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RIVISTA ITALIANA DI ERGONOMIA

THE RIVISTA ITALIANA DI ERGONOMIA, *of the* S.I.E. - *Italian Society of Ergonomics, is a scientific journal that operates nationally and internationally for the promotion and development of ergonomics and the study of human factors, and the dissemination and systematization of knowledge and experiences related to the ergonomic approach, in close relationship with the social, environmental and productive realities where human beings, operate and live, coherently with the goals of the* SIE.

Supported by an international scientific committee and using a double-blind reviewing process, the journal publishes original contributions from research and applications on ergonomic issues, in its various aspects and related to the different contexts and human activities.

The RIVISTA ITALIANA DI ERGONOMIA *is aimed at ergonomic professionals and all those interested in applying the principles and methods of ergonomics / human factors in the design, planning and management of technical and social systems, in work or in leisure.*

INDEX

Design for behaviour change to foster product longevity: a case study on sustainable mobility

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Keywords: design for behaviour change, sustainable mobility, light-vehicle design, design for longevity, user engagement, technology acceptance.

Abstract

This article focuses on the role of product-service system design as a driver to guide and motivate behaviours for active and sustainable mobility. The article refers to the systemic link between microergonomics and sustainable development and addresses how the concept of behavioural change fits into the relationship between human and environmental aspects. The research domain encompasses sustainable urban mobility. The aim is to identify inquiry directions for product-service system design solutions to be consistent with environmental sustainability goals. Behaviours related to sustainable mobility and factors influencing modal choice have been analysed. Finally, through developing a design concept, the article discusses and defines new design opportunities at the

micro level of the urban scale stimulating the adoption of desirable mobility behaviours over existing ones. The developed case study fuels the debate on the effectiveness of ergonomic interventions to better use and consumption of resources, implementing the vision of the tools and processes to be adopted in defining reusable product-service systems with low environmental impact.

Introduction

Chavez et al. (2022) inquire into the environmental impact of user actions during product usage and reuse phases and assert that focusing Ergonomics and Human Factors objectives solely for anthropocentric benefit is restrictive. Therefore, they delve into and visualize the relationship between micro-ergonomics (micro-systemic), macro-ergonomics approach (meso-systemic) and Design for Sustainable Development (macro-systemic). The ergonomics-ecodesign link identified in the use phase of the Life Cycle of the System Product (see Vezzoli & Manzini, 2008) gives rise to new areas of ergonomic experimentation characterized by eco-friendly aspects. In particular, this article focuses on the reuse phase, i.e. the design model "design for longevity" (see RSA, 2013), as i) a key factor to minimise negative environmental impacts in the context of sustainable mobility; and ii) a behavioural attitude to be observed to extend the lifespan of products, in line with the preferences of the reference users.
In the debate about sustainability, the literature suggests that the design of ergonomic interventions should entail a further exploration of additional interdisciplinary, design-oriented contributions. Indeed, Piscicelli and Ludden (2016) introduce Design for Behaviour Change as a methodological approach applicable to the circular economy context to understand user behaviour, guide user choice "towards circular business models" and foster acceptance of disruptive products characterised by sustainability values. In the framework of 'Design for Behaviour Change', Clune (2010) argues that endorsing environmental sustainability objectives entails more than just developing new solutions, it also stimulates the user towards the adoption of desirable 'behaviours' for existing solutions. Sadeghian et al. (2022) argue that technical efficiency must be accompanied by a broader holistic perspective, where sustainability is a clear overarching goal, and technology design considers: i) what stage of behavioural change do users position themselves; ii) what opinions they hold regarding sustainable mobility; iii) what factors influence

their intentions. To harness the advantages of emerging technologies (such as electric vehicles, automation, micromobility, and shared mobility), lifestyle and behavioural changes should precede the proposal of innovative transportation solutions, particularly in the context of individual mobility practices.

Holden et al. (2020) point out the need to act on human values towards the environment and patterns of behaviour and consumption. Related to this, Sadeghian et. al. (2022) identify and analyse factors influencing people's mobility behaviour choices to help instil change through the vector of 'technology design'. Attaianese and Rossi (2023) assert the Human Centred Design (HCD) approach correlates and converges Human Factors and Ergonomics (HFE) techniques in the definition of sustainable design scenarios. They delved into the possible explorations of sustainable HCD to define new scenarios linking HFE and sustainability useful to frame new research paths. Chavez et. al. (2022) broadened product vision from an individual entity to a 'sustainable product-service system' (SPSS). Attaianese and Rossi (2023) indirectly support these statements. The point out that the holistic interaction between human behaviour, creative design practices, and the sustainable quality of contexts of use (International Ergonomics Association, 2022) extends from the micro to the macro level. In other words, they assert that HCD visions and strategies can define sustainable interventions at the human scale, addressing behaviours and well-being ones, proper to the HFE. Therefore, they are capable of supporting relevant macro-themes posed by the sustainability domain.

The connection between the product and the macro-systemic level can be supported by good practices assessing: i) the environmental impact and effects of the product, such as Design for Environment, Ecodesign, and Product Life Cycle; ii) the ergonomic aspects of the product, such as Inclusive Design, "design adjustable", Universal Design and Specialised Design; iii) the user acceptance and perception concerning the use of the product (Chavez et al., 2022). Regarding the third point, this paper proposes to integrate insights from behavioural sciences into the HCD process. It means integrating some steps of the "Design for Behaviour Change" methodological approach as a good practice to foster social acceptance of reuse products in the sustainable mobility field. Therefore, the study presented in this paper explores the potential contribution of sustainable HCD at the 'product-service system innovation (PSS)' level. It proposes the integration of HCD methodologies and HFE knowledge in the field of Design for Behaviour change for sustainability (cf. Attaianese and Rossi, 2023).

Factors influencing sustainable mobility choices

Climate change highlights the urgency and imperative to adopt new behavioural habits, especially in the sustainable urban mobility field (Intergovernmental Panel on Climate Change, 2022). The shift in lifestyles and behavioural attitudes is fundamental to innovative design actions that integrate sustainability objectives and steer individuals in the use and reuse of products. Design for Behaviour Change is a field of design research and practice that focuses on human behaviour, through social and behavioural science theories, and studies how design can change behaviours (Ceschin, F., & Gaziulusoy, İ. 2019; Niedderer, et al. 2017; Piscicelli, L. & Ludden, G. 2016; Wever, R., 2012). In the context of upcycling research, Sung et al. (2022) conducted a research project in the UK to scale up upcycling, both in households and businesses. The results highlighted the effectiveness of adopting Darnton's Nine Principles (see Darnton, 2008) as a framework for understanding and defining behavioural intervention strategies. Concerning the HCD process, the two phases and related steps of the above-mentioned framework can support and implement the 'user research' phase through i) identifying the behavioural model for exploration; ii) understanding consumer behaviour; iii) refining the behaviour model for operationalisation; iv) identify key drivers, facilitators and barriers (Sung et al., 2022).
In support of the sustainable urban mobility research domain, Sadeghian et al. (2022) propose integrating the Theory of Planned Behaviour (TPB) and Prochaska's Transtheoretical Model of Behaviour Change (cf. Prochaska et al., 2015) to identify factors influencing behavioural change across various stages of user transition. In their conclusions, Sadeghian et al. (2022) categorize factors supporting sustainable mobility objectives into components of behavioural intention (see Tab. 1).
Factors influencing user mobility choices analysis highlight the individual needs to address and guide opportunities for design improvement, including interventions that promote acceptance of new mobility technologies and product-service systems. Sung K. (2017) lays the foundations for exploring target users' behavioural intentions by

re-evaluating factors derived from methods such as literature reviews, semi-structured interviews, questionnaires, and online surveys. Building on Sung et al.'s (2022) framework, these methods aid the final phase of "developing interventions" and its corresponding steps which are: i) designing promising interventions and ii) evaluating and refining the draft interventions.

Table 1. Factors influencing sustainable mobility choices.

Components of behavioral intention	Factors influencing mobility choices
Affective attitude	Joy of driving
	Product attractiveness
	Support for local industries
	Rejection of climate change
Instrumental attitude	Comfort
	Safety
	Costs
	Time efficiency
Descriptive norms	Status symbol
	Social values
	Personal values
	Social norms
	Personal norms
Control beliefs	Access to services and infrastructure
	Desire for green energy and eco-friendly driving
Perceived Behavioral Control	Trade-offs
	Radical approaches, such as political or legislative actions

The study presented in the subsequent chapter initiates a discourse on potential technological and design opportunities.

Methodological approach

This study is based on a design experimentation that relies on employing a practice-oriented research strategy that offers enhanced insight into complex, future-oriented issues: research through design (cf. Godin and Zahedi, 2014). The overarching objective of the design research process addressed in this study is to foster the acceptance of new, more sustainable individual mobility technological perspectives through the proposition of an electric bike conversion kit. Specifically, the concept of upcycling within the sustainable urban mobility field was explored to enhance the longevity and desirability of human-powered bicycles. The solution entailed maximizing material utilization through the definition of an easily applicable artefact that renews existing micromobility solutions, meeting the needs of personal mobility.

Methodologically, this study adopts an HCD approach. In parallel, the design innovation process is founded on a design-oriented model integrating theoretical elements derived from behavioural and social sciences into the design process. In other words,, : the "Double-Diamond-one-dot process model for behaviour behaviour change interventions" (DDfBC), as proposed by Van Essen et al. (2016), has been adopted.. The design experimentation unfolds in three stages: discover, define, develop/deliver.

The research activities included HCD evaluation methods and were structured into design steps within the framework proposed by Sung et al. (2022), as described in Table 2. The development of the first research phase (discover) focussed on target users' needs, requirements, and behavioural intentions to introduce technological, sustainable, and human-centered innovations based on parameters from social and behavioural sciences. In this phase, literature review, stakeholder identification, and focus groups were performed. Users were categorized based on Prochaska's "Transtheoretical Model of Behaviour Change" and framed as "users in the contemplation stage" (cf. Prochaska J. et al., 2015). The preparation of the two focus group events involved organizing literature data into semi-structured interviews, starting from the influencing factors of mobility choices, and investigating the main modes of transportation and key determinants that could motivate healthier, more aware, and sustainable lifestyles.

The results of the first research stage converge and lay the foundations for the development of the second design phase (define). During the "designing promising interventions" (Darnton, 2008) design step, analysis and collection of results from previously conducted research was carried out. It led to the identification of the present design vector: a bike-to-e-bike conversion kit. The following phases have been made to identify the bike-to-e-bike kit: i) analysis of the state-of-the-art products on the market; ii) selection of product type; iii) breakdown of the hierarchical sequence of actions that the user performs in installing the conversion kit onto the bicycle; and iv) understanding the product usage modes. Therefore, three methods, "benchmarking" "hierarchical task analysis" and "applied ethnography", were structured to understand and categorize the set of actions that users perform in interacting with and/or installing the product. These activities led to the identification of a strategic brief prepared to systematically arrange the emerged objectives (cf. Rinaldi et al., 2020). The third research phase (develop/deliver) explored various types of creative and innovative solutions to diversify the bike-to-e-bike conversion kit as a key product of the design process. The objective was to outline the broad vision associated with sustainability goals. This converges in the development of a design concept, a synthesis of the conducted research, through the use of 3D modeling and rendering software.

Table 2. Research activities planning.

Stages		**Phases**	**Steps**	**Methods**
DDfBC	**HCD**		**(cfr. Sung et al. 2022)**	
Discover	User research	Understand and specify the context of use	Identify behaviour model for exploration	Literature review
			Understand consumer behaviour	Identify stakeholder
				Focus group
			Refine the behaviour model for operationalisation	Literature review
			Identify key drivers, facilitators and barriers	Focus group
Define	User research	Defining the requirements of the design	Designing promising interventions	Secondary research
				Identification of the behavioral change vector
			Specify the user requirements	Benchmarking
				Hierarchical task analysis
				Applied ethnography
"Design pressure cooker"			**Definition of the strategic brief**	
Develop/ deliver	Design solution	Produce design solutions to meet requirements	Evaluate and improve the draft interventions	Brainstorming
				Idea generation
		Evaluate the designs against requirements		Visual prototyping

Results: a case study of an electric bike conversion kit

As a result, the emerging design proposal is an electric conversion kit for bicycles enhancing the product's lifecycle and includes formal, technical, functional, and systemic innovations regarding: i) ease of use and pleasantness; ii) product engineering; and iii) the definition of engagement strategies through post-purchase services.

The target audience is individuals who are aware of environmental issues and are undergoing a transition towards more sustainable personal mobility actions. From the focus groups, there was significant interest in nudge solutions that support positive social relationships to reduce high levels of work-related stress and technologies that meet green mobility needs, with zero environmental impact, extending the life of their personal bicycles.

From the secondary research (as a result of the first stage of the Double Diamond process), the analysis conducted by Sadeghian et al. (2022) led the research to identify three inputs for the design process: i) meeting individual needs and shaping positive experiences; ii) guiding individuals by providing information on available opportunities and the impact of individual and collective behaviours; iii) being salient in social contexts and allowing connection to peers. Gabrielli et al. (2014) outline a guide to support the development of future mobility solutions and highlight inputs conducive to designing persuasive means, which align with the former inputs. These include: i) creating collective challenges shared at the local level; ii) designing solutions that provide feedback to users regarding their mobility choices and environmental impacts; and iii) supporting mechanisms of social influence. Similarly, Klecha and Gianni (2018) identified how technology can facilitate the behavioural change process by: i) designing persuasive solutions accessible from mobile devices; ii) defining persuasive strategies to facilitate access to mobility information, personalize data, and enable self-monitoring; iii) designing co-design and participatory laboratory activities to involve users in the process phases.

In this research phase, electric bike conversion kits were selected as a design opportunity to further support project objectives. The results of the activities in the first two stages of research converge towards identifying the best solution to implement and prototype. To support the development of the third research phase (develop/

deliver), a technical document was prepared to synthetically and systematically frame the design requirements for defining an output oriented towards change (refer to Table 3).

Table 3. Strategic brief to foster technological, sustainability and human-centred innovations within the parameters of the social and behavioural sciences.

Strategic brief		
R1	Designing the **technological acceptability** of the product-service system	
R2	Designing a product **extending the life cycle of existing mobility solutions**, supporting 'design for longevity'	
R3	Designing for a **target group in the 'contemplation' phase** (cf. Sadeghian et. al., 2022), i.e. aware of the environmental problem and intending to change their mobility choices	
R4.1	Designing **a product-service system motivating the behavioural change process**:	solutions characterised by ease of use and agile applicability
R4.2		compact, all-in-one solutions characterised by modularity
R4.3		persuasive solutions exploiting the potential of mobile devices
R4.4		collective challenges, shared at the local level or by shaping positive experiences and creating social influence mechanisms
R4.5		data accessibility on the environmental impacts of users' individual and collective mobility choices
R4.6		informing about available modal opportunities
R4.7		codesign workshops and participatory design activities, for user involvement in the final stages of the process.

In order to increase user-friendliness and ease of use, the design proposal aims to favour the use of the bicycle and increase its attractiveness for last-mile commuting through the installation of a light, all-in-one, modular component that i) can be applied to any commercially available bicycle; ii) is an attribute of the micro-vehicle; and iii) improves the user experience. Product engineering includes analysing the design constraints, i.e. the minimum components required to make up the kit, the maximum overall dimensions between the fork and the wheel, and the positioning point for the effective extraction of the removable battery modules. Before the definition of the engagement strategies, the design choices concern: i) the minimum adaptability of the kit on bicycles with 20-inch wheels (see Figure 1); ii) the positioning of the kit on the front wheel, which facilitates assembly by the user without the need for an installer (see Figure 2); and iii) the removable and modular battery pack to allow the bike to be recharged without having to carry it all the way home or to the office (see Figure 3).

Figure 1. *The conversion kit is compatible with bicycles ranging from 20 to 29 inches in size. Design by Michele Marco Tizza - IDEE Lab.*

Figure 2. *Assembly system of the electric conversion kit. Design by Michele Marco Tizza - IDEE Lab.*

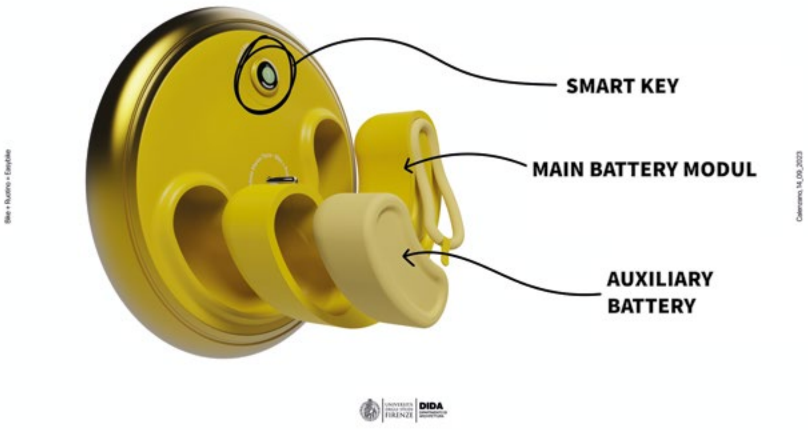

Figure 3. The electric conversion kit consists of two modular, removable battery packs. Design by Michele Marco Tizza - IDEE Lab.

The smart key, illustrated in Figure 3, acts as a bridge between offline and online engagement services. Its user interface serves three functions: i) it displays the battery charge status; ii) encourages vehicle usage through attractive daily notifications; and iii) provides the user with information on personal statistics regarding environmental, health, and sports goals (refer to Fig. 4).

Figure 4. Smart key user interface. Design by Michele Marco Tizza - IDEE Lab.

Finally, the mobile app supporting the product system shapes positive socialisation experiences through collective challenges. These persuasive strategies activate gamification processes through nudges - including challenges between players, challenges with the community and challenges with oneself - and the reward system (see Figure 5).

Figure 5. Mobile app linked to the conversion kit with collective challenges at local level, for user engagement. Design by Michele Marco Tizza - IDEE Lab.

Conclusions

The paper focussed on understanding how designing sustainable product-service system that can facilitate the transition towards a circular economy. Consequently, this study fosters the debate about integrating behavioural and social sciences theories, ergonomic factors, environmental considerations, and eco-compatibility in a unique framework. The aim is to improve the utilization and consumption of existing technological solutions. The findings suggest the interplay between microergonomics and Design for Sustainable Development, specifically at the macro-systemic level, by: i) implementing processes for shaping product-service systems that are socially acceptable, reusable, and environmentally low-impact (Van

Essen et al., 2016); and ii) delineating new project objectives concerning behavioural change (Sung et al., 2022) in support of sustainable and active mobility.
The "Double-Diamond-one-dot process model for behaviour change interventions" (Van Essen et al. 2016) has been adopted as a design model to introduce and correlate the conceptual framework of "Design for behaviour change" with theoretical support tools that assess environmental effects and ergonomic aspects.
Within the practice-oriented process, following the design steps of Darnton's Nine Principles framework for behaviour change (Sung et al., 2022), target users and motivational strategies for adopting desirable behaviours have been identified through secondary research on factors influencing modal choices.
The results related to the design of a product-service system support the concept of "design for longevity" (see RSA, 2013) in the context of sustainable urban micro-mobility and propose a solution that responds to the inputs identified during the initial research phase, aimed at motivating a change in mobility patterns.
Finally, the results lay the groundwork for future work to be focussed on stakeholder engagement regarding the evaluation phase through co-design laboratory activities and participatory design activities aimed at finding behaviour interventions.

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