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Mind Over Waste: Decoding the Mental Models of Hard-to-Reach in Household Waste Practices

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***Abstract* – A resource-efficient society that reduces waste is one of the European Union's long-term objectives. Waste that cannot be prevented should be reused as far as possible through sorting, recycling and minimizing landfill. Achieving this goal requires the active and coordinated participation of all stakeholders, including households. However, the low involvement in waste reduction measures of certain consumer groups, especially hard-to-reach consumers, poses a significant challenge. This paper investigates the mental models of waste reduction practices of different consumer groups using cognitive maps as an analysis tool. The Mental Modeler tool is used to predict behavioural patterns of different consumer groups and simulate the impact of various scenarios on these behaviours. The results show that different groups of consumers develop different reactions to the waste management measures foreseen in the legislation, with the hard-to-reach exhibiting particularly minimal engagement. The study highlights significant differences between the mental models of consumer groups, emphasizing the need for a tailored, interdisciplinary approach to understand consumer motivations and effectively promote sustainable behaviour change. The findings suggest that to transition to a circular economy successfully, specific strategies and policy interventions targeting hard-to-reach groups are essential to stimulate their engagement in waste reduction and resource reuse practices.**

***Keywords* – Circular economy; cognitive mapping; consumer behaviour analysis; scenario analysis; waste management; waste reduction.**

1. INTRODUCTION

The growing world population is projected to reach 9.7 billion by 2050 [1], increasing the demand for sufficient production of products and services [2]; however, even with its current size of 8.2 billion in 2024, humanity is consuming resources at a rate 1.8 times faster than those resources are generated [3]. The increasing demand and pressure on natural resources due to excessive consumption has led to significant environmental problems [4]–[6]. Producing enough products and services to meet the consumption demands of the world's population without causing negative environmental impacts and ensuring sustainability has now become a major challenge worldwide.

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Dominant consumption patterns are based on the extraction of resources, their use in the production of a product and their disposal at the end of the product's life cycle, demonstrating a linear practice where only a small proportion of the resources used are recycled, the rest ending up in waste [7].

This approach has created a critical problem. The European Union (EU) generates more than 2.2 billion tons of waste every year, whereas 27 % of this is municipal waste, mainly generated by households [8]. According to data from the European Commission (EC), the average European produces 5 tons of waste per year, and only 38 % of these are recycled, while the remaining waste is landfilled [9].

Given the increasing trends in waste generation, it is essential to develop effective and sustainable strategies to reduce waste volumes and adverse environmental impacts. Waste prevention is an integral part of a comprehensive transition to a circular economy [10].

One of the United Nations Sustainable Development Goals is to significantly reduce the amount of waste generated, including at least halving the amount of food waste generated per capita by 2030. The EU has set its Member States strict and ambitious targets – 60 % of municipal waste must be recycled and prepared to be reused by 2030, and the proportion of municipal waste disposed of in landfills must be reduced to 10 % by 2035 [8]. To achieve these goals, governments are taking various measures, including the development of policies, programs and funding initiatives, as well as educational campaigns, which aim to promote the sustainable use of resources and technological development with the long-term aim of increasing the amount of total recycled waste [11].

The set targets are also binding for Latvia as an EU Member State. Waste management in Latvia is regulated by various regulatory acts: the Waste Management Law regulates the most important waste management processes and basic principles [12] based on this law, the Regulations of the Cabinet of Ministers of the Republic of Latvia [13] specify the requirements of the law and establish certain procedures, Waste Management State Plan 2021–2028 (LNWMP) [14] highlights recycling targets, outlines the strategy of this phase, aims to reduce waste generation, improve sorting and recycling infrastructure and minimize environmental impact. According to Eurostat data, in 2022 Latvia generated 461 kg of municipal waste per inhabitant per year [15]. This is comparatively less than the EU figure of 513 kg [15], but at the same time, the share of landfilled waste in EU Member States is on average 18 %, while in Latvia it reaches 25 % [8]. Like in all the Europe, municipal waste volumes in Latvia are increasing: in 2022, the population generated 2.75 million tons of municipal waste, or 19 % more than in 2021 [16].

It is clear that achieving the targets requires the active involvement of all actors in the system, including citizens who are currently not fully engaged in waste reduction. A study on the waste sorting habits of Latvian residents reveals that only half of the population regularly sorts waste in their households, 29 % do it only sometimes, while almost a fifth or 19 % do not sort waste at all [17]. Another study on waste sorting behaviours among Latvian residents shows that while they rate their knowledge of waste sorting as good (7 out of 10), they assess their actions as mediocre (6 out of 10), indicating that actual behaviour lags behind knowledge [18]. Waste management behaviour in households is significantly influenced by both the attitude towards personal waste generation – promoting waste management, and the attitude towards overall waste management – negatively affecting waste reduction and recycling behaviour [19]. Those citizens who understand that they themselves contribute to the waste problem are more likely to engage in waste management more. On the other hand, those who are not aware of the problem take little or no action to reduce waste, and their inactivity can significantly hinder overall efforts to achieve the targets.

Such hard to engage, motivate and reach (HTR) consumers represent a major challenge for policy makers [20]. Engaging HTRs and changing behavioural patterns is critical to achieving long-term environmental sustainability goals, but HTR mental models, drivers and levers have been infrequently documented in prior studies [21]. Although circular economy goals have received increasing attention in recent years, research on mental models, behavioural drivers, and system dynamics of HTR groups is still insufficient. Previous studies [22]–[25] explore broad public engagement without focusing in detail on the involvement of HTR in circular economy initiatives. Furthermore, little research has been conducted to date that links mental model analysis with scenario modelling [26], [27] to predict system development and identify specific factors that could facilitate sustainable behavioural change specifically in HTR groups.

This study aims to address the challenges of engaging HTR groups in achieving circular economy goals by analysing the mental models and factors that influence their participation in sustainable resource use and waste reduction practices. The aim of the study is to understand how HTR mental models differ from those of easy-to-reach consumers (ETR) and experts (EXP), and what factors and scenarios could effectively stimulate HTR engagement in achieving circular economy goals at the household level. The study hypothesizes that HTR mental models are fundamentally different from ETR and EXP models. Exploring these differences allows for the identification of factors that hinder or facilitate HTR engagement. This approach not only allows for an understanding of existing barriers, but also provides an opportunity to predict how different policy measures and environmental initiatives could influence long-term behaviour.

The results provide valuable information on the patterns of mental models across consumer groups, as well as on the barriers and drivers that influence behaviour, especially with regard to HTR engagement, which contributes to the development of EU’s sustainability strategy.

2. METHODOLOGY

2.1. General Overview of the Methodology

In order to understand the behavioural patterns, beliefs and attitudes of individuals, their mental models and attitudes towards waste reduction were analysed using a cognitive mapping approach. It allows the identification of factors influencing individuals' choices and behaviour, thus helping to design and tailor efficiency programs to consumers' specific needs and requirements.

A multi-stage cognitive mapping approach is used to solve problems using human knowledge-based mental models. Cognitive maps are quality system models that consist of variables and causalities between them. Variables and causalities are determined by the chart compiler, giving causalities a subjectively determined relative strength on a scale from –1 to +1. The compiler shall also indicate the direction of the causal relationship, indicating which factor is affected [28]. Cognitive mapping is used where a modelling tool would be useful to identify the perceptions of the actors involved and help to model their likely behaviour under different scenarios. Using this tool, maps of different groups can be tested, compared for similarities, differences and discussed [28]. The term fuzzy cognitive maps was coined by Kosko (1993), who was the first to calculate the outcomes of individual cognitive maps and to model the effects of different policies using neural network computation [29]. The lack of knowledge contained in individual maps can be compensated to a certain extent by the addition of multiple maps [21].

The multi-stage cognitive mapping approach used in this work involved the following steps: selection of respondents, drawing individual cognitive maps, determining a sufficient sample size, standardizing the maps by aggregating concepts into categories, simplifying individual maps by condensation method, combining individual maps into group maps, scenario analysis.

2.2. Obtaining Cognitive Maps

For the selection of respondents, data was collected from a wide audience through a combination of questionnaires, purposive sampling and interviewers selected from local communities.

To identify HTR and ETR, respondents were asked to complete a five-question questionnaire designed to evaluate their willingness, confidence and attitudes toward household waste reduction, using a Likert response scale with a response format range of 1–6, where 1 indicated the lowest level (e.g., "not willing" or "no influence") and 6 indicated the highest level (e.g., "very willing" or "strong influence"). The questions were as follows:

1. To what extent would you be willing to reduce your household waste by 25 % in the next two months?
2. To what extent do personal factors (e.g. lack of information, financial constraints) influence your willingness to reduce waste?
3. To what extent do external factors (e.g. lack of infrastructure or availability of resources) influence your willingness to reduce waste?
4. How confident are you in your ability to effectively reduce household waste?
5. How sceptical are you about the effectiveness of waste reduction measures?

In total, completed questionnaires were obtained from 115 respondents.

A respondent was classified as HTR if they scored between 1–2 on questions 1–4 (indicating low willingness and confidence) and 5–6 on question 5 (indicating high scepticism).

A respondent was classified as ETR if they scored between 5–6 on questions 1–4 (indicating high willingness and confidence) and 1–2 on question 5 (indicating low scepticism).

Respondents who scored 3–4 on all five questions were categorized as having a neutral attitude, reflecting a mixed or uncertain perspective.

Respondents were ranked based on their responses, from the most sceptical to the most confident. The ten most sceptical respondents were selected as HTR, while the ten most confident were selected as ETR. The eight experts were selected based on their industry experience, scientific publications and professional qualifications.

In-depth interviews were conducted with twenty-eight selected participants using a common framework: each respondent was asked to create their own model using the online tool Mental Modeler [17], [30], [31], by drawing how products (textiles, packaging, food, electronics) circulate within the household and indicating the factors that influence the amount of materials present in the household. This approach allowed to reveal the participants' understanding of the connection between consumption in households and the resulting waste generation as well as waste prevention. Before the interviews, the interviewer created their own cognitive map. This approach enables the interviewer to identify personal biases, maintain a neutral stance when respondents express views differing from their own, and avoid unintentionally influencing respondents' answers. Additionally, it helps identify potential challenges in the mapping process, ensuring that the study focuses on the respondents' mental models rather than the interviewer's perspective. This is a recommended practice in cognitive mapping studies [32].

To determine a sufficient sample of the representative population, the relation between the number of interviews and the number of concepts (key ideas or factors identified by respondents) mentioned in the interviews was examined. The accumulation curve showed that the number of new concepts decreased from the nineteenth map and stabilized by the twenty-fourth map, indicating that the sample size is sufficient. As the number of interviews and maps produced increased, the total number of concepts levelled off, but it can be expected that one or two new concepts may still be introduced in each additional interview [28].

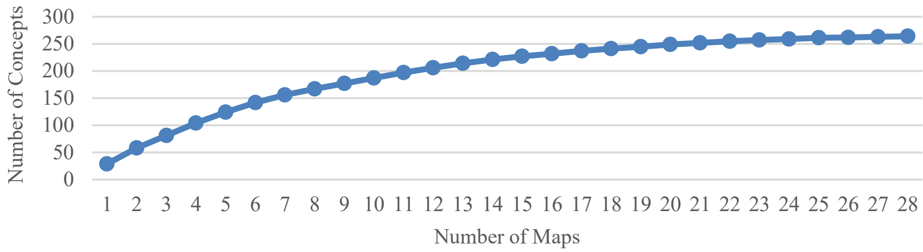

Fig. 1. Accumulation curve of new concepts.

2.3. Standardization of Maps by Grouping Concepts into Categories

A total of 264 concepts were mentioned in the maps drawn by respondents. To reduce information overload and to standardize the maps, allowing more transparent exploration of relationships, a qualitative aggregation of concepts was carried out by subjectively grouping similar concepts into categories. In qualitative aggregation, map concepts can be aggregated into categories represented by a larger spanning variable [33].

All these concepts were aggregated into 25 categories: consumption behaviour, consumer characteristics, product quality, affordability, weather, knowledge, informative events, policy, material, packaging, resources, production, shop, use, unsorted waste, sorting, infrastructure, reuse, charity, repair, recycling, sharing economy, re-trade, recycled resources, production from recovered materials.

Other similar studies have also aggregated and reduced large volumes of variable concepts into smaller and easier-to-review components [28], [34]. After aggregation, at least one member of EXP, ETR and HTR group confirmed the combination of concepts into categories. Each map was then redrawn, replacing the original concepts with new category or unified concept names.

2.4. Map Simplification Using Condensation

Maps with more than 20–30 variable concepts are difficult to view and understand, and they do not provide a comprehensive overview [35]. Such maps can be simplified using the condensation method, which involves replacing groups of variable sub-factors connected by lines with a single unit [36]. Therefore, each respondent's map was simplified by consolidating identical concepts obtained during the map standardization process into a single unit, while preserving the directions of the connecting arrows. The simplification reduced the maximum number of concepts in the maps from 32 to 14, making them more transparent.

2.5. Combining Individual Maps into Group Maps

To facilitate system level analysis and gain a clearer understanding of patterns across respondent groups, individual cognitive maps from ten hard-to-reach, ten easy-to-reach, and eight expert respondents were aggregated into three distinct group maps: expert (EXP), easy-to-reach (ETR), and hard-to-reach (HTR). Aggregating individual maps into a group map, as described by Gray *et al.* (2012) [37], allows for a more comprehensive view of the system. Similarly, Nakamura *et al.* (1982) demonstrated that combining maps can provide information that cannot be captured from individual maps [33].

When combining the maps, a matrix with all the factors from the individual cognitive maps was first created for each group. The data from each individual cognitive map were then placed in the matrix and summed, taking into account that pairings with opposite signs reduce causality, while pairings with the same signs strengthen it. Based on the combined data on the concepts and the strength of their connecting links, a new group map was constructed for each of three groups (EXP, ETR and HTR), resulting in a total of three distinct group maps.

2.6. Analysis of Cognitive Map Benchmarks

The main indicators of the maps of the three groups were summarized (Table 1), so that their comparison would allow conclusions to be drawn on the dynamic characteristics of all the systems modelled [28] and the level of differences between the groups to be established.

TABLE 1. BENCHMARKS OF STAKEHOLDER GROUP MAPS

Parameters	**Measure and Cognitive Inference** [30]	**EXP**	**ETR**	**HTR**
Total Components	Number of variables included in model; higher number indicates more components in the mental model	25	16	13
Total Connections	Number of links between variables; more connections indicate stronger interactions between components	163	51	27
Density	Ratio of actual to possible connections; higher density indicates more potential management policies	0.27	0.21	0.17
Connections per Component	Average number of connections per component; indicates the degree of interconnectivity within the system. Higher values suggest more complex relationships between components	6.52	3.19	2.08
Driver Components	Number of components with "forcing" functions; effect other system components but are not affected by others	0	3	3
Receiver Components	Number of components with receiving functions, are affected by other system components but have no effect to others	0	1	4
Ordinary Components	Number of components with both forcing and receiving functions, effect and are affected by other concepts	25	12	6
Complexity Score	Ratio of Receiver to Driver components; indicates the level of detail and how much driving forces' outcomes are considered.	NaN	0.33	1.33

In order to analyse cognitive differences between groups and to make conclusions about decision-making behaviour, the number and frequency of common, semi-shared and different concepts were collected [38] (Table 2).

For the group maps analysed in the study, of the twenty three concepts, only nine were common to all three maps, and seven concepts were partially common. Seven other concepts were mentioned only by the experts; the other group maps did not include these concepts.

To understand the importance of each concept, a centrality score was calculated by summing the number of incoming and outgoing connections to the concept. This showed the centrality of each concept in the context of other concepts, and also reflected the cumulative strength of connections with other concepts. Concepts with a higher centrality score meant that they were more important in the model. The centrality scores of the concepts in the three systems were compared to test the relative importance of the factors in each system (Fig. 2).

TABLE 2. CONCEPT MENTION FREQUENCY % AND FUNCTION TYPE IN STAKEHOLDER GROUP MAPS

Concepts	Groups					
	EXP		ETR		HTR	
	%	Function	%	Function	%	Function
unsorted waste	100	ordinary	90	receiver	60	receiver
sorted waste	100	ordinary	50	ordinary	40	receiver
consumption habits	75	ordinary	70	ordinary	50	ordinary
shop	63	ordinary	40	ordinary	60	ordinary
usage	38	ordinary	40	ordinary	90	ordinary
financial opportunities	38	ordinary	30	ordinary	40	driver
recycling	38	ordinary	20	ordinary	20	receiver
charity	25	ordinary	40	ordinary	10	receiver
resources	13	ordinary	20	ordinary	10	driver
reusing	88	ordinary	20	ordinary	–	–
knowledge	50	ordinary	10	driver	–	–
seasonality	38	ordinary	20	driver	–	–
infrastructure	25	ordinary	10	driver	–	–
repairing	13	ordinary	20	ordinary	–	–
production	38	ordinary	–	–	40	ordinary
product quality	13	ordinary	–	–	10	driver
consumer characteristics	63	ordinary	–	–	–	–
secondary resources	38	ordinary	–	–	–	–
secondary trade	38	ordinary	–	–	–	–
informative events	38	ordinary	–	–	–	–
politic	25	ordinary	–	–	–	–
sharing	13	ordinary	–	–	–	–
production from recovered materials	13	ordinary	–	–	–	–

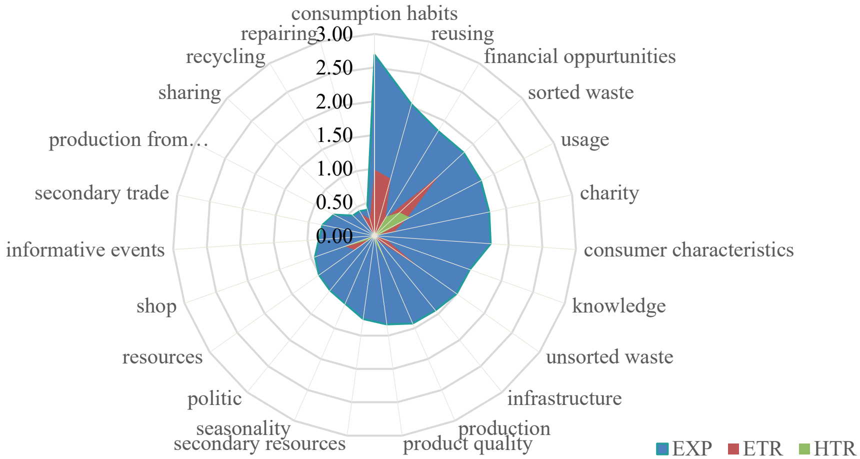

Fig. 2. Comparison of concept centrality indicators in group maps.

2.7. Scenario Analysis

To investigate possible differences in system development between groups, the groups' fuzzy cognitive maps were used to model scenarios in the Mental Modeler tool. This approach builds on methods used in similar studies [25], [26], [40], [41] to study system evolutions, where different scenarios are generated based on group perceptions and their results are compared with the initial state of the maps, to analyse the magnitude of the changes and identify the most significant impacts on the system components, their interconnections and changes in the strength of interactions, investigating the effectiveness of the solutions and predicting actions to avoid undesirable consequences.

During the modelling process, three "what-if" scenarios (see Table 3) were generated, in which the weights of connections between components were changed, simulating different solutions. The goal of the modelling was to investigate how the mental model system would develop, reinforcing the influence of different model components, and to identify the factors that would most effectively influence behaviour towards waste reduction implementation. To ensure comparability of the scenarios, the connection weights were changed in all three maps simultaneously, exploring how the behaviour of each group would change in the same situation.

TABLE 3. MODELLED SCENARIOS

Scenario Name	**Modelling Parameters**	**Factors**
Amplification of Driver components impact	The weights of the driver components of all three groups of maps were changed to maximize their impact	financial opportunities; product quality; resources; infrastructure; weather; knowledge
Implementation of Waste Prevention Measures	The measures outlined in the Scenario of the LNWMP with the Implementation of Waste Prevention Measures	sorting; infrastructure; recycling
Implementation of Circular Economy Measures	The measures outlined in the Scenario of the LNWMP with the Implementation of Circular Economy Measures	sorting; infrastructure; recycling; reuse; charity; informative events; policy; financial opportunities

In the first scenario, the weights of driver components of all three group maps were changed to maximize their impact, with the aim of examining how variations in driver component weights influence the overall dynamics of the system. This approach builds on the insights of Kokkinos *et al*. (2018) [42], who highlight that clamping should logically be applied exclusively to driver components, as these primarily influence the receiver concept. In contrast, modifying the weights of receiver components would not result in changes that propagate throughout the rest of the map. Driver components are concepts that affect other concepts but are not themselves affected.

The HTR map was found to have the following driver components: financial opportunities, product quality and resources. In the ETR map, the components were: infrastructure, weather and knowledge. In the EXP map, on the other hand, no factors were identified as having only outgoing links, indicating that the experts perceive the system to be interconnected and dependent on the interaction of different factors.

For the modelling of the second scenario, the measures outlined in the Scenario of the LNWMP with the Implementation of Waste Prevention Measures [12] were used: separating new waste streams, promoting the development of a separate waste collection system and consequently increasing the amount of recycled waste, so that factors such as sorting, infrastructure and recycling were given more weight in the group maps.

The third scenario was modelled using the measures outlined in the Scenario of the LNWMP with the Implementation of Circular Economy Measures [12]. This would involve, in addition to the factors mentioned above, the extension of the producer responsibility scheme to promote the re-use of waste and the implementation of a range of measures [15]: increased rates for landfilling municipal waste/charges for the amount of waste actually generated, anticipating an increase in waste management charges; incentivized product donation; informing and educating the public about responsible consumption and donation process; deposit system; investments in waste management infrastructure; developing appropriate regulatory frameworks for more targeted use of funding and other means.

Accordingly, the group maps maximized weight of factors such as sorting, infrastructure and recycling, reuse, charity, informative events, politic; and minimized weight of the financial opportunities factor.

3. RESULTS

3.1. Analysis of Key Indicators of Group Maps

The resulting group maps were analysed based on main indicators (see Table 1).

The EXP group map (see Fig. 3) included 25 concepts with 163 connections. The density score of 0.27 indicated a wide range of possible connections in the system, indicating many ways of influencing the components. There were no driver components in the map, indicating highly interconnected causal relationships and a well-stratified system structure. The Complexity Score is reported as NaN (Not a Number), because the method used for the calculation is based on the ratio of receiver and driver components [30]. In a given EXP map, there are no components that explicitly correspond to the driver or receiver roles only, since all components are interconnected, influencing and receiving feedback from others. This situation prevents the possibility to unambiguously calculate the ratio between the receiver and driver components, resulting in a value that is mathematically interpreted as NaN. However, when evaluated using the methods of Wiesner and Ladyman (2019) [43], the EXP map is considered to be complex due to its high density of connections and multiple interdependent cycles, indicating the non-linearity and dynamics of the system. This suggests a perfectly balanced and highly complex system, whose causes and effects are not easily separated.

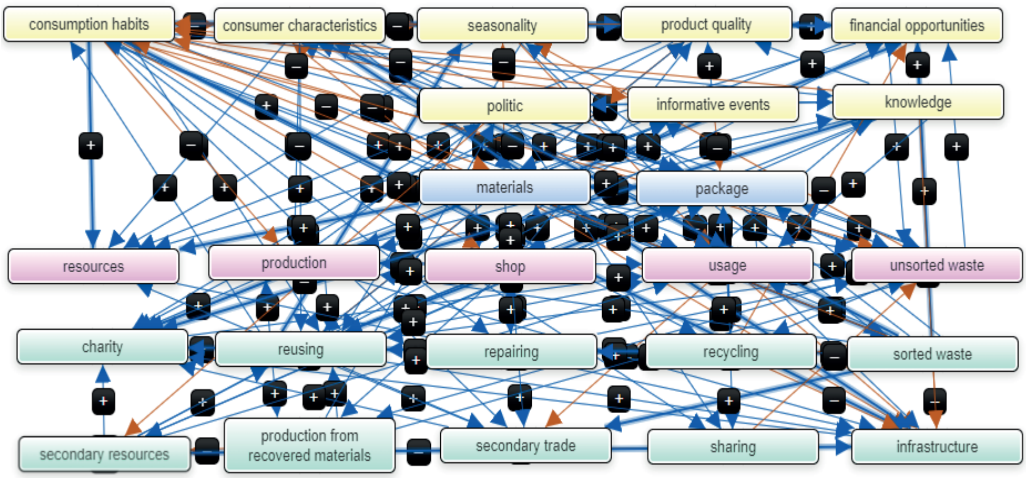

Fig. 3. EXP group fuzzy cognitive map.

The ETR group map (Fig. 4) shows 16 concepts and 51 connections. The map density score of 0.21 indicated a relatively more limited range of ways of influencing the components. In contrast to the EXP map, this map showed a number of driver components (see Table 2) and the map structure suggested a relatively more hierarchical system with less pronounced causal relationships.

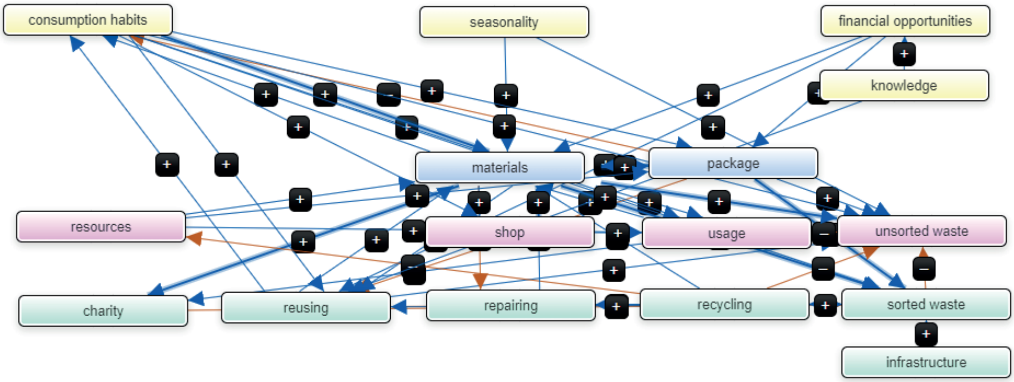

Fig. 4. ETR group fuzzy cognitive map.

The HTR group map (Fig. 5) consisted of 13 concepts with 27 connections and had the lowest density score of 0.17, indicating that this group was aware of the smallest range of component influences. The complexity score of 1.33 indicated that it has more receiver than driver components (see Table 1). The map has a hierarchical structure and no clear causal links.

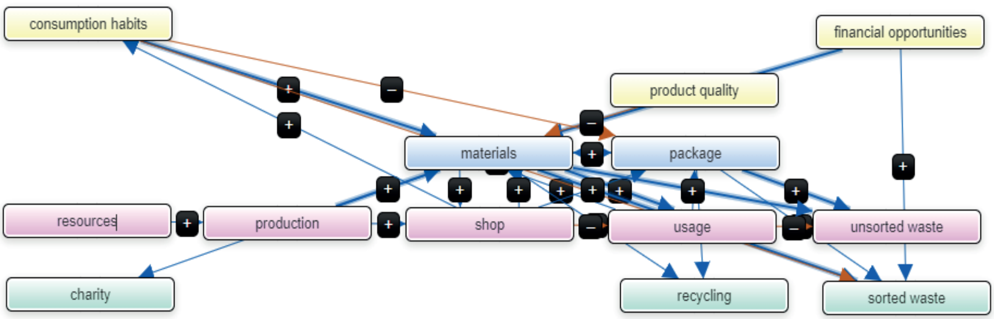

Fig. 5. HTR group fuzzy cognitive map.

Analysis of the group maps core indicators showed significant differences between the mental models of the EXP, ETR and HTR groups. Each group had different number of concepts, density of connections, and level of understanding of causalities.

3.2. Common and Different Concepts in Group Maps

By analysing the amount of common and different concepts in group maps, it is possible to understand how each group perceives factors in relation to the circular and linear economy models.

Table 2 illustrates the different perceptions of the groups on the functioning of the circular economy system and the factors influencing it. For example, consumption habits were frequently mentioned in the EXP (75 %) and ETR (70 %) groups, suggesting the importance of this factor, but less frequently in the HTR (50 %). Knowledge was also mentioned much more frequently in the EXP (50 %) than in the HTR group (10 %). In the context of a linear economy, HTR gave more importance to shop (60 %) and use (90 %), indicating a greater group orientation towards consumption and shopping processes. In the circular economy context, EXP demonstrated a stronger focus on recycling (100 %) and reuse (88 %) compared to ETR and especially HTR who mentioned these factors less frequently (40 % and 20 %). These data suggest that HTRs gave less importance to elements of the circular economy such as recycling and reuse, which may indicate a lower awareness or presence of these factors in their households. The data show that the EXP approach is more inclusive of circular economy principles, where recycling and reuse are central, while the HTR group focuses more on linear economic behaviours such as consumption and waste generation. This suggests that HTR may be less exposed to or involved in circular economy practices.

Common concepts, such as unsorted waste and shop, were recognized across groups, but their prioritization varied. EXP perspective was broader and reflects a more developed understanding of sustainable practices, possibly influenced by a higher level of knowledge or education. HTR focused more on linear economy concepts and that can signal that their waste management model may be more reactive than proactive, possibly due to less engagement in sustainability-oriented behaviour or a lack of available solutions that promote circular economy indicating lower awareness of circular economy practices.

3.3 Centrality Indicators of Group Maps

Analysing the centrality of concepts in the group maps (see Fig. 2), notable differences revealed. In the EXP group map, all concepts had a high centrality, especially when assessing consumption habits and reuse. This showed the importance of these concepts in the overall functioning of the system. In the ETR group map, concepts were assigned relatively lower centrality scores, but almost all exceeded the HTR scores in importance. ETR gave the highest weight to concepts such as recycling, consumption habits and reuse. The HTR group map gave much lower weight to concepts such as consumption habits, recycling, charity, resources and recycling compared to the EXP and ETR groups. Concepts such as reuse, knowledge, infrastructure and repairs were rated as completely unimportant or zero weight. Packaging, unsorted waste, shop and production were considered most important by the group. This showed that HTR believed that the system's performance was mainly dependent on external aspects, such as economic and commercial aspects, with factors that depended on their own actions considered to be of minor importance.

3.4. Impact of Modelled Scenarios on Group Behaviour

The scenario modelling revealed a number of important trends. A graphical representation of the relative changes in the importance of the concepts across the three scenarios for each group map is shown in Table 6, giving an overview of how the importance of the concepts increased or decreased under the different scenarios. The table allows for a comparative analysis of changes, highlighting areas where the groups showed the most pronounced change, as well as areas where there was minimal or no change. A more detailed description of each scenario and its corresponding impact on the group maps is provided in the following subsections.

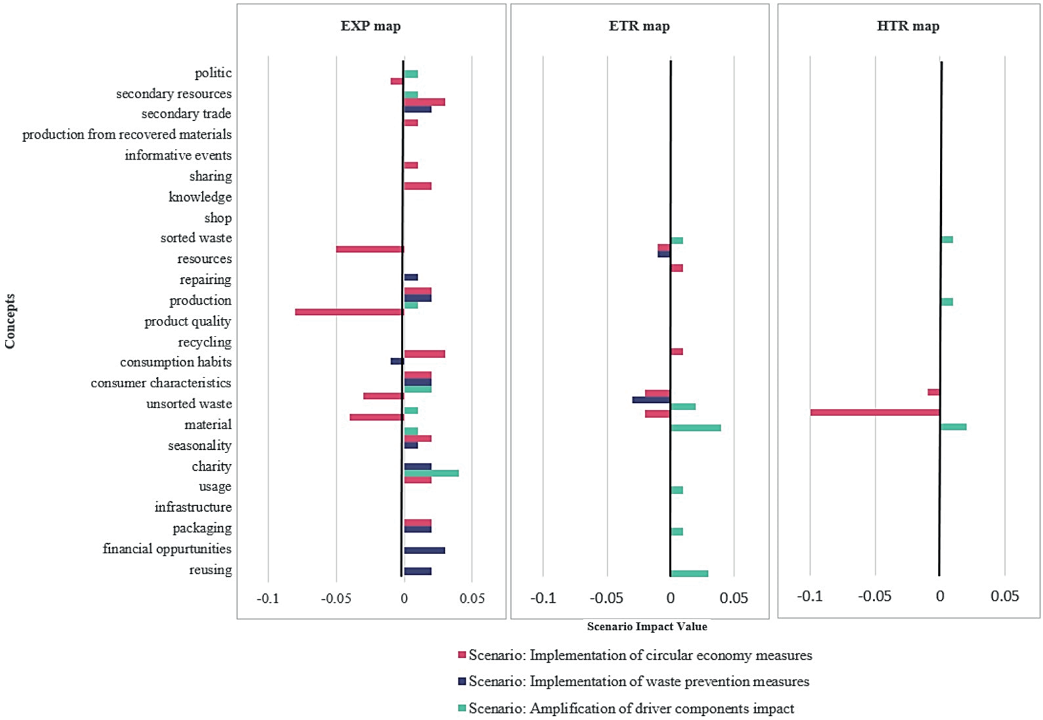

Fig. 6. Relative changes in the importance of concepts in the modelled scenarios.

3.4.1. Scenario of amplification of the driver components' impact in the maps

Increasing the impact of driver components led to a significant increase in the volume of material flows to households in all three groups. However, the impact on the other components of the system varied from map to map.

The EXP map showed a significant increase in the volume of materials donated to charity and in the number of household consumers, while the importance of unsorted waste, production, reuse and policy importance also increased.

The results of the ETR map showed a significant increase in the amount of materials and packaging. At the same time, reuse and sorting volumes also increased, indicating an active participation of this group of consumers in waste recycling and resource reuse. However, an increase in unsorted waste was also estimated, which could indicate a growing overall consumption and material flows in the system.

Production and sorting volumes increased in the HTR map, but this increase was smaller than the increase in material volumes, indicating that this consumer group may be less engaged in sustainable solutions or have limited access to sorting options.

3.4.2. Modelling the impact of implementation of waste prevention measures

In this scenario, the EXP Group's map showed a significant change, with an increase in the reuse factor as well as in the amount of repaired, charity donated and recycled materials, showing a trend towards more focus on returning material flows back into circulation. Financial opportunities increased significantly, showing the economic benefits of extending the life cycle of materials. Material consumption per person decreased, indicating a positive trend towards more efficient use of resources in households. In addition, the importance of seasonality increased, which could be related to seasonal variations in consumption and resource availability.

The ETR map showed a positive trend in terms of resource use reduction, as well as a significant decrease in unsorted waste, reflecting the effective implementation of sorting measures.

No changes were observed in the HTR map (see Fig. 6), indicating the ineffectiveness of the measures foreseen in the LNWMP scenario for this group and the need for additional measures or strategies to involve HTRs.

3.4.3. Modelling the impact of implementation of circular economy measures

The results of the scenario modelling indicated a broad change in the map of the EXP group: as the number of household consumers and knowledge increased, so did the importance of factors such as healthy lifestyles, length of time spent using materials and the importance of seasonality. These changes pointed towards more sustainable lifestyle habits. The amount of materials, consumption of resources (including recycled ones) and the amount of unsorted waste in the household decreased. In addition, the sharing economy, recycling and production increased, including from recovered materials. This showed the effectiveness of the circular economy measures envisaged in the scenario to engage this group.

The ETR map showed similar trends. The amount of materials and unsorted waste decreased, as did resource consumption. Significantly, the planning of consumption patterns and the amount of repairs increased, showing a move towards a more sustainable use of materials.

The HTR map did not include factors such as policy, informative events, reuse, so the number of factors used to model the scenario was smaller. Of these, only the reduction in financial opportunities in the form of higher waste management fees had an impact, resulting in a significant reduction in the material flow within the household and a slight reduction in the amount of unsorted waste. There were no changes in other factors.

4. CONCLUSION

The study on mental models and factors influencing participation in waste reduction practices reveals significant differences between different groups of consumers, indicating the complexity of the interaction between waste reduction measures and consumer behaviour.

The comparison of mental models carried out in this research has highlighted the important fact that the EXP, ETR and HTR mental models are significantly different. The EXP group model shows a higher level of integration and understanding of system interconnectedness, while the ETR group model reflects a more limited vision with more pronounced hierarchical structures. The HTR group mental model, on the other hand, is formal, hierarchical, with an underdeveloped understanding of causality.

These differences between the models demonstrate the different groups' different understanding of how the system works and their ability to identify pathways of influence between factors. The cognitive differences between the groups point to different views and approaches to circular and linear economies. This is also reflected in the fact that HTR does not include in its models essential elements of the circular economy such as reusing, repairing, sharing, production from recovered materials. It might seem that this gap can be filled by large-scale informative activities, but concepts such as knowledge and informative events are also not included in their model. This suggests that increasing awareness-raising activities will not have an impact on the hard-to-reach level of consumer involvement in waste reduction activities. However, further in-depth analysis is needed to fully understand the social and psychological aspects of HTR barriers.

By identifying the differences in the models, it can be concluded that consumer behaviour also differs. This is also confirmed by carrying out the scenario modelling, which showed that the same policy interventions can affect different groups of individuals in different ways (see Fig. 6), sometimes even leading to markedly different behaviour within each group. For example, measures in the LNWMP might stimulate positive changes in the EXP and ETR groups, but have minimal effect in the HTR group and require additional attention from policy makers to create engagement measures.

The results of the scenario modelling highlight the challenges of engaging different groups in the waste reduction process, pointing to the need for different policies to engage all consumers and promote a more effective transition to a circular economy. However, further empirical research would be needed on how effective specific policy measures will be in stimulating the behaviour of different groups. Social science and humanities perspectives can offer a deeper understanding of consumer motivations, decision-making structures and habits. Such a further interdisciplinary research perspective would allow for the development of more targeted and effective policies to promote sustainable behaviour change across consumer groups.

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