Linking Tourism, Local Environment and Waste Generation in Indian Himalayan States Using CGE Model: Case-study of Uttarakhand

Working Paper 2

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I. Introduction

The 'Urban Municipal Solid Waste Management Action Plan for State of Uttarakhand' was launched in 2017 with the objective of managing the growing Municipal Solid Waste (MSW) in the state of Uttarakhand. According to the 2014-15 Annual Report of Central Pollution Control Board (CPCB), around 3000 metric tons solid waste is generated in the state every day. The total MSW generation is estimated to further increase to 7500 metric tons per day by 2041, resulting in an annual generation of approximately 2.7 million tons of MSW. In order to tackle this, the Action Plan has identified existing gaps between the state's MSW generation and scientific disposal, along with the key strategies required to bridge it by 2021. A total of 58 projects have been planned under the same in three phases, covering almost every ULB in Uttarakhand. It seeks to assist these ULBs in selecting the right technologies for waste collection, segregation, transportation, storage, processing and scientific disposal in compliance with provisions laid-out under the nation-wide Solid Waste Management (SWM) Rules, 2016. It has also estimated the project costs, accruing to the ULBs over the next 10 years and suggested different ways to ensure that the projects can be financially sustained, based on the "Polluters to Pay" principle.

The Action Plan is also a part of the Swachh Uttarakhand vision, which resonates with the larger Swachh Bharat Mission, and seeks to make the state of Uttarakhand clean, hygienic and litter free. It further aspires to manage the state's solid waste scientifically and in sustainably, while ensuring that zero waste is dumped in the landfills by 2040. The State of Uttarakhand has been making conscious efforts towards effectively and sustainably managing its solid waste since the commencement of Jawaharlal Nehru National Urban Renewal Mission (JNNURM) in 2005-06. Initially, only three SWM projects were introduced in Dehradun, Nainital and Haridwar as a part of the said scheme during 2007, with an outlay of INR50.6 Crore. While the need for an integrated SWM Action Plan for all the Urban Local Bodies (ULBs) in Uttarakhand was always felt, experience gained in managing these projects compelled the policy makers to rethink the management of solid waste in hilly areas.

The Swachh Bharat Mission was launched by the Government of India in October 2014 to ensure hygiene in the country through the scientific disposal and management of MSW. Soon after, in 2016, the Indian government , through the Ministry of Environment and Forest enacted the SWM Rules, 2016 for the "segregation, collection, storage, transportation, processing and disposal of municipal wastes"[1]. In accordance with this, Uttarakhand also released its State Level Action Plan for the years 2017-21.

[1] Available at: https://udd.uk.gov.in/files/20170825_SWM_action_plan__revised_final_draft_with_comments_sent_to_state-_August_II.pdf

The Action Plan focuses on various challenges and constraints faced by the state's ULBs and provides measurable, practical, reliable and sustainable solutions, by undertaking supportive studies and analysis. It has highlighted that the state is already experiencing a paucity of usable land, since only approximately 35% of state's total land is suitable for the planning and development of industries and other infrastructure. Therefore, the functioning of ULBs is constrained due to the unavailability of land. Most of the ULBs have also expressed that the land available is insufficient for their 30-year waste management requirements. Further, the plan recognizes various resource challenges as faced by the ULBs such as the lack of competent staff, expertise and experience; inadequate infrastructure, such as transfer stations, storage community bins, sanitary landfills and waste processing facility; lack of GIS mapping of waste, collection vehicles and the route plan; absence of a 24x7 complaint redressal cell; and insufficient monitoring mechanisms, etc. The plan has suggested that comprehensive strategies need to be formulated to manage the different aspects of scientific waste management with the involvement of the private sector, wherever necessary.

About the study

The present study carried out under the aegis of NMHS intends to provide guidance on state-level policies for the aforementioned better management of MSW in Uttarakhand. Additionally, as the rise in tourism in the state has led the state government to allocate more resources to tourism-based schemes and policies, we try to focus on tourism related increased MSW generation as well. NMHS or "National Mission on Himalayan Studies (NMHS)" a central sector grant-in-aid scheme with a vision ''to support the sustenance and enhancement of the ecological, natural, cultural and socio-economic capital assets and values of the Indian Himalayan Region (IHR)''[2].

The objectives of the study are as follows:

- Understanding the linkages between tourism, local environment and waste generation at state level.
- Finding the ideal policy instruments for effective waste management in the state.

The research work conducted as part of the study is published as a two-part working paper series. The previous working paper titled *"Linking Tourism, Local Environment and Waste Generation in Indian Himalayan States: Constructing a Tourism SAM for Uttarakhand 2015-16",* discussed the construction of a tourism I-O model and SAM for the state of Uttarakhand. The paper also presented results from the Tourism Multiplier Analysis as well as commented on the tourism policy of the state. The current working paper utilizes this aforementioned SAM

[2] https://nmhs.org.in/pdf/publication/Mission_Documents/MIssion_Document.pdf

to prepare a working CGE model for Uttarakhand and links it with a waste model of the state. Waste data collection, existing technologies as well as its future possibilities are discussed as a part of this paper.

This working paper is organized in the following manner: section II focuses on the existing waste management scenario in India and Uttarakhand. Section III provides a brief background of various CGE models. Furthermore, section IV details out the methodology adopted in this study and section V provides the results from linking the CGE model and the waste model . A detailed discussion of the results obtained is presented in section V. Lastly the conclusion and areas of future work have been described in section VI.

II. Waste Management in India and Uttarakhand

Waste is a perennial issue and its management continues to pose a challenge for various countries. As economies develop and populations grow, the amount of waste generated also increases. Countries are faced with the grappling challenge to mobilize sufficient funds and reduce the volumes of waste generated. The World Bank report, *"What a Waste 2.0"* has mentioned that around 2.01 billion metric tons of annual MSW was generated worldwide in 2016. The high-income economies accounted for the largest share of 34%, followed by the upper-middle income countries (32%), lower-middle income countries (29%) and low-income countries at only 5% of the total waste generation. The study also highlighted that only 13.5% of the total waste is recycled and a mere 5.5% goes for composting. The World Bank has also projected that the total annual waste is expected to increase to 2.59 billion tonnes by 2030 and 3.4 billion tons by 2050 (Kaza, et al., 2018). It has further pointed out the need for greater reforms in waste management, arguing that if sufficient steps are not taken, the worldwide emissions of CO_2-equivalent Greenhouse Gases (GHGs) are poised to increase to 2.6 billion tonnes by 2050, a significant rise from 1.6 billion tonnes in 2016.

India is amongst the fastest developing countries in the world and home to the second highest population. According to the 2011 Census data, India's population stood at 1210.2 million, living in 7,935 towns. Around 31% of the total population was residing in the urban areas (377 million), while remaining 69% belonged to the rural areas (833 million). The decadal growth rate for India's population was observed at 17.6% while the growth rates of urban and rural populations were 31.8% and 12.18%, respectively[3]. The total number of towns in the country also increased over the decade from 5,161 in 2001 to 7,935 in 2011.

[3] Available at: https://censusindia.gov.in/2011-prov-results/paper2/data_files/india/paper2_1.pdf

This highlights how India has been experiencing a high-paced growth in its population and urbanization. This has also resulted in the humongous generation of MSW. According to the Central Pollution Control Board (CPCB), the urban population generates a rather huge 1,43,449 metric tons of MSW daily (Ministry of Urban Development, 2016). It has been estimated that only approximately 60% of the waste is collected in the country and an even smaller proportion is recycled (Balasubramanian, 2015). According to the Environmental Statistics, 2020 published by the Ministry of Statistics and PI, around 152077 Tonnes per day (TPD) of waste was generated in India during 2018-19. Only 36.7% of this waste was treated, while 33% went into landfills (MOSPI, 2020). Along with this, a change in the composition of waste is being observed as the use of plastics, paper and other inorganic substances has increased. India is also generating greater biodegradable waste as compared to the other wastes. This carries a high recycling potential that has not yet been fully exploited (Balasubramanian, 2018).

In India, ULBs are responsible for the management of MSW, which also forms a core component of their functioning. They are involved with all aspects related to the MSW system, including the planning, implementation and monitoring works (Ministry of Urban Development, 2016). However, most ULBs are unable to manage such large quantities of solid waste owing to the lack of financial capability and adequate infrastructure. Collection of waste at doorsteps, segregation at source, recycling, reuse, waste treatment technologies, availability of land, etc. also pose various challenges (Sharma & Jain, 2019).

The maximum amounts of waste during 2018-19 was generated in Maharashtra, which alone accounted for 15.7% of the total volume, followed by Uttar Pradesh and West Bengal with 11.4% and 9.6% shares, respectively (Annexure Table 1). At the same time, the number of compost plants across these states was considerably low at 307, 2 and 13, respectively, while the number of landfill sites was much higher at 320 in Maharashtra and 82 in Uttar Pradesh. Interestingly, Kerala accounts for only 2.6% of the total waste in India but has set up roughly 721 compost plants, against only one landfill site. Further, the five most populous Indian cities- Mumbai, Delhi, Bengaluru, Chennai and Hyderabad together produced 32400 TPD of waste in 2015-16, which was 41% of the total waste generation in the 45 metro cities. Moreover, the highest increase of 4500 TPD in generated waste over five years from 2010-11 to 2015-16 was observed in Mumbai (Annexure Table 2).

As the amount of MSW generated is rising, studies have also pointed out that the untreated waste is increasingly being dumped at various dumpsites in India. Sharma and Jain (2019) have estimated that around 72% of the total municipal waste collected during 2015 in India was dumped at open sites. A report by the Task Force on Waste to Energy of the Planning Commission in 2014 also highlighted that around 80% of the solid waste collected in urban areas is being dumped indiscriminately in open dump yards, leading to environmental degradation and health concerns (Planning Commission, 2014). The decomposition of these heaps of waste produces various GHGs , contributing to global warming (Ahluwalia & Patel, 2018). Inappropriate waste management is also one of the contributing factors to the environmental pollution, which is the root cause of approximately 25% of diseases suffered by the mankind, according to the World Health Organization (WHO) (TERI, 2014).

However, as awareness around the detrimental effects of the large-scale waste disposal on the environment and human health is growing, efforts have been initiated towards the creation of an effective waste management system. The Municipal Solid Waste (Management and Handling) Rules, 2000 was a pioneer in this direction. It assigned the responsibility of managing the waste collection, segregation, transportation and disposal to all the municipal authorities in the country (Balasubramanian, Economics of solid waste in India, 2015). The Government of India also launched its flagship programme, Swachh Bharat Mission in 2014, which provided a funding push for the solid waste management to all 4041 ULBs. The objective of this programme is to provide basic sanitation infrastructure in every household, including toilets and supporting scientific methods for the collection, procession and disposal of MSW. Other programmes like JNNURM, AMRUT and Smart Cities also continue to provide a strategic direction to waste management in the country (Ahluwalia & Patel, 2018).

Evolution of Municipal Solid Waste Management Rules 2000 and 2016 in India and Uttarakhand

The issue of soaring MSW in India, with disproportionately higher generation in the urban areas, hadn't received much attention from policymakers of the country till the Almitra Patel v. Union of India case came into limelight. Until then, though, there were environmental rules such as Hazardous Wastes (Management and Handling) Rules, 1989 and Biomedical Waste (Management and Handling) Rules 1998 to deal with specific types of wastes, tackling rising MSW through policy-driven actions was disregarded.

The Supreme Court of India ordered a formation of a committee in 1998 to carry out a detailed review of all aspects of urban solid waste management. Following the submission of the report of the committee, the draft Municipal Solid Waste (Management and Handling) Rules 1999 was notified by the Government of India (GoI). Subsequently, the Municipal Solid Waste (Management and Handling) Rules 2000 came into effect[1]. The rules applied to every municipal authority responsible for the collection, segregation, storage, transportation, processing, and disposal of MSW.

Key Highlights of MSW (Management and Handling) Rules 2000

i. The rules emphasized cooperation between central, state, and local governments for the systematic handling of MSW in the country. The municipal authorities, state governments, state pollution control board as well as central pollution control board were imposed responsibility to set up an appropriate infrastructure for waste management.
   - Apart from ensuring proper implementation of the rules, the responsibility of municipal authorities also included infrastructure development for collection, storage, transportation, processing, and disposal of solid wastes.
   - The state department of urban development was entrusted with enforcement of the provision of the rules in the metropolitan cities.
   - The state pollution control board was responsible for monitoring the compliance of the standards of the groundwater, air, quality of the compost as well as incineration standards.
   - The central pollution control board was authorized to co-ordinate with state boards and committees on review of norms and compilation of monitoring data.

ii. The rules also set compliance criteria for the collection of MSW. These involved establishing door-to-door collection from households and formulating ways to collect waste from commercial areas and slums. Avoiding mixing of bio-medical waste and industrial waste with MSW was also included.

iii. The rules stressed on the treatment of waste using the latest technologies to minimize the burden on landfills. Landfilling was restricted to non-biodegradable, inert waste, and other types of waste not suitable for recycling and biological processing.

iv. A special provision for hilly areas was also introduced. The municipal authorities were required to set up an infrastructure for the utilization of biodegradable organic waste. As a solution to the issue of the paucity of land in hilly areas for waste disposal, it was suggested that the inert and non-biodegradable waste could be used in building roads or filling-up of appropriate land on the hills. Further, waste not suitable for road-laying or filling-up was to be disposed of in specially designed landfills.

Uttarakhand, which was formerly a part of the state of Uttar Pradesh, came into existence as the 27th state of India on 9th November 2000. Uttarakhand hosts millions of tourists every year, and since its formation, it has been rapidly urbanizing. The rising economic activity has led to a rise in MSW and, the unscientific treatment of this waste has become a persistent issue in the state. It was after the launch of the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) in 2005 by the GoI, MSW started to gain importance. SWM projects were started in four municipal areas of Uttarakhand which were, Dehradun, Haridwar, Nainital, and Haldwani[2]. The projects focused on building an organized set up for efficient waste management in these four urban areas. Furthermore, it was not until the release of the state's MSW management action plan in 2015, the need for a comprehensive waste management strategy for the hilly areas of the state began to receive the much-needed attention.

The MSW Rules 2000 laid a foundation for efficient dealing of solid waste in the country. However, waste management continued to face hurdles. These included lack of a system of storage of waste at source, landfilling without any environmental impact analysis, and several others. Furthermore, the rules were criticized as they failed to introduce any penalty in case of

As a revision, the new Solid Waste Management Rules was released by GoI in 2016[3]. This new version replaced the old rules and further expanded the ambit of MSW rules by including urban agglomerations, census towns, notified industrial townships, areas under the control of Indian Railways, special economic zones, pilgrimage places, and places of religious and historical importance, and state and central government organizations.

Key Highlights of New MSW (Management and Handling) Rules 2016

i. The rules mandate segregation of waste at source to promote waste to wealth by recovery, reuse and recycle.
ii. In a first, the role of generators is delineated. The generators are responsible for three different streams which, were wet, dry, and domestic hazardous wastes, and handing over of the segregated wastes to the waste collector. They are also mandated to pay user fees to waste collectors and are to be penalized for littering and non-segregation.
iii. The biodegradable waste should be processed, treated, and disposed of through composting or bio-methanation. The Department of Fertilizers, Ministry of Chemical, and Fertilizers should aid the development of the market for city compost.
iv. Setting up waste to energy plants to reduce burden on landfills.
v. Construction of landfills in mountainous areas is not allowed. Land for construction of sanitary landfills would be identified in a plain region, within 25 kilometers. Transfer stations and processing facilities remain to be operational in hilly areas.

These SWM Rules in the country are also accompanied by several ancillary rules which deal with specific types of waste such as E-waste Management Rules 2016, Bio-medical Waste Management Rules 2016, Plastic Waste Management Rules 2016, etc. However, experts argued that much like the older version, the SWM Rules 2016 also neglect the informal sector and are not a step towards the decentralization of solid waste management in the country.

But, in the state of Uttarakhand, the revised rules paved the way for a new era in SWM . Along with the recent announcement of a waste to energy policy by the state government, the state has been actively engaged in decreasing landfills[4]. Following the mandate of source segregation in the new rules, some of the ULBs in the hilly districts are implementing complete source segregation. Some of the private waste management organizations such as KRL Waste Management Ltd., Zero Waste Inc., are working with ULBs in public-private partnership (PPP) mode in waste collection and processing. The sale of end products such as compost, plastic bricks has also opened the door to a constant source of revenues to the ULBs which could be invested in better processing technologies.

The effects of the new rules in India and Uttarakhand are remained to be seen. But, as noted in Uttarakhand's waste management action plan, an effort towards successful waste management is incomplete without active community engagement. This is true for the entire country. Apart from ensuring compliance with SWM rules, the government authorities also have to undertake to dedicate campaigns to educate and spread awareness among the public.

Footnote:

[1] https://www.mpcb.gov.in/sites/default/files/solid-waste/MSWrules200002032020.pdf

[2] https://udd.uk.gov.in/files/20170825_SWM_action_plan__revised_final_draft_with_comments_sent_to_state-_August_II.pdf

[3] http://cpheeo.gov.in/upload/uploadfiles/files/SWM%202016_0.pdf

[4] https://www.newindianexpress.com/good-news/2020/jul/15/uttarakhand-planning-to-generate-5-megawatt-of-electricity-from-waste-2170290.html

Different technologies are also being deployed for the conversion of waste in India, which include "a wide array of thermal, biological, chemical and mechanical technologies capable of converting MSW into useful products like compost and energy such as steam, electricity, natural gas and diesel/ ethanol" (Planning Commission, 2014). The Indian states have also taken various initiatives like setting up of Plastic Collection Centre (PCC) in Indore to reuse their plastic waste for construction of roads and fuel generation; bio-methanation of wet waste to produce biogas and manure and processing of coconut waste to generate fibrous material and sawdust in Bengaluru; and vermicomposting and generation of biogas from kitchen waste in Coimbatore, etc. (NIUA, 2019).

However, the existing programmes, policies and management structure in India have been found to be inadequate in addressing the long-standing challenge of waste management, which is projected to increase to "165 million tonnes by 2031 and 436 million tonnes by 2050" (Planning Commission, 2014). There is a need for a change in the attitude of municipal authorities and citizens towards waste. Serious efforts will be required for the reduction and management of waste, including the recovery of recyclable materials in order to maintain a healthy ecosystem and derive energy from waste (Planning Commission, 2014).

III. Computable General Equilibrium Models

As a part of the study, a computable general equilibrium (CGE) model has been built to estimate the economic effects of different waste management strategies and policies on the state economy. CGE models are widely used to assess the direct and indirect economic impact of a policy intervention or shocks such as tax reforms, trade policies, and income distribution policies.

A CGE model is a system of equations describing an economy and the interactions present in an economy. Apart from being a popular tool in capturing the macroeconomic effects of policy interventions, mainly in the field of trade theory, the models have also started gaining importance in reviewing environmental policies. For instance, in a study by Viguier et al. (2003), the model was applied to assess the impact of the obligation imposed on industrialized countries to abate anthropogenic GHGs by the 1997 Kyoto Protocol. Similarly, Guo et al. (2014), in their study entitled, 'Exploring the impacts of a carbon tax on the Chinese economy using a CGE model with a detailed disaggregation of energy sectors' simulated the effects of a carbon tax on Chinese economy using this model. Further, Siriwardana et al. (2013) studied the impact of a carbon tax on the Australian economy using a CGE model.

In India, the CGE models have been commonly used to evaluate trade policy interventions. Chadha et al. (1997), in a working paper series published by NCAER, discussed the effect of reforms introduced in the trade policies of India in 1991 on the economy. Pradhan and Sahoo (2002) built a CGE model for India to study the impact of international oil price shock on welfare and poverty of different socio-economic household groups. Pohit and Saini (2015) used the CGE model to elucidate the gains from India-Pakistan mutual trade liberalization. As part of the NCAER working paper series, Ojha and Pradhan (2006) published a macro-economic assessment of HIV and AIDS in India using the CGE model. Furthermore, Pal et al. (2015) built the model to analyze the effect of carbon taxes on the economic growth of the country.

CGE models have also been used to assess the impact of policy measures related to waste management on an economy. Sjöström and Östblom (2009) built a CGE model of Sweden to study the policy measures necessary to achieve non-increasing future waste quantities in the country. In another study by Östblom et al. (2010), an integrated bottom-up approach was undertaken by linking a CGE model of Sweden with a systems engineering model of the waste management system. It helped in capturing the effects of waste management-related policy interventions on overall economic welfare.

The CGE model for Uttarakhand economy has been discussed in the following section.

IV. Methodology

To fulfil the project objectives, the research was focused on three components that melded together which were: a) Development of an Input-Output (I-O) model and Social Accounting Matrix (SAM) with tourism and waste as separate sectors, b) Development of a separate waste model to integrate it into the SAM, c) Development of a CGE model for the state economy and d) Formulation of policy recommendations for better waste management in Uttarakhand based on the model results. Component (a) has already been covered as part of a previous working paper 1. The current paper focuses on Components (b) and (c). For the integration of waste into the constructed SAM, specific data was required. This included data not just on waste generation but also the costs and revenues of the waste management process.

A. Data on Waste Generation

Preliminary data on district-level waste generation was is being collected by ENVIS, UEPPCB. (ENVIS, 2017). However, as the data required was much more detailed than was available from

secondary sources, a district level survey was done. For this purpose, key districts and municipalities were selected that had both-high tourist footfall as well as MSW generation. As a part of this venture,
field surveys were conducted by the team in seven districts in Uttarakhand- Haridwar, Dehradun, Chamoli, Nainital, Rudraprayag and Udham Singh Nagar. The data on per day waste generation was collected from the ULBs for municipal areas of Haridwar, Dehradun, Gopeshwar, Rudraprayag, Nainital, Haldwani and Kashipur.

This interaction also showed that most of the ULBs in Uttarakhand have not been successful in 100% processing of waste. On being asked about the reasons, respondents revealed four critical constraints to effective management of waste in the state:

1. Unavailability of land: There is a limitation on land that can be diverted for landfill as a large part of the state is under forest cover. As waste treatment is limited, most of the waste is directed for open dumping or to landfills. This option is very land intensive.

2. Lack of buyers for end-products produced from treatment of waste: While composting is done by some nagar-palikas, some of the larger cities have opted for complex integrated waste processing plants producing refuse derived fuel (RDF). There is however a lack of demand for these by-products that affects the overall financial feasibility of operations. It is interesting that among by-products, segregated and compacted plastic was the product with the highest market value

3. Transportation and collection at hilly terrains: With its hilly terrain, there are multiple ULBs located at a height that make waste collection and transportation cumbersome. There are multiple areas where normal collection vehicles such as cycle-rickshaws, canters, etc. cannot reach. In such cases, innovative approaches such as pulleys, etc. are being tried.
4. Understaffed departments: Multiple ULBs reported that they are understaffed wherein the requisite manpower for normal waste related operations are not available. This hampers the day-to-day working of the ULB.

Subsequent to these field visits, telephonic surveys were conducted to cover more districts and nagar-palikas in the state. Field surveys had to be halted due the risks from COVID-19. Collectively 28 ULBs and waste management companies were interviewed through face-to-face meetings or surveyed telephonically. Figure 1 shows the geographical location of ULBs that were surveyed as part of this study. Care was taken to cover municipal areas that lay across size categories. Figure

2 shows the broad composition of cities surveyed according to size. Due the wide coverage of survey, this study was able to cover areas that accounted for accounted for 1070 tonnes per day(tpd) of waste generation in the state or around ~66%.

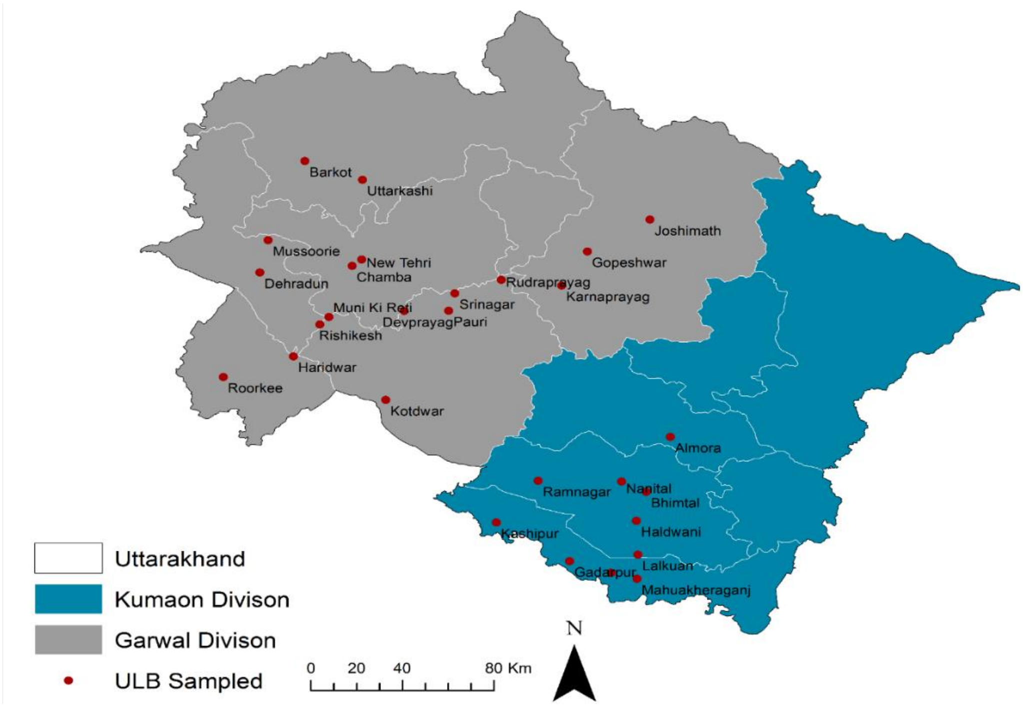


Figure 1: List of ULBs surveyed

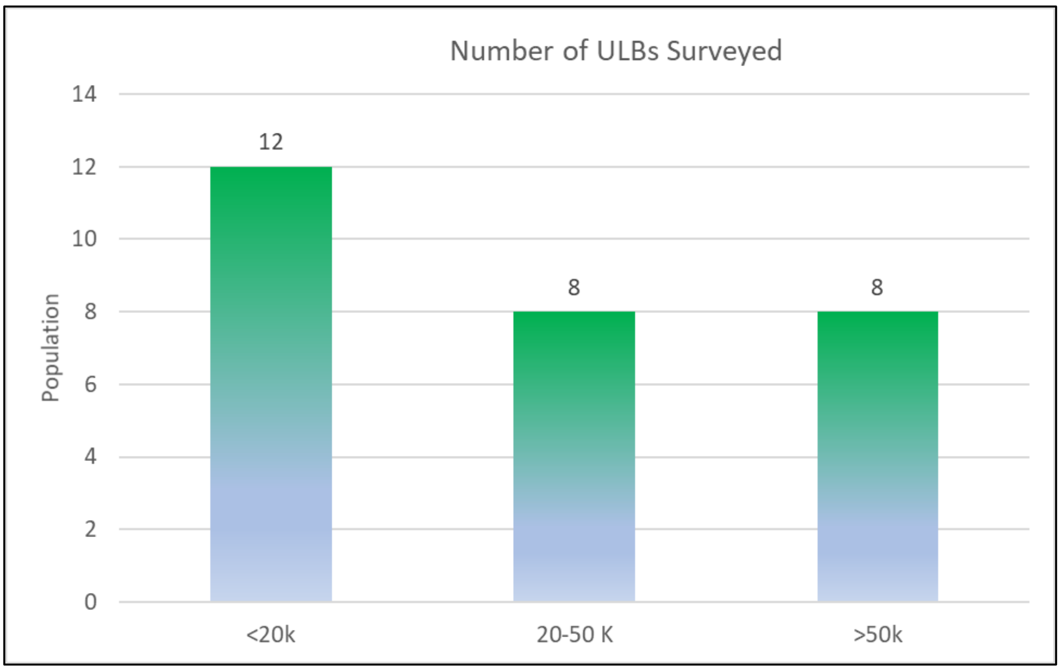


Figure 2: Distribution of ULBs According to Population

Waste Management Case Study: Project Tsang-da

The Ladakh Autonomous Hill Development Council (LAHDC) implemented a waste management project called Project Tsang-da in 2018 with the objective of achieving zero landfills. Since its inception, the project has been a huge success and highly acclaimed in popular media.

Ladakh, declared a Union Territory in October 2019, was earlier a part of the state of Jammu & Kashmir. With a geographical area of about 59000 square kilometers and a population of 2.74 lakhs (Census, 2011), it lies between the Himalayas and the Kunlun mountain range at an average elevation of 3000 meters above sea level. Project Tsang-da, initiated by LAHDC in rural parts of Ladakh, is an excellent example of successful cooperation among government authorities, NGOs, and the local community critical for the success of a waste management strategy. The challenges faced in waste management in Ladakh are similar to those confronted by mountainous regions of Uttarakhand, which makes Project Tsang-da a relevant case study for this research project.

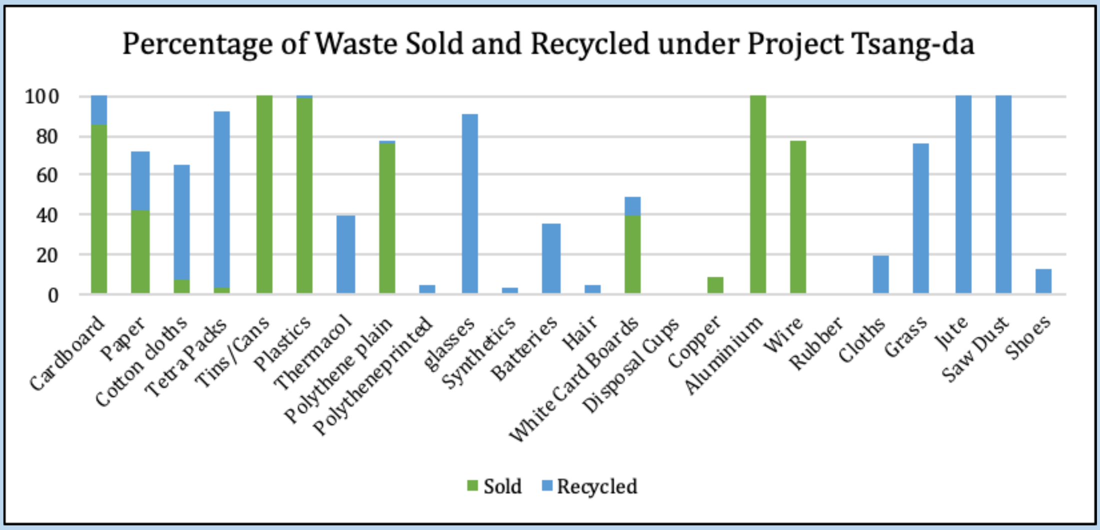
Under the project, five solid resource management centers (SRMC) were set up at Choglamsar, Nimmu, Nubra Valley, Khaltsi, and Pangong with the help of initial investment by the district government. In addition to this, LAHDC collects user fees (Rs. 50 from households and Rs. 200 from commercial establishments) to cover the operational costs. The waste is segregated at source into dry and wet which is then collected and transported to the nearest centers. At the center, the wet waste is processed into compost and, dry waste is further segregated into 18 different categories such as:

- Batteries or wire
- Plastic (Printed, plain and metal-coated)
- Paper (Cardboard, Newspaper)
- Thermocol

The promotion of recycling and reduction of waste has been the focal point of the project. Cardboard pieces are processed and sold for roofing; newspaper waste is shredded to pulp and converted into paper bricks and, the thermocol waste is used as paneling for heat insulation in the buildings. Finally, the plastic waste is fed into the shredder which, converts it into plastic bits of range 10 mm. These bits are used in the construction of roads.

The project also succeeded in generating livelihood opportunities for the locals in the area. The center at Choglamsar at present employs ten workers who work on waste segregation and operation of scrap grinding machines. The paper waste and tetra pack are being sold to an NGO in Leh, PAGIR (People's Action Group for Inclusion and Rights), which is actively engaged with the differently-abled section of the community and works on their livelihood generation. The paper waste and tetra packs are recycled to make decorative items, notebooks, and paper bricks.

Awareness creation played a critical role in the success of this project. This included the sensitization of the locals to the issue of waste management and the distribution of two separate dustbins for biodegradable and non-biodegradable waste to the households. Besides, arrangements to replace the plastic dustbins with locally-produced baskets to further drive the reduction of waste and amplify the livelihood opportunities in the area are also in the pipeline.



Data Source: *SRMC, Choglamsar, Leh*

Hauling of waste on rough terrain and the lack of adequate storage facilities have been the major hurdles to the project. Transportation becomes a challenge during the winters, which further pushes the demand for space to store the accumulated waste. Nonetheless, Project Tsang-da serves as an exceptional demonstration of collaboration amongst the local community, local government, and local NGOs pivotal to smooth on-ground execution of a waste management policy.

From Left*: Plastic shredder at SRMC Choglamsar, ICRIER team with Choglamsar SRMC team*

The data collected showed the very distinct seasonality in waste generation. However, there wasn't a very large variation in type of waste generation. Respondents revealed that floating population caused waste generated tpd to increase by 25-26% during tourist months. While Haridwar showed the highest variation, all tourist cities (such as those on the Char Dham route) showed this trend. This interaction also helped us collect data on land availability, costs incurred, capital investment on disposal technologies as well as revenue raised from by-products. This was used in the subsequent waste model.

B. Modelling Waste

The study's entry point to literature on previous modelling work in the field of waste generation was "Modelling Municipal Solid Waste Generation: A Review" (Beigel, 2008). The paper surveys 45 previous modelling works in the domain to conduct a systematic review. The paper found that the models exhibit high heterogeneity in terms of the regional scale, the modelled waste streams and the modelling method and with these three criteria it establishes taxonomy of the models. The paper observes that micro models such as cost benefit analyses, life cycle analyses and multi-criteria decision analyses are well established in the domain the macro models that can support planning at a broader scale lag in terms of modelling standards. However, these lack the overall economy-level insights provided by more top-down input-output based frameworks.

In this regard an important paper titled 'Waste Input-Output Model: concepts, data, and application' (Nakamura & Kondo, 2002) was used while developing the modelling framework. As our study builds a CGE model for the state adapted to specify waste and tourism sectors, it is important to understand waste input-output model as the precursor to CGE. In this context, Nakamura and Kondo (2002) is a very relevant model for our present study. Even though input-output model is a well-established tool to understand and measure interdependence of economic sectors, it does not include interdependence of production of goods and waste treatment sectors. Nakamura and Kondo (2002) fill this gap by providing waste input-output (WIO) model.

While conducting the study however it was found that the data requirement for the WIO model is too large for the current state level data systems to supply. The model was thus broken into two parts that were soft-linked to serve the CGE model. The first part i.e. the waste model, was developed as an optimization model where different scenarios were simulated. The second part was designed as a tourism SAM (see working paper 1) that would ultimately feed into the CGE analysis.

Optimization Modelling for waste management strategies

Waste management systems are quite complex. Figure 3 provides an illustrative case of the various stages that disposed MSW goes through. It is therefore important that its complexity is reflected in the modeling part as well.

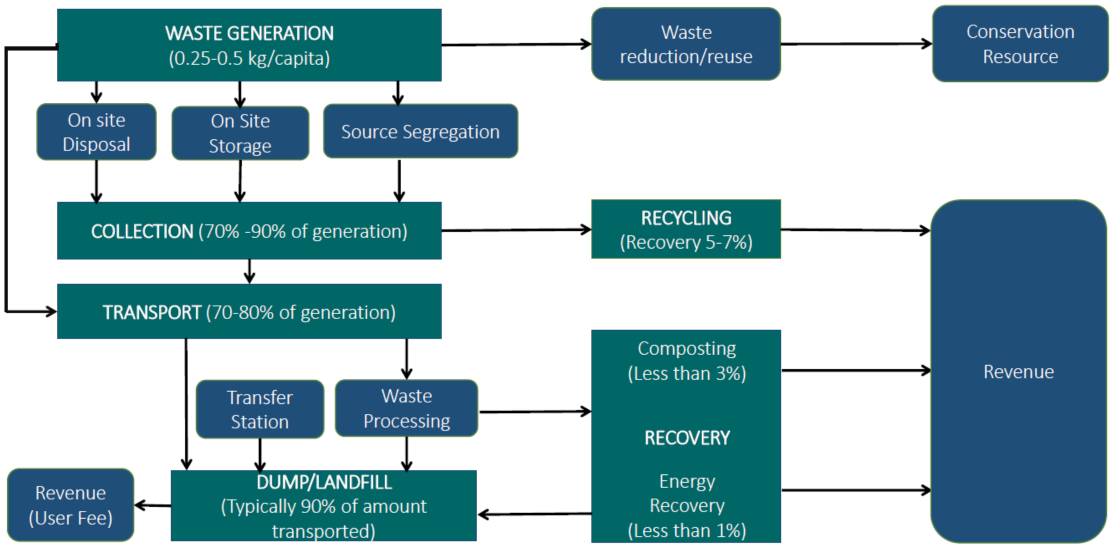


Figure 3: Stages of Waste Management

Source: World Bank, 2006

It should however be noted here that both input-output as well as SAM models are in monetary units. It is thus critical that all of the above steps get translated into monetary units, i.e. how much was spent in waste management and what were the benefits or additional revenue sources that were realized from processing by-products. As there were high specificities with respect to data, it was found prudent to collect the data via primary survey rather than relying on secondary sources of information. The field visits and telephonic surveys mentioned earlier were used in the collection of said data as well.

Four specific technologies were modeled as part of this model- (a) Composting, (b) ISWM and RDF production, (c) Segregation and compacting, and (d) landfills. For each of these technologies, ULB experiences were recorded. Where applicable, details of costs and benefits were requested and noted as well. These costs and revenue streams were used to create additional rows and columns in the existing Tourism IO model.

Results from the Waste Management Strategy Optimization

The optimization exercise sought to seek answers to the question of increasing waste generation and what would the state do if the waste generation increased from 1099 tpd in 2015-16 (analysis baseline year) to 3592 tpd in 2021. For this purpose, a linear programming model was developed on the GAMS software.

Four different scenarios were created in-line with the targets of the Uttarakhand SWM Action Plan that incorporated varying portfolio combinations of waste treatment options. The scenarios that were considered were:

1. Baseline Scenario- Assuming no change in portfolio
2. Waste_Cost Scenario-Assuming that costs need to be minimised
3. Waste_Land Scenario- Assuming that land required for waste treatment needs to be minimized.
4. Waste_Revenue Scenario-Assuming that revenue from by-products needs to be maximized. This is a highly unrealistic scenario as most urban governments would work on welfare maximization principles rather than revenue (or profit) maximization principles.

Other constrains such as sunk costs and existing technology deployments were also used in each scenario to avoid fallacious corner solutions. The results from the optimization exercise is presented in figure 4. The figures are in annual waste treatment tonnes.

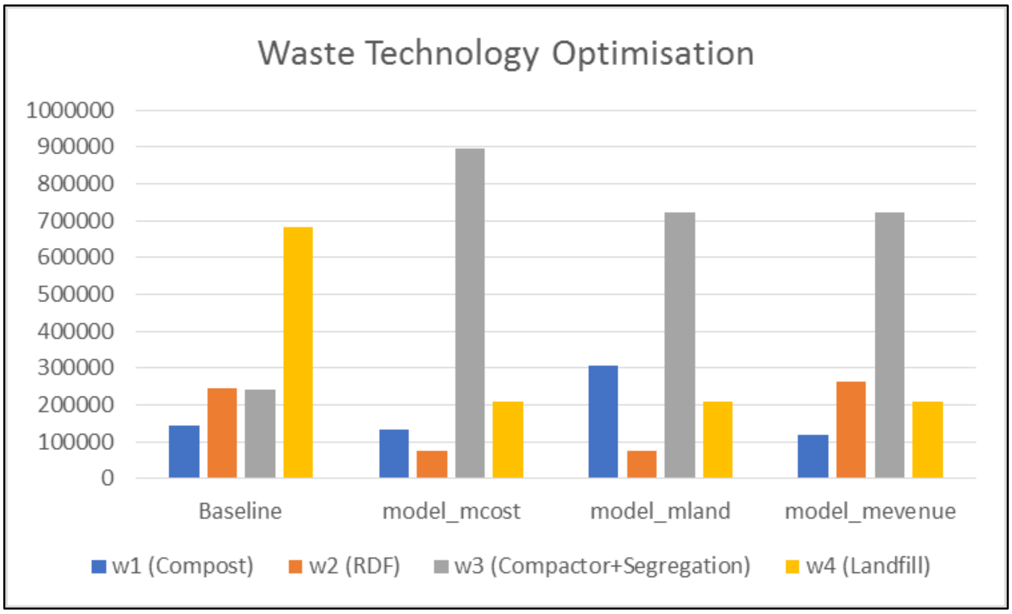


Figure 4: Tonnes of waste treated by various technologies annually by 2021

The results for tonnes of waste treated were multiplied by the average costs of treatment and revenues to convert these into monetary values so that they could be incorporated into the CGE framework

C. CGE Model for Uttarakhand

The CGE model for Uttarakhand in the study has been built on the basis of the SAM developed for the state for the year 2015-16. The model contains 26 production sectors, including tourism and waste sectors, and three factors of production, which are land, labor, and capital. Additionally, the model is static and, therefore, investment is only a demand variable and doesn't add to capital formation. The households are classified into two categories: rural households and urban households. The economy is assumed to be closed. Following are the salient features of the CGE model:

i. The model is neo-classical and Walrasian in nature. The market for all commodities and non-fixed factors clears through adjustment in prices, and the model only determines relative prices.
ii. It is a static model. That is, investment is a demand variable and doesn't add to capital formation.
iii. The model has 26 production sectors and three factors of production, which are labor, land, and capital.
iv. Capital and land across different sectors of production are fixed, whereas labor is flexible.
v. The production function is Cobb-Douglas in nature.
vi. Producers are profit maximizers in a perfectly competitive market.
vii. Households are classified into two categories: Rural and Urban. The factor endowments of households are fixed.
viii. The utility function of the households is Cobb-Douglas in nature.
ix. Households save a constant proportion of their income and pay taxes to the government.
x. Investment in the economy is savings-driven.
xi. The model also consists of the tourism sector and four waste sectors. Both the tourism sector and waste sectors are assumed to be Cobb-Douglas in nature, with producers maximizing profit in a perfectly competitive environment.
xii. Economy is closed.

The model is developed on statistical software R using the gEcon package[4].

[4] https://gecon.r-forge.r-project.org/

Sectoral Disaggregation

Production Sectors and Factor Market

Each production sector produces a single and distinct commodity. Further, every producer is assumed to have a Cobb-Douglas technology. Producers maximize profit by choosing levels of labor, subject to the constraint of their production technology. Capital and land are fixed. As the primary objective of the study is to find optimum waste management strategies for Uttarakhand, the model has an additional four waste sectors, the details of which have been elucidated in an earlier section. The waste sectors have also been assumed to be of Cobb-Douglas technology, with producers being the profit maximizers in a perfectly competitive market.

The producers in the model generate revenues by selling their products and also pay indirect taxes to the government. They pay wages to labor, rents to capital and land, and other producers for intermediate inputs. The receipts are equal to payments for producers, i.e., zero profit condition is followed (Pradhan & Sahoo, 2002). Labor is assumed to be mobile across sectors, whereas land and capital are immobile. The households are the only suppliers of labor which they supply inelastically. The factor endowment of land comes from households, government, and the corporate sector. Lastly, the endowment of capital is supplied from the previously-mentioned three sectors and the public sector.

Households

In the model, the households are divided into two categories: rural and urban. They have been assumed to have Cobb-Douglas preferences. They maximize their utility functions with respect to their budget constraints to derive the optimum levels of consumption. The budget constraints include income which, they earn from supplying the factors of production they possess. It also contains the taxes paid and transfers received by them from the government. The households save a constant proportion of their disposable income and spend the rest on consumption.

Government and Other Institutions

The government sector has been treated as exogenous in the model. That is, the government is a non-optimizing agent, and government consumption, transfers, and tax rates are assumed to be given.

The private and public sectors do not have any consumption expenditure. They derive their income from rent on capital and land and government transfers.

Model Equilibrium

The sectors delineated above are the building blocks of the model, which, when bound together with the general equilibrium conditions, complete the model. The model is static, and the economy is closed. Walras' law holds, that is, both demand and supply are only dependent on relative prices. The equilibrium conditions of the model are as follows:

i. Market clearance condition which, implies that excess demand for each commodity is zero at equilibrium.
ii. The excess demand for each factor of production stands at zero. That is, the quantity of a factor of production used by all producers is equal to the amount supplied by the households, public and private sectors.
iii. The total nominal investment in the economy is equal to gross savings. The gross savings include public savings, private savings, corporate savings, and government savings.

Calibration and Benchmark Equilibrium

The model is calibrated on the basis of the SAM developed for the economy of Uttarakhand for the year 2015-16. Calibration involves a deterministic approach to specifying parameter values such that the model solution replicates the base year input data (Ojha & Pradhan, 2006). The step is extremely crucial as the parameter values so derived in this process are applied to find the general equilibrium of the model.

For a Cobb-Douglas economy, as considered in this model, calibration involves treating all prices as index numbers with a value of utility in the benchmark and al values in the SAM as benchmark quantities. Following these assumptions, the elasticity parameters and technical coefficients of the production functions and utility functions are solved (Wing, 2004).

D. Waste Model and CGE Interface

The soft-linking interface between the two models lies in the government sector. There is a large subsidy element in waste management services sector. We assume that the difference between the treatment costs and revenues (through sale of by-products, penalties, etc.) is absorbed by the government sector. This assumption helps calculate the change in government expenditure (GE) and the resultant economy-wide impacts.

V. Results

The results from linking the CGE model and the waste model are summarized as follows:

Scenario I: Baseline Scenario

Technology	Change in GE from base year	Rise in state value added from base year
	(in Rs. Lakhs)	(in percentage)
Composting	1796.29	2.92
ISWM and RDF Production	3164.51	
Segregation and Compacting	897.73	
Landfills	7193.90	
Total	13052.43	

Scenario II: Cost Minimization

Technology	Change in GE from base year	Rise in state value added from base year
	(in Rs. Lakhs)	(in percentage)
Composting	1568.09	1.34
ISWM and RDF Production	0.00	
Segregation and Compacting	4435.29	
Landfills	0.01	
Total	6003.39	

Scenario III: Land Minimization

Technology	Change in GE from base year	Rise in state value added from base year
	(in Rs. Lakhs)	(in percentage)
Composting	4720.52	1.34
ISWM and RDF Production	0.00	
Segregation and Compacting	3491.26	
Landfills	0.01	
Total	8211.79	

Scenario IV: Revenue Maximization

Technology	Change in GE from base year	Rise in state value added from base year
	(in Rs. Lakhs)	(in percentage)
Composting	1357.60	1.87
ISWM and RDF Production	3456.33	
Segregation and Compacting	3491.26	
Landfills	0.01	
Total	8305.20	

VI. Discussion

It is interesting that despite the large increase in activity in the waste management sector, there is not too much of an impact in terms of the increase in state value added. However, even this needs to be treated as a key result from this study. If we drill down into what is actually driving this low figure, two key points can be noted. Firstly, waste management is largely the responsibility of the ULBs and welfarist principles predominate. There are many parts of this puzzle that are largely non-remunerative and thus cannot be accounted for in a monetary system. For example, kitchen waste is regularly supplied by hotels, restaurants, etc. for composting. However, as this is given free, this service is not accounted for either as a cost or as an economic service rendered.

To add to this feeling of malaise is the low focus on by-products. During our interactions multiple ULBs said that they were giving off compost for free or the volume was so less that it was being used in their own public gardens. Barriers to RDF usage have also been discussed earlier. This has an impact on waste product usage and sales that thereupon impacts the forward linkages of successful waste management strategies.

VII. Recommendations and Future Work

For the success of Uttarakhand SWM Action Plan, greater stress laid on data collection and later digitalization of waste data will go a long way. While there have been significant improvements in this front from the earlier days of assuming certain per capita generation norms and multiplying them with area population, more needs to be. While local level officials (health officers, sanitary inspectors, etc.) were generally aware of the waste generated and treated in their municipal area, few were aware of the capital and operational costs of treatment. This data is required for the successful planning of strategies.

The second recommendation stems from our analysis of waste management strategies and scenarios. As obvious, one technology will not be sufficient to solve the problem. A blend of technologies needs to be thought of based on geography, size and financial viability to minimize land and maximize revenue opportunities. For example, integrated waste management systems would work in larger cities or large clusters but finding a suitable market for produced RDF needs to identified . It need not be just within the state, but markets in nearby states can be looked at as well. Just as the markets for compacted plastics and recycled glass and paper have grown organically. Similar thrust needs to be given for the sale of compost and RDF. For smaller municipalities with not too complex composition of waste discarded, composting and compacting might be sufficient.

Greater thrust needs to be placed on recycling as well. There is an opportunity for tying up with industrial estates located in certain districts such as Udham Singh Nagar, wherein specific wastes such as waste paper for packaging, etc. could be picked up and used.

The third recommendation is with respect to the cluster approach. It was generally found that this system was working well and made economic sense when land parcels for disposal were hard to come by and when larger projects were sought to be set up. This needs to be developed further and maybe tied in with the data collection/management exercise (mentioned earlier), for improved planning of systems.

In terms of future work, it is proposed that this modelling exercise gets carried out at a district level as well. District level optimization is the key to account for land unavailability and to model the potential of a cluster approach. The second potential work that we see emanating from our study is the creation of a Waste IO model that would help evaluate both backward and forward linkages of the waste sector and where modeling units would be both in monetary and physical units. This would help avoid the problem of accounting for the services that are provided free of charge and inputs that are received for free. The third idea pertains to waste management and employment linkages. The issue of skilling and informality is central for improving the efficiency of waste management systems.

References

Ahluwalia, I. J., & Patel, U. (2018). *Solid Waste Management in India: An Assessment of Resource Recovery and Environmental Impact.* New Delhi, India: Indian Council for Research on International Economic Relations.

Balasubramanian, M. (2015). Economics of solid waste in India. *Economic & Political Weekly, 50*(25), 17-20.

Balasubramanian, M. (2018). Municipal solid waste management in India: Status, problems and challenges. *International Journal of Environment and Waste Management, 21*(4), 253-268. doi:10.1504/IJEWM.2018.093435

Beigel, P. (2008). Modelling Municipal Solid Waste Generation: A review. *Waste Management*, 200-214.

Bhatt, M., & Munjal, P. (2013). Social Accounting Matrix to Study the Socio-Economic Linkages of Tourism Sector- A Case Study of India. *Indian Economic Review, Vol. 48, No. 2*, 381-412.

Chadha, R., Pohit, S., Deardoff, A. V., & Stern, R. M. (1997). *Analysis of India's Reforms- A CGE Modelling Exercise.* National Council of Applied Economic Research, United Nations Development Programme.

Chadha, R., Pohit, S., Deardoff, A. V., & Stern, R. M. (1997). Analysis of India's Reforms: A CGE Modelling Exercise. *NCAER Working Papers, 65*.

Critical Ecosystem Partnership Fund. (2005). *Ecosystsem Profile- Eastern Himalayas Region.*

Guo, Z., Zhang, X., Zheng, Y., & Rao, R. (2014, September). Exploring the impacts of a carbon tax on the Chinese economy using a CGE model with a detailed disaggregation of energy sectors. *Energy Economics, 45*, 455-462.

Kaza, S., Yao, L., Bhada-Tata, P., & Woerden, F. V. (2018). *What a Waste 2.0: A Global snapshot of Solid Waste Management to 2050.* Washington, D.C.: World Bank.

Ministry of Environment, Forest and Climate Change. (n.d.). *Mission Document- National Mission on Himalayan Studies.*

Ministry of Urban Development. (2016). *Municipal Solid Waste Management Manual.* New Delhi, India: Ministry of Urban Development, Government of India.

MOSPI. (2020). *EnviStats India 2020.* India: Ministry of Statistics and Programme Implementation, Government of India.

Munjal, P., Kolli, R., & Sharma, A. (2012). *Second Tourism Satellite Account for India, 2009-10.* National Council of Applied Economic Research.

Munjal, P., Siddiqui, K., Sharma, A., Grover, M., Singh, S., & Kolli, R. (2012). *Regional Tourism Satellite Account Uttarakhand, 2009-10.* National Council of Applied Economic Research.

Nakamura, S., & Kondo, Y. (2002). Waste Input-Output Model: Concepts, Data and Application.

NIUA. (2019). *Solid Waste Management Initiatives in Urban India: A Compendium.* New Delhi, India: National Institute of Urban Affairs.

Ojha, V. P., & Pradhan, B. K. (2006). *The Macro-Economic and Sectoral Impacts of HIV and AIDS in India: A CGE Analysis.* National Council of Applied Economic Research.

Östblom, G., Söderman, M. L., & Sjöström, M. (2010, May). Analysing future solid waste generation - Soft linking a model of waste management with a CGE-model for Sweden. *Working Paper Series NIER, 118*.

Ostblom, G., Soderman, M. L., & Sjostrom, M. (2010). Analysing Future Solid Waste Generation- Soft linking a model of waste management with CGE-model for Sweden.

Pal, B. D., Ojha, V. P., Pohit, S., & Roy, J. (2015). *GHG Emissions and Economic Growth: A Computable General Equilibrium Model Based Analysis for India.* Springer India.

Planning Commission. (2014). *Report of the Task Force on Waste to Energy (Volume I).* New Delhi, India: Planning Commission, Government of India.

Pohit, S., & Saini, R. (2015). India-Pakistan Trade Liberalization: A CGE Modelling Approach. In N. Taneja, & S. Pohit, *India-Pakistan Trade.* New Delhi: Springer.

Pradhan, B. K., & Sahoo, A. (2002, July). Oil Price Shock and Poverty in a CGE Framework. *Discussion Paper Series NCAER*(18).

Sharma, K. D., & Jain, S. (2019). Overview of Municipal Solid Waste Generation, Composition, and Management in India. *Journal of Environmental Engineering, 145*(3). doi:10.1061/(ASCE)EE.1943-7870.0001490

Singh, K., & Saluja, M. (2016). *Input-output table for india: 2009-10.* NCAER.

Siriwardana, M., Meng, X., & McNeill, J. (2013). A CGE assessment of the Australian carbon tax policy. *International Journal of Global Energy Issues, 36*, 242-261.

Sjöström, M., & Östblom, G. (2009). Future Waste Scenarios for Sweden based on a CGE Model. *Working Papers NIER, 109*.

Srivastava, P., Shukla, R., Saluja, M., Siddiqui, K., Munjal, P., & Virmani, A. (2006). *Tourism Satellite Account for India.* National Council of Applied Economic Research.

TERI. (2014). *Waste to Resources: A Waste Management Handbook.* New Delhi, India: The Energy and Resources Institute.

Viguier, L., Babiker, M., & Reilly, J. (2003). The costs of the Kyoto Protocol in the European Union. *Energy Policy, 31*, 459-481.

Wing, I. S. (2004). *Computable General Equilibrium Models and Their Use in Economy-Wide Policy Analysis.* MIT Joint Program on the Science and Policy of Global Change.

Annexure 1

Table1: State- wise municipal solid waste generation in India (2018-19)

S. No.	State	Quantity Generated (TPD)	Collected (TPD)	Treated (TPD)	Landfilled (TPD)	Nos. of compost plant	Nos. of landfill
1	Andhra Pradesh	6440.0	6140.0	548.0	203.0	49	-
2	Arunachal Pradesh	271.0	215.0	Nil	Nil	2	11
3	Assam	1293.7	1119.4	-	-	2	76
4	Bihar	2272.0	Yes	-	No	11	93
5	Chhattisgarh	1650.0	1386.0	1271.0	115.0	489	2
6	Delhi	10817.0	10614.0	5714.0	5225.0	4	2
7	Goa	236.4	235.9	154.7	1.5	14	2
8	Gujarat	-	11119.0	1127.0	9992.0	39	36
9	Haryana	4635.8	4430.3	815.9	3614.3	14	26
10	Himachal Pradesh	389.0	340.0	150.0	190.0	-	3
11	Jammu & Kashmir^	1530.5	1452.9	-	-	1	12
12	Jharkhand	2205.0	2043.4	836.7	0.0	Nil	Nil
13	Karnataka	11958.0	10011.0	4515.0		143	215

14	Kerala	3903.0	742.2	437.7	-	721	1
15	Madhya Pradesh	8000.0	7500.0	6100.0	1400.0	36	378
16	Maharashtra	23844.6	23675.7	12623.3	11052.4	307	320
17	Manipur	218.6	126.6	80.0	46.6	1	-
18	Meghalaya	170.6	170.6	8.7	161.9	1	1
19	Mizoram	251.4	213.1	29.2	-	Nil	1
20	Nagaland	339.5	216.9	135.8	34.0	1	1
21	Odisha	2564.4	2255.3	91.6	2163.7	1	54
22	Punjab	4634.5	4574.9	917.6	3657.4	1	150
23	Rajasthan	6625.6	6475.4	780.2	4187.2	1	174
24	Sikkim	75.1	67.1	13.1	51.4	2	2
25	Tamil Nadu	13968.0	12850.0	7196.0	5654.0	608	4
26	Telengana	8497.0	8360.0	5747.0	869.0	63	4
27	Tripura	445.7	389.5	150.1	239.4	1	17
28	Uttar Pradesh	17377.3	17329.4	4615.0	0.0	2	82
29	Uttarakhand	1527.5	1437.4	524.0	-	12	13
30	West Bengal	14613.3	13064.6	916.0	334.0	13	-
31	Andaman And Nicobar Islands	120.0	117.0	65.1	37.9	5	1
32	Chandigarh	470.0	458.5	150.0	361.3	1	1
33	Daman Diu & Dadra Nagar Haveli	98.0	94.5	5.0	89.5	1	1
34	Lakshadweep	35.0	18.0	18.0	-	-	Nil
35	Puducherry	599.3	505.0	24.0	481.0	2	1
TOTAL		**152076.7**	**149748.6**	**55759.6**	**50161.3**	**2548**	**1684**

Source: Environmental Statistics, 2020, Ministry of Statistics and Program Implementation
TPD : Tonnes per day
^ :This is the unified data for UT of Jammu and Kashmir & UT of Ladakh

Table 2: Municipal solid waste generation in Metro Cities / State Capitals

S. No.	**Name of City**	**Population (Census-2011)**	**Waste Generation (TPD)**				
			1999-2000	**2004-2005**	**2010-11**	**2015-16**	**2018-19**
1	Mumbai	12442373	5355	5320	6500	11000	7700
2	Delhi	11034555	400	5922	6800	8700	10817
3	Bengaluru	8443675	200	1669	3700	3700	5700
4	Chennai	7088000	3124	3036	4500	5000	-
5	Hyderabad	6731790	1566	2187	4200	4000	-
6	Ahmedabad	5577940	1683	1302	2300	2500	-
7	Kolkata	4496694	3692	2653	3670	4000	-

8	Surat	4467797	900	1000	1200	1680	-
9	Pune	3124458	700	1175	1300	1600	3627.82
10	Jaipur	3046163	580	904	310	1000	-
11	Lucknow	2817105	1010	475	1200	1200	-
12	Kanpur	2765348	1200	1100	1600	1500	-
13	Nagpur	2405665	443	504	650	1000	1594.97
14	Vishakhapatnam	2035922	300	584	334	350	-
15	Indore	1960631	350	557	720	850	1010
16	Thane	1818872	-	-	-	700	1970.85
17	Bhopal	1798218	546	574	350	700	1060
18	Pimpri-chinchwad	1729359	-	-	-	700	874.08
19	Patna	1683200	330	511	220	450	770
20	Vadodara	1666703	400	357	600	700	-
22	Ludhiana	1613878	400	735	850	850	-
23	Coimbatore	1601438	350	530	700	850	990
24	Agra	1585704	-	654	520	790	-
25	Madurai	1561129	370	275	450	450	630
26	Nashik	1486973	-	200	350	500	1986.04
27	Vijayawada	1476931	-	374	600	550	-
28	Faridabad	1404653	-	448	700	400	1236
29	Meerut	1309023	-	490	520	500	-
30	Rajkot	1286995	-	207	230	450	-
31	Kalyan-dombivali	1246381	-	-	510	650	650
32	Vasai-virar	1221233	-	-	-	600	625
33	Varanasi	1201815	412	425	450	500	-
34	Srinagar	1192792	-	428	550	550	450
36	Dhanbad	1161561	-	77	150	180	-
37	Amritsar	1132761	-	438	550	600	-
38	Navi Mumbai	1119477	-	-	-	675	711
39	Allahabad	1117094	-	509	350	450	-
40	Ranchi	1073440	-	208	140	150	-
41	Howrah	1072161	-	-	-	740	-
42	Jabalpur	1054336	-	216	400	550	-
43	Gwalior	1053505	-	-	285	300	606
45	Raipur	1010087	-	184	224	230	-
Source: Environmental Statistics, 2020, Ministry of Statistics and Program Implementation TPD: Tonnes per day							

Annexure 2

Equations of the CGE Model

Production Structure

1. The production technology is Cobb-Douglas in nature. A producer of commodity, j, produces, X_j, by choosing optimum levels of labour, Z_{Lj}. Capital, $\overline{Z_{KJ}}$, and land, $\overline{Z_{LDJ}}$,are fixed and immobile across sectors.

$$X_j = A_j \prod_{f \in F} Z_{fj}^{\zeta_{fj}}$$

where $j = 1 \ldots 26$, $F = \{L, K, LD\}$ and $\sum_{f \in F} \zeta_{fj} = 1$

2. The optimum level of labour for a Cobb-Douglas technology is given by:

$$Z_{Lj} = \zeta_{Lj} \frac{P_j X_j}{W_L}$$

3. The zero-profit condition for producer is the following:

$$P_j \times X_j \times (1 - indt_j) = W_L \times Z_{Lj} + W_K \times \overline{Z_{KJ}} + W_{LAND} \times \overline{Z_{LDJ}} + \sum_i PD_i \times a_{ij} \times X_j$$

Labour Market Equilibrium

4. The labour market equilibrium condition is outlined as follows:

$$\sum_j Z_{Lj} = LS$$

Commodity Market Equilibrium

5. The commodity market is in equilibrium when the total demand for the commodity in the economy is equal to its total supply.

$$AD_j = X_j$$

Incomes

6. The income earned by households by supplying the factors of production is presented as follows:

$$Y_h = W_L \times L_h^s + W_K \times K_h^s + W_{LD} \times LD_h^s$$

where $h \in H$ and $H = \{Rural, Urban\}$

7. The disposable income of the household is given by:

$$YD_h = Y_h - it_h \times (Y_h - W_{LD} \times LD_h^s) + TRNG_h$$

8. Households savings are given by the equation: $SAV_h = sav_h \times YD_h$

9. The corporate sector disposable income equation is as follows:

$$YD_{pvt} = (1 - corpt) \times \left(W_K \times K_{pvt}^s + W_{LD} \times LD_{pvt}^s\right) + TRNG_{pvt}$$

10. The corporate sector disposable income is saved.

$$SAV_{pvt} = YD_{pvt}$$

11. The public sector disposable income and savings are given by:

$$YD_{pub} = W_K \times K_{pub}^s$$

$$SAV_{pub} = YD_{pub}$$

Households

12. The household preferences are Cobb-Douglas in nature.

$$U_h = B_h \prod_{j=1}^{26} C_{hj}^{\alpha_{hj}}$$

where, $\sum_{1}^{26} \alpha_{hj} = 1$

13. The optimum levels of consumption are given by:

$$C_{hj} = \alpha_{hj} \frac{(YD_h - SAV_h)}{PD_j}$$

Government Budget

14. Tax Revenue

$$TAXREV = it_h \times (Y_h - W_{LD} \times L_{LD}^s) + corpt \times \left(W_K \times K_{pvt}^s + W_{LD} \times LD_{pvt}^s\right) + \sum_j INDT_j$$

15. Government Revenue

$$GREV = TAXREV + W_{LD} \times LD_G^s + W_K \times K_G^s$$

16. Government Expenditure

$$GEXP = \sum_j C_{gj}$$

17. Government Savings

$$SAV_g = GREV + YD_{pub} - GEXP - TRNG_h - TRNG_{pvt}$$

Investment Demand

18. Real investment by sector of destination

$$INVD_j = v_j \times INVAGG$$

19. Real investment demand by sector of origin

$$ID_j = \mu_j \times INVAGG$$

Final Demand

20. The aggregation demand for a commodity in the economy is given by:

$$AD_j = \sum_h C_{hj} + ID_j + C_{gj} + \sum_i a_{ji} \times X_j$$

Savings and Investment

21. The total savings in the economy:

$$TS = \sum_h SAV_h + SAV_{pvt} + SAV_g$$

22. Savings-Investment Equilibrium:

$$TS = \sum_j PD_j \times ID_j$$

Notations

Endogenous Variables		Exogenous Variables & Parameters	
AD_j	Aggregate demand for commodity j	A_j	Shift parameter in production function
C_{hj}	Consumption of commodity j by household group h	a_{ij}	Input-output coefficient
$GEXP$	Government total expenditure	α_{hj}	Share parameter in household utility function
$GREV$	Government total revenue	B_h	Share parameter in household utility function
$INVAGG$	Real aggregate investment	C_{gj}	Real government consumption
ID_j	Real investment demand by sector of origin	$corpt$	Corporate tax rate
$INVD_j$	Real investment by sector of destination	$indt_j$	Indirect taxes rate
$INDT_j$	Government revenue from indirect taxes on commodity j	it_h	Income tax rate for household group h
P_j	Producer's price	K_h^s	Total capital endowment of household
PD_j	Price of sales	K_{pvt}^s	Total capital endowment of private corporate sector
SAV_g	Government savings	K_{pub}^s	Total capital endowment of public sector
SAV_h	Household savings	L_h^s	Total labour supply by household
SAV_{pvt}	Private corporate sector savings	LD_h^s	Total land endowment of household
SAV_{pub}	Public sector savings	LD_{pvt}^s	Total land endowment of private corporate sector
$TAXREV$	Government tax revenue	LD_g^s	Land endowment of government sector
TS	Total savings of the economy	LS	Total labour supply in the economy

W_L	Wage for labour	μ_j	Share of real aggregate investment by sector of origin
W_K	Price of capital	ν_j	Share of real aggregate investment by sector of destination
W_{LD}	Price of land	sav_h	Savings rate of household group h
X_j	Output of commodity j	$TRNG_h$	Government transfers to household
Y_h	Income of household group h	$TRNG_{pvt}$	Government transfers to private sector
YD_h	Disposable income of household group h	ζ_{fj}	Share parameter in production function
YD_{pvt}	Private corporate sector disposable income		
YD_{pub}	Public sector disposable income		
Z_{fj}	Factor f employed by producer j		

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