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Research Paper

Mixed method analysis of household recycling challenges and the development of a sustainable recycling indicator

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ABSTRACT

Westminster City Council in London, like many local authorities in the UK, has faced challenges in meeting national recycling targets of 50 % by 2020. The current target is now set at 65 % by 2035. This research examined closely the issues contributing to the low recycling rate, aiming to guide the formulation and implementation of an effective waste management policy. Employing a mixed-method approach, data were gathered through online surveys from 417 residents, 12 telephone interviews with residents, and virtual interviews with 3 staff members in the council recycling team between 2019 and 2022. Data indicate that individuals aged 22–38 and 39–45 years (65 % and 72 %, respectively) strongly advocate for clearer labels to enhance recycling participation. Interestingly, only 31 % of secondary school leavers find bin labelling clear, in contrast to 50 % of participants with post-graduate qualifications. The research identified the key barriers to achieving a high recycling rate (greater than 65 %) in the City of Westminster, including communication and public engagement, service constraints, policy constraints, and physical factors. In response, a sustainable recycling indicator (SRI) was proposed as a functional tool to inform decisions and actions aimed at boosting council recycling rate. The indicator categorises enabling factors to achieve high recycling outputs, with potential applications beyond Westminster to improve the recycling rate in other urban areas in the UK and internationally.

1. Introduction

Westminster, a borough in the UK with a population of 204,236 (Westminster City Council, 2022), produced a significant volume of municipal waste of 107,333 tonnes in 2020–21 (Defra, 2022). The City Council manages over one million collections per week, serving more than 23,000 households with daily waste collection services (Westminster City Council, 2017). Despite concerted efforts, the local authority faced challenges in meeting the national government's annual recycling target of 50 % by 2020. Table S1 indicates the annual recycling rate between 2011 and 2021. The current goal is to achieve a 65 % recycling rate by 2035 (Defra, 2020).

Numerous studies (Ayçin and Kayapinar, 2021; Ferronato et al., 2021; Oluwadipe et al., 2021; Yakob et al., 2020; Siepelmeyer et al., 2023) highlighted recycling challenges in the UK, including policy constraints, communication gaps, physical barriers, service constraints, and human factors. Effective waste policy emerges as a crucial factor for sustainable waste management (Ayçin and Kayapinar, 2021; Ferronato et al., 2021), while inadequate communication and incentives impact recycling adversely (Lee and Krieger, 2020; Díaz-Meneses et al., 2020; Zhou et al., 2021; Halvorsen, 2012).

Inadequate infrastructure hinders material capture (Yukalang et al., 2017), and there is a need for enabling infrastructure, including adequate space and different waste streams bins (Bernstad, 2014; Dai et al., 2017) to eliminate contamination of materials (Christensen and Matsufuji, 2011). Service constraints, such as poorly designed recycling services, can limit recycling participation (Andersson et al., 2023; Siepelmeyer et al., 2023), especially when not aligned with the local context. Human behaviour, influenced by motivation and habit, plays a vital role in recycling participation (Oluwadipe et al., 2021). Behavioural attitude may affect recycling activities positively or negatively (Sung et al., 2019).

To address these challenges, this research employed a sequential methods approach to investigate the infrastructural, service-related and behavioural barriers to household recycling in the City of Westminster. Building on these insights, the research introduced a novel performance measurement tool, the Sustainable Recycling Indicator (SRI), to assess and enhance household recycling outcomes. The SRI integrated multiple

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dimensions of recycling performance into a unified framework for a more comprehensive and actionable means of evaluation. This tool has the potential to inform policy and practice both locally and globally as a recognised performance indicator and enhance recycling strategies.

2. Materials and methods

2.1. Method of data collection

The research was conducted in the Borough of Westminster, one of the thirty-two London boroughs sharing local government powers with the Greater London Authority (GLA). Demographical details of the Westminster borough are detailed in Supplementary A and Fig. S1. The research utilises quantitative and qualitative methods (sequential methods) to collect data, ensuring a comprehensive analysis of resident behaviours and perceptions towards recycling (detailed in Supplementary B, Fig. S2, and Table S2). Recycling behaviours are influenced by multifactorial barriers as identified in literature (Andersson et al., 2023; Ayçin and Kayapinar, 2021; Yakob et al., 2020). Six categories of recycling barriers were identified (Table S3) and guided the research.

The research was conducted in three iterative phases (Fig. 1). In Phase 1, qualitative interviews were carried out to explore recycling complexities and identify key issues. Findings from this phase informed the development of a questionnaire in Phase 2, which was used to collect quantitative data to generate insights for the broader population. Results from both phases were analysed to design the staff interview guide in the final Phase 3, which tested and refined the tools developed. The paper limitations are detailed in Supplementary C.

The research conducted with residents revealed their recycling experiences which directly informed tailored service improvements. Residents' responses shaped the development of research questions and guided the analysis outcomes. As an insider researcher, the lead author was uniquely positioned to extract meaningful insights from residents that could be implemented at both policy and operational levels to enhance the Council's recycling rate. These findings were ultimately distilled into the SRI tool.

The research focused on residents from households within the twenty wards in the Borough of Westminster. Interviews were also conducted with staff from the council recycling team and innovation team due to their involvement in managing the council recycling service.

2.1.1. Sampling strategies

In Phase 1, a volunteer sampling strategy was adopted, as identified by Gill (2020). Residents who volunteered to participate were required to meet two main criteria: currently live in Westminster and represent the borough's diverse housing types. This ensured the research captured perspectives reflective of the borough's demographics. Phase 2 employed a self-selection sampling approach, allowing any interested Westminster resident to participate in an online survey. Despite the disadvantages of participant bias (Sharma, 2017), its strength lies in attracting individuals with strong opinions on recycling issues. To mitigate potential biases, triangulation of data from all three phases was employed. In addition, pilot studies were designed to minimise researcher bias by randomising participants and limiting exclusion criteria, following the recommendation of Pannucci and Wilkins (2010).

2.1.2. Data collection

Qualitative data were collected through in-depth telephone interviews with 12 Westminster residents and 3 council staff, selected to reflect borough demographics, including the property type, level of education, and residency duration. Quantitative data were collected through a self-completion online survey by 417 residents. Detailed demographical profiles are presented in Supplementary A and Tables S4 and S7.

Data collection occurred between April and December 2020, organised in three phases, with data from each phase informing subsequent phases (Fig. 1). Detailed interview guides and the questionnaire are available in Supplementary D, E, and F.

Phase 1 focused on exploratory interviews to uncover residents' perspectives on recycling issues. Telephone interviews, lasting between 30–50 min, were conducted with participants recruited via email, social media, the council website, and the council's online magazine. Phase 2 involved a self-completion online survey to collect broader quantitative data, while Phase 3 refined and validated findings through further qualitative interviews, ensuring iterative development of the research tools.

2.2. Method of data analysis

Thematic analysis (TA) was employed to analyse the data from Phases 1 and 3 (Fig. 1), utilising NVivo (version 1.0). An inductive approach ensured that coding and themes were data-driven, allowing insights to emerge directly from the interview data as recommended by Caulfield (2022).

Phase 2 data were analysed using Pearson's chi-square test of independence using SPSS (version 28) to examine associations between categorical variables (detailed in Section 3.2). Questionnaire data were adjusted to represent the borough's demographic profile, but no

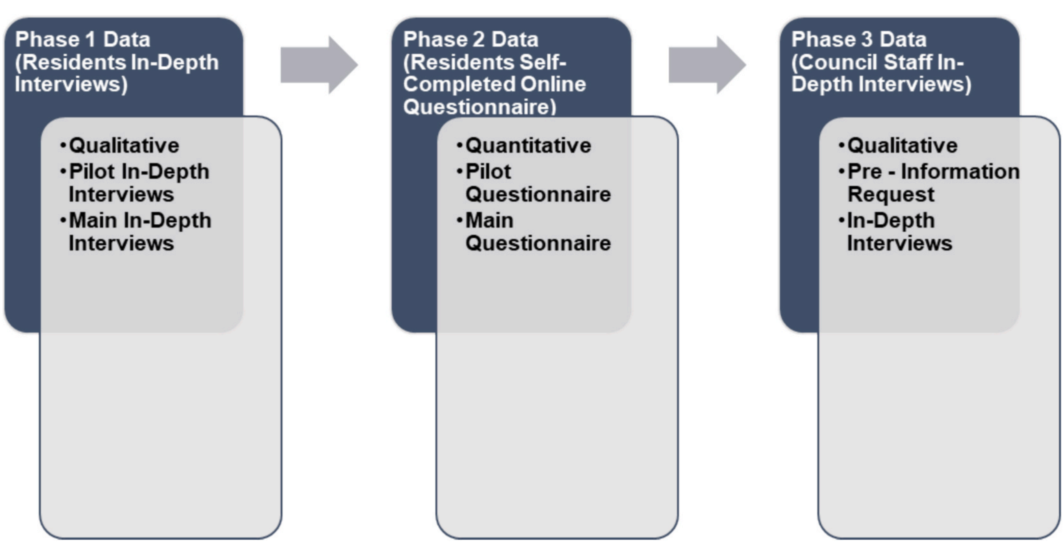

Fig. 1. Study phases showing 3 stages and sequence of data collection..

statistical differences were found between the raw and adjusted data sets. Therefore, the raw data was used for analysis.

Data triangulation across all three phases provided a comprehensive overview of barriers to recycling. This process also identified enabling factors for developing a Sustainable Recycling Indicator (SRI), envisioned as a practical tool to monitor and implement an effective recycling regime, ultimately enhancing household recycling efforts.

2.3. Triangulation and interventions

The data collected across the three research phases, employing various methods and participant groups, underwent triangulation to enrich the depth and validity of the findings. In accordance with Flick (2018), triangulation served as a methodological strategy, converging data from different sources to reinforce and validate the research outcomes.

The triangulation process is illustrated in Table 1, where Phase 1 identified key issues (physical, service, and political factors) that were subsequently quantified in Phase 2 using variables such as education, property types, and age variation to evaluate recycling behaviours and barriers. This confirmed the barriers identified in Phase 1, while also revealing that human factors were less significant and primarily interconnected with service factors. Phase 3 in-depth interviews provided professional perspectives on the issues raised by residents and helped identify four key recycling barriers—physical, communication, service, and political—as shown in Fig. 2. Recognising these barriers forms the foundation for developing the Sustainable Recycling Indicators (SRI), enabling targeted interventions to improve household recycling practices.

2.4. Sustainable recycling indicator design process

Drawing from the insights garnered in the three research phases, a Sustainable Recycling Indicator (SRI) was formulated. The SRI was designed by integrating the proposed interventions, referred to as enabling factors (EF), aimed at mitigating the diverse barriers identified during the research phases. The first step in constructing the SRI involved identifying and mapping seven EFs to the three barriers out of the four key central barriers that emerged during the triangulation (Fig. 3). These three barriers are: communication & engagement, physical, and service factors. Political factor (see Table 1) was excluded from the SRI because waste legislation lies outside the jurisdiction of local authorities.

The SRI provides a visual framework to evaluate recycling performance. When all the enabling factors are green, a high recycling rate is indicated; yellow reflects a medium rate, and red signals a low rate (Fig. 4). Implementation begins with evaluating current circumstances by assessing the availability or effectiveness of EFs, marked green, yellow or red. Municipalities compare their current recycling rates with the benchmark rates outlined within the SRI, categorising them as A (high), B (medium) or C (low). The definitions for each category and their corresponding EFs are detailed in Supplementary G, Tables S9, and S10.

2.5. Sustainable recycling indicator utilisation example

Fig. 4 also illustrates the SRI assessment process, depicting the current evaluation of EFs and Westminster City Council's recycling rate. Based on the council's recycling rate of 24 % in 2020/21, and triangulated findings from participant-reported issues, Westminster currently falls under Category C. Each EF's status is determined and colour-coded.

As an initial step, it is recommended the council aim for Category B before progressing to Category A, targeting a 45 % recycling rate within the next decade. This aligns with the council's waste strategy to achieve recycling rate of 35 % by 2020, 40 % by 2025, and 45 % by 2031.

Following the SRI assessment, municipalities can utilise the flow chart (Fig. 5) as a planning guide for additional interventions. By addressing EFs flagged as red or yellow, a systematic approach to monitor and improve recycling rate can be achieved.

When adopting the SRI for application, municipalities have the flexibility to incorporate new enabling factors or substitute existing ones to tailor the model according to their specific needs. Irrelevant factors can be omitted, while new ones can be introduced to align with local circumstances.

3. Results and discussions

3.1. Phase 1 data (Residents In-Depth Interviews)

The thematic analysis of the Phase 1 data revealed 10 initial themes leading to three main themes: physical factors, service factors, and political factors, each containing individual sub-themes. The comprehensive breakdown of these themes and the sub-themes is presented in Table S5.

3.1.1. Theme 1: Physical factors

This theme encapsulates the physical barriers encountered by resident participants, with specific sub-themes including bin capacity, storage space, and building types, all identified as barriers limiting effective recycling participation, as reported by residents.

3.1.1.1. Bin capacity. The bin capacity sub-theme emerged prominently, particularly among participants residing in flatted properties. These residents expressed concerns about inadequate or lacking recycling bins both internally and externally. External storage capacity was a

Table 1
The triangulation process of merging the results from the 3 phases of the research into 5 central barriers.

Phase 1 Results	Phase 2 Results	Phase 3 Results	Converged Results for the 3 Phases into 5 Central Barriers	Components of the Converged Results
Physical factors (bin capacity, storage space, and building types)	**Education vs Recycling Behaviours**	**Communication and Engagement** (Transient Population and media strategy)	**Human Factors***	Recycling behaviours, and transient population.
Service Factors (recycling collection service, food waste, and recycling bag availability)	**Age vs Recycling Enabling Factors** (Packaging labelling, Incentives, and Storage Space)	**Service** (Property types, collection, recycling bags)	**Physical Factors**	Physical factors, recycling enabling factors, packaging labelling, micro recycling centres proximity, property types, and storage space.
Political Factors (waste legislation, recycling regimes, and packaging labelling)	**Property Types vs Micro Recycling Centres Proximity**	**Legislation** (Political agenda and recycling rate calculation)	**Communication Factors**	Communication, public engagement, and incentives.
			Service Factors	Recycling bag accessibility, collection frequency, and food waste.
			Political Factors	Waste legislation, political agenda, recycling regimes, and recycling calculation methods.

* Not a significant barrier.

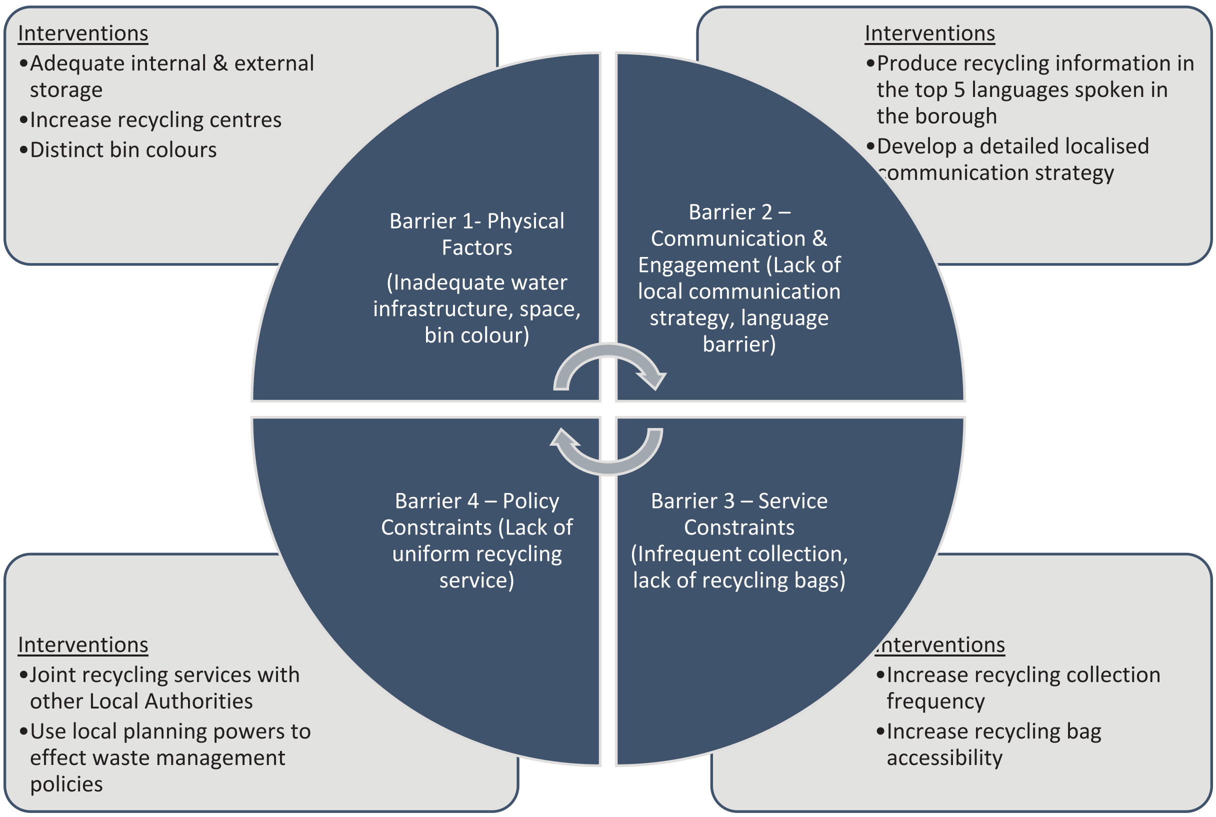

Fig. 2. Summary of the 4 main barriers identified in the research resulting from merging the results of the 3 data collection phases and the various interventions to mitigate the barriers.

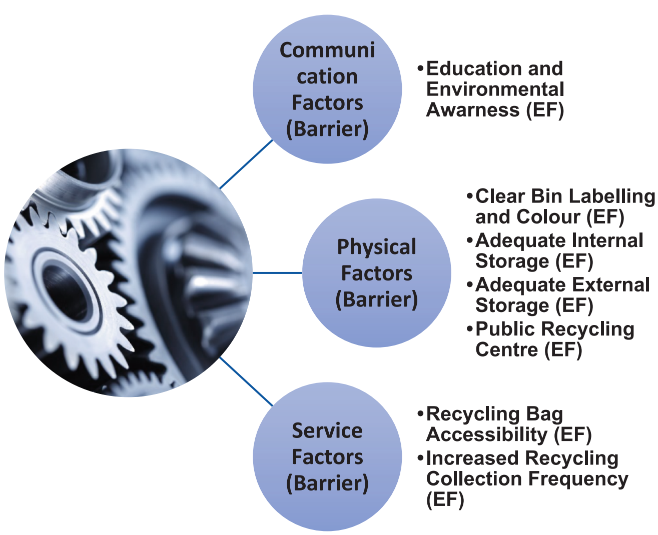

Fig. 3. The SRI design process showing how the 3 main barriers from the triangulation were mapped to relevant interventions known as enabling factors.

significant challenge, with some residents highlighting the absence of external recycling facility in high rises.

3.1.1.2. Internal Spaces. The internal space sub-theme revealed difficulties faced by participants in flatted properties when conducting source separation. Lack of internal space hindered proper recycling practices, as expressed by Participant P6: *"There is no internal space to separate recycling and rubbish so as not to contaminate the recycling. This means I do not have separate bins for recycling"*.

In contrast, residents in houses, such as Participant 11, navigated internal space challenges by using the front garden for source separation.

Interestingly, participants living in flatted properties and some houses faced similar challenges regarding the lack of internal spaces for recycling activities. This result aligns with studies carried out by Timlett and Williams (2011) & Du Toit and Agner (2020) affirming that physical factors pose barriers to effective recycling participation.

3.1.2. Theme 2: Service factors

The theme of service constraints delves into participants' experiences with the council recycling collection service, emphasising sub-themes such as collection frequency, food waste, and recycling bag availability. The focus is on how these services impact the participants' ability to engage in effective recycling activities.

3.1.2.1. Collection Frequency. Residents living in flatted properties, especially participants P1, P4, P7, P8 and P9, highlighted the frequency of mixed recycling collection as a significant barrier. They urged the council to increase the collection frequency for recyclable materials. Interestingly, participants residing in houses did not feel the impact of collection frequencies due to the availability of adequate external storage spaces within their properties. This observation underscores the interconnectedness of the collection service with the physical factors theme, where insufficient storage facilities have a knock-on effect on the experience related to collection frequency.

Some participants, such as P7 and P9, questioned the council's commitment to recycling schemes, expressing scepticism about the council's dedication to increasing the recycling rate. The discrepancy in collection frequencies between cycling (collect weekly) and rubbish, (thrice a week or daily), raised concerns among residents. The pressure on the council to maintain clean streets, particularly in tourist areas,

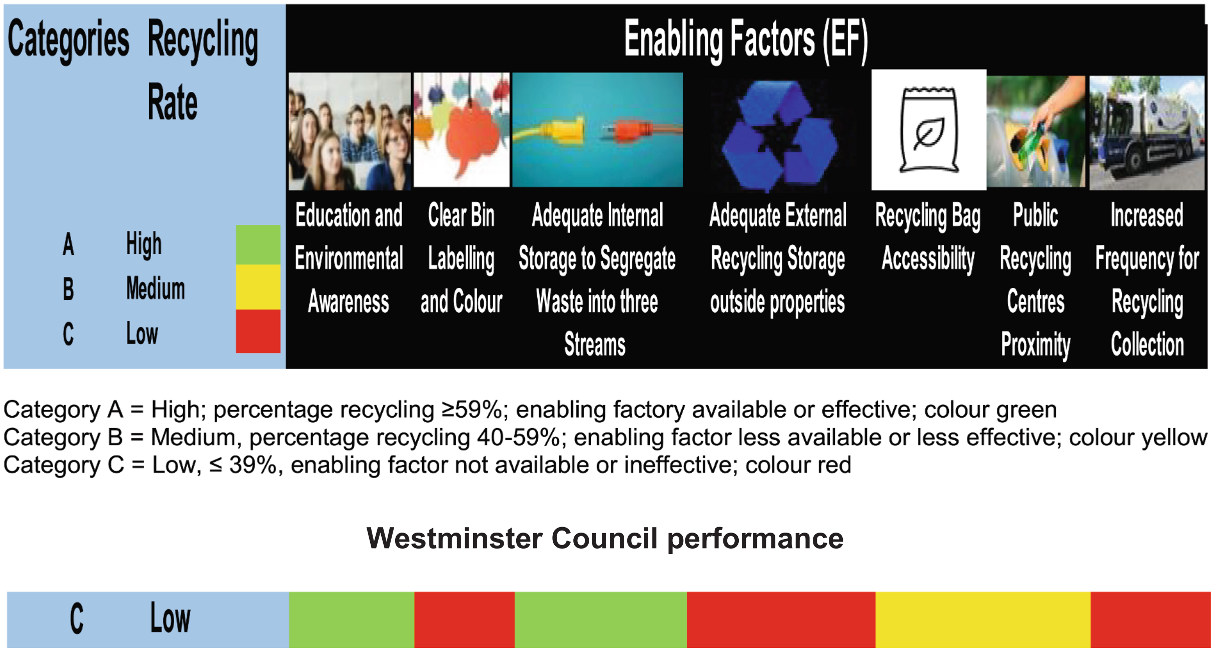

Fig. 4. Sustainable recycling indicator standard developed based on this study, which can be used as a monitoring strategy to achieve a high recycling rate. An example of using the SRI model is provided: after the initial assessment, Westminster Council is overall placed in **category C**. The SRI should be used in conjunction with the flow chart shown in Fig. 5 as a functional tool to increase recycling rate at municipal levels.

influenced the collection frequency dynamics (CP1-recycling staff).

Participants generally agreed that the current rubbish collection frequency should remain while advocating for an increase in recycling collection frequency. However, P8 and P9 expressed dissenting opinions, suggesting that reducing rubbish collection frequency might incentivise residents to recycle more.

3.1.2.2. Recycling bag Accessibility. Another identified service barrier was the inaccessibility to recycling bags, particularly affecting residents without external storage facilities, mainly those in high-rise buildings. Participants, regardless of dwelling type, encountered challenges obtaining free recycling bags from the council, except for P10 who lives in a house.

However, participants such as P12 and P6 were not aware of these two avenues and faced difficulties obtaining bags, exacerbated by the unavailability of bags at libraries during the COVID-19 pandemic. P12 also called for a recycling system without bag use.

3.1.2.3. Food waste Collection. The council's non-collection of food waste during in Phases 1 and 2 garnered dissatisfactions from half of the participants. The absence of food waste collection, as expressed by P4, was seen as a substantial loss of recyclable material ending up in rubbish bins. The data collection timeframe coincides with the initiation of food waste collection in 2022, following a successful trial in 2019. P2 made a critical point regarding space constrains for additional food waste bins, potentially hindering the new collection service. Overall, the results from this theme agree with the study of Tsalis et al. (2018), emphasising the importance of tailoring recycling services to the diverse needs of the local community.

3.1.3. Theme 3: Political factors

This theme examines the participants' perspectives on the current and future UK waste legislation and its influence on recycling participation. The three sub-themes discussed are waste legislation, recycling regimes and labelling standards for packaging.

3.1.3.1. Waste Legislation. Many participants, spanning both property types (P4, P7, P9, P10, P11, and P12), engaged in discussion about waste legislation. Suggestions were made for a mandatory recycling rule for all residential property owners, with fines imposed on non-compliance, as proposed by P9 and P10. This approach, according to the participants, would negate the impact of the lack of adequate recycling infrastructure in residential buildings. There was also a popular call for proposals to ban non-recyclable packaging materials, with P11 succinctly stating, "*… manufacturers of goods should be encouraged not to use materials that are not recyclable*".

3.1.3.2. Recycling Regimes. Participants (P4, P9, and P10) commented on the different recycling regimes operating throughout the UK and their specific impact on Westminster borough, given its status as a government seat and a tourist attraction. Recommendations were strong for a consistent national recycling regime in terms of colours, material collected, and labels. This aspiration of the participants was reflected in the new national government waste reforms announced in October 2023. This reform aimed to standardise recycling practices across England, eliminating confusion over different recycling regimes.

3.1.3.3. Labelling standard for Packaging. The sub-theme on labelling standards for packaging focused on participants' concerns about the ambiguity in determining the recyclability of a packaging material. P7 and P12 emphasized the need for clarity in the packaging labelling, highlighting the current ambiguity and confusion among participants. The challenge arises from conflicting advice received from different councils about the recyclability of certain packaging materials and the lack of explicit labelling indicating whether materials are recyclable. Participants expressed difficulty in ascertaining the recyclability of packaging materials based on unclear labels, with P7 admitting to discarding packaging materials in the rubbish bin when the packaging labels were not clear enough.

This theme's results resonate with Jesson and Stone's (2009) study, which identifies different recycling regimes and labelling issues as limitations to effective recycling. The participants' insights underscore the importance of clear, standardised regulations and labelling practices to enhance recycling participation and reduce ambiguity among residents.

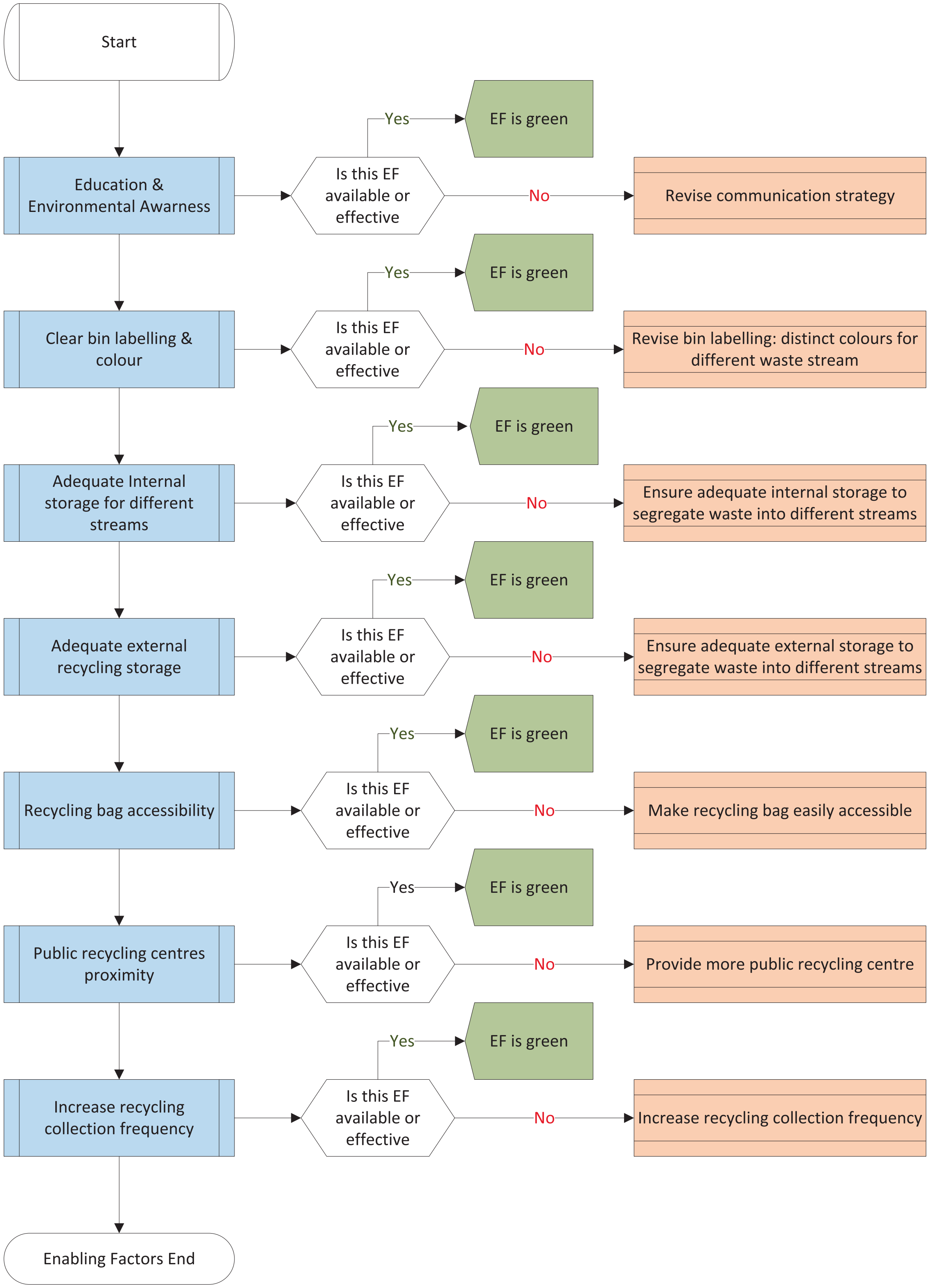

Fig. 5. Sustainable Recycling Indicator (SRI) flow chart process to increase recycling rate using enabling factors (EF).

3.2. Phase 2 data (Residents Self-Completed Questionnaire)

The outcomes of chi-square tests, incorporating three explanatory variables (age, education, and type of residence) against twelve response variables, revealed a mix of significant and non-significant relationships, as shown in Table 2. This section focuses on the discussion of two of the primary explanatory variables (Age and Education) in conjunction with two of the three response variables (1 and 2). The analysis of the explanatory variables of residence type and its correlation with the third main response variable (11) is presented in Supplementary H and Table S11. It should be noted that all three primary explanatory variables are important.

Table 2
Chi-square tests results showing significant and non-significant relationships between explanatory and response variables for data collected in Phase 2.

Explanatory variables	Response Variables 1	2	3	4	5	6	7	8	9	10	11	12
Age		*		*			*	*	*	*		*
Education	*		*	*					*			
Residence Type		*			*	*					*	

Keys: 1 = recycling behaviour; 2 = recycling enabling factors; 3 = commitment; 4 = bin labelling and colours; 5 = recycling bag accessibility; 6 = collection frequency; 7 = food waste collection; 8 = communication methods; 9 = communication effects; 10 = recycling events; 11 = micro recycling centre proximity; 12 = future waste legislation. Number of participants (N) = 417.
* Denotes a significant relationship ($p < 0.05$).

3.2.1. Age and recycling enabling factors

In the self-completed questionnaire, participants were asked about the enabling factors – clear labels on packaging, incentives, and adequate internal and external storage space – that would encourage effective recycling.

The analysis revealed significant differences in age proportions concerning preferences for various enabling factors (response variable 2), χ^2 (df = 33, n = 417) = 63.56, *p-value < 0.01*. This implies that age plays a significant moderating role in shaping responses to situational recycling factors.

Younger generations, especially the age groups of 22–38 years (65 %) and 39–45 years (71 %), expressed a strong inclination towards the importance of clear labelling on packages for facilitating recycling activities, surpassing the sentiments of the older generations (46–54 years – 62 % and over 55 years – 62 %). Moreover, older generations (above 46 years) exhibited less motivation from incentives compared to their younger counterparts (22–45 years). Concerning storage space, younger generations indicated a need for more internal and external storage spaces to actively participate in recycling activities (see Fig. S3). The results also highlighted the influence of socio-economic factors on recycling participation, as a significant portion of younger generations resides in flats (with limited storage space) compared to the majority of older generations living in houses (with adequate storage space).

This outcome suggests that the younger generations encounter more barriers than their older counterparts. This aligns with the descriptive data from the questionnaire (see Fig. S4), illustrating millennials (22–38 years) recycle less compared to the older generation (39 to over 55 years). In summary, older participants appear to be inherently motivated, facing fewer barriers and requiring fewer incentives to recycle. Conversely, the younger generation encounters these barriers, often disguised as enabling factors, necessitating a more comprehensive set of facilitators to enhance their participation in recycling activities. These findings agree with studies by Du Toit and Wagner (2020), indicating higher recycling participation among older generations, and Eichler (2017), identified a lack of clarity on packaging labels as one of the main barriers for the younger generation.

3.2.2. Education and recycling behaviour

Responses from participants to the question "how often do you recycle" in the self-completed questionnaire are detailed below. The test analysis between level of education and the inclination to participate in recycling activities yielded a significant result, χ^2 (df = 10, n = 417) = 66.0, p-value = 0.01. This indicates that education is a predictor that influences recycling behaviour significantly.

While there was observed high recycling participation across all the levels of education (see Table S6), the proportion of positive recycling behaviour increased with the level of education. Respondents with post-graduate degree qualifications exhibited the highest proportion (93 %), while respondents with secondary school qualifications have the highest percentage (20 %) of those who never recycled, compared to other education levels.

This trend could be attributed to factors such as increased exposure to environmental awareness among respondents with higher qualifications as they progressed through their studies. Conversely, respondents with lower educational qualifications might have limited exposure to environmental awareness. The results validate data collected in Phase 1, where participants with higher educational qualifications displayed higher recycling behaviour, while lower recycling activities were observed among those with lower educational qualifications.

It implicates education as a significant factor influencing recycling behaviour, whether positively or negatively is dependent on the level of education. This finding agrees with studies by Seng et al. (2018) and Vieira and Matheus (2018), which concluded that a higher level of literacy skills facilitates a better understanding of recycling benefits, influencing positive recycling behaviours.

3.3. Phase 3 data (Council staff In-Depth Interviews)

The thematic analysis of Phase 3 initially identified seven themes, which were further distilled into three final themes encompassing communication/public engagement, service, and legislation (see Table S8).

3.3.1. Communication and public engagement

This theme delves into the council staff recycling communication and engagement strategy, with sub-themes including reliance on general communication modules and the impact of a transient population. Prior to the interviews, documentation on council communication objectives and engagement strategies were requested. Staff responses highlighted a dependency on ReLondon communication assets, particularly the 'Be That Person' campaign toolkit launched in December 2021. The reliance on a general communication strategy poses challenges, potentially overlooking localised barriers unique to the borough, creating communication challenges for short-term residents unfamiliar with the recycling service. Staff participants acknowledged relying on the corporate communication department for efficient resource utilisation. Furthermore, under-utilisation of social media, as revealed by the low following of the Westminster Recycle Facebook page (around 500 followers), poses a barrier to effective communication, especially with the younger generation. While acknowledging the potential of social media, there seems to be a prioritisation challenge due to perceived low interest.

> *CP2 noted: "… it is quite niche in terms of the residents that would have that level of interest".*

However, this may limit outreach to the wider resident population, particularly the younger demographics. Despite recognition that more could be done to engage the younger generation through social media, the council attempts to strike a balance, using alternative communication methods like door knocking to engage with residents effectively. This finding aligns with studies conducted by Mee and Clewes (2004), WRAP (2014), and Kaplowitz et al. (2009), emphasising the influence of targeted communication tools on recycling participation. However, it diverges from Willman's (2015) study, which concluded that door-to-door communication has the greatest impact on increasing recycling rates. In this case, the borough's recycling rate did not increase, possibly due to other factors like the lack of recycling receptacles or other situational barriers.

3.3.2. Service

Within the service constraints outlined by staff participants, the dominant sub-themes revolved around physical constraints, collection challenges, and accessibility of recycling bags.

The physical factors impacting recycling activities were highlighted by participants CP1, CP2, and CP3, who pointed to the borough's central London location and the structural characteristics of its buildings as significant barriers. With Westminster being one of the densest boroughs (12,564/km2) (City Population, 2020), characterised by historical properties, narrow roads, and old infrastructure, providing an efficient recycling service becomes intricate. The challenges include limitations on service types, infrastructure placement, collection frequencies, and the type of vehicle employed.

The impact of these physical constraints is particularly evident in dealing with historical properties, often listed and challenging to modify for modern waste management. CP1 emphasised the myriad barriers faced from a residential perspective due to the diverse housing stock.

Results from Phases 1 and 2 revealed resident dissatisfaction with daily rubbish collection and weekly recyclable materials collection. Residents expressed a preference for maintaining current rubbish collection frequencies while increasing mixed recycling collection frequencies. Staff members acknowledged the different collection frequencies based on sensitive locations, such as tourist attractions and business districts. They highlighted the pressure to keep these areas clean, defending the current collection frequency as comparable or better than other local authorities. A proposed one-day collection scheme for refuse, recycling, and food waste is anticipated, contingent on higher storage capacity for recycling and food waste to prevent overflow into residual bins. Service issues extended to accessibility of freely available bags. While different methods (by telephone, council website, email, and libraries) exist for residents to obtain bags, phase 2 results indicated that 20 % faced difficulties accessing them. CP1 emphasised the availability of information online and encouraged realistic expectations regarding residents' responsibility to seek recycling information.

Notably, some residents (P6 and P12) in phase 1 experienced challenges accessing bags, either ongoing or exacerbated during the COVID-19 pandemic. However, concerns arise regarding the sustainability of using bags for the collection system due to their single-use plastic nature. Studies, such as Workentin et al. (2022) and Lyas et al. (2005), highlighted environmental and economic concerns and the potential misuse of bags for lining residual bins. The overarching theme underscores the need to design recycling services tailored to local situational needs, aligning with the findings of Mattsson et al. (2003).

3.3.3. Legislation

Staff participants (CP1 and CP2) identified two key sub-themes, political agenda and recycling rate calculation, as significant impediments to the provision of efficient recycling services.

CP1 noted the lack of political motivation to enact stringent waste legislation, attributing it to the removal of local authorities' powers to compel residents to recycle. The shift towards a "lighter touch" approach is seen as a political decision, driven by economic considerations. CP1 highlighted the inherent tension between waste reduction and economic interests, as waste reduction could curtail consumerism, impacting the economy. Emphasising the need to move beyond economic concerns, CP1 urged the national government to implement strategies that transform waste into valuable resources, aligning with the principles of a truly circular economy.

The second legislation sub-theme centred on the methodology for calculating recycling rates, which requires local authorities to submit annual waste data (WasteDataFlow, 2021). CP1 and CP2, criticised the current method as unfair, arguing that it neglects to account for geographical location and urban characteristics of certain boroughs. CP2 proposed the mixed recycling percentage be calculated as segregation rate to provide a more accurate recycling output. CP1 highlighted the current methodology disproportionately impacts densely populated urban boroughs, like Westminster, portrayed as underperforming councils. The discussion underscores the complex interplay of political decisions, economic considerations, and methodological nuances in shaping waste legislation and recycling outcomes. These findings echo broader discussions on the challenges local authorities face in balancing political will, economic imperatives, and fair assessment methodologies in waste management.

3.4. Impact of the SRI

The development of the SRI was guided by the core principles of indicator selection proposed by Data for Impact (2021) among which are: relevance to the research outcomes, practicality in monitoring recycling barriers, and uniqueness in avoiding duplicating existing waste indicators. The SRI designed meets these tests in introducing an innovative tool that is unique and effective in managing household waste. Unlike existing waste indicators (Table 3), which focus primarily on processes, raw materials flow, overall efficiency rate, or treatment, the SRI is an operational indicator designed to monitor and improve household recycling rates by addressing situational barriers and household recycling service, and identify interventions. It is a nuanced and practical tool for evaluating and enhancing recycling outcomes.

The rigorous methodology applied in this research, combining mixed methods, methodological consistency, accurate representation of the

Table 3
Existing Waste Indicators used in the Waste Management Industry to Monitor Circularity of Recycled Materials and References.

Existing Waste Indicators	Acronyms	Purpose	References
Circular Economy Indicators	CEI	Monitor and evaluate waste generation to assess performance towards a circular economy, applicable to all recyclable and recoverable waste.	(De Pascale et al., 2021)
Resource Efficiency Indicators	REI	Assess waste generation and performance toward circularity, applicable to all recyclable and recoverable waste.	(Moraga et al., 2022)
End-of-Life Recycling Input Rate	EOL-RIR	Track material improvements toward circularity; primarily metals.	(Espinoza, 2021)
Municipal Solid Waste generation	MSW GEN	The indicator describes the amount of total MSW generated in a local waste authority per year.	(European Commission, 2025)
Municipal Solid Waste Collected	MSW COLL	The indicator describes the amount of mixed MSW collected per capita per year. Its calculation considers the waste collected as non-source separated mixed waste.	(European Commission, 2025)
Municipal Solid Waste Disposal	MSW DISP	The indicator measures the annual amount of MSW that is sent to disposal, such as landfill or incineration, without energy recovery (all disposal operations are defined in Annex I to the WFD).	(European Commission, 2025)
Capture Rate (e.g. Recycling Rate)	CR (RR)	The capture rate is the percentage of the estimated generation of a specific waste	(European Commission, 2025)

studied population, and the triangulation of the data from three phases, established confidence in the findings. These findings challenge prevailing assumptions that recycling barriers are universally uniform, highlighting the importance of addressing individualised, localised factors.

Post-research testing and implementation of the SRI through the introduction of a separate household food waste collection in Westminster increased the council's recycling rate by 3.7 % (Veolia, 2024; London Post, 2024). The SRI played a key role in enabling effective food waste infrastructure and an efficient collection service that drove this positive outcome. Therefore, it has served as a valuable benchmark for future development. The three core principles underpinning its design provide a solid foundation for real-life application, enabling further research to enhance its robustness.

4. Conclusions

This research highlights the complexity of recycling barriers, showing that despite positive behaviours, respondents face persistent physical, political, communication, and service-related challenges. To address these challenges, the SRI offers a promising tool, strategically designed to empower effective resident recycling activities. The SRI incorporates targeted interventions aimed at mitigating recycling barriers prevalent in municipalities, offering a practical framework for increasing recycling outputs. By utilising this indicator, municipalities can tailor interventions to their specific needs, fostering a more adaptable and responsive approach to recycling challenges. Its application in Westminster has contributed to improving recycling outcomes. The SRI fills a gap in monitoring and supporting recycling efforts, offering actionable insights that can enhance participation and performance both locally and internationally.

CRediT authorship contribution statement

Saeed Oluwadipe: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Diane Purchase:** Writing – review & editing, Supervision. **Hemda Garelick:** Writing – review & editing, Supervision. **Simon McCarthy:** Writing – review & editing, Supervision. **Huw Jones:** Writing – review & editing, Supervision.

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Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.wasman.2025.115170.

Data availability

Data will be made available on request.

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