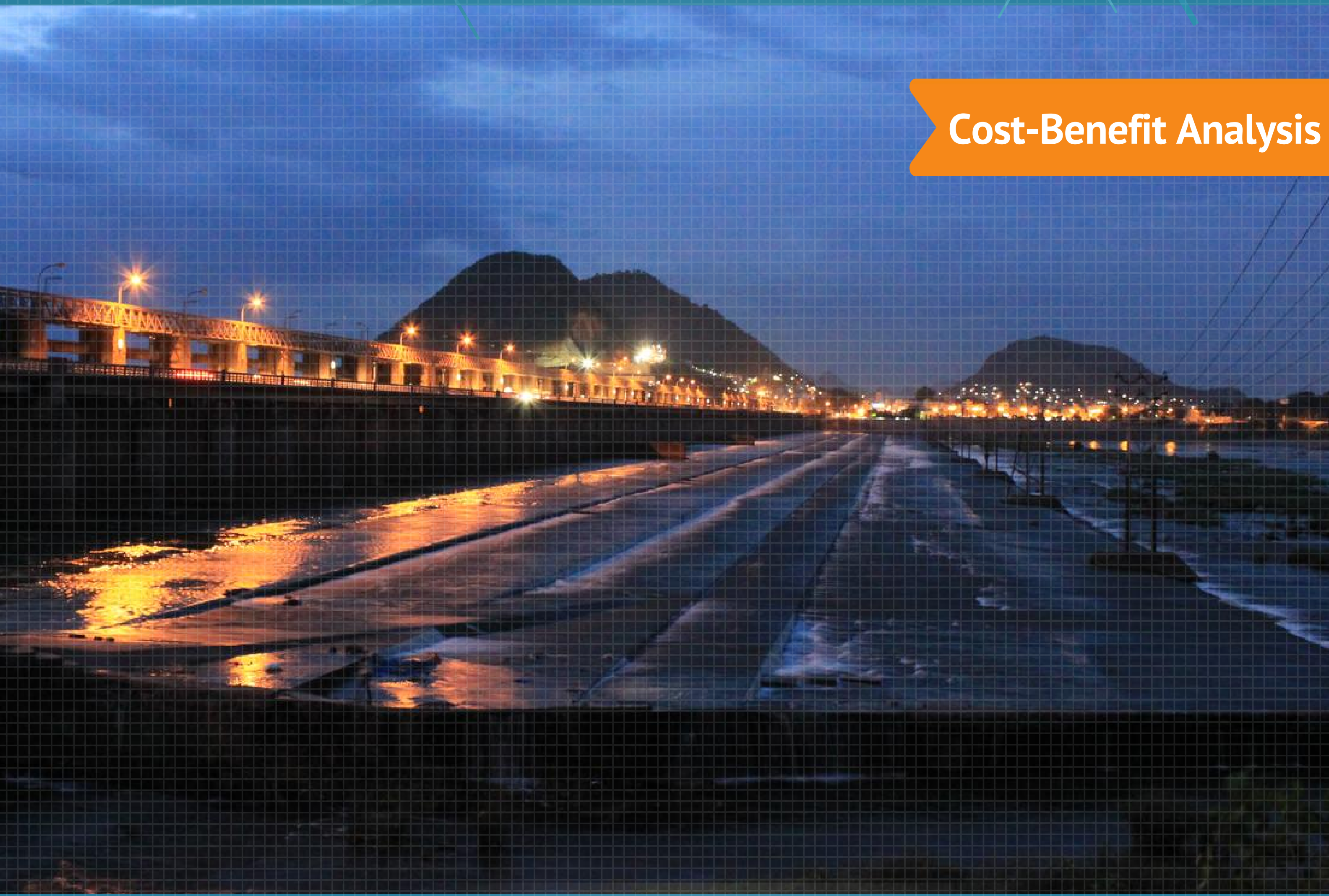
URBAN INFRASTRUCTURE

Analysis of Urban Infrastructure Interventions, Vijayawada City, Andhra



Cost-Benefit Analysis

AUTHORS:

Parijat Dey
Senior Manager
IL&FS

O Rajesh Babu
Assistant Vice President
APUIAML

ANDHRA PRADESH PRIORITIES
AN INDIA CONSENSUS PRIORITIZATION PROJECT

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info@copenhagenconsensus.com
www.copenhagenconsensus.com

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Cost Benefit Analysis of Urban Infrastructure Interventions, Vijayawada City, Andhra Pradesh

Andhra Pradesh Priorities
An India Consensus Prioritization Project

Parijat Dey[1], O Rajesh Babu[2]

[1]*Senior Manager, IL&FS*

[2] Assistant Vice President, APUIAML

IL&FS Academy of Applied Development

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List of Abbreviations

AMRUT:	Atal Mission for Rejuvenation and Urban Transformation
APCRDA:	Andhra Pradesh Capital Region Development Authority
APUIAML:	Andhra Pradesh Urban Infrastructure Asset Management Limited
APUFIDC:	Andhra Pradesh Urban Finance and Infrastructure Development Corp Limited
Bn:	Billion
Capex:	Capital expenditure
CAGR:	Compounded Annual Growth Rate
CBA:	Cost Benefit Analysis
CCC:	Copenhagen Consensus Center
CPI:	Consumer Price Index
DALY:	Disability Adjusted Life Year
GHMC:	Greater Hyderabad Municipal Corporation
HPEC:	High Powered Expert Committee
HRIDAY:	Heritage City Development and Augmentation Yojana
HSCs:	Household Service Connections
ICRIER:	Indian Council for Research on International Economic Relations
IEISL:	IL&FS Environmental Infrastructure & Services Limited
ILO:	International Labor Organization
IMF:	International Monetary Fund
IRR:	Internal Rate of Return
ITUAL:	IL&FS Township & Urban Assets Limited
JNNURM:	Jawaharlal Nehru National Urban Renewal Mission
Km:	Kilometer
Lakh:	1 Million = 10 Lakh
Lpcd:	Liters per Capita per Day
MSW:	Municipal Solid Waste

NPV: Net Present Value

NRW: Non-Revenue Water

Opex: Operating expense

PCIC: Per capita investment cost

PHED: Public Health and Municipal Engineering Department

RDF: Refuse Derived Fuel

RR: Relative Risk

Sq ft: Square feet

UFW: Unaccounted-for-water

ULBs: Urban local bodies

VMC: Vijayawada Municipal Corporation

WHO: World Health Organization

WPI: Wholesale Price Index

WTP: Willingness to pay

YLDs: Years Lost to Disease

YLLs: Years of Life Lost

Academic Abstract

Vijayawada is the third largest city in the state of Andhra Pradesh after Hyderabad and Visakhapatnam. Growing economic activity and population expansion have put heavy pressure on urban infrastructure and there is an urgent need to address present and emerging infrastructure needs.

The aim of this study is to evaluate urban infrastructure investments towards meeting the challenge of improving water and sanitation services. The following three interventions were considered relevant:

1. 24x7 piped water supply to 100 percent population in Vijayawada
2. Provision for sewerage for all households in Vijayawada with 100 percent collection and treatment of waste water
3. 100 percent door-to door collection, processing and treatment of solid waste

This study uses a cost–benefit analysis (CBA) methodology to assess the suitability of selected interventions. CBA approach enables capturing of both direct and indirect costs as well as benefits for the three interventions.

The authors' analysis reveals that piped water supply is the most viable intervention, followed by improved solid waste management and sewerage in that order. The results indicate a BCR of greater than one in all cases, thereby supporting the case to invest in all three. Hence, the study recommends that investment in all three is required but the results can be used for prioritization, particularly under budget constraints. Furthermore, sensitivity analysis was conducted to assess the impact of identified risks and uncertainties on the 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 is expected to increase further to 87 by 2031 (HPEC, 2010). It is expected that India's urban population of 400 million will double by 2050 at approximately 2 percent compounded growth rate (Shah, https://counterview.org/, 2017). As a result, all cities are expected to witness rapid increase in demand for urban services such as piped water supply, sewage and waste water treatment, and solid waste management (Mckinsey, 2010). As per a high-powered expert committee report (HPEC, 2010), the duration of water supply in Indian cities ranges from 1 - 6 hours; about 21 percent of the waste water generated is treated, and less than third of municipal solid waste is segregated (HPEC, 2010).

The government of Andhra Pradesh has estimated an investment requirement of Rs 1.02 lakh crore over next five years (Vijayawada Commissioning, 2018) to address the gaps in urban infrastructure such as piped drinking water supply, sewerage lines and roads across the state. As a part of this plan, significant infrastructure development is intended for Vijayawada considering that it is the town city of the new capital Amaravati. Government of Andhra Pradesh has given utmost importance for providing safe and adequate water supply (APUIAML, 2017). Additionally, Andhra Pradesh Urban Finance and Infrastructure Development Corporation has prepared a detailed project report for sewerage system to identify and close the service delivery gap. Similarly, several initiatives for solid waste management, including a plan to set up a centralized waste processing unit near Amaravati have been proposed. Most of these initiatives, however, are still in the conceptualization stage due to various factors, including but not limited to capital constraints. Thus, this study is topical and provides a comparative analysis of cost and benefits, particularly relevant under hard budget constraints.

Infrastructure Gap in Water Supply:

Vijayawada city has adequate raw water to meet the demand of its consumers. The per capita water supply was 168 Lpcd in 2016. An estimated 61 percent of total households are connected to piped water supply. However, there are shortcomings in the service delivery owing to deficiency in the water distribution network. Most of the pipes are old and damaged leading to leaks and contamination. The contribution of NRW (non-revenue water) was assessed to be 46 percent (APUIAML, 2017). Inadequate coverage, intermittent supplies and low pressure, are some of the most prominent issues related to water supply.

Infrastructure Gap in Sewage Infrastructure:

Approximately 36 percent of the households have access to sewerage connections and 35 percent of the sewage generated by the city is treated (APUFIDC, 2017). Vijayawada has inadequate sewer connections, and flooding of sewers is common in various areas. Several parts of the city such as Bhavanipuram, Vidyadharapuram, Housing Board Colony, Kabela surroundings, Joji Nagar, K.L. Rao Nagar, Chitti Nagar, Kotha Peta, Wynchipeta and I-town commercial areas have underground bulk sewer pipelines, but households are yet to be connected to the sewerage network. Poor coverage, and damaged and unserviceable network are the most prominent sewerage issues.

Gap in Solid Waste Management Infrastructure:

The estimated municipal waste generation is estimated to be about 550 tons per day from various sources. Vijayawada Municipality Corporation (VMC) claims a collection efficiency of 100 percent, however, waste processing and treatment is almost non-existent. The bulk of mixed waste is transported to dumping sites for disposal. In the past, VMC had taken several initiatives, including setting up of compost and bio methanation plants for treatment of waste. However, none of them are presently functional. Despite past initiatives by VMC, segregation of waste at the household level is low. Most of the segregation is carried out in the informal sector, where ragpickers and *kabariwalas* take out high-value recyclable waste and sell it to recyclers.

Intervention 1: 24x7 Provision of Piped Water Supply

Overview:

The intervention aims to address the following:

- 24x7 piped water supply distribution to 100% household in Vijayawada
- 80 percent of existing distribution network pipes to be replaced

The intervention will be implemented by the public health and municipal engineering department (PHED) and is expected to provide piped water connection to all households in Vijayawada. This intervention will also provide water connections to the incremental population as the population grows over the project life. Funding for such large projects is normally through a mix of grants from state/central government or loans. It is assumed that the project will start in 2019 and will be implemented through the mix of grants from multinational funding agencies, including ADB, WB or central government assistance through various infrastructure schemes. The intervention will result in economic benefit through recovery of water tariff.

Implementation Considerations:

It has been assumed that the intervention will start in 2019 and all households without piped water connections will be connected during the year. The project life is for 25 years. The success of the intervention will be measured through 24X7 piped water supply to all households and revenue realization through water tariff by VMC and improved health outcomes.

Risk Infrastructure projects with long life cycles are exposed to various kind of risks; including economic, financial, social and political risks. Cost overruns, delays and failed procurement are common in nature. Change in social cost of disruption due to construction and relative risk of diseases due to poor water quality are identified as major risks for the intervention.

Quality of Information: The overall quality of information for this intervention is strong. As most of the data has been sourced from the HPEC report and detailed report prepared by Andhra Pradesh Urban Infrastructure Asset Management Limited on 24x7 water supply in Vijayawada, which has been validated with the local municipality.

Costs and Benefits

Costs

Total capital investment and opex requirement has been derived from the per capita investment cost (PCIC) norm. Key cost items include capital expenditure for water production, extension of distribution network and replacement or upgradation of existing network; and operating expenses. Summary of cost of Intervention 1 is presented in table 1 below.

Table 1: SUMMARY of Cost for Intervention 1

Direct Cost (in Rs. billion)	
Capex for production	3.4
Capex for distribution extension	3.8
Capex for distribution replacement and upgradation	2.1
Opex	40.8
Indirect Cost (in Rs. billion)	
Social cost of disruption due to construction	4.9
Total	**54.8**

Note: All values are at 5% discount rate

Estimated Benefits

Water revenue is calculated based on the tariff schedule provided by VMC for 2013 and escalated at 7 percent annually till 2017. Post 2017, the tariff has been escalated at the real wage growth of Andhra Pradesh to account for increase in WTP. The avoided cost of bore water pump installation and maintenance is considered as an indirect benefit. While calculating the cost of bore water pump installation and maintenance, various elements including borewell drilling cost, pump cost and maintenance cost (energy consumption), and cost of basic RO and their corresponding maintenance cost have been considered.

Salvage value of the asset at the end of the life of the project has been estimated using a depreciation rate of 3 percent. Positive health impacts from clean drinking water has been estimated based on the burden of disease data, relevant to water and sanitation, sourced from meta-studies and *Global Burden of Disease* database. Relevant data has been used to calculate the 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) at different discount rates. Summary of benefits of Intervention 1 is presented in Table 2 below.

Table 2: Summary of Benefits for Intervention 1

Direct benefits (in Rs. billion)	
Water revenue	103.5
Salvage value of the asset	2.2
Consumer surplus	51.6
Indirect benefits (in Rs. billion)	
Avoided cost of water supply through alternate source (Bore Water)	17.5
Avoided Disability Adjusted Life Year (DALY)	8.1
Total	**183.0**

Note: All values are at 5% discount rate

Intervention 2: 100 percent Sewage and Waste Water Treatment

Overview:

The intervention aims to address the following:

- Underground sewerage system with complete coverage
- 100 percent collection and treatment of waste water

The intervention may be implemented by the PHED or through private sector participation. It intends to connect the remaining 74 percent of households to the sewerage network in 2019 and treat the entire bulk of 148 MLD of waste water generated. Similar to the intervention for piped water supply, multinational funding agencies, including ADB, WB or central and state governments are potential sources of funding such a project through a combination of grants and soft loans.

Implementation Considerations:

The intervention will be implemented from 2019 and the project life is 25 years. The success of the intervention will be measured through sewerage connections to all households and revenue realization for VMC through sewerage tariff.

Risk: Similar risk factors and project implementation timeframe as the piped water supply intervention is considered for this intervention.

Quality of Information: The overall quality of evidence is 'strong' for the intervention. The data has been sourced from a detailed report prepared by the Andhra Pradesh Urban Finance and Infrastructure Development Corporation on sewerage and the HPEC report. The data has been validated with the local municipality.

Costs and Benefits

Costs

Total capital investment and opex requirement have been derived by from the per capita investment cost (PCIC) norms. Summary of cost of Intervention 2 is presented in Table 3 below.

Table 3: Summary of Cost for Intervention 2

Direct Cost (in Rs. billion)	
Capex for treatment	0.9
Capex for network - last mile connection	1.1
Capex for network - Incremental population	2.0
Capex for distribution replacement and upgradation	2.4
Opex	24.8
Indirect Cost (in Rs. billion)	
Social cost of disruption due to construction	2.7
Total	**33.9**

Note: All values are at 5% discount rate

Estimated Benefits

The benefits comprise direct benefits – revenues accrued through the tariffs, salvage value of the project, cost avoided for river cleaning and indirect benefits – disability adjusted life years (DALYs). Summary of benefits of Intervention 2 is presented in Table 4 below

Table 4: Summary of Benefits for Intervention 2

Direct Benefits (in Rs. billion)	
Sewerage revenue	7.1
Salvage value of the asset after project life	1.7
Indirect Benefits (in Rs. billion)	
Avoided river/ canal cleaning cost	0.1
Avoided Disability Adjusted Life Year (DALY)	29.5
Total	**38.3**

Note: All values are at 5% discount rate

Intervention 3: Provision for Solid Waste Management:

Overview:

The intervention aims to address the following:

- 100 percent door-to door collection of waste
- 100 percent processing and treatment of waste

The financing option for this intervention will be similar to other interventions i.e. funding from multinational funding agencies or central and state governments through a combination of grants and soft loans. Processing of municipal solid waste creates recycled products that have some market value. It is estimated that 10% of total collected waste is recyclable and 25% is inert, which is sent to the landfill. Approximately 50 percent of input is converted to compost and 16 percent of the input is converted to refuse derived fuel (RDF) (Tata Consulting Engineers Limited, 2016).

Implementation Considerations:

The success of the intervention will be measured on 100 percent collection, processing and treatment of municipal solid waste generated in Vijayawada, and revenue realization for VMC through sale of compost and RDF. In addition, there would be a significant reduction in space requirement for landfills in the city.

Quality of Information: The overall quality of evidence is 'strong' for the intervention as most of the data has been sourced from detailed report prepared by VMC on solid waste in Vijayawada and HPEC report. The data has been validated with the local municipality.

However, the authors have found limited evidence on offtake of compost and RDF. Additionally, the quality of evidence for willingness to pay for better waste management is medium.

Costs and Benefits

Cost

Total capital investment and opex requirement have been derived by multiplying per capita investment cost (PCIC) with the city population. Summary of cost of Intervention 3 is presented in Table 5 below.

Table 5: Summary of Cost of intervention 3

Direct Cost (in Rs. billion)	
Capex for collection and transport	0.2
Capex for treatment	0.4
Capex for disposal	0.2
Opex	12.6
Total	**13.4**

Note: All values are at 5% discount rate

Benefits

Revenue for local municipality through sale of compost and RDF, salvage value of the project, willingness to pay for improved solid waste management and avoided landfill cost are considered as benefits. The cost of remediation of that landfill can be avoided through the intervention on solid waste management, as the average life of a landfill is 25 years (Mahadevia, n.d.), as a result the landfill would need closure in the year 2043. Land value savings due to this intervention is also considered as benefits, as improved solid waste management will result in lesser space requirement for landfills. The summary of benefits of Intervention 3 is presented in Table 6 below.

Table 6: Summary of Benefits of intervention 3

Direct Benefits (in Rs. billion)	
Revenue for local municipality through sale of compost and RDF	1.5
Salvage value of the asset after project life	0.1
Land value savings due to intervention	5.0
Indirect Benefits (in Rs. billion)	
Avoided landfill closure cost	2.1
Willingness to pay for improved solid waste management	19.6
Total	**28.2**

Note: All values are at 5% discount rate

The summary of BCR is presented in Table 7 below

Table 7: BCR Summary

Interventions	Benefit	Cost	BCR	Quality of Evidence
Intervention 1: Piped Water Supply	183	55	3.3	Strong
Intervention 2: Sewerage	38	34	1.1	Strong
Intervention 3: Solid Waste Management	28	13	2.1	Strong

Note: All figures assume a 5% discount rate

Introduction

India has 17 percent of the world's population and 15 percent of its livestock, whereas it occupies 2.45 percent of the landmass and a relatively small share of 4 percent of world's water resources. The country ranks 133 (out of 180 nations) on water availability and 120 (out of 122 nations) on water quality. It is estimated that 80 percent of India's surface water is polluted, resulting in a loss of US$6 billion annually due to water-borne diseases (Bose and Srivastava, 2017). As per a report on urban infrastructure and services by ICRIER, 64 percent urban Indians are connected to a household water system as compared to 91 percent in China, 86 percent in South Africa and 80 percent in Brazil. Daily water supply is limited to 1-6 hours as compared to 24 hours in Brazil and 22 hours in China and Vietnam (ICRIER, 2011).

India generates around 40 billion liters of waste water every day, which is expected to double in the next 15 years according to the McKinsey Global Institute (Chibber, 2018). Currently, only 2 percent of India's urban areas have both sewerage systems and sewage treatment plants (Shah, 2016). Around 80 percent of sewage flows untreated into rivers, lakes and ponds, thereby polluting water resources and causing significant damage to end users (Centre for Science and Environment, 2013). Additionally, about 40 percent of the total sewage treatment capacity of the country exists in just two cities - Delhi and Mumbai.

India generates over 150,000 tons of municipal solid waste (MSW) per day. Yet only 83 percent of waste is collected and less than 30 percent is treated (Ahluwalia, 2016). About three-fourths of the municipal budget for solid waste management goes into collection and transportation, leaving very little for processing/resource recovery and disposal.

As per 2011 Census, the decadal growth rate of urban population in Andhra Pradesh is 36.3 percent, compared to a national average of 31.8 percent. Including Greater Hyderabad Municipal Corporation (GHMC), there are about 182 ULBs comprising 19 corporations, 113 municipalities (of all grades) and 50 *nagar panchayats*. Growing urban population and increasing economic activity have brought multiple issues to the front from governance and management of these areas to the provision of basic civic services.

According to a report by IRC, water supply in majority of ULBs in Andhra Pradesh are far below the prescribed norms for water supply depending on the size of the town. Adequacy and equitable distribution are the major problems (Rao et al., 2012).

On an average, ULBs in Andhra Pradesh generate about 9,754 MT of waste per day with per capita waste generation ranging from 0.2-0.4 kg/per day (Swachh Bharat Mission, 2016). It has been estimated that ULBs in Andhra Pradesh spend Rs. 500 - 1500 per ton/day, of which, 60-70 present is spent on collection, 20-30% on transportation and less than 10% on processing and disposal activities. Low investments by majority of the ULBs result in lack of proper treatment and disposal facilities (Swachh Bharat Mission, 2016). As much as 92 percent of households in Andhra Pradesh was covered by door-to-door collection services in 2016, and source segregation covered 8% of households in the states (CPCB, 2016). Manual handling of the waste is still carried out in most municipalities, except in Hyderabad, Visakhapatnam and Vijayawada, where MSW is transported in covered vehicles. The Greater Hyderabad Municipal Corporation is the only ULB in Andhra Pradesh that has constructed and that operates a sanitary landfill facility. The rest of the ULBs dump MSW in existing dump sites (CPCB, 2016).

The Andhra Pradesh government has taken a positive approach to encourage ULBs in the state to comply with the MSW rules 2000 and has spent Rs. 374 crore - the entire allocation under the 12th Finance Commission grants - for development of solid waste management infrastructure and services. However, the success of such initiatives was limited to primary collection and transportation of waste (Swachh Bharat Mission, 2016).

The recent progress in the collection and transportation of waste is visible in the recent ranking of Andhra Pradesh's cities in *Swachh Survekshan 2017*, the Swachh Bharat Abhiyan survey. In 2017, eight of Andhra Pradesh's 32 ULBs that participated in Swachh Survekshan were ranked among the top 50 clean cities (Press Information Bureau, 2017). This brings Andhra Pradesh to among the top three states with the highest number of clean cities or towns in the country, after Madhya Pradesh (23 cities) and Gujarat (22 cities) (Press Information Bureau , 2017).

The aim of this study is to evaluate urban infrastructure investments towards meeting challenges of 24x7 piped water supply, sewage and waste water treatment, and solid waste management. This study uses a cost–benefit analysis (CBA) to assess the suitability of the chosen interventions using the CBA approach. This study investigates the following key research questions:

(i) What is the relevance of the three interventions for Vijayawada?

(ii) What are the costs of these interventions?

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

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

The aim of the study is to provide inputs to policymakers, planners, development partners, and concerned citizens on prioritizing various urban interventions. The CBA findings are also used to assess the sensitivity of outcomes to identified risks and uncertainties. This sensitivity analysis offers policymakers an idea of the degree of uncertainty surrounding key variables and the significance of that uncertainty.

CBA should be considered as an aid to the debate on relative attractiveness of investments in the improvement of public utility services. Given the vital nature of all the three services, the result from this study should not be treated as a recommendation to deny or defer investments in any of the interventions. Further, the results indicate a BCR of greater than one in all cases, thereby supporting the case to invest in all three. The output from the study is, hence, an indicator of relative attractiveness. The BCRs should not be interpreted to mean the relative investment is not required or unimportant. Under budget constraints, these results can be used to prioritize investments in conjunction with implementation considerations.

Theory

To evaluate the potential socio-economic impact of different interventions, the study has adopted the CBA approach. 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:

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

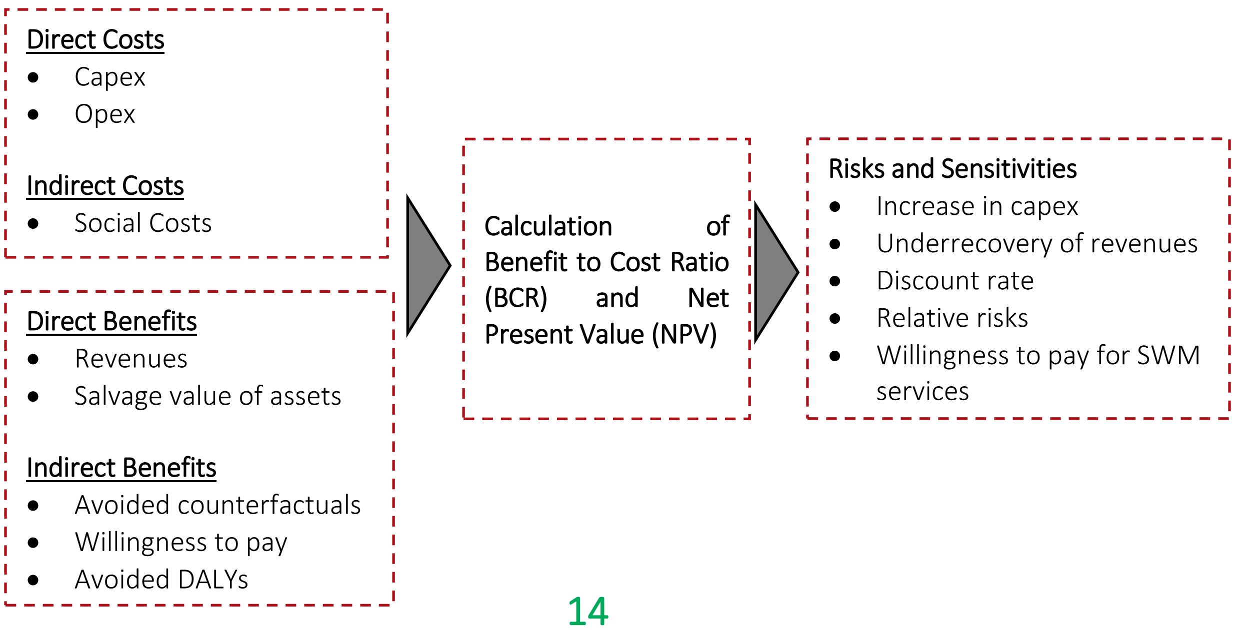
Here, B, C, r and t denote benefit, cost, discount rate and time frame of the project (t = 1,..., n), respectively. The discount rate was used to calculate net present value for costs and benefits.

A BCR greater than 1 indicates the 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.

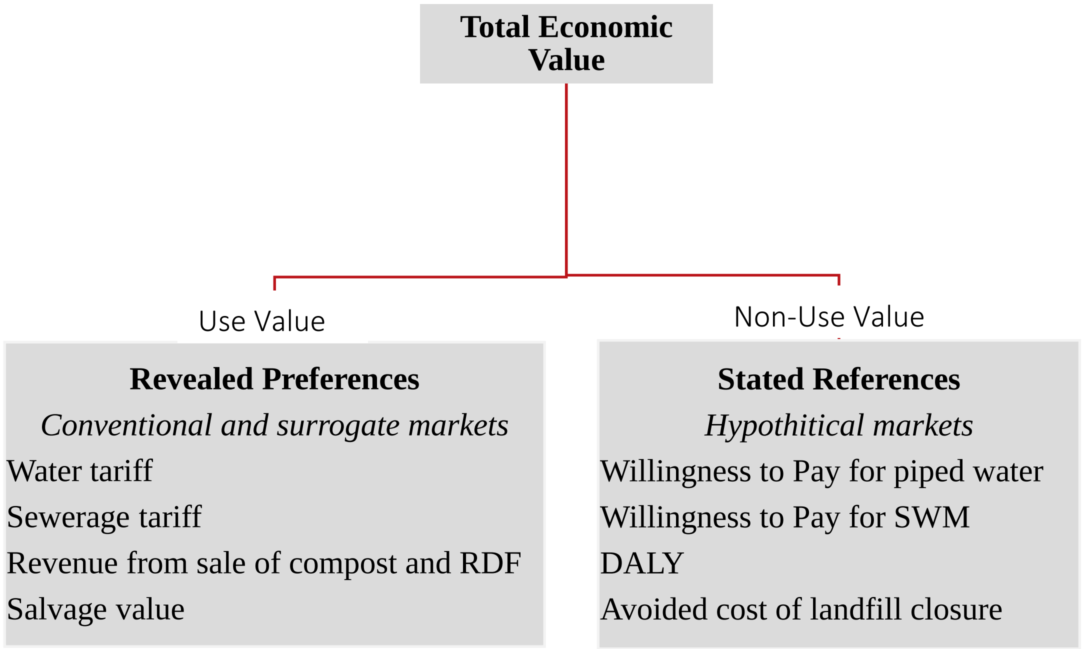
CBA Methodology

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

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



This research used Cost Benefit analysis (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 used '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 chart below.



Source: (Pearce and Howarth, 2000)

Overview: Vijayawada

The second largest city in Andhra Pradesh, Vijayawada is situated on the banks of the Krishna river. It is a municipal corporation and the headquarters of the state's Krishna district. The city lies in the Andhra Pradesh Capital Region area and houses the headquarters of Andhra Pradesh Capital Region Development Authority (APCRDA). The city is also popularly known as 'Bezawada'.

Over the years, Vijayawada has grown as a major economic, cultural and administrative nerve center in coastal Andhra Pradesh. The city is well-connected to other regions by road, air and rail. It has the second biggest railway junction in India. The city also has a few places of historic importance. Vijayawada municipal corporation, a selection grade municipality since 1960 that became a corporation in 1981. The jurisdictional area of the corporation is spread over an area of 61.8 sq.km with 59 wards. As per the 2011 Census of India, the city had a population of 10, 49,536, making it the second-largest city in the state in terms of population. The city's population is expected to reach 2.5 million by 2025. The increased population has put tremendous pressure on the management of different utilities and service facilities, including water supply, and sewage and waste water treatment, and waste management.

Geography

Located at 16.5193°N 80.6305°E, Vijayawada is situated at an altitude of 11 m (36 ft.). It lies on the banks of the Krishna river and is also surrounded on the north by the river Budameru. The northern, northwestern, and southwestern parts of the city are covered by low-range hills, while the central, southwestern and northwestern parts are covered by rich and fertile agricultural lands with three major irrigation canals. The topography of Vijayawada is flat, with a few small to medium-sized hills. These hills are part of the Eastern Ghats cut through by the Krishna river, which runs along the city. Three canals originating from the north side of the Prakasam barrage reservoir - Eluru, Bandar and Ryves - run through the city.

Demographics

As per the 2011 census, the city had a population of 10,49,536 with 5,24,918 males and 5,24,618 females. The Vijayawada urban agglomeration had a population of 1,491,202. Vijayawada falls under Class 1B as per the city classification system based on population, i.e. population between 1-5 million (ICRIER, 2011). Population information for this study has been sourced from Vijayawada municipal corporation, and the growth in population is projected using the average of annual decadal population growth rates of the last two decades.

Household Size

For the purpose of the current study, data on average household size has been sourced from the Census 2001 and 2011 database. The average household size is projected from 2012 onwards, considering half the CAGR between 2001 and 2011. It is assumed that in the coming days, the average household size would decrease at a rate slower than the historical rate, as families land up in the city for livelihoods and employment opportunities. Additionally, the research has assumed that the average household size will stabilize at 3 members per family from 2033 onwards.

Economy

Agriculture, commercial trade, tourism, industries, transportation and tertiary sectors etc., are the major sectors that contribute to the economy of the city. Vijayawada is famous for processing of agricultural products, automobile body manufacturing, textiles, consumer goods and small-scale industries. The fact that Vijayawada is well-connected through rail and road makes it a hub for commercial activities. Agro-based industries such as cotton, turmeric, and Virginia tobacco are located in the surrounding areas. Oil, dal and rice mills are present in Kondapalli. Moreover, the city's real estate prices are comparable to that of the top cities of India.

Industrial estates

The two well-equipped industrial estates in Vijayawada are Auto-Nagar and Kondapalli. The Jawahar Lal Nehru Auto Nagar Industrial Estate in Vijayawada is one of Asia's largest auto industry hubs. The industrial estate in Kondapalli suburbs is spread over 450 acres (1.8 km^2) and houses more than 800 industries.

Table 8: Salient Details of Vijayawada Municipality

Sl. No	Description	Details
1	Project city	Vijayawada
1	Grade	Municipal corporation
2	Area (in sq. km)	61.88
3	Total no. of wards	59
4	Population, as per 2011 census	10,49,536
5	No. of property tax assessments	1,89,291
6	No. of HSCs - water	1,18778
7	Length of ULB roads (in km)	1141
8	Capacity of STP (in MLD)	80 MLD and 70 MLD under construction
9	Length of sewer (in km)	798
10	No. of HSCs – sewer	71129

Intervention 1: Provision of 24x7 Piped Water Supply

Description of intervention

This intervention has been designed to ensure 24 x 7 piped water supply to all households with significant improvement in the service quality

Current Status: VMC meets its water supply requirements through surface and sub-surface sources. The approximate quantity of water supplied to the Vijayawada city is about 216 MLD to 12,44,000 (projected population for the year 2017) citizens. Last available data on service level indicators is presented in Table 9 below.

Table 9: Details of Existing Water Supply System

Description	Details
Source	Krishna river (including infiltration wells) 273 MLD
Headworks	273 MLD
Installed capacities of WTPs (MLD)	227 MLD
Installed capacity of Infiltration wells	46 MLD
Net Supply (MLD)	216 MLD
Water supply frequency	(Total 2 to 4 hrs.) Twice every day

Source: APUIAML

Vijayawada has 3.3 lakh households, according to estimations for 2017. Presently, there are around 1.2 lakh house service water connections. Among the 1.2 lakh connections, around 1.08 lakh (93 percent) are unmetered; water tariff for them is charged on a flat rate base calculated as per the half yearly property tax. Additionally, approximately 5,700 of the 1.2 lakh connections have been given to group housing projects and multi-storied apartments. It is estimated that 61 percent of all households in Vijayawada have piped water connection. The per capita water availability/ consumption of 135 Lpcd (Liters per Capita per Day) is assumed based on the HPEC Report (ICRIER, 2011).

Literature Review

With rapid increase in urban population and continuing expansion of city limits, it has become increasingly challenging to deliver water and sanitation services in Indian cities. It has been 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 bn) over the 2007-2020 period. (World Bank, 2011).

Continuous piped water supply can offer significant economic and financial gains through water tariff revenues. A meta study on willingness to pay for improved water services for 41 different countries 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 Houtiven, Pattanayak, Usmani, Yang, 2017). Besides, the intervention to provide 24x7 continuous water supply helps in reducing contamination of water flowing through the pipelines, even if there are breaks in the pipes and joints. Lack of constant pressure of water in the lines leads to the possibility of street run-off, drainage water, and raw sewage from adjacent sewer lines and leaky septic tanks getting sucked into the main lines (ICRIER, 2011).

There are multiple potential benefits associated with improved water and sanitation services, ranging from the easily identifiable and quantifiable to the intangible and difficult to measure. But even under pessimistic scenarios the potential economic benefits generally outweighed the costs (Hutton & Haller, 2004).

Additionally, there is ample evidence to show there are positive health impacts to having access to piped water and sanitation. Results of meta studies show inadequate water and sanitation services are associated with considerable risks of waterborne born and diarrheal diseases and that there are notable differences in illness reduction depending on the type of water and sanitation intervention implemented (Pruss-Usten et al., 2015, following Wolf et. al 2014). WHO estimated the disease burden from lack of water, sanitation, and hygiene to contribute to 4.0% of all deaths and 5.7% of the total disease burden (in DALYs) occurring worldwide (Prüss, Kay, Fewtrell, & Bartram, 2004).

The economic benefits of piped water supply are well-documented in multiple studies. A Cost Benefit analysis 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, investing every US$1 to meet the combined water supply and sanitation lead to a return of at least US$5 (Hutton, Holler and Bartram, 2007). OECD, estimates that that Millennium Development Goals (MDGs) for water and sanitation would generate benefits amounting to US$ 84 billion per year with a benefit to cost ratio of 7 to 1 (OECD, 2011).

Hence, it can be concluded that there are many and diverse potential benefits associated with improved water and sanitation. In order to capture the economic benefits, a social cost-benefit analysis is needed, and such analysis includes both cost savings as well as additional economic benefits resulting from the interventions, compared with a do-nothing scenario. (Sugden & Williams, 1978; Hutton and Haller, 2004).

Data

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

Project Life:

The project period of the three urban interventions has been considered to be 25 years with investment being made in 2019. The benefits occur over the lifetime of the interventions.

Capex and Opex:

The capex and opex data has been sourced from the high-powered expert committee Report by the Ministry of Urban Development (ICRIER, 2011) and escalated to 2017 prices using the inflation data for the respective years (WPI for Capex and CPI for Opex).

Per capita investment cost (PCIC) or capex for water supply is categorized into four: water production, 24x7 distribution extension, 24x7 replacement/ upgrade and opex sourced from HPEC report (HPEC, 2010). In line with the HPEC estimate, the cost of land acquisition is not considered in the analysis, considering the government will provide land at almost nil value for such interventions that have wider social and economic benefits.

Depreciation of Assets and Salvage Value:

The salvage value of assets at the end of the project life has been included. A depreciation rate of 3 percent has been used based on the guidelines by Ministry of Drinking Water and Sanitation, Government of India (Ministry of Drinking Water and Sanitation, 2013). A reducing balance method been used to estimate the salvage value of the asset at the end of the project life.

Social Costs of Disruption:

The social costs of disruption (such as traffic disruption, inconvenience to public) due to laying of pipelines, in the first year, has been sourced from a study by the National Research Council Canada (Rahman, Vanier and Newton, 2005). The social cost of disruption has been assumed to be at 78 percent of construction cost, considering that conventional methods will be used (e.g. tunneling, trenching) to lay the network.

Summary of key data for piped water supply is presented in Table 10 below.

Table 10: Piped Water Supply: Key Assumptions and Cost Basis

Benefits	Assumption	Source
Replacement of existing connections	80 percent	(HPEC, 2010)
Per Capita capex for incremental population	100 percent	Own assumption
Per day water supply	135 Lpcd	(HPEC, 2010)
Minimum water needed for survival	20 Lpcd	(WHO, 2010)
Yearly escalation of tariff till 2017	7 percent	(Vijayawada Municipality, 2013)
Yearly escalation of tariff from 2018	Andhra Pradesh, Real Growth Rate	CCC
Capex per capita (Water Production) (2)	Rs. 1,350	(HPEC, 2010) (1)
Per Capita Capex for incremental population (2)	Rs. 2,654	(HPEC, 2010) (1)
Capex per capita (24x7 Replacement/ Upgradation) (2)	Rs. 2,440	(HPEC, 2010) (1)
Opex	Rs. 613	(HPEC, 2010)
Social Cost (First Year)	78 percent	(Rahman, Vanier, and Newton, 2005)
Water Tariff : Charges Residential Metered Connection (18-25KL)(2)	Rs. 408 / month	(Vijayawada Municipality, 2013)
Service Connection Charges (residential houses)(2)	Rs. 5,500	(Vijayawada Municipality, 2013)
Meter Reading Charges(2)	Rs 20 / month	(Vijayawada Municipality, 2013)
Service Connection Charges (multi storied houses)(2)	Rs. 1,55,000	(Vijayawada Municipality, 2013)
Depreciation rate	3 percent	(Ministry of Drinking Water and Sanitation, 2013)
Willingness to pay (3)	Rs 4, 513/ annum	(Van Houtiven, Pattanayak, Usmani, Yang, 2017)

Note: (1) Adjusted for Industrial Water production for IB class cities (2) 2009 prices (3) 2008 prices

Calculation of Costs and Benefits

Estimation of Cost Elements:

- Total capital investment and opex requirement are estimated based on the per capita estimates in the HPEC report. All costs are at 2017 price levels, based on appropriate adjustments.
- To estimate the value of capex and opex from 2018 onwards, the items are divided into two components: labor and capital. A labor component of 20 percent and 50 percent each are considered for capex and opex, respectively. The labor component for both capex and opex have increased at the real wage growth rate for Andhra Pradesh, provided by CCC. However, the capital component is considered constant over time.
- While the capex for water production has been assumed on the entire population, the distribution extension is towards the population not covered by piped water supply and it is assumed that 80 percent of existing connections shall be replaced. Capex on the incremental population is considered to be 100 percent of original distribution extension capex, as it is assumed that pipelines will be laid in the city's peripheral areas, where new houses are expected to come up.
- Social cost of disruption is also considered, as the construction and upgradation work will result in traffic disruptions and inconvenience to public.

Estimation of Benefit Elements:

- To estimate the cost of installation and maintenance of bore water pumps in the absence of piped water supply, a conservative approach has been used and electric consumption of bore well pump is estimated using the 'minimum water needed for survival as per the World Health Organization (WHO, 2013). Additionally, it has been assumed that 50 percent of the borewells in Vijayawada supply improved water or water quality at par with piped water. The water quality of the rest 50 percent is considered to be unimproved.
- The present water tariffs of VMC are used to estimate the tariff of 24x7 piped water supply. All water-related tariffs have been escalated at a y-o-y rate of 7 percent from 2013 - the last available tariff schedule, till 2017 - as per the revised tariff for water

supply by the Vijayawada Municipality (Vijayawada Municipality, 2013). Post that, the service charges are increased as per real income growth of Andhra Pradesh, reflecting increased willingness to pay.

- The research has assumed that there are 15 households per multi-storied house. It is worth mentioning that the research has observed minimal impact on the final BCR even after changing the number of households per multi-storied house to 20.
- It has been assumed that the multi-storied building will grow at 20 percent of the growth rate of normal household growth rate. The rationale is that as the city expands, the cost of land and property will rise, which will lead to increased demand for social housing. However, the authors observe that changing the growth rate of multi-storied buildings as percent of household growth rate to 10 percent or 30 percent will have negligible impact on the final BCR.

Water Revenue Estimation:

The existing water revenue earned by the VMC is adjusted to the total water revenue to estimate the net water revenue attributable to the intervention. The projected water revenue from existing connections is increased at per real income growth of Andhra Pradesh, as provided by CCC.

Consumer surplus:

The research found that the willingness to pay (WTP) for piped water supply is much higher than the existing water tariff. Hence, consumer surplus i.e. WTP over existing water tariff has been considered as a benefit accrued by private citizens. Willingness to pay for improved water access in terms of US$ for Andhra Pradesh is sourced from the 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 at the real income growth of Andhra Pradesh. Finally, the water revenue for VMC (due to the piped water supply intervention) is subtracted from the corresponding year's willingness to pay number to arrive at the consumer surplus value.

DALY

Positive health impacts from clean drinking water has been estimated based on the burden of disease data, relevant to water and sanitation, sourced from meta studies to assess the health impact of drinking water and global burden of disease data relevant to Andhra Pradesh. The data has been 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 years (DALYs) at different discount rates. Additionally, necessary adjustments were made to calculate health benefits, considering that 50 percent of bore wells in the state offer unimproved water.

Assessment of Quality of Evidence

This research on piped water supply intervention attempted to capture high quality evidence, which are highly or moderately consistent and contextually-relevant. Still, there are some benefits that may not have been captured in this study due to the absence of empirical evidence. The quality of evidence for capex and opex information, sourced from the HPEC report, and water tariff information, sourced from VMC tariff schedule, are very strong. DALY has also calculated based on the most commonly-accepted approach in health economics and results from meta studies have been used to calculate the health benefit. However, the quality of evidence for social cost of disruption is medium, considering the number is sourced from an international study, in the absence of region-specific research.

Sensitivity Analysis

All projects are exposed to various types of risks during the life of the project. Specially, large infrastructure projects are exposed to high risks practically during the development phase. (McKinsey, 2013). Cost overruns, delays, failed procurement and/or unavailability of private financing are common. Hence, a sensitivity analysis has been conducted to assess the potential impact of uncertain variables. This sensitivity analysis will provide policymakers with an idea of the degree of uncertainty surrounding the interventions and the relative degree of importance (Alam, 2016).

A number of assumptions have been made for each separate cost and benefit assessment. A detailed analysis has been conducted to identify the variables (both cost and benefits) with high level of uncertainty. Additionally, a number of assumptions are made for each separate cost and benefit assessment. Some may have a significant effect on the results, while others will make only a minor difference. Finally, in order to see the effect on the net results, sensitivity analysis has been performed on three factors:

1. Increase in capex by 10 percent and 30 percent
2. Under recovery in revenues by 10 percent and 25 percent
3. Various levels of Relative Risk of Piped water

It is evident that upsides in capex and opex have lesser impact on the final BCR. Similarly, under recovery in revenue has limited significance on the ratio. However, falling relative risk (i.e. quality improvement of high-quality piped water over basic piped water and unimproved sources on diarrhea) has potential to make the project more attractive. Additionally, any upside or downside in social cost of disruption can significantly impact the final ratio. However, considering the low coverage area of piped water supply in Vijayawada, the intervention remains attractive even after considering all odds (i.e. under recovery in revenue and cost overrun) together.

The summary of the sensitivity analysis is presented in table 11 below

Table 11: Sensitivity Analysis: Piped Water Supply

Scenarios	NPV at 5 percent (in Rs. bn)	BCR at 5 percent
Relative Risk of Piped water (0.77) (Base Case) (RR of basic piped water over unimproved sources on diarrhoea)	128.2	3.3
Relative Risk of Piped water (0.27) (RR of high quality piped water over basic piped water on diarrhoea)	170.9	4.1
Relative Risk of Piped water (0.21) (RR high quality piped water over unimproved sources on diarrhoea)	182.4	4.3
Social cost increase by 50 percent	125.8	3.2
Social cost decrease by 50 percent	130.7	3.5

Note: Relative Risk from Pruss-Usten et al 2015, following Wolf et al 2014

Intervention 2: 100 percent sewage and waste water treatment for all households

Description of intervention

The sewerage intervention has been designed to ensure underground sewerage network across the city and 100 percent collection and treatment of the waste water.

Current Status: Vijayawada has a decentralized sewerage system that is divided into four sewerage zones. The city has six sewerage treatment plants with a total treatment capacity of 120 MLD. The main sewerage network covers about 80 percent of the city. However, 36 percent of the households have access to sewerage connections and 35 percent of the sewage generated by the city is treated. Hence, sewerage coverage for the rest 64 percent of the households needs to be done along with upstream and downstream investments. In the absence of comprehensive master plan of entire existing underground drainage scheme, the city faces a problem with lack of sewer connections and flooding of sewers in various areas of the city. The latest available data on service level indicators can be referred in Table 12 below.

Table 12: Current status of sewerage network

Zone No	STP Name	Sewerage Network Length (KM)	Sewerage Network Gap (KM)
1	Jakkampudi	270	35
2	Ajit Singh Naga	333	52
3	Auto Nagar	95	17
4	Ramlingeswara Nagar	140	12

Literature Review

As many as 2.4 billion people live without access to a basic sanitation service globally; almost 900 million of these people practice open defecation (World Bank, 2017). Poor sanitation costs India 6.4 percent of its GDP every year and the losses are mainly driven by premature deaths, increasing cost of healthcare, time and productivity lost seeking treatment, and time and productivity lost finding access to sanitation facilities. The HPEC report has also highlighted that the current service levels in sewerage in India are relatively low in comparison to the needs of urban households (HPEC, 2010). Approximately 70 percent of all urban sewage is left untreated. As per the draft policy on National Urban Sludge and Septage Management, 33 percent urban households are yet to be connected to the municipal sewer system (MoUHA, 2017). It is estimated that about 29 percent of India's population uses septic tanks (USAID, 2010). The investment requirement for urban sanitation during 2013-2032 has been estimated to be at Rs. 8,440 billion, which includes capital, O&M and support costs (World Bank, 2016).

A cost benefit study on water and sanitation in developing countries shows that the return on a US$1 investment has been in the range of US$5 to US$46, depending on the intervention. For the least-developed regions, every US$1 invested to meet water supply and sanitation needs leads to a return of at least US$5 (Hutton, Haller and Bartram, 2007). The OECD estimates that Millennium Development Goals (MDGs) for water and sanitation would generate benefits of US$ 84 billion per year with a benefit to cost ratio of 7 to 1 (OECD, 2011).

Additionally, there is ample evidence to show there are positive health impacts of having access to piped water and sanitation. Results from meta studies show inadequate water and sanitation services are associated with considerable risks of waterborne and diarrheal diseases and that there are notable differences in illness reduction, depending on the type of improved water and sanitation implemented (Pruss-Usten et al 2015, following Wolf et al 2014). Improved sanitation can result in reduction in premature death and would yield an annual economic value of US$1.7 billion (WHO, 2008). Improved sanitation and sewerage can boost tourism revenues through better health, safety, and aesthetic considerations that profoundly influence people's choice of a holiday destination.

According to a study on water and sanitation services in Indonesia, the benefit-cost ratio for sewerage range between 1.7 and 1.1. For septic tanks with collection & treatment the ratio range from 1.9 to 1.4. For wet pit latrine, the ratio ranges from 3.2 to 2.4 (WSP, 2011).

This research uses the cost benefit analysis (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 used 'total economic value' for estimating different types of benefits.

Data

Data on benefits and costs of interventions have been sourced from secondary sources – published papers and in some cases, unpublished documents. A systematic review of literature has been undertaken from research papers, reports, and other documents relating to the key domains of this research and with particular reference to Vijayawada. Further, most data points have been validated in discussion with the sectoral experts. Additionally, a site visit was conducted in the third week of January 2018 to validate the data and secondary information.

The summary of the assumptions relevant to sewerage is presented in Table 13 below.

Table 13: Sewerage: Key assumptions and cost basis

Cost	Assumption	Source
Population with access sewerage network	36 percent	(APUFIDC, 2017)
Percent Sewage Treated	35 percent	(Vijayawada Municipality, 2013)
Sewerage network (bulk) coverage	80 percent	(APUFIDC, 2017)
Capex per capita (network)	Rs. 2,573	(HPEC, 2010)
Capex per capita (treatment)	Rs. 1,268	(HPEC, 2010)
Opex per capita	Rs. 373	(HPEC, 2010)
Per Capita Capex for incremental population	100 percent	Assumption
Social cost (First year)	78 percent of capex	(Rahman, Vanier and Newton, 2005)
Benefits	**Assumption**	**Source**
Avoided capex towards river cleaning	Rs. 5 lakh per MLD	CSE
Avoided opex per year	Rs. 3 lakh	CSE
Yearly escalation of tariff (till 2017)	7 percent	(Vijayawada Municipality, 2013)
Yearly escalation of tariff (post 2017)	Real growth rate of Andhra Pradesh	CCC

Calculation of Costs and Benefits

Estimation of Benefit Elements

- The assumptions for the labor and capital components in capex and opex are same as that for Intervention 1. Capex data for network and treatment have been sourced from the HPEC report and brought to 2107 price levels based on appropriate adjustments. However, for calculation purposes, three types of capex have been considered in the study: capex for main sewerage network, capex for last-mile sewerage network connection and sewerage treatment capex. Capex network for last-mile connection (for families under network coverage but don't have sewerage connections) is considered at 50 percent of original network capex, as that authors believe the cost for installing last-mile connectivity will be significantly lower than that for installing sewerage connectivity in the new areas.
- The incremental capex (to serve incremental population) from the second year is considered to be 100 percent of the original network capex, as it is assumed that laying of new sewerage lines will be in the peripheral areas.
- Similar to piped water supply, the cost of land acquisition is not considered in the analysis, considering the government will provide land at almost nil value for such interventions that have wider social and economic benefits.
- Similar to piped water supply, social cost of disruption has also been considered as a cost item in the first year.

Estimation of Benefit Elements

- Sewerage revenue is calculated based on the tariff schedule provided by VMC and is escalated at 7 percent annually from 2013 - the last available tariff schedule, till 2017. Post 2017, the tariff has increased as per real income growth of Andhra Pradesh, as provided by CCC. Salvage value of the asset at the end of the project life is also considered as direct benefit. A depreciation rate of 4% on reducing balance has been considered to calculate the salvage value.
- In order to estimate the requirement for new sewerage connections, it has been assumed that each household has a single sewerage connection or WC (water closet). In the absence of actual break-up of house sizes in the city, the cost of installation for

sewerage connection is calculated considering that 75 percent of the houses in Vijayawada have an area of 90 sq. mt (~960 sq. ft.).

- In order to estimate the sewerage revenue due to the intervention, the existing income on drainage charges by the VMC is adjusted to the total sewerage revenue to estimate the net revenue attributable to the intervention. Future drainage charges from existing connections are estimated using the same growth rate as the growth in real income in Andhra Pradesh, as provided by CCC.
- The avoided cost for river cleaning is an indirect benefit. It is assumed that Rs. 5 lakh per MLD would be required to clean the river, along with Rs. 3 lakh in annual maintenance.
- A similar methodology as was used for the piped water intervention is used here to calculate the value of (disability adjusted life year) DALYs avoided at different discount rates and considered as indirect benefit.

Assessment of Quality of Evidence

This research on the sewerage intervention has attempted to capture high-quality evidence; however, there are some benefits that may not have been captured in this study due to the absence of empirical evidence. The quality of evidence for capex and opex information, and sewerage tariff information, is strong as the numbers have been sourced from the HPEC report and VMC tariff schedule, respectively. Similarly, results from the meta study were used to calculate the health benefits, which are of high quality. The quality of evidence for river cleaning cost was strong, considering the information has been sourced from Centre for Science and Environment.

Sensitivity Analysis

The purpose of sensitivity analysis is to analyze different outcomes by varying levels of cost and benefit estimates. Similar to the piped water supply intervention, two parameters have been used to select the variables for sensitivity analysis.

- Variables with high level of uncertainty
- Impact of the variable on the final result

A number of assumptions were made for each separate cost and benefit assessment. A detailed analysis has been conducted to identify the variables (both cost and benefits) with high level of uncertainty. Additionally, a number of assumptions are made for each separate cost and benefit assessment. Some may have a significant effect on the results, while others will make only a minor difference. Finally, in order to see the effect on the net results a sensitivity analysis has been performed on the four factors:

- Increase in capex by 10 percent and 30 percent
- Under recovery in revenues by 10 percent and 25 percent
- Zero Tariff escalation
- Various levels of relative risk for sewerage

The authors' analysis has revealed that while capex doesn't have significant impact, falling relative risk of health for sewerage (i.e. overall relative risk for improved over unimproved sanitation on diarrhea) has the potential to make the project more attractive. However, low coverage area and tariff make the overall BCR for the sewerage intervention the least attractive among the three interventions. The summary of the sensitivity analysis is presented in Table 14

Table 14: Sensitivity Analysis: Sewerage

Scenarios	NPV at 5 percent (in Rs. bn)	BCR at 5 percent
Relative Risk of Sewerage (0.72) (Base Case)	4.4	1.1
Relative Risk of Sewerage (0.59)	20.5	1.6
Relative Risk of Sewerage (0.88)	-13.2	0.6

RR from Pruss-Usten et al 2015, following Wolf et al 2014

Intervention 3: 100 percent Solid Waste Management

Overview: This intervention targets 100 percent of management of solid waste in terms of collection, transportation, and treatment for Vijayawada, as per Municipal Solid Waste 2000 Rules.

Current Status: The estimated waste generation in Vijayawada is about 550 tons per day from all sources. The waste generation rate is about 450 grams-per-capita-per-day, which is similar to other comparable cities of India.

Primary and Secondary Collection

The VMC claims a collection efficiency of 100 percent. Currently, 536 tricycles and 656 wheel barrows have been deployed on a daily basis to collect waste across the city. Additionally, the VMC has 60 collection vehicles (details of fleets in Table 15) and 410 dumper bins for secondary collection.

Table 15: Details of Secondary MSW Collection

No. of Dumper Bins	410
Road Length	1250 km
Average Dumper Bin Capacity	1.1 ton
No. of dumper placers	15
No. of small tippers	8
No of hook loaders	2
No. of big tippers	9
No. of autos	26

Source: VMC

Waste Processing and Treatment:

The Vijayawada municipal corporation has commissioned three processing units for processing of municipal waste (Tata Consulting Engineers Limited, 2016). However, none of them is presently operational.

Compost plant: The compost plant, developed by Excel Industries Ltd. in Ajit Singh Nagar has a plant capacity of 125 MT/day. It started the production of compost in 1996. However, the plant was shut down in 2016 due to various reasons.

Bio-methanation plant: This plant was constructed by Mailhem Engineers Pvt. Ltd. with a capacity of 20 MT/day. Situated near Ajit Singh Nagar, the plant was meant to process dedicated waste from markets and slaughter houses. Though commissioned in 2004, it was operational only until 2009. The plant was shut down due to various O&M problems.

Disposal:

There is no engineered landfill site in the Vijayawada urban agglomeration. (Vijayawada Municipal Corporation, n.d.). Most of the collected solid waste is dumped at Jakkam Pudi, an open site close to forest land about 10 km away from the city. Ajit Singh Nagar is the oldest dumping ground in the city. Recently, the government has come up with multiple proposals to clear and process garbage. This included the signing of an MoU with Zigma Global Environ Solutions to clear the garbage dump at Ajit Singh Nagar (Vijayawada Commissioning, 2018). But till date, most of the initiatives have remained only on paper.

Literature Review

The management and disposal of solid waste generated in Indian cities call for immediate attention, although the generation of solid waste is at much lower rates than in most countries. Unscientific practices in processing and disposing solid waste pose serious environmental hazards (HPEC, 2010). More than 70 percent cities face inefficient collection and inadequate transportation and disposal services owing to the presence of very few sanitary landfills. As a result, biomedical waste, slaughterhouse waste and industrial waste often reach the MSW dumpsites, posing serious hazards to sanitary workers and waste pickers (Ganesan, 2018). The cost of providing landfill facilities to meet requirements of the MSW rules over the next ten years is estimated to be about Rs. 100 billion – approximately US$2 billion (World Bank, 2006).

Improved solid waste management can result in substantial enhancement of the city's cleanliness. It can also offer new revenue streams for the municipality through sales of recyclables or recovery of resources and/or energy, thus increasing the value chain of waste (Christian, Ephraim, & Zurbrügg, 2014). A cost benefit analysis for improved SWM for Dhaka shows a calculated BCR of 5.67. The analysis has identified selling of compost, biogas and recyclable products, and users' fees as direct benefits. Indirect benefits were emission reductions and avoided landfill costs (Alam, 2011).

Additionally, there are multiple studies that sought to examine the willingness to pay for improved solid waste management. A study in Lahore suggests that despite belonging to the middle-income class, there is a willingness to pay US$ 4.8 per month for improved solid waste management (Akthar, Ahamad and Shahraz, 2017). A similar study conducted in

Kolkata shows citizens are willing to pay Rs. 750 per month for improved solid waste management services. Another study on developing countries shows respondents are willing to pay US$1.98 per month for improved residential waste management services. Further, improved solid waste management can also result in considerable savings on landfill closure costs. As per the dumpsite rehabilitation manual published by the Center for Environment Studies, the typical cost to close a landfill can be Rs. 12-15 million per ha (CSE, n.d.).

Data

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

The summary of key general assumptions and cost basis of MSW is presented in Table 16 below

Table 16 MSW: Key Assumptions and Cost Basis

Benefit	Assumption	Source
MSW generation in Vijayawada City	550 TPD	Vijayawada Municipality
Door to door collection	100 percent	Vijayawada Municipality
Compostable waste	25 percent	Vijayawada Municipality
Moisture loss in compostable waste	30 percent	(IEISL)
RDF producing waste	16 percent	Vijayawada Municipality
Landfill area required	15 acre per lakh population	(Mahadevia, n.d.)
Land require for waste processing	2 hectares per 100 MT	Concession agreement
Average land price in Vijayawada (per hectare)	Rs. 19.37 crore	Registration and stamp department
Cost	**Value**	**Source**
Capex per capita (C&T)	Rs. 134	(HPEC, 2010)
Capex per capita (Treatment)	Rs. 168	(HPEC, 2010)
Capex per capita (Disposal)	Rs. 91	(HPEC, 2010)
Opex per capita	Rs. 189	(HPEC, 2010)

Calculation of Costs and Benefits

Estimation of Cost Elements

- Total capital investment and opex requirement are derived by multiplying the per capita investment cost (PCIC) with the city population. As per the HPEC report, three type of capex are considered for improved SWM services: capex on collection and treatment, capex on treatment and capex on disposal. Additionally, as per the income tax guideline, a life of 8 years has been ascribed to waste collection vehicles, and subsequent replacement capex has been considered in the study. A depreciation rate of 12 percent is used for solid waste collection and transportation vehicles, as per the income tax guideline. For treatment and disposal, a deprecation rate of 7 percent been used, as per the common industry practice. A reducing balance method been used to estimate the salvage value of the asset at the end of project life.

- In line with the HPEC estimates, the cost of land acquisition is not considered in the analysis, considering that the government will provide land at almost nil value for such interventions that have wider economic and social benefits.

- Lifestyle changes, especially in urban areas, are leading to increased use of packaging material and resultant per capita waste generation. The authors have assumed the same trend will continue in the coming years and per capita solid waste generation will increase at an annual growth rate of 1.3 percent, in line with the HPEC estimates (ICRIER, 2011).

Estimation of Benefit Elements

- Revenue from selling compost and RDF is considered as direct benefit. Considering the experience of compost manufacturers for the offtake of compost by fertilizer companies, it has been assumed that about half the compost manufactured in Vijayawada will be sold at a government-approved compost price of Rs. 2,500 per ton. Additionally, the selling price of RDF (Refuse Derived Fuel) is assumed to be Rs. 300 per ton (excluding transport cost), considering the experience of IL&FS Environmental Infrastructure & Services (IEISL), a leading waste management company in India.

- The salvage value of the assets is considered as a direct benefit and is calculated based on the written down value of the assets at the end the intervention, i.e. in 2043. Avoided cost for closure of landfill was calculated as per the dumpsite rehabilitation manual published by the Center for Environment Studies, which estimated the typical cost of landfill closure to be at Rs. 15 million per ha. Additionally, it has been assumed that the average life of a landfill is 25 years (Mahadevia, n.d.); as a result, the landfill would need closure in 2043.

- Considering the waste characteristics of Vijayawada, it has been assumed that after processing, 25 percent of the remainder (mainly inert) would go to landfills (Tata Consulting Engineers Limited, 2016). In other words, the intervention would lead to a reduction in the gross landfill area requirement by approximately 75 percent. Waste processing plants would be set up for manufacturing of compost and RDF, for which land requirement is estimated based on industry norms. The land required for landfill in Vijayawada has been estimated to be 60 percent lower, i.e. approximately 45 hectare lower compared to counterfactual. The capital value of these 45 hectares would be available for alternative uses. The average prices of the bottom 50 percent residential and commercial land values have been considered to calculate the average land value in Vijayawada, as the authors believe that new landfills would come up in the city's peripheral areas, where the cost of land would be significantly lower than in the prime areas of Vijayawada.

- The willingness to pay for SWM has been considered as a benefit and is estimated from various India-specific WTP studies on SWM. The WTP case studies considered for this analysis are conducted in Cachar district of Assam (Roy and Deb, 2013), Palakkad district of Kerala (Mahima and Thomas, 2013), Pune city (Khadke and Sovani, 2018) and Kolkata (Hazra, Goel and Maitra, 2013).

Assessment of Quality of Evidence

The quality of evidence for capex and opex information, sourced from HPEC report, and water tariff information, sourced from VMC tariff schedule, is considered strong. Similarly, results from the meta study have been used to calculate the health benefit, which are of high quality. The quality of evidence for compost and RDF offtake are medium, considering the research used IEISL's experience in the absence of published research. Additionally, the quality of evidence for the willingness to pay for improved MSW was medium, as they have been sourced from multiple India-specific reports, in the absence of any meta-analysis.

Sensitivity Analysis

This section analyzes different outcomes by varying levels of cost and benefit estimates. It helps policy makers to observe how valuations move with changes in key variables and to address them in the most acceptable form of mitigation. Two parameters have been used to select the variables for sensitivity analysis.

- Variables with high level of uncertainty
- Impact of the variable on the final result

The authors' analysis has revealed that while capex doesn't have significant impact, willingness to pay for improved solid waste management has the potential to make the project more attractive. The summary of the sensitivity analysis is presented in Table 17 below

Table 17: Sensitivity Analysis: SWM

Scenarios	NPV at 5 percent (in Rs. bn)	BCR at 5 percent
WTP for improved SWM (Average of the study result) (Base case)	14.9	2.1
WTP for improved SWM (Max of the study result)	27.6	3.1
WTP for improved SWM (Min of the study result)	2.7	1.2

Conclusion

Since Vijayawada is an important city in Andhra Pradesh, any improvement in hygiene and sanitation in the city shall be beneficial for its future growth. This CBA study should be considered as a supporting tool to debate on whether to invest in the urban interventions identified.

Form the study, it is clear that all the three interventions for piped water supply, improved sewerage and waste water treatment, and solid waste management are expected to be economically beneficial interventions with BCRs of 3.3, 1.1 and 2.1, respectively at 5 percent discount rate.

A combination of these three key interventions – 24x7 piped water supply, improved sewerage and waste water treatment, and solid waste management can positively impact habitability and sustainability, thereby making Vijayawada a world-class city. However, the successful implementation of these interventions will require significant management expertise, as well as positive involvement and contribution from stakeholders; including citizens, businesses, state and national government agencies, and NGOs.

Table 18*: Summary BCR Table*

Interventions	Discount	Benefit (in Rs. bn)	Cost (in Rs. bn)	BCR	Quality of Evidence
Intervention 1: 24x7 piped water supply	3%	Rs 249	Rs. 69	3.6	Strong
	5%	Rs. 183	Rs. 55	3.3	
	8%	Rs. 121	Rs. 41	2.9	
Intervention 2: 100 percent sewage and waste water treatment	3%	Rs. 60	Rs. 43	1.4	Strong
	5%	Rs. 38	Rs. 34	1.1	
	8%	Rs. 22	Rs. 25	0.9	
Intervention 3: 100 percent solid waste management	3%	Rs. 40	Rs. 17	2.3	Strong
	5%	Rs. 28	Rs. 13	2.1	
	8%	Rs. 18	Rs. 9	1.9	

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