

Responsible Configuration Using LLM-based Sustainability-Aware Explanations

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Abstract

Configuration systems play an important role in achieving the sustainable development goals (SDGs) defined by the United Nations. As decision support systems, configurators help users to decide which components or features to include in or exclude from a configuration. An important task of configurators is the provision of explanations which help to achieve goals such as increasing configuration understandability, increasing a user's trust, and persuading users/customers to include specific configuration components. Our goal in this paper is to introduce the concept of „sustainability-aware explanations“ which can help to support the sustainable development goals. The type of explanations we propose in this context are somehow orthogonal to typical explanations used in industrial configuration environments. A major objective in this context is to follow a „less-is-more“ principle focusing on different aspects of the idea of „responsible configuration“ which refers to configuration techniques explicitly supporting the mentioned sustainability goals. We report the initial results of an evaluation that provide insights on potential impacts of the proposed explanations.

Keywords

Explanations, Sustainability, Green Configuration, Responsible Configuration, Configuration for Good, Nudging, Persuasion, Knowledge-based Configuration

1. Introduction

The 17 *sustainable development goals* (SDGs) defined by the United Nations provide a blueprint for peace and prosperity on our planet.¹ Examples of such goals are *good health and well-being* (e.g., in terms of fostering the consumption of healthy food), *responsible consumption and production* (e.g., in terms of reduced energy consumption), and *sustainable cities and communities* (e.g., in the context of tourism, avoiding negative environmental impacts and taking into account the local communities and cultural heritage) [1].

Knowledge-based configuration [2, 3, 4, 5] can be regarded as a core-technology of mass customization [6]. On the basis of configurators, users are enabled to design a product in an individualized fashion that

fits their wishes and needs. In configuration settings, we can observe an ever-increasing demand for taking into account sustainability aspects [7, 8]. Following the basic definition of „*configuration*“ given by Sabin and Weigel [3], i.e., „*configuration is a special case of design activity where the configured artifact is assembled from a fixed set of well-defined component types and components are interacting in predefined ways*“, we define „*responsible configuration*“ as „*configuration which takes into account the United Nation's sustainable development goals*“.

In knowledge-based systems, explanations can be applied for different purposes [9]. First, so-called *why* explanations [10, 11, 12] focus on the aspect of mentioning the most relevant user requirements that lead to the determination of a specific configuration. Furthermore, *why not* explanations focus on supporting users in situations where no solution can be identified [13, 14, 15]. From the application point of view, explanations can be applied to achieve different goals [16].² Examples thereof are *efficiency* (reducing the time that is needed to complete a configuration task), *persuasiveness* (convincing users to change their component selection behavior), *transparency* (making the inclusion or exclusion of specific components transparent to the user), *trust*

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¹<https://sdgs.un.org/goals>

²The categorizations of [11, 16] have been developed in the context of recommender systems but can also be applied in configuration contexts.

(increasing a user’s confidence in the configuration system), *scrutability* (making it possible for the user to adapt the configurator behavior, e.g., in terms of the used component inclusion/exclusion strategy), and *satisfaction* (e.g., increasing the usability of a configuration system). These goals must be regarded as examples – for related details we refer to [11, 16, 17, 18].

In this paper, we focus on the *persuasion aspect* of explanations [19]. More precisely, we analyze possibilities to formulate explanations in such a way that users are nudged towards more sustainability-aware configuration decisions. Following a „less-is-more“ principle, we show how to formulate explanations following Cialdini’s six principles of persuasion [20] (see Table 1).

Table 1
Cialdini’s principles of persuasion [20].

principle	semantics
reciprocity	feeling of an obligation to give something back
scarcity	reduced item availability increases preparedness to purchase
authority	experts have an increased influence on users
commitment and consistency	users prefer to be consistent with their articulated preferences
liking	users like to comply with other users who are similar to themselves
social proof	users follow the opinions (of a representative set) of other users

Sustainability-aware explanations have to focus on argumentations including sustainability aspects. Our formulation of such explanations is based on *large language model* (LLM) prompts [21] which help to associate sustainable development goals with the mentioned persuasive principles. For example, in the context of car configuration, explanations could refer to the positive environmental aspects of purchasing smaller cars or on the advantages of electric vehicles compared to gasoline-driven ones.

Positive impacts of such sustainability-aware explanations can be, for example, higher-quality configuration decisions, a lower amount of unneeded components, and components with less negative environmental impacts [8]. From a commercial point of view, such explanations might appear – at least to some extent – counterproductive due to potential consequences in terms of decreasing turnovers. Thus, sustainability-aware explanations are often in contrast to explanations in mainstream configuration environments which focus on increasing sales rates in most of the cases.

The contributions of this paper are the following. First, we propose the concept of sustainability-aware explanations for configurations. Second, we provide reference examples of such explanations in the automotive domain. Third, we present initial results of a corresponding evaluation.

The remainder of this paper is organized as follows. In Section 2, we provide different examples of LLM-generated sustainability-aware explanations in the car configuration domain. Thereafter, we discuss initial results of a related evaluation (Section 3). In Section 4, we discuss threats to validity. Finally, we conclude the paper with Section 5.

2. Sustainability-Aware Explanations with LLMs

In the following, we discuss scenarios where sustainability-aware explanations can have an impact on user decisions. All scenarios are related to *car configuration* where users receive explanations of current configurations. The major goal of such explanations is to make users think about their current configuration settings and to potentially adapt their articulated preferences. Consequently, our explanations are not in the line of *why* or *why not* explanations but focus more on indicating potential alternatives to the current configuration, i.e., a kind of *why not choose something else* explanation. All example explanations in this paper have been generated on the basis of the LLM *ChatGPT 3.5*.³

Scenario 1: SUV vs. smaller car. The idea is to make persons (configurator users) who intend to purchase an SUV more aware of sustainability aspects of smaller cars. To support this, we have generated LLM-based explanations using the following (example) LLM prompt: *Assume the following scenario: person A wants to purchase a car and is interested in an SUV. Please provide persuasive explanations against purchasing an SUV following the six persuasion principles of Cialdini.* The resulting explanations are depicted in Table 2.

Scenario 2: Long vs. standard range battery. The idea is to make configurator users interested in purchasing a car with a long-range battery aware of the sustainability aspects of standard range batteries. To support such explanations, we have generated LLM-based explanations using the following LLM prompt: *person A wants to purchase an electric car and is interested in a long*

³<https://chat.openai.com>

Table 2

Sustainability-aware explanations related to the aspect of *purchasing a smaller car compared to an SUV*.

principle	LLM explanation
reciprocity	Consider the environmental impact and how it affects everyone. Choosing a more eco-friendly vehicle can be your way of giving back to the community and environment. Others will likely appreciate and reciprocate your thoughtful decision, fostering a positive cycle of environmentally conscious choices.
commitment and consistency	You've always been committed to sustainability and reducing your carbon footprint. Opting for an SUV contradicts these values due to its higher emissions and fuel consumption. Staying consistent with your commitment to the environment means choosing a more fuel-efficient and eco-friendly car.
social proof	Look at the growing trend among your peers and the wider community towards hybrid and electric vehicles. Many people are switching to these options because they are better for the environment and more economical in the long run. Following this trend shows you're in tune with progressive, responsible choices.
authority	Environmental experts and automotive industry leaders are advocating for smaller, more efficient vehicles to combat climate change and reduce pollution. Following the guidance of these authorities can help you make a well-informed decision that aligns with expert recommendations.
liking	Your friends and family who care about the environment will appreciate and support your choice of a more sustainable vehicle. This decision can strengthen your relationships, as they see you aligning your actions with shared values and concerns.
scarcity	With increasing regulations and shifts towards renewable energy, fuel-efficient and eco-friendly vehicles may soon become the norm, potentially leading to fewer incentives for traditional gas-guzzling SUVs. Take advantage of the current incentives for hybrid or electric vehicles before they become more scarce.

Table 3

Sustainability-aware explanations related to the aspect of *purchasing a standard compared to a long-range battery*.

principle	LLM explanation
reciprocity	Think about the balance between what you get and what you give. By opting for a standard-range battery, you're reducing the environmental impact associated with producing larger batteries. This considerate choice benefits the community and environment, and others may appreciate your mindful decision, leading them to reciprocate with similar sustainable choices.
commitment and consistency	You've been committed to reducing your carbon footprint and promoting sustainability. A standard-range battery is more aligned with these values, as it requires fewer resources to produce and has a lower environmental impact. Staying consistent with your commitment to sustainability means choosing the option that minimizes ecological harm.
social proof	Many environmentally conscious drivers are opting for electric vehicles with standard-range batteries because they strike a good balance between range and environmental impact. By choosing a standard-range battery, you're aligning with a growing community of eco-friendly drivers who prioritize sustainability over convenience.
authority	Experts in environmental science and sustainable technology often highlight the advantages of smaller, more efficient batteries. They point out that while long-range batteries offer more convenience, the production and disposal of larger batteries have a higher environmental cost. Following the advice of these authorities can help you make a more environmentally responsible decision.
liking	Your friends and family who are also concerned about environmental issues will likely appreciate your choice of a standard-range battery. This decision can enhance your relationships as they see you making sacrifices for the greater good and staying true to your shared values.
scarcity	As technology advances, the efficiency of electric vehicle batteries is continually improving. Standard-range batteries are becoming more capable, offering longer ranges and better performance. By choosing a standard-range battery now, you can take advantage of current technologies and innovations without feeling the pressure to invest in a long-range battery that may soon become less necessary.

range battery. Please provide persuasive arguments against purchasing a long range battery following the six persuasion principles of Cialdini. The corresponding LLM-generated sustainability-aware explanations are depicted in Table 3.

Scenario 3: Car not needed in city center.

Configurator users should think about the advantages of not having a car when living in the city center. We have generated related LLM-based persuasive explanations using the following LLM prompt: *person A who lives directly in*

Table 4

Sustainability-aware explanations related to the aspect of *waiving a car in the city center*.

principle	LLM explanation
reciprocity	Consider how much the city has invested in developing a robust public transportation system. By using these resources instead of buying a car, you show appreciation and reciprocate the city's efforts to provide efficient and sustainable transportation options. This can inspire others to also rely on public transport, enhancing the community's collective effort to reduce traffic and pollution.
commitment and consistency	You've always been committed to living a minimalist and environmentally friendly lifestyle. Owning a car might contradict these values, adding unnecessary expenses and contributing to urban pollution. Staying consistent with your principles means continuing to use the excellent public transportation available to you.
social proof	Many city dwellers are moving away from car ownership in favor of public transportation, biking, and walking. This trend reflects a growing recognition of the benefits of car-free living in urban areas. By following this trend, you align yourself with a progressive community that prioritizes sustainability and efficient urban living.
authority	Urban planning experts and environmental authorities advocate for reduced car usage in city centers to decrease congestion and pollution. By heeding their advice and utilizing public transport, you're supporting proven strategies that improve city life and contribute to a healthier environment.
liking	Your friends and neighbors who also rely on public transportation will likely appreciate and support your decision to avoid car ownership. This shared experience can strengthen your bonds with those around you, as you collectively benefit from less traffic, cleaner air, and a more vibrant urban community.
scarcity	Parking spaces and road capacity in the city center are limited resources. By not purchasing a car, you're helping to reduce the demand for these scarce resources, making the urban environment more livable for everyone. Additionally, public transport allows you to avoid the hassle and expense associated with finding and paying for parking.

the city center with various connections to public transportation wants to purchase a car. Please provide persuasive arguments against purchasing a car following the six persuasion principles of Cialdini. The corresponding sustainability-aware explanations are depicted in Table 4.

Scenario 4: Less costly car due to financial situation. The idea is making configurator users with limited financial resources intending to purchase an expensive car to change their mind and purchase a less expensive car. To support such explanations, we have generated LLM-based explanations using the following (example) LLM prompt formulation: *person A with very limited financial resources and a family with three children wants to purchase an expensive car. Please provide persuasive arguments against purchasing an expensive car following the six persuasion principles of Cialdini.* The related LLM-generated explanations are depicted in Table 5.

3. Evaluation

Properties of LLM-based explanations. In Table 6, we summarize the different argumentation lines generated by the large language model (LLM). (1) In the context of the persuasion dimension

reciprocity, LLM-generated explanations refer to the aspect of „giving something back to the community“, for example, purchasing an eco-friendly vehicle can be a way of giving back to the environment. (2) Explanations related to the persuasion dimension *scarcity* on the one hand refer to decreasing incentives for sustainable equipment (e.g., cars), on the other hand to limited resources (e.g., financial resources). (3) In the context of the persuasion dimension *authority*, different experts such as environmental experts are used as representatives of authorities. (4) Explanations related to the persuasion dimension *commitment* assume an existing commitment of the current user, for example, already proved in previous configuration sessions. (5) In the context of the persuasion dimension *liking*, LLM-generated explanations refer to a user's family, friends, and neighbors (e.g., your family will like your decision). (6) Explanations related to the persuasion dimension *social proof* refer to trends of peers, the wider community, and similar families.

LLM-based impact estimates. Using the LLM prompt *which of these explanations would have the highest persuasive impact on a user? Please provide a ranking.*, we asked the LLM also for a ranking of the impact of the generated explanations following

Table 5Sustainability-aware explanations related to the aspect of *purchasing an affordable car*.

principle	LLM explanation
reciprocity	Think about the support you’ve received from friends, family, and community during tough financial times. By opting for a more affordable car, you demonstrate financial responsibility and can reciprocate their support by being in a better position to help others when they need it.
commitment and consistency	You’ve always been committed to providing the best for your family while managing your limited financial resources wisely. Purchasing an expensive car contradicts this commitment and could put unnecessary financial strain on your household. Staying consistent with your goal of financial stability means choosing a car that fits within your budget.
social proof	Many families in similar financial situations prioritize practicality and affordability when it comes to transportation. By choosing a more economical vehicle, you’re following a proven path that many others have taken to ensure they can meet their family’s needs without financial stress.
authority	Financial advisors and experts consistently recommend living within your means and avoiding large, unnecessary expenses, especially when money is tight. By following this expert advice, you’re making a prudent decision that aligns with sound financial practices and secures your family’s financial future.
liking	Your friends and family will likely admire and respect your decision to prioritize your family’s well-being over the allure of an expensive car. Making a practical choice shows that you value their advice and shared values of financial prudence and responsibility.
scarcity	Financial resources are currently scarce for your family. By not purchasing an expensive car, you conserve these limited resources for more critical needs like education, healthcare, and everyday living expenses. This ensures that you have the financial flexibility to handle unexpected costs and opportunities that arise.

Table 6

LLM-based argumentation lines for Cialdini’s principles of persuasion[20].

principle	argumentation line
reciprocity	giving something back to the community and the environment
scarcity	fewer incentives for sustainable equipment, limited available financial resources
authority	environmental experts, urban planning experts, financial advisors
commitment and consistency	existing commitment to sustainability in the past
liking	family, friends, neighbors
social proof	trends of peers, wider community, and similar families

Table 7

Scenario-dependent preferred explanations (top-2 LLM and study participant-preferred explanations).

scenario	top-2 (LLM)	top-2 (study participants)
SUV vs. smaller car	(1) commitment & consistency, (2) authority	(1) authority, (2) liking
Long vs. standard range battery	(1) authority, (2) commitment & consistency	(1) authority, (2) social proof
Car not needed in city center	(1) social proof, (2) authority	(1) authority, (2) reciprocity
Less costly car due to financial situation	(1) authority, (2) commitment & consistency	(1) authority, (2) commitment & consistency

the idea of LLM self-evaluation [22]. In most settings, the dimensions *authority* and *commitment & consistency* have been regarded as the two most impactful persuasion dimensions (see Table 7). The related LLM-based argument is that the latter appeals directly to a person’s desire to act in accordance with their past beliefs and statements and the former has a high impact specifically in scenarios where the underlying topic involves

technical details. Finally, the dimension of *social proof* can be impactful in situations where social trends and peer behaviors impact decisions.

Feedback of study participants. For a very first evaluation beyond the LLM feedback, we conducted a small user study in our research group with N=10 participants (computer science students at our university). The participants were asked to rank the different explanations according to their potential

persuasive impact. The results are included in Table 7. Overall, there exists an overlap between the explanations ranked highest by the LLM and those selected by the study participants. In this context, the *authority* principle has been regarded as relevant in all example configuration scenarios. This initial result indicates basic LLM capabilities to recommend persuasion strategies.

4. Threats to Validity

The explanation concepts presented in this paper are based on one selected configuration scenario (car configuration). These explanations are just high-level examples and many further (also more detailed ones) can be envisioned for car configuration (e.g., the sustainability aspects of a less powerful car engine) and beyond. In our work, we did not focus on a specific phase of a configuration process, i.e., the mentioned explanations could even be used before the configuration process has been started (e.g., as explanations in wish lists or product information). Gaining more related insights is a major focus of our future research. The presented impact ranking of explanations has been primarily discussed on the basis of an LLM-generated ranking [22] including corresponding argumentations that help to understand the proposed ranking. More detailed studies with real users (and more detailed related preference and context information) are planned within the scope of future work also to better understand the limitations of LLMs with regard to the recommendation of persuasion strategies. Up to now, no LLM-related hallucination effects could be observed, however, this is an important aspect to be taken into account in future work. A recently mentioned new persuasion principle (identification) [23] will be taken into account in future studies. Finally, more detailed LLM prompts better taking into account the context (and preferences) of the current user are regarded as an important topic of future work.

5. Conclusions

In this paper, we have introduced the concept of sustainability-aware explanations of configurations. Using the example of car configuration, we have explained and exemplified this type of explanation. Following a set of persuasion dimensions, we have analyzed the LLM-generated explanations with regard to the used argumentation lines and analyzed the impact of the generated explanations on the user. In this context, LLMs show to be applicable

in terms of generating explanations in a flexible fashion but also to recommend explanations in specific configuration contexts. Our future work will include detailed studies with real users with the goal to compare LLM-based rankings with the perception of explanations by real users. Further research will include an analysis of the effects of combining explanations (e.g., integrating authority-based with commitment-based explanations).

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