirect costs (in Rs. billion)	
Social cost of disruption	1.4
Total	**12.9**

3.4.2 Calculation of benefits

Key benefit items are covered in Table 18. They include:

- Sewerage revenue
- Salvage value of the project
- Avoided cost of cleaning the river receiving the entire drainage of the city: capex assumed for the first year, and opex subsequently
- Avoided Disability Adjusted Life Year (DALY)

Table 18: Benefits from 100 percent sewerage network and treatment

Direct benefits (in Rs. billion)	
Sewerage revenue	0.1
Salvage value	0.6
Indirect benefits (in Rs. billion)	
River cleaning cost avoided	0.1
DALY	14
Total	**14.8**

3.5 Assessment of Quality of Evidence

Data on benefits and costs of interventions has been sourced from secondary sources – published papers and a few unpublished documents. Research papers, reports, and other documents relating to the key domains of this research and with particular reference to Udaipur have been considered. Relevant documents have been analyzed to review estimated costs and benefits of the interventions. Further, most of the data points have been validated in discussion with sector experts. The data sources are summarized in Table 16. Most of the assumptions and data points have been sourced from strong sources, which makes them high-quality inputs for the cost benefit analysis.

3.6 Sensitivity Analysis

Several variables were tested in order to arrive at the key sensitivities towards BCR and NPV of Intervention 2: Increase in capex (10% and 30%), increase in opex (10%), under-recovery in revenues (10% and 25%), falling relative risk of health for sewerage (i.e. overall relative risk for improved over unimproved sanitation on diarrhoea) (Usten, 2015), and increase/ decrease in the social cost. Significant sensitivities are summarized in Table 19.

Table 19: Risks and sensitivities for 100 percent sewerage network and treatment

Scenarios	NPV of net benefit (in Rs. bn)	BCR	Significance
Base case: *Relative risk of sewerage (0.72)*	*2*	*1.15*	
Relative risk of sewerage (0.59)	10	1.73	Significant upside
Relative risk of Sewerage (0.88)	(6)	0.50	Significant downside
Social cost at 200% (Base case: 78%)	(0.3)	0.98	Significant downside

Note: All figures assume a 5% discount rate

The intervention for provision of 100% sewage and waste water treatment emerges as a marginally safe one. In spite of that, it is not impacted significantly by sensitivities of variables such as capex, opex overruns. The only parameters to which the intervention BCR responds significantly are various considerations for relative risk and substantial increase in social costs.

4. 100 percent solid waste management

4.1 Description of intervention

Intervention 3 shall ensure solid waste management standards as follows:

- 100% solid waste management (collection, transportation and processing)
- Open up alternative revenue sources for UMC through the sale of RDF and compost
- Reduction of environmental impacts and outbreak of vector-borne diseases
- Help to avoid landfill closure cost
- Social and economic benefits to citizens

4.2 Literature review

With high population growth rates, rapidly varying waste characterization and generation patterns, growing urbanization and industrialization in developing countries (Troschinetz & Mihelcic, 2009), it is crucial to focus on SWM as more area is required to accommodate waste (Idris, Inane, & Hassan, 2004).

The focus of municipal waste management services in Europe over the past 30 years has been shifted from its original aim – removing garbage from urban areas – to the more far-reaching objective of governing materials flows through the economy and fostering resource efficiency, in order to divert as much waste as possible from landfills (Massarutto 2007a). This transformation has been driven by the need to face a quantity of waste that since 1980 has increased 65% in absolute and 40% in per capita terms (OECD 2008).

Waste processing can also offer new revenue streams for municipality through sales of recyclables or recovery of resources and/or energy and thus increase of the value chain of waste (Christian, Ephraim, & Zurbrügg, 2014).

In Indian cities, the management and disposal of solid waste generated leaves a great deal to be desired, although the generation of solid waste is at much lower rates than in most countries. Unscientific practices in processing and disposal compound the environmental hazards posed by solid waste. (HPEC, 2010). More than 90% of MSW is disposed of in low-lying lands in unsanitary conditions (Nandi & Gamkhar, 2013).

A Planning Commission report (Government of India, 2014) reveals 377 million people residing in urban areas generate 62 million tons of MSW per annum currently, and it is projected that by 2031 these urban centers will generate 165 million tons of waste annually and by 2050 it could reach 436 million tons. To accommodate this amount of waste generated by 2031, about 23.5 × 107 cubic meter of landfill space is required and in terms of area it would be 1,175 ha. of land per year. The area required from 2031 to 2050 would be 43,000 hectares for landfills piled in 20-meter height. These projections are based on 0.45 kg/capita/day waste generation.

The cost of providing landfill facilities to meet the requirements of the MSW rules over the next ten years is estimated at some Rs 100 billion – about US$2 billion (World Bank, 2006). More than 70% cities in India face problems due to inefficient collection, inadequate transportation facilities and disposal owing to the presence of very few sanitary landfills. As a result, biomedical waste, slaughter house waste, and industrial waste often reaching the MSW dumpsites pose potential health hazards to sanitary workers and waste pickers (Ganesan, 2018).

4.3 Data

Data on costs and benefits of interventions was sourced from secondary sources – published papers and a few unpublished documents. Additionally, a site visit was conducted in January 2018 in order to validate the data and primary results. Exhaustive data set and assumptions are summarized in Table 20. Following are the set of assumption relevant to Intervention 3:

Coverage: Udaipur currently generates about 120 TPD waste with 20% door-to-door collection and negligible segregation and treatment. No collection fee is currently being charged from the residents.

Production and sales of compost and RDF: It is assumed that the solid waste intervention would enable the production of RDF and compost that can be sold in the market. Considering the experience of compost manufacturers on offtake of compost by fertilizer companies, it has been assumed that about half of the compost manufactured in Udaipur shall be sold at a cabinet-approved compost price of Rs. 2,500 per ton. Additionally, RDF (Refuse Derived Fuel) offtake is also assumed at 50% at Rs. 300 per ton (excluding transport cost), considering the experience of IL&FS Environment.

Savings in space and land value: This intervention focuses on waste processing that would reduce the requirement of gross landfill area by approximately 75%. Waste processing plants would be set up for manufacturing of compost and RDF, for which land requirement is estimated based on industry norms. In case of Udaipur, the land required for landfill was estimated to be 70% lower, i.e. approximately 38 hectares less compared to counterfactual. An average of DLC (District Level Committee) land prices for various areas of Udaipur have been used to arrive at the capital value of 38 hectares, which will be available for alternative use.

Avoided cost of Landfill Remediation: The thumb-rule assumed for landfill remediation is assumed as Rs. 15 million per hectare, as per the Dumpsite Rehabilitation Manual, prepared by University of Kalmar (Sweden), Asian Institute of Technology (Thailand) and Anna University (Chennai).

Salvage value of assets and depreciation: A depreciation rate of 12% is used for solid waste collection and transportation vehicles, as per the income tax guideline. For treatment and disposal, a deprecation rate of 7% been used as per the common industry practice. A reducing balance method has been used to estimate the salvage value of the asset at the end of project life.

Willingness to Pay for improved solid waste management: The willingness to pay for SWM was estimated from various India-specific WTP studies on SWM. The case studies considered for this analysis are based in Cacher district of Assam (Assam University, 2013), Palakkad district of Kerala (Thomas, 2013), Pune city (Prof. Mansi Khadke, 2018) and Kolkata (International Journal of Environment and Waste, 2013)

Table 20: Data-related assumptions for intervention to ensure 100 percent solid waste management

Parameter	Assumption	Sources
Generic		
Population (2011)	488019	
Population growth rate	1.99%	
Household size (2011)	4.76	
Household size growth rate	(0.4)%	
Project life	25 years	Own assumption
Intervention specific		
MSW generation in Udaipur City	120 TPD	
Coverage of door-to-door collection	20%	
Segregation and treatment	Zero percent	
Compostable waste	44%	
Moisture loss in compostable waste	30%	(IEISL)
RDF producing waste	30%	
Offtake of Compost and RDF	50%	Assumption
Landfill area required	15 acre per lakh population	(Mahadevia and Wolfe, 2008)
Per Capita Capex for incremental population	100%	Assumption
Yearly escalation on the RDF & Compost prices	Raj. Real wage growth	CC
Cost Assumptions		
Capex per capita (collection & transportation)	Rs.140	
Capex per capita (Treatment)	Rs. 175	

Capex per capita (Disposal)	Rs. 95	
Opex per capita	Rs. 135	
Labour: Capital split in capex	20:80	Own assumption
Labour: Capital split in opex	50:50	Own assumption
Escalation in labour component in capex & opex	As per Raj. Real wage growth	CC
Escalation in capital component in capex & opex	NIL real increase	Income tax guidelines
Benefit Considerations		
Revenue from sale of compost	Rs. 2,500 per ton	Government order and industry practice
Revenue from sale of RDF	Rs. 300 per ton	Industry practice
Waste going to landfill after processing due to intervention	25%	Industry norm
Thumb rule for space required towards waste processing plant	2 hectare per 100 TPD	Industry norm
Udaipur land prices	Average of various area prices belonging to bottom 50 percentile)	Land registration and stamps department, Govt. of Rajasthan
Avoided cost of landfill closure	Rs. 15 M per ha	Dumpsite Manual, CES
Depreciation for collection and transportation	12%	Income tax department
Depreciation for treatment and disposal	7%	Industry practice
Willingness to pay	Calculation	Meta-study and papers

Social cost is not considered for this intervention.

4.4 Calculation of costs and benefits

4.4.1 Calculation of costs

The cost items are captured in Table 20.

- *Total capital investment and opex requirement*: Derived by multiplying per capita investment cost (PCIC) with the city population. Key cost items include:
    - Collection and Transportation
    - Treatment
    - Disposal
    - Opex

The collection and transportation infrastructure will need to be replaced multiple times during the project life given that the life of vehicles in this application is on an average about 8 years.

Cost of land acquisition is not considered in the analysis, considering government shall provide land at almost nil value for such interventions that have wider social and economic benefits.

- *Coverage*: Present coverage of door-to-door collection is 20% and zero segregation.

The costs are presented in Table 21.

Table 21: Costs of intervention to ensure 100 percent solid waste management

Direct costs (in Rs. billion)	
Capex	0.6
Opex	4.0
Total	**4.6**

4.4.2 Calculation of benefits

The benefit items are presented in Table 20. Estimated benefits items are as follows:

- Production and sale of compost and RDF
- Space savings due to reduced land required for landfilling
- Avoided cost of landfill remediation in 25th year
- Salvage value of assets at the end of project duration

The benefits are presented in Table 22.

Table 22: Benefits of intervention to ensure 100 percent solid waste management

Direct benefits (in Rs. billion)	
Compost and RDF sales	0.5
Salvage value of the project	0.1
Saving in space due to reduction in landfill	1.6
Indirect benefits (in Rs. billion)	
Landfill closure cost avoided	0.9
Willingness to pay for improved waste management	6.1
Total	**9.1**

4.5 Assessment of quality of evidence

Data on benefits and costs of interventions has been sourced from secondary sources – published papers and a few unpublished documents. Research papers, reports, and other documents relating to the key domains of this research and with particular reference to Udaipur have been considered. Relevant documents were analyzed to review estimated costs and benefits of the interventions. Further, most of the data points have been validated in discussion with sector experts during site visits. The data sources are summarized in Table 20.

4.6 Sensitivity Analysis

Several variables were tested in order to arrive at the key sensitivities towards BCR and NPV of Intervention 3: increase in capex (10% and 30%), increase in opex (10%), fall in RDF and compost prices, various levels of willingness to pay and variation in landfill remediation cost. Significant sensitivities are summarized in Table 23.

Table 23: Risks and sensitivities for 100 percent solid waste management

Scenarios	NPV (INR Bn)	BCR	Significance
Base case	*4*	*1.97*	
WTP for improved SWM (Max of study result)	8	2.83	Significant upside
WTP for improved SWM (Min of the study result)	1	1.16	Significant downside

Note: All figures assume a 5% discount rate

This intervention emerges as a safe one. In spite of that, it is not impacted significantly by sensitivities of variables such as capex, opex overruns. The parameters to which the intervention BCR responds significantly are the various levels of willingness to pay for the SWM services, as currently no charges are being charged from households for waste collection and processing.

5. Conclusion

Increasing urbanization has posed multiple challenges with respect to service delivery of urban services in cities. The CBA analysis conducted in this study compares three urban interventions. From the study, it is learnt that all three interventions aimed at - 24x7 piped water supply, 100 percent sewage and waste water treatment and 100 percent solid waste management pass the CBA litmus test and are economically viable. The summary is presented in Table 24.

Table 24: Summary table

Interventions	Discount	Benefit	Cost	BCR	Quality of Evidence
24x7 piped water supply	3%	71	28	2.50	Strong
	5%	53	23	2.27	
	8%	35	18	1.95	
100 percent sewage and waste water treatment	3%	26	16	1.59	Strong
	5%	15	13	1.15	
	8%	8	10	0.78	
Solid waste management	3%	13	6	2.16	Strong
	5%	9	5	1.97	
	8%	6	3	1.73	

The sensitivity analysis shows the interventions are not significantly sensitive to the capex and overruns. This is primarily due to the overall environmental and health benefits they generate and increased users' willingness to pay for the urban services. They also enable Udaipur municipality and PHED to recover their costs, and in case of the solid waste management intervention, earn some revenue for UMC by selling processed recycled waste in form of RDF and compost. Further, there are other innovative ways for UMC to earn revenues through means such as the use of value financing capture tools. However, these are not included in the scope of the current study due to lack of data.

Udaipur is considered to be one of the oldest cities in India and an important tourist destination with high international tourist footfall. However, it is also said to one of the cities that are on the brink of a public health and environmental "emergency" that needs immediate remedial action (CRISIL, 2014). A balanced combination of the three key interventions can positively alter the natural balance in the city's environment and its sustainability, thereby making Udaipur a more habitable place.

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