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Impact of Barriers in Construction and Demolition Waste Management in Small Scale Construction

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***Abstract* — Rapid urbanization has sharply increased the generation of construction and demolition waste, yet small-scale builders, who carry out a large share of construction activity in growing Indian cities, remain largely outside regulatory and recycling frameworks. This study develops and validates a questionnaire to assess the managerial, cultural and financial barriers that small-scale builders face in managing construction and demolition waste in Coimbatore and Erode, Tamil Nadu. An initial pool of 51 items drawn from the literature was reduced to 20 items mapped to the three barrier categories, validated by six industry experts, and refined through a pilot survey of 30 respondents into a final 22-item, five-point Likert instrument. Exploratory factor analysis of the pilot data confirmed factorability, with a significant Bartlett test and all initial communalities above 0.6. The field survey raised the sample to 139 respondents and returned a Kaiser-Meyer-Olkin value of 0.741, seven components with eigenvalues above one explaining 64.3 percent of the variance, and a Cronbach alpha of 0.702. Mean-score analysis identified inadequate instruction of site supervisors, high disposal cost and high operational cost as the most significant barriers, while face-to-face interviews exposed weak enforcement of municipal debris charges. The study proposes targeted measures, including vehicle impoundment against illegal dumping, tax relief on recycled products and stronger regional enforcement of recycling-facility mandates.**

Keywords* — *Construction and demolition waste; small-scale construction; barriers; questionnaire validation; exploratory factor analysis; waste management policy

I. INTRODUCTION

Urbanization is expanding cities worldwide, and the resulting surge in building activity has made the daily management of construction and demolition (C&D) waste a pressing concern. Poorly handled C&D waste raises disposal costs, depletes valuable resources and damages the environment; rapid, human-driven urban growth alters land-use patterns and contributes to soil contamination, degradation of soil ecosystems and loss of habitat and biodiversity [1]. In India, the problem is compounded by poor record keeping: waste generation is seldom documented by construction firms [2], and estimates of annual C&D waste range widely from 110 to 700 million tonnes [3], while the Building Materials and Technology Promotion Council places the figure at about 150 million tonnes.

A substantial share of this waste originates from small-scale construction: individual houses, small commercial buildings, renovations and minor demolitions executed by local builders, contractors and developers. Individually, such projects generate modest quantities, but their sheer number makes their cumulative contribution significant. Because the waste is produced intermittently and in small lots, it rarely reaches formal collection or recycling channels and is instead used as informal fill, stockpiled on site or dumped on vacant land, roadsides and low-lying areas, where it obstructs drainage, degrades land and imposes clean-up costs on local bodies.

Small-scale builders are particularly poorly placed to respond. They operate with limited finances and few skilled workers, and their labour force rarely has the skills needed to segregate, store and dispose of waste; firms tend to rely on unskilled labour rather than on trained workers who could manage waste productively [4]. Irregular cash flow creates hesitation to spend on waste management, the small and irregular quantities generated make formal disposal channels uneconomical, and demand for recycled products remains weak. Collaboration between government, agencies and the public is therefore considered essential for increasing the use of recycled C&D materials [5].

The regulatory framework reinforces this gap. The 2016 C&D waste management rules require an individual waste management plan only from generators producing 20 tonnes per day or 300 tonnes per month, and the 2024 policy extends Extended Producer Responsibility (EPR) registration only to projects above about 215,000 sq ft (20,000 m²). The large number of firms executing projects of 1,000 to 200,000 sq ft, which collectively generate considerable waste, thus falls outside both instruments. Coimbatore and Erode, both in western Tamil Nadu illustrate the problem: both districts have a dense population of small-scale builders, share a Regional Chief Engineer office in Coimbatore, and show limited awareness, training and infrastructure for structured waste handling.

Understanding why small-scale builders do not adopt structured waste management is therefore a prerequisite for effective policy. Barriers may be financial, such as limited budgets and high disposal costs; managerial, such as the absence of designated responsibility, record keeping and internal rules; or cultural, such as entrenched routines and a preference for speed over sustainability. These barriers interact, and their relative importance is likely to depend on local market conditions, the availability of disposal infrastructure and the strength of enforcement, which makes region-specific evidence essential.

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Assessing these barriers systematically requires a validated measurement tool that can support both qualitative and quantitative analysis and help policymakers identify recurring challenges. EFA is well suited to this task because it reveals the core dimensions and underlying structure of a questionnaire and exposes problems such as item redundancy, thereby guiding refinement of the instrument. Accordingly, this study pursues three objectives: (i) to identify and categorize the predominant managerial, cultural and financial barriers to C&D waste management through a review of the literature; (ii) to develop a valid and reliable questionnaire tailored to small-scale builders through expert validation and a pilot survey; and (iii) to analyse the impact of the identified barriers through a field survey, using Exploratory Factor Analysis (EFA) to assess the structure of the instrument, and to derive policy recommendations. Section II reviews the literature, Section III describes the methodology, Section IV presents and discusses the results, and Section V concludes the paper.

II. LITERATURE REVIEW

A. Global Practices in C&D Waste Management

C&D waste management is closely linked to sustainability in construction, yet practices and regulations differ considerably across regions. The United States has no federal policy dedicated to C&D waste; the Environmental Protection Agency enforces the Resource Conservation and Recovery Act (RCRA) of 1976, which governs the disposal of solid and hazardous waste including C&D debris [6]. The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980 addresses the clean-up of sites contaminated by hazardous substances, applies the polluter-pays principle to contractors and waste transporters, and excludes non-hazardous waste [7].

European practice emphasizes material recovery and reuse, supported by pre-demolition audits [8]. The Waste Framework Directive set a target of preparing at least 70% of non-hazardous C&D waste by weight for reuse or recycling by 2020, and the non-legislative EU C&D Waste Protocol of 2016 addressed demolition contractors, recyclers, transporters, public bodies and users of recycled materials [9]. These measures have helped the European Union achieve recycling rates close to 90% [10]. China was among the first countries to adopt circular economy as a national policy term [11]; its Circular Economy Promotion Plan advises construction companies to engage certified producers that apply the 3R principle or dispose of C&D waste safely.

B. Indian Policy Landscape

Reliable data on C&D waste in India remain scarce because generation is rarely recorded at project level [2], and the wide spread of available estimates signals considerable uncertainty [3]. Policy attention has nevertheless grown. The Guidelines for Sustainable Habitats issued by the Central Public Works Department (CPWD) in 2014 called for systematic demolition planning to reduce waste and encouraged the use of recycled C&D materials. The C&D Waste Management Rules of 2016 [12] made waste generators responsible for segregation and disposal and required cities with populations above 1 million and 0.5 million to establish recycling facilities within 18 and 24 months, respectively.

For small-scale projects, the 2016 rules are promising in principle but difficult in practice. Segregation, collection and recycling impose costs and logistical burdens that small firms cannot readily absorb, collection and recycling facilities are often absent in smaller towns and rural areas, and recycling incentives largely favour large projects. Targeted incentives or subsidies, together with awareness programmes delivered through local authorities and non-governmental organizations, have been suggested to bridge this gap. The 2024 policy introduces EPR, under which waste generators, recyclers and storage operators of large projects must register on an online portal and report recycling modes and quantities; however, by excluding projects below its area threshold it again leaves out the numerous small and mid-sized builders.

C. Barriers in Small-Scale Construction

The literature groups the obstacles facing small-scale builders into three broad categories. Financial barriers arise because waste management is costly and time-consuming while liquidity is limited, so builders prioritize revenue generation; transport and disposal costs, the higher wages of skilled staff, and weak market demand for recycled products that are often more expensive than virgin materials all discourage action. Managerial barriers include the absence of strict regional regulations, poor coordination between planning and execution, a lack of data and documentation on waste generated, and slow adaptation to market opportunities. Cultural barriers stem from resistance to change and entrenched routines in family-owned businesses, misconceptions about the cost of waste management that lead to illegal dumping, and a focus on revenue over sustainability.

Table I summarizes the barriers reported in the literature and the sources that informed the construction of the questionnaire items.

TABLE I. BARRIERS TO C&D WASTE MANAGEMENT REPORTED IN THE LITERATURE

Category	Key barriers	Sources
Financial	Limited liquidity and budget; transport and disposal costs; wages of skilled staff; weak demand for, and higher price of, recycled products; tax structures favouring virgin materials	[4], [5], [13]
Managerial	Weak or absent regulation and enforcement; no data on waste generated; poor coordination between planning and execution; inadequate collection and transport arrangements	[2], [14], [15], [16]
Cultural	Resistance to change in family-owned firms; misconceptions about cost leading to illegal dumping; priority on speed and revenue over sustainability	[17], [18]

D. Methodological Approaches and Research Gap

Three methodological approaches informed this study. The first is a systematic literature review and bibliometric analysis that examined managerial, financial, cultural, waste-quantification and information-modelling barriers using trend-topic analysis, h-index calculation, cluster analysis and thematic mapping in RStudio [19]. The second selects sites according to contractor engagement and project budget, conducts a pilot survey to refine the method, and then holds face-to-face interviews with site managers and contractors to study reduce, recycle and disposal practices. The third applies an extended Theory of Planned Behaviour to the environmental behaviour of construction practitioners, including small and medium enterprises, using heterogeneous purposive sampling.

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E. Role of Expert Validation and Pilot Testing

Across these approaches, expert validation and pilot testing are recognized as essential for establishing the reliability, validity and quality of survey instruments. Expert validation draws on professionals with subject knowledge and field experience to confirm that each item falls within the intended domain, to remove potential flaws and to keep the instrument focused on its core constructs. Pilot testing is a preliminary administration that checks whether the response pattern aligns with the topic, whether respondents understand the items, and whether practical problems exist in the wording or sequence of the questionnaire. Together, these steps refine the method, minimize measurement error and improve usability before large-scale data collection.

Despite this body of work, several gaps persist. Studies and data on small-scale builders are scarce, which weakens policymaking [14]; stronger regulation is needed for implementation [15]; awareness of waste management methods and the behaviour of industry actors remain under-examined [17]; and practical solutions for collection and transport are required [16]. No validated instrument exists to measure the managerial, cultural and financial barriers faced specifically by small-scale builders in tier-2 Indian cities, the gap this study addresses.

III. RESEARCH METHODOLOGY

A. Research Design

The study adopts a descriptive research design that combines the three approaches reviewed above (Fig. 1). The categorisation of barriers into managerial, financial and cultural groups was drawn from the first approach; the process of site selection, the pilot survey and the criteria for identifying small-scale construction, obtained from the Public Works Department (PWD) of the Coimbatore region, were drawn from the second; and the fixing of the target group and the procedures for establishing reliability and validity were drawn from the third.

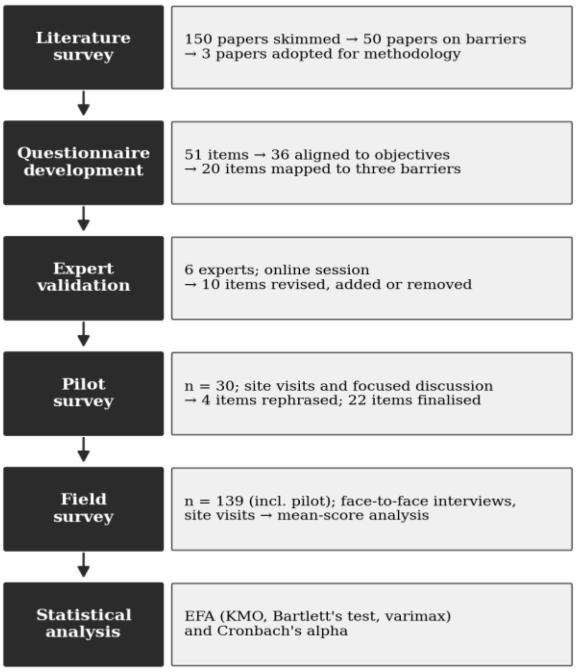

Fig. 1. Methodology flowchart

B. Study Area

Coimbatore (257.04 km², population 3,458,045) is an industrial and rapidly urbanizing centre in western Tamil Nadu with an estimated gross domestic product of USD 45 billion. Erode (109.52 km², population 2,251,744), located to the north of Coimbatore, is predominantly agricultural but is witnessing growing construction activity, with a gross domestic product of about USD 41 billion. The two districts share a Regional Chief Engineer office, similar geography and similar construction methods, which makes them suitable for a joint study. Both lack the technology and awareness required for structured C&D waste management.

C. Questionnaire Development

Of about 150 research papers screened, 50 dealing directly with barriers to C&D waste management were used to frame an initial pool of 51 questions. Questions not aligned with the problem statement were removed, reducing the pool to 36 [20]; open-ended items and items unsuited to a Likert format were then rephrased or removed, leaving 20 questions that matched the barrier categories [21]. The resulting initial instrument is shown in Table II. Items on budgeting and costs were mapped to financial barriers, items on administration and responsibility to managerial barriers, and items on waste-handling practices and traditional methods to cultural barriers [22].

TABLE II. INITIAL QUESTIONNAIRE MAPPED TO BARRIER CATEGORIES

Code	Statement (initial version, before validation)
M1	I know the estimated quantity of C&D waste generated from my site
M2	Our C&D waste is transported to a licensed facility
M3	Specific regulations governing C&D waste disposal exist in our organization
M4	Waste management practices are communicated to workers on site
M5	The supervisor in charge is instructed to handle waste on site
M6	Designers take responsibility for waste as part of their role
M7	Difficulties in defining project parameters and allocating resources hinder C&D waste management
C1	Construction waste such as concrete and brick could be reused to reduce waste on site
C2	Fines, vehicle impoundment and criminal indictment at panchayat level will reduce illegal dumping
C3	Clients are concerned about C&D waste management
C4	Cost is an issue in managing C&D waste
C5	Estimation of material plays a role in the waste generation rate
C6	Organizational norms prioritize quick completion over sustainable waste management
C7	Traditional practices combined with waste minimization techniques are preferred in our team
F1	There is a designated area for waste storage within our site
F2	Waste-based sustainable construction materials are cost effective
F3	Our budget does not allow for additional expenses on C&D waste management
F4	C&D waste management methods result in higher operational costs than traditional methods
F5	C&D waste management increases project expenses without clear financial returns
F6	Without external funding or incentives, sustainable C&D waste management is feasible

M – managerial; C – cultural; F – financial barrier.

Responses were captured on a five-point Likert scale ranging from strongly agree to strongly disagree, chosen for its ease of use and versatility in measuring agreement with closed-ended statements. The items were ordered to begin with simple questions, place the crucial questions in the middle and the sensitive questions at the end to minimize negative bias, and maintain a logical flow that keeps respondents engaged [23].

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D. Stakeholder Discussion and Expert Validation

The draft was first discussed with stakeholders, whose insights led to the inclusion of relevant questions and the removal of those not aligned with the barriers [24]. The revised questionnaire was then sent to six professionals in the C&D waste management industry [25], who assessed whether each item technically aligned with its intended barrier; an online session was held to consolidate their feedback. Ten items were edited, added or removed as a result. Representative revisions are summarized in Table III.

TABLE III. KEY REVISIONS AFTER EXPERT VALIDATION

Original item	Expert remark	Action taken
Difficulty in defining project parameters hinders C&D waste management	Respondents rarely admit difficulty in executing projects	Reworded as a general statement on management
Cost is an issue in managing C&D waste	Some waste can be reused or sold as scrap	Added items on salvage and sale to recyclers
Waste-based sustainable materials are cost effective	Knowledge of such materials is limited in small projects	Removed
C&D waste is transported to a licensed facility	Some waste is reused on site	Added items on on-site and off-site reuse
Material estimation affects waste generation	Demolition forms a large share of C&D waste	Restricted to the construction stage
Supervisor is instructed to handle waste on site	Workers are instructed only if supervisors are	Merged with the item on communication to workers

E. Pilot Survey

A pilot survey of 30 respondents (30 valid responses from 35 forms distributed, a rejection rate of 14.29%) was conducted in the same manner as the expert validation to check whether the responses reflected actual site practice [26]. Site visits enabled face-to-face interviews with private-sector respondents (contractors, consultants and developers) and public-sector respondents (government contractors, site engineers and PWD officials), and geo-tagged photographs documented on-site waste handling (Fig. 2). The pilot showed that four items were difficult for respondents to understand; these were rephrased in simpler language (Table V), producing the final 22-item questionnaire listed in Table IV. The weighted mean work experience of respondents was computed using (1), where E is the work experience and f the frequency.

$$Average\ experience = \Sigma(E \times f) / \Sigma f \tag{1}$$

Fig. 2. Geo-tagged photographs of on-site waste sorting, Coimbatore

TABLE IV. FINAL QUESTIONNAIRE ITEMS

Code	Statement (five-point Likert scale)
Q1	Our organization encourages handling waste in a way that is good for the environment
Q2	Our team prefers traditional construction practices with C&D waste minimization techniques
Q3	I keep track of the estimated quantity of C&D waste generated from my site
Q4	C&D waste from the site is transported to a licensed facility (recyclers and collection centres)
Q5	There is a designated area for waste storage in or outside the construction site
Q6	Our organization has a designated professional responsible for C&D waste management
Q7*	The site supervisor in charge is properly instructed to handle waste on site
Q8	Defining key project factors such as resources, time and budget can be challenging for management
Q9*	Accurate estimation of building materials helps reduce waste during construction
Q10*	Cost of disposing waste is a significant issue in C&D waste management
Q11	Clients are genuinely concerned about C&D waste management
Q12	Structural engineers (designers) see waste management as part of their role
Q13*	Our budget does not allow for additional expenses related to C&D waste management
Q14	Without external funding or incentives, sustainable C&D waste management is feasible for our projects
Q15	Salvaged materials other than steel (bricks, concrete, wood, plastics) are sold to recyclers
Q16	A major portion of the waste generated on our site is sold as scrap
Q17	Specific regulations governing C&D waste disposal exist in our organization
Q18	Rules at the local panchayat level (fines, towing vehicles, legal action) will help stop illegal dumping
Q19	Construction waste materials such as concrete and bricks can be reused to reduce waste on site
Q20	Our C&D waste is reused on site
Q21	Our C&D waste is reused off site
Q22*	C&D waste management practices often result in higher operational costs than traditional methods

** Reverse-coded during analysis.*

TABLE V. ITEMS REPHRASED AFTER THE PILOT SURVEY

Pilot wording	Final wording
Our organization encourages managing waste sustainably	Our organization encourages handling waste in a way that is good for the environment
Defining construction project parameters is a difficult task for management-level authorities	Defining key factors such as resources, time and budget can be a challenging task for management
Estimation of building material plays a role in the waste reduction rate	Estimating building materials accurately helps reduce waste during construction
Law enforcement policies such as fines, vehicle impoundment and criminal indictment will reduce illegal dumping	Rules at panchayat level such as fines, towing vehicles and legal action will help stop illegal dumping

Reason for all revisions: difficulty in understanding reported by pilot respondents.

Of the 30 pilot respondents, 56.7% were from Coimbatore and 43.3% from Erode, and 63.3% worked in the private sector, 26.7% in the public sector and 10% in both (Fig. 3); respondents of both genders participated. The weighted mean work experience of 16.67 years indicates that the responses reflect considerable field experience.

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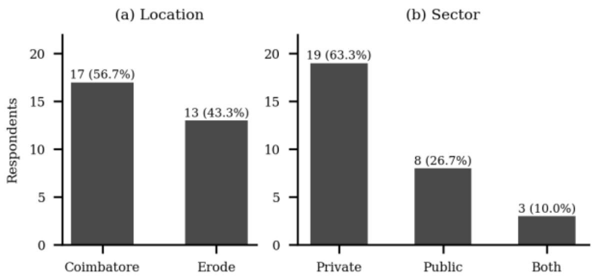

Fig. 3. Profile of pilot survey respondents (n = 30)

F. Field Survey

The final questionnaire was administered to a further 109 respondents across Coimbatore and Erode, giving a total of 139 responses including the pilot. The target group again comprised private contractors, consultants and developers, and public-sector contractors, site engineers and PWD officials. Face-to-face interviews and site visits were conducted alongside the survey to capture qualitative insights into prevailing practices.

G. Data Analysis

EFA was performed in SPSS to identify the underlying structure of the data and explain the pattern of correlations among the items [27], grouping items into factors based on shared variance to assess construct validity [28]. Suitability for factor analysis was tested with the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity; factors were retained using the eigenvalue-greater-than-one criterion together with the scree plot, and items with communalities below 0.4 were to be removed. Varimax rotation, an orthogonal method that maximizes the variance of squared loadings and minimizes cross-loadings, was applied to obtain an interpretable structure [29], [30]. Internal consistency was assessed with Cronbach's alpha, using 0.7 as the acceptance threshold. Finally, mean scores were computed for each item; negatively worded items (Q7, Q9, Q10, Q13 and Q22) were reverse-coded as 6 minus the original value before interpretation.

IV. RESULTS AND DISCUSSION

A. Respondent Profile

The respondent profile of the pilot survey (Fig. 3) shows a predominance of private-sector professionals with substantial experience. This predominance is consistent with the composition of small-scale construction in the region, although it may shape perceptions of sector-specific policies. The field survey extended coverage to owners of building firms, project managers, site engineers and supervisors, architects, valuation engineers, demolition contractors and PWD officials across the two districts and neighbouring towns such as Salem, Namakkal and Pollachi, giving a broad cross-section of small-scale construction.

B. Insights from Face-to-Face Interviews

Private-sector respondents described extensive informal reuse. Intact paver blocks were re-laid after renovation, excavated earth was used for plinth filling, and concrete rubble was used to raise ground levels on other sites, saving the cost of gravel. Rebar offcuts longer than 2 ft were reused as stirrups, while shorter pieces were sold as scrap at about 40% of the original price. Teakwood doors and frames were resized and reused, or sold to furniture makers because of strong demand for reclaimed teak. Manual demolition, where time permitted, allowed 30–40% of bricks and blocks to be recovered, which is not possible with mechanized demolition. In Erode, some firms offer free demolition in exchange for debris, which they resell at ₹2,000–3,000 per unit. Private builders have no designated disposal areas, so disposal is driven by demand for fill material, and plastics and cardboard are sold by weight. Fig. 4 shows an example of creative reuse, in which two old doors retrieved during a residential renovation were combined using cornice beading and wood strips, giving end-of-life products renewed aesthetic value.

Fig. 4. Waste recovery through reuse of doors retrieved during renovation

A significant regulatory weakness also emerged. Coimbatore Corporation levies a debris charge of ₹125 per 10 m^2 of plinth area in its building approval schedule of rates (Fig. 5), yet there is no corresponding collection infrastructure or enforcement, so the charge functions as a fee rather than a waste management service. Public-sector respondents reported that a C&D waste management fund is included in the bill of quantities only when an existing structure is demolished and deconstruction costs exceed salvage value; if salvage value is higher, the surplus is returned to the government. Although 15–20% recycled content is permitted in government projects, compliance is difficult to monitor in small projects, reused materials are restricted to non-load-bearing applications such as filling and weathering courses, and construction waste, which accumulates in stages, is much harder to estimate and manage than bulk demolition waste.

Shedule of rates

COIMBATORE CORPORATION

R.O.C NO.3087/2002/M.H.5 DATED 12.04.2002

SL.NO	DETAILS OF FEES	QUANTITY (PlinthArea)	LICENCE PERIOD	RATE
1	New /Alteration/Addition Construction and also Roof conversion c Residential Building	10sqm	2 years	
	a.Ground Floor or Part			70
	b.Semi Basement Cellar			135
	c.Stilt or Mezzanine floor			80
	d.First Floor			90
	e.Second Floor			120
	f.Third Floor			140
	g.Fourth floor and for every additional floor			250
2	Debris Charges for Residential,Commercial & Industrial Building	10sqm		125

Fig. 5. Debris charges in the Coimbatore Corporation schedule of rates for building applications

C. Exploratory Factor Analysis

For the pilot data, Bartlett's test was significant ($\chi^2 = 365.016$, df = 231, $p < 0.001$), confirming that the correlation matrix was not an identity matrix. Initial communalities ranged from 0.630 to 0.917, so all 22 items were retained. Seven factors had eigenvalues above one; the scree plot, however, levelled off after the fifth factor, and the five-factor solution explaining 65.287% of the variance was considered adequate for the pilot instrument.

For the field data (n = 139), the KMO value of 0.741 indicated adequate sampling, and Bartlett's test was significant ($\chi^2 = 915.113$, df = 210, $p < 0.001$). Seven components had

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eigenvalues greater than one and together explained 64.336% of the total variance. All extraction communalities exceeded the 0.4 threshold (range 0.496–0.765), so no item was removed. Cronbach's alpha of 0.702 exceeded the 0.7 criterion, confirming acceptable internal consistency. Table VI compares the two stages.

TABLE VI. EFA RESULTS FOR PILOT AND FIELD SURVEYS

Measure	Pilot (n = 30)	Field (n = 139)
KMO measure of sampling adequacy	–	0.741
Bartlett's test χ^2 (df)	365.016 (231)	915.113 (210)
Bartlett's test p-value	< 0.001	< 0.001
Range of communalities	0.630–0.917 (initial)	0.496–0.765 (extraction)
Factors with eigenvalue > 1	7 (5 retained by scree plot)	7
Cumulative variance explained	65.287% (5 factors)	64.336%
Cronbach's alpha	–	0.702

The field-stage extraction of seven components, compared with the three barrier categories proposed a priori, suggests that the managerial, cultural and financial constructs contain finer sub-dimensions, such as reuse and salvage practice, responsibility allocation and cost perception. This supports the use of EFA as a refinement step and motivates the confirmatory analysis proposed in Section V.

D. Mean-Score Analysis of Barriers

Fig. 6 presents the mean score of each item. The highest means were recorded for Q7 (4.40), Q10 (4.29), Q9 (4.15) and Q22 (4.15), identifying inadequate instruction of site supervisors, high disposal cost and higher operational cost relative to traditional methods as the most significant barriers, together with the recognized the role of accurate material estimation in reducing waste. Respondents also strongly supported local enforcement (Q18, 3.86), with 70% agreeing that fines, towing of vehicles and legal action at panchayat level would curb illegal dumping, and acknowledged the reuse potential of concrete and bricks (Q19, 3.75). The lowest means were for Q6 (2.25), Q12 (2.37) and Q17 (2.52), reflecting the absence of designated waste management professionals, designers' limited sense of responsibility for waste, and the lack of internal regulations on disposal.

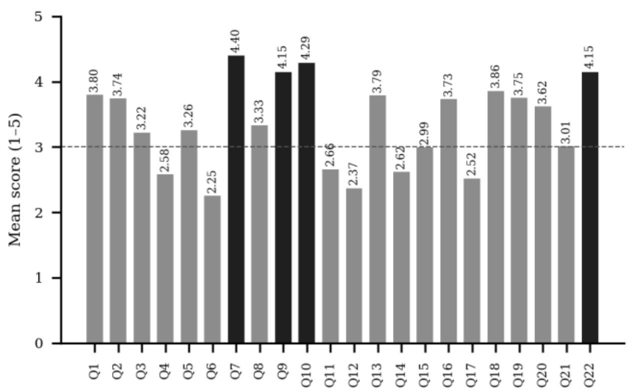

Fig. 6. Mean scores of questionnaire items (dark bars: mean of 4.0 or above)

These findings mirror the interview evidence: informal salvage and reuse are common where they generate immediate savings, whereas formal management functions such as training, designated personnel and regulated disposal are largely absent. The barriers are therefore less a matter of unwillingness than of cost structures and weak institutional support.

E. Policy Implications

Four policy directions follow. First, command-and-control measures such as vehicle impoundment should be prioritized to curb illegal dumping; a similar policy proved effective in Israel because it targets the hauler's most valuable revenue-generating asset, the truck [18]. Second, the gap between fee collection and actual debris collection calls for dedicated oversight committees at national, state and regional levels, backed by investment in manpower, transport and recycling infrastructure. Third, transport costs and the tax differential between virgin and recycled materials lead contractors to favour virgin materials; subsidies and reduced tax rates on recycled C&D products would stimulate demand and lower prices [13]. Fourth, recycling plants are under-supplied, as illustrated by a facility in Noida that receives about 450 t/day against a capacity of 800 t/day; local response teams that track waste generation at sites and direct debris to recyclers would secure a steadier supply. More broadly, although the 2016 rules require recycling facilities in all cities above the population thresholds, only 34 facilities were active in 2024 against 125 eligible cities [31], [12], showing that regional enforcement must be strengthened.

V. CONCLUSION AND FUTURE SCOPE

This study examined the managerial, cultural and financial barriers to C&D waste management among small-scale builders in Coimbatore and Erode and developed a validated instrument for measuring them. A 22-item questionnaire was derived from the literature, refined through stakeholder discussion, validation by six experts and a pilot survey, and administered to 139 respondents. The data proved suitable for factor analysis (KMO = 0.741; significant Bartlett's test), all item communalities exceeded 0.4, and the instrument showed acceptable reliability (Cronbach's alpha = 0.702), establishing it as a reliable tool for evaluating barriers in small-scale construction.

The most significant barriers were inadequate instruction of site supervisors, high disposal cost and higher operational cost of C&D waste management practices. To address them, the study recommends mandatory certification for personnel handling C&D waste, vehicle impoundment and related enforcement to drive disposal at designated collection points, tax relief and industry status for the waste management sector, and stronger regional enforcement of the recycling-facility mandate of the 2016 rules. Overall, financial constraints, limited awareness and inefficiencies in project management emerge as the principal obstacles to effective C&D waste management in small-scale construction.

The study is limited to two districts of Tamil Nadu, relies on self-reported perceptions, and uses a modest pilot sample for the initial factor analysis. Future work will apply Confirmatory Factor Analysis (CFA) using structural equation modelling in JASP to validate the factor structure against prior theory, after checking normality and sample-size adequacy, and will report the chi-square statistic, Composite Reliability (CR), Average Variance Extracted (AVE) and the Root Mean Square Error of Approximation (RMSEA) [32]. Extending the survey to other regions and quantifying waste generated on

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small sites would further strengthen the evidence base for policy.

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