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The Sustainability Potential of Upcycling

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Abstract: The upcycling trend has received renewed attention in the past few years due to growing concerns for the environment related to increased resource consumption and waste volumes. Indeed, cities across the world are supporting resource upcycling initiatives by establishing do-it-yourself (DIY) repair cafes and makerspaces as a means to transform societies towards sustainable development. However, the sustainability potential of such upcycling initiatives is unknown due to the lack of theoretical frameworks. This research aims to explore the direct and indirect social, economic, and environmental implications of upcycling activities at DIY bicycle repair studios. The main objectives of the study were to: (1) examine the upcycling activities in these studios that contribute to slowing and closing the material cycles, (2) explore the behavioral implications of the users of these maker spaces in the context of environmental sustainability, and (3) propose ways to evaluate the broad environmental impacts of the upcycling activities at these studios. The objectives were explored in three case studies—2 in Sweden (Cykelköket in Malmö and Bagarmossens Cykelköket in Stockholm) and 1 in Switzerland (Point Vélo, Lausanne). Semi-structured interviews, user surveys, and participant observation methods are employed to collect qualitative, and quantitative data to formulate a systemic exploration of major activities and socio-economic exchanges at these repair cafes. The study identified multiple social, economic, and environmental impacts of upcycling activities and represented them in causal loop diagrams. Based on this, a framework for evaluating and governing the overall sustainability potential of upcycling activities is proposed.

Keywords: upcycling; do-it-yourself (DIY); presumption; bike repair kitchens; makerspaces; sharing economy; collaborative production; sustainability framework; social impacts

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1. Introduction

1.1. Background

Upcycling is defined as "a process in which products and materials that are no longer in use, or are about to be disposed of, are instead repurposed, repaired, upgraded and remanufactured in a way that increases their value" [1] (p. 1). In contrast to recycling, upcycling maintains the resource quality and increases the overall value of the product. This research work studies upcycling in the context to do-it-yourself (DIY) repairing activities performed at initiatives, such as repair cafes and DIY makerspaces that focus on encouraging the circular economy and sustainable production and consumption in cities.

Upcycling trend has received renewed attention in the past few years due to growing concerns for the environment related to increased resource consumption and waste volumes. In the context of the circular economy, upcycling is regarded as a strategy to reduce resource consumption by slowing and closing material cycles [1–3] by improving the quality of products and materials in the value chain [4] and countering the planned and premature obsolescence [5]. Upcycling also has the potential to create economic and employment opportunities, encourage entrepreneurship [6], and promote environmentally sustainable consumption behaviors through re-use [7].

Recently, cities have been recognized as leading forces in achieving sustainable development goals including sustainable resource management. Indeed, several cities in

Europe are encouraging a circular economy by establishing product repair initiatives. Such initiatives have been studied in relation to providing technological solutions for degrowth [8]; reducing overall consumption through time expenditure in repairing [9]; improving resource efficiency by enhancing product longevity and spare parts recovery from urban waste flows [1]; and offering added social benefits by establishing social interaction, co-creation and mutual learning [1,10]. DIY repair studios could act as catalysts for reviving the repair culture in our societies by providing platforms for skills, tools, and resource exchanges. Indeed, Bradley [8] proposed that bike repair cafes have the potential to enhance autonomy and creativity among citizens, assist them in liberating themselves from commercial relationships, and enable them in establishing non-capitalist relationships.

These DIY repair activities have been identified with closing and slowing the material flows by extending the lifespan of products through repair, upgrade, reuse, and recovery of spare parts or material resources from urban waste. Product sharing, mending, and repairing initiatives have the potential to prevent the purchase of the new products and spare parts and, therefore, are considered environmentally sustainable [3,10]. In addition, these initiatives are closely linked with creating positive social and economic benefits, for example, enhancing repair skills and sufficiency, as well as social cohesion in the local communities. This research assesses multifaceted social, economic, and environmental impacts of DIY bike repair [10].

Literature suggests that carbon footprint related to individual consumption are closely linked to personal time use, socio-economic situation, and material consumption [11]. Repairing a product requires spending time on carrying out the repair activity. The time spent may replace or induce other activities impacting the overall resource consumption. Therefore, DIY repair activities have high prospects of stimulating behavioral changes in individual time use and consumption patterns to create a new set of complex socio-economic interactions driving sustainable consumption in societies. This research explores the potential and implications of the users' behavioral changes induced by the DIY repair activities.

In summary, the upcycling activities through DIY repair offer several positive social, economic, and environmental opportunities. However, the design, operational, and institutional contexts may impact the overall sustainability profile of collaborative production initiatives [12,13]. Therefore, from a sustainability viewpoint, these initiatives need to be evaluated from socio-economic and environmental perspectives.

1.2. Research Aims and Objectives

This research aims to explore the direct and indirect social, economic, and environmental implications of upcycling activities at DIY bicycle repair studios. For this purpose, three DIY bicycle repair studios are studied—2 in Sweden (Cykelköket in Malmö and Bagarmossens Cykelköket in Stockholm) and 1 in Switzerland (Point Vélo, Lausanne). The main objectives of the study were to: (1) examine the upcycling activities in these spaces that contribute to slowing and closing the material cycles, (2) explore the behavioral implications of the users these maker spaces in the context of environmental sustainability, and (3) propose ways to evaluate the broad environmental impacts of the upcycling activities at these makerspaces. The study employs multiple research methods for empirical data collection and analysis to draw inferences. The study contributes to the understanding of the multifaceted sustainability impacts of upcycling activities. The study proposes a framework to assess and govern the sustainability profile of upcycling initiatives.

The rest of the article is organized as follows: a theoretical background of the upcycling activities is presented in the context of the concept of collaborative production and presumption (Section 2.1), circular economy and sustainable consumption (Section 2.2), and the potential time-use rebounds in the context of collaborative production and consumption (Section 2.3). Section 3 describes the materials and methods employed in the study. The article then reports results and discussion (Section 4) and ends with the key conclusions of the study (Section 5).

2. Theoretical Background

This section contextualizes the concept of upcycling with the relevant literature on collaborative production, circular economy, and indirect and indirect impacts.

2.1. Collaborative Production: Production, Consumption, and Presumption

Until the 19th century, upcycling in the forms of repairing and repurposing products or resources was an integral part of society [1]. The consumers of products were often also their producers. However, the industrial revolution in the past century has gradually replaced such sufficiency-based lifestyles with new ways of (over)consumption, characterized by exchangeability, replaceability, and throwing away. Some of the reasons for this shift were increase in productivity of industrial processes, and an increased focus on the marketing of products [9]. These not only delinked the producer and consumer of a product [14], but also cut their traditional relationships with a product established through its repair, maintenance, or up-gradation. Consequently, the rise of consumerism in the western world has largely led to the loss of several traditional skills of maintenance and repair [15]. Moreover, this shift in the consumption paradigm has resulted in rapid product replacement and discarding.

In today's economies, the production follows consumption and vice versa. However, in the beginning of the industrial revolution, this was not the case, the western societies were defined predominantly by production [14]. In the latter half of the 20th century, consumption became important in economies, as compared to production, due to an increase in the number of consumer products and the consumers and intensification of consumption processes through marketing, advertising, and branding. According to Toffler [16], this was called "the second wave" of marketization [14]. Consequently, production and consumption became two separate functions dividing two entities—the producers and the consumers [14].

The term "prosumer", i.e., the one who consumes and produces a product was first coined by Toffler [16]. According to Toffler, the present-day presumption known as "the third wave", was an integral part of the pre-industrial societies. Collaboration production through the sharing of skills and locally available material resources was an integral part of several societies throughout history.

Proponents of collaborative production argue that it offers economic empowerment, improves social cohesion, and reduces environmental impacts [17]. The marketed interests in DIY repair and skills, tools, and spaces sharing have indeed been supported by many European cities to support sustainable production and consumption among their citizens.

2.2. Circular Economy and Upcycling Activities at the DIY "Bike Repair" Studios

Grassroot DIY repair initiatives are supported by government, and non-governmental organizations and volunteer groups [8,9] because of their sustainability potential. Bradley [8] explored the "Bike Kitchens" in relation to degrowth. The concept of a bike kitchen is not new. Indeed, one of the oldest bike kitchens, Biciclot, Barcelona, was initiated in 1987. Biciclot has become an established institution that cooperates with the City Council of Barcelona to promote cycling and walking in the city.

The DIY bike repair studios create positive environmental benefits by (1) recovering and reusing parts from the urban discards, (2) sharing of tools needed for repairing or servicing, and (3) extending products' lifetime through repair and servicing. The upcycling activities at these repair studios have positive social and economic impacts for the users and society. According to Bradley [8], bike kitchens enhance autonomy and creativity among citizens and help them in forming noncapitalist relations with others. Bike kitchens are explored in the context of the democratization of technology because they enable everyone to access the technology, tools, and skills needed for repairing or servicing [8].

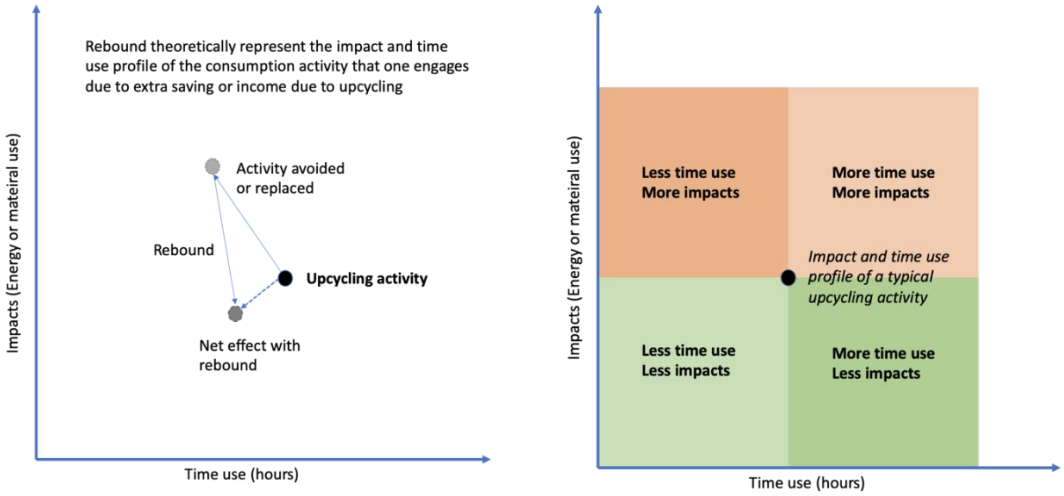
2.3. Time Use Rebound Effects and Collaborative Production and Consumption

Everyday consumption activities are closely interlinked with the product and services and the temporal dimension in which these are utilized to satisfy the consumers' needs. To reduce environmental impacts, efficient consumption of products and services is needed. Indeed, taking a functional perspective on consumption activities, a significant amount of research focuses on the eco-efficiency of products. However, Jalas [18] contends that modern consumption serves needs that are not always functional and universal, but are subjective and obscured from products. Jalas [18] describes these subjective consumer preferences and needs as driven by cognition of goals and available means for striving towards them. Therefore, the consumption being interlinked with everyday life activities makes it important to include their temporal dimension because it requires both physical inputs and time. Considering that not only money but also time is a scarce resource to fulfill a consumer need, it is important to understand the intricate relationships between time use and the environmental impacts (energy or material consumption) of the activities.

Understanding these interrelationships requires analyzing time use or a rational allocation of time. The concept of rational allocation of time has been studied and theorized in the field of household economics [19]. To rationally allocate individual time use, Smetschka [20] utilizes a functional time-use analysis to evaluate the environmental footprints of everyday activities in Austria. For this purpose, the direct and indirect carbon footprints of time use were evaluated, including the time use rebounds. The time use rebound effect was defined as the new activities that a consumer engages in when an existing activity is replaced by a less environmentally harmful product or service [20,21]. These new activities are termed rebound activities. In this context, the rebound activities, i.e., the activities that are induced or replaced due to time spent on the activity in focus, can provide insights into understanding the intricate relationships and dynamics driving everyday consumption.

Understanding these relationships and dynamics further requires establishing a link between time use and carbon footprint of the consumed or avoided products and services. Previously, studies [11,18,20,21] evaluated the direct and indirect carbon footprints of time use in everyday activities. For this purpose, these studies classify daily functional time available into personal time for personal care and sleep, committed time for household, family care and support, contracted time for employment and study, free time for social activities, culture, and leisure, and travel time taken to link spatially distinct activities. This classification makes the basis for assigning carbon intensity to a particular activity that requires time use.

From the perspective of individual time, bike kitchens make an important case because repairing activities require spending individual users' time. In fact, Lehner [9] and Singh et al. [10] highlighted that bike kitchens have the potential to reduce consumption among the users of the bike kitchens based on their time expenditure on the repair activities and the environmental intensities of the rebound activity. In the context of the repair activities at the bike kitchens, the rebound activity can be defined as the activity the user would have otherwise engaged in instead of the time spent on repairs. A sustainable lifestyle, from a time-use perspective, can be defined as a lifestyle with no increase in the materials intensity of everyday life [21,22]. Bike kitchens could contribute to a sustainable lifestyle among the users in case the repairing activity is concurrent with or replaces another existing activity with a greater environmental impact (see Figure 1). This research highlights the potential contribution of repair activities in driving environmentally sustainable consumer behaviors and proposes a framework to evaluate the environmental impacts such behavior changes.



(**a**) (**b**)

Figure 1. (**a**) A hypothetical example illustrating the net effect of upcycling activity due to changes in user behavior leading to replacement or avoidance of another activity that is more impactful than the upcycling activity. (**b**) An illustration of possible activities that can be avoided or replaced or induced due to upcycling with various impacts and time-use profiles depending on their impacts and time use. The activities that fall in the upper quadrants represent more impacts, and the activities in the lower quadrants represent lower impacts.

3. Materials and Methods

This research employs multiple methods for data collection and analysis. These include semi-structured interviews, a user survey, participant observation, case studies, and causal loop diagrams.

3.1. Semi-Structured Interviews

This research employs semi-structured interviews to collect qualitative data on the key activities performed at the repair studios and their societal impacts (see Table 1)—three in Sweden and two in Switzerland. These interviews were recorded and transcribed. The interviewees were selected from different types of bike studios to include diverse perspectives on the repair activities and their societal and environmental impacts. These interviews were conducted between March 2018–August 2018. The following questions were asked during these interviews:

1. What was the main purpose to establish the bike studio?
2. What are the organizational characteristics of these bike studios in terms of financing and operational structure?
3. What are the main societal and environmental impacts of the bike studio?

Table 1. Information on the interviewees used in the study.

Country	Organization(s)	Total Interviewees
Sweden	Bike Kitchen, Malmö (in person) Bagarmossens Cykelköket, Stockholm (online)	3
Switzerland	Point Vélo, Lausanne (in person)	2

3.2. Online Survey

To gather empirical information on the socio-economic benefits of Cykelköket Malmö for the users, an online user survey was employed (conducted between April 2018 to August 2018). The survey was focused on gathering data on (1) the major activities that the individual users performed during their visits, (2) the intentions or motivations of the

users to conduct repair or servicing activities at the bike studio; (3) the socio-economic and environmental benefits perceived by the users, and (4) average time spent by the users at the bike kitchen for repair activities and socialization. In total, the survey collected 46 individual responses.

The survey was designed to understand the motivations of the users and their time-use profile of repairing or servicing activities (e.g., frequency of visits and time spent during visits), and the social, economic, and environmental impacts of the activities at the bike kitchen. The survey also included general questions about personality traits and demographic information (e.g., age, gender, education, and income level) to understand the socio-economic profile of the users.

3.3. Participant Observation

This research employs the participant observation method to identify various social, economic, and environmental interactions taking place during the upcycling activities in the studied DIY repair studios (conducted between July 2018 to August 2018). In participant observation, the observer takes part in the social setting being investigated to gain firsthand inferences or knowledge [23]. The observer in this study (the author) not only observed the participants, but often actively took part in the upcycling activities as a participant to gain an in-depth understanding of the activity [24]. Therefore, the observer acted as both complete participant and participant as observer. The participant observation was covert, i.e., during both roles, the observer did not inform the participants being observed the true purpose of taking part in the upcycling activities. To identify and collect relevant information, an event sampling method was used, wherein it was decided beforehand what events to record. In this study, the observer focused on upcycling activities that resulted in the reuse of recovered spare parts, repair or service, and social interactions among users.

3.4. Causal Loop Diagrams

Causal loop diagrams are used to represent various cause-and-effect interactions and feedback loops in a system through arrows and polarity [25]. The arrows represent a cause-and-effect relationship among two system variables, along with a polarity sign of positive ("+") or negative ("−") (see Figure 2). A positive sign denotes that both variables change in the same direction, i.e., when one of them increases, the other also increases and vice versa [26]. A negative sign means that the variable changes in the opposite direction, i.e., if one increases, the other decreases and vice-versa. A feedback loop in a causal loop diagram is represented as either reinforcing or balancing, as shown in Figure 2. In this research, causal loop diagrams are employed to represent various social, economic, and environmental interactions and feedback loops established due to upcycling activities at the studied repair studios. The causal loop diagrams are based on the qualitative data collected through semi-structured interviews, user surveys, and participant observation conducted in this study. A similar approach has been employed previously in analyzing the success factors and challenges to upcycling (see [1]).

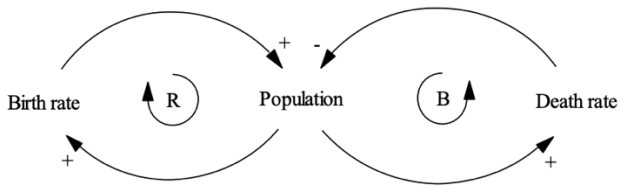


Figure 2. A causal loop diagram of an example of variables such as birth rate, population, and death rate showing causal links among them with a polarity and feedback loops—reinforcing (R) and balancing (B). Adapted from [25]. Source: [27].

3.5. Case Studies

The organizational characteristics, such as the financial and operational structure of the three bike repair studios significantly vary (shown in Table 2). Nonetheless, a common

motivation behind establishing these remains the lack of DIY spaces recognized by bicycle enthusiasts with a shared interest in cycling and DIY repair (for their bikes).

Table 2. Key characteristics of the investigated repair cafes.

Characteristics	Cykelköket, Malmö	Bagarmossens Cykelköket, Stockholm	Point Vélo, Lausanne
Financed by	Municipality of Malmö, Sweden	Self-financed by volunteers through membership fees	Partly by École Polytechnique Fédérale de Lausanne (EPFL) Lausanne, Switzerland
Established in	2012	2013	2005

Further, these repair initiatives are often supported by ongoing sustainability-driven activities in the society. For example, Bagarmossens Cykelkök in Stockholm was initially supported by the local municipality and an insurance company due to the ongoing projects with a similar focus in these organizations. A recent trend of bicycling has also resulted in demand for such places. For instance, Point Vélo, Lausanne, was started with the help of EPFL when a need for DIY space on the university campus was felt due to an increasing number of students bicycling. The university collaborated with an existing bike repair shop on the campus to allow students and volunteers to repair and service their bicycles themselves. The university supports the activities at Point Vélo to achieve its goals to improve access to the university and support individual mobility shift towards bicycling. This was in line with the federal policy goals (The Confederation: Exemplary in Energy) to achieve environmental sustainability by reduction of CO_2 and a modal shift to promote cycling and walking.

These repair spaces are financed through different means, such as the local governments, non-governmental organizations, and individuals. These spaces are also supported by numerous volunteers who exchange their resources such as time and repairing skills for free or by part-time workers supported by membership fees and paid events. For example, Point Vélo, Lausanne, employs students for part-time work during the 1 h lunch break. This is because university students come to repair or service their bikes during the lunch break. Malmö Municipality financed the monthly wages of two members of staff at Cykelköket, Malmö. Bagarmossens Cykelköket is supported by volunteers and membership fees from the users. Point Vélo, Lausanne, has signed a contract with the EPFL that offers the students free use of tools and small repair, or service works assisted by the part-time-employed students.

4. Results and Discussion

This section presents the key results of the study—the potential direct and indirect sustainability impacts of upcycling activities at the bike repair studios. These results are discussed in the context of the business model of the studied repair studio. A proposed framework to evaluate and govern the overall sustainability potential of upcycling activities is described.

4.1. The Direct Sustainability Impacts of Upcycling Activities

The semi-structured interviews and the user survey provided an overview of various activities performed at bike studios. These activities contribute to organized urban resource mining in cities. Overall, these include the collection of discarded or abandoned bikes in cities, recovery of re-usable parts from these wasted bikes, tools and skills sharing for bike repair and servicing, offering DIY courses on bike repair, providing bikes for rent, and donating the recovered bikes to underprivileged sections of society after repairing and servicing them. The recovery of bikes and spare parts contributes to circular material flows by avoiding the purchase of new spare parts and prolonging the lifetime of the spare parts.

The recovered spare parts are clean and restored by users and volunteers for further reuse. The discarded or abandoned bikes are repaired and restored before being sold or given further. Figure 3 presents a causal loop diagram with various system variables in upcycling activities contributing to the circular economy through the recovery and reuse of spare parts from discarded products.

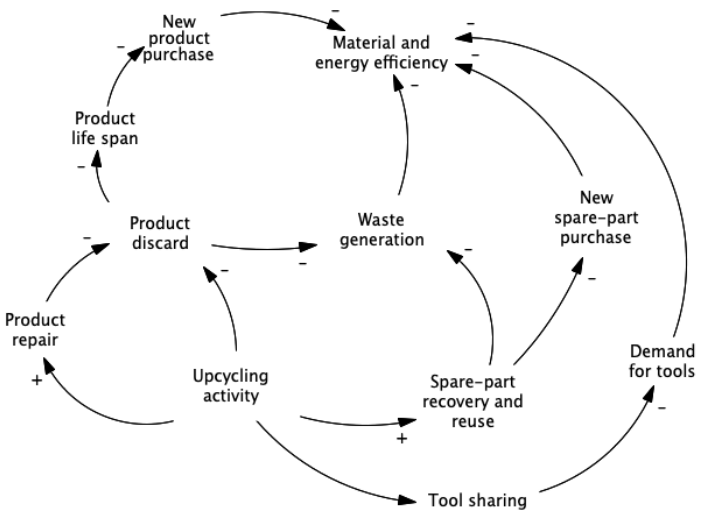


Figure 3. A causal loop diagram representing various system variables in upcycling activities contributing to the circular economy through recovery and reuse of spare parts from discarded products.

Based on the business model of the bike kitchen, the reuse of spare parts is offered in a variety of ways. For instance, the users often visit the bike kitchen in Malmö to have broken spare parts replaced rather than buying new ones. Point Vélo provides labor and small bike repairs and servicing for free. Point Vélo, Lausanne, repairs the abandoned bikes and rents or sells them to university students at discounted prices. Bagarmossens Cykelköket charges money for the spare parts from non-members but offers them for free to members.

> *"We still have lots of spare parts that people could get for free to fix their bikes." (Interviewee 1) "there is no charge for the labor, oiling, changing tubes etc."* (Interviewee 3)

> *"The use of tools is free for all. Spare parts are often sold to those who are not members, but for members the spare parts are for free."* (Interviewee 4)

> *"Students are happy that prices are low (students 150 CHF and the student federation pays 50 CHF) for postdocs, researchers and staff the price is 200 CHF."* (Interviewee 3)

The user survey in Cykelköket in Malmö provided insights on typical user motivations to take part in the activities of the bike kitchen. Out of the 46 users, 29 agree that they come to reuse the bike spare parts from the discarded bicycles (29 out of 46 responses). Repairing and servicing bicycles saves money for the users. Out of the 46 users who responsed, 36 agree that they come to the Cykelköket for repair, servicing, using tools, or changing spare parts of a bicycle because it does not cost them, and 33 users agree that it saves them money. This shows that the users have direct or indirect perceived economic benefits from their participation in the activities of Cykelköket Malmö.

The environmental impacts of resource savings from spare part reuse need to include the impacts from the avoided production of new spare parts and lifetime extension of the product and recovered spare parts. Since the users save money by not spending it on the spare part, the impacts from this extra saved money when spent on other consumption activities need to be included in the overall evaluation (shown in Figure 4).

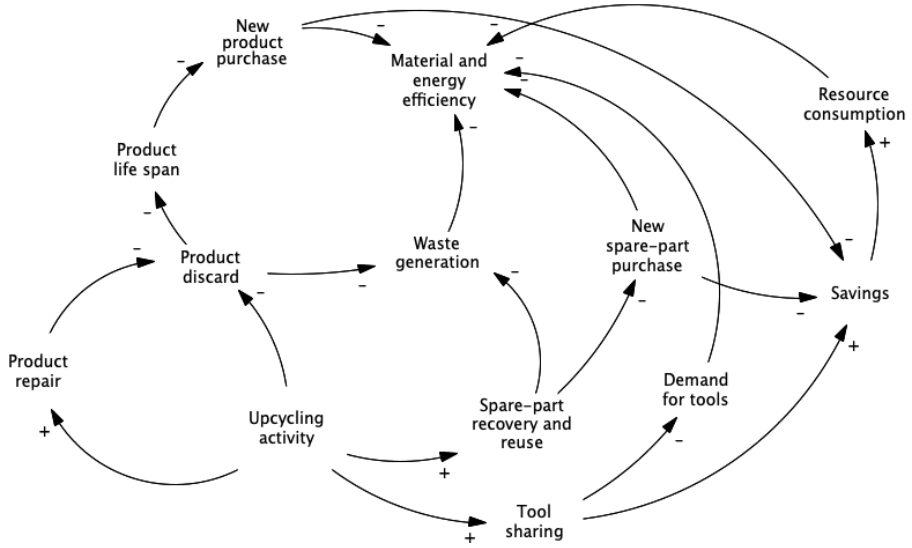


Figure 4. System variable interactions represent economic benefits of upcycling activities for users and their indirect effects on consumption.

These bike kitchens provide spaces for people to learn how to repair and service their bikes. In this regard, the bike kitchens promote sufficiency among the bike users. The bike kitchens also provide spaces for socialization and cultural exchange among citizens.

> *"Each time we open, 8–9 languages are spoken at the same time. It is very diverse in a way, with people coming in from all around the city."* (Interviewee 1)

> *"Sometimes people just come to hang out even when they have nothing to repair."* (Interviewee 4)

Further, most of the users like socializing with the other users even outside the bike kitchen activities (38 out of 46 responses), and many of them met for the first time at the Cykelköket in Malmö (25 out of 46 responses). The DIY repair and servicing culture enables close social interactions at the bike studio, resulting in positive social impact, e.g., social cohesion, self-sufficiency, and empowerment (shown in Figure 5).

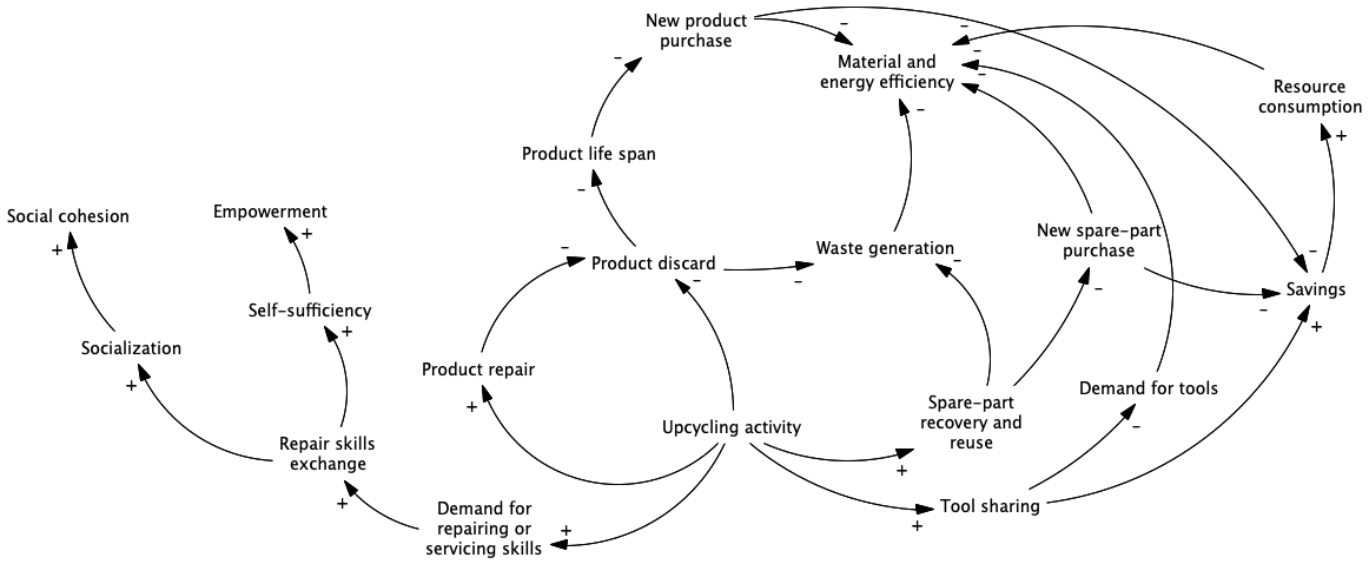


Figure 5. Causal links showing the social impacts due to the upcycling activities at the repair studios.

In summary, the direct impacts of the repair studios include material resource recovery through the reuse of the spare parts from the discarded bicycles, and the avoided purchase

of new spare parts. These studios produce net positive economic benefits for the users despite the varied business models. Further, there is a potential to create positive social benefits such as social cohesion, self-sufficiency, and empowerment among the users.

4.2. The Indirect Impacts of the Upcycling Activities at the Bike Repair Studios

Previous studies [11,18,21,28,29] have identified a relationship between time use, consumption, and carbon footprint. This assumes that consumption is not only limited by economic factors (such as disposable income), but also the individual time available for engaging in the consumption activities. The user survey showed that out of the total 46 respondents, 30 had spent more than 3 h every time they had visited the Cykelköket, Malmö. The main motivations for visiting the Cykelköket, Malmö, were to carry out bike repair and servicing works and to attend special events. Thirty-six participants in the survey had visited Cykelköket, Malmö, more than 10 times in the past year. Overall, this indicates that the users spend a significant amount of time at the bike studio. If the users spend their limited individual time on repairing activities, this could directly (1) prevent or replace some of the consumption activities that the users would have otherwise engaged in during this time and (2) leave the users with overall less time available for engaging in other consumption activities. Since the time spent on repair activities requires very less energy or resource use, the time spent on repair has a high potential to replace resource-intensive consumption activities, resulting in overall smaller environmental impact (shown in Figure 6).

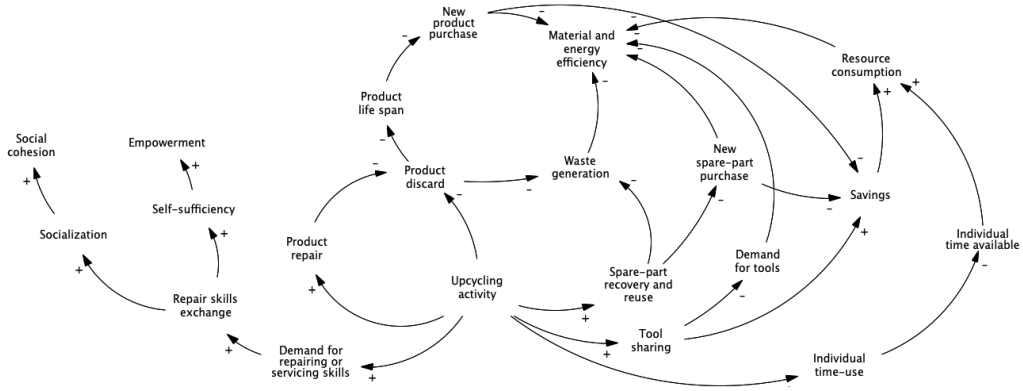


Figure 6. A causal loop diagram representing the indirect environmental impacts (both positive and negative) due to the behavioral change in individual time use.

Evaluating environmental impacts resulting from this behavioral shift in users requires understanding the amount of time spent on repairing activities and the activities that were replaced or altogether avoided. The user survey in this study focused only on the time spent on repairing activities only. This is because it is difficult to access accurate information on daily activities from a small sample size, as used in this study. However, the national time-use surveys can provide accurate information on typical daily activities that are more likely to be replaced or avoided due to the time spent on repairing activities. However, some of the household activities are essential and the user will eventually do them despite the time spent on repairing. Yet, since the time available is a limited resource, the time spent on repairs will be taken from other household activities. Thus, it is important to explore which typical user activities are more likely to be replaced, or avoided or reduced, in order to accurately estimate the environmental gains. Based on the hourly carbon intensity of daily household activities (for Austrians) according to a study by Smetschka and colleagues [20], Table 3 shows estimated environmental benefits that could be achieved if different household consumption activities were replaced or avoided or reduced through the time spent on upcycling according to this study (i.e., 30 h, based on 10 visits per year and 3 h spent during each visit).

Table 3. Environmental impact reduction if and when typical household activity categories are replaced or avoided or reduced due to time spent on upcycling activities.

Typical Household Activity Categories * That Will Be Replaced or Avoided or Reduced	Probability of the Activity Category Being Replaced or Avoided or Reduced [!]	Hourly Impacts [#] (CO_2 Equivalent per H)	Annual Environmental Impact Potential [%] (CO_2 Equivalent)
Sleep and rest	Low	0.64	19.2
Personal care	Low	2.67	80.1
Eating and drinking	High	3.30	99
Repairs and gardening	Low	1.92	57.6
Food preparation and dishwashing	Low	1.51	45.3
Caring for others	Low	1.79	53.7
Cleaning, tidying	Low	1.51	45.3
Shopping, civic matters, and services	High	0.14	25.5
Entertainment and culture	High	9.74	292.2
Pet care	Low	1.02	30.6
Sports and outdoor activities	High	1.08	32.4
Spending time with friends/family/neighbors	Low	1.00	30
Reading	High	1.05	31.5
Recreational course and study	Low	3.37	101.1
Hobbies and games	Low	4.13	123.9
Watching TV and videos/DVDs, listening to radio and music	High	1.00	30
Eating out	High	9.82	294.6
Volunteering	Low	0.14	4.2

* The categories are derived from the classification of Individual Consumption by Purpose (COICOP) and are based on Smetschka and colleagues [20]. [!] The probability of the activity category being affected is assumed based on whether the activities are indispensable or not. The indispensable activities are the least likely to be completely avoided, but are postponed or reduced. [#] The hourly impacts including holidays are based on Smetschka and colleagues [20]. [%] The environmental impact potential is based on the average annual time spent by a typical user on upcycling activities according to the user survey conducted in this study (i.e., 30 h = average 10 visits per year × 3 h spent during each visit).

Further, the environmental impacts from the spending of extra income or savings from the upcycling activities on other products and services need to be included in the overall analysis. These impacts will depend on the amount of extra income or savings and the type of purchased products and services. It is, however, often difficult to establish clear causation between a person's total income budget and spending. This calls for further research to understand the user's behavioral dynamics.

The overall environmental impacts of behavioral shifts in users can vary significantly based on the institutional setup of the bike studios. For example, municipality-run non-profit organization Cykelköket, Malmö, provides spare parts and skills for free to its users. Therefore, because of the organizational and municipal regulations, Cykelköket, Malmö, is not able to sell refurbished bikes without official auctions. Therefore, economically, the users benefit from free repairs, servicing, or recovery of spare parts; however, Cykelköket, Malmö, lacks a viable financial model to support its running costs.

> *"One challenge we have been having is stemming from the financial part, changing to be more a volunteer-based organization."* (Interviewee 1).

Whereas, Point Vélo, Lausanne, partly supported by EPFL, provides free use of tools by the university students and staff and subsidizes prices for repair operations and replacement of spare parts. Point Vélo also offers bikes for rent for the students and staff at a very low price. Due to this viable economic model, Point Vélo has been creating positive economic benefits for both the users as well as its organizers. However, this does not imply that volunteer-run repair organizations may not be successful. Indeed, volunteer-run Biciclot in Barcelona has been functioning for over 25 years because of its social cause.

The user survey conducted in this study included only one type of organization, i.e., a municipality-supported repair studio. Study of other types of upcycling repair studios,

therefore, could provide further insights into the activities that could be replaced and their sustainability implications. These repair studios can be examined under a variety of institutional settings in order to identify conditions for an enhanced sustainability profile. These institutional settings can be guided by preset sustainability criteria and business model settings to produce the desired social, economic, and environmental impacts.

4.3. A Framework to Evaluate and Govern the Overall Sustainability Potential of Upcycling Activities

This study explored the potential sustainability impacts of upcycling activities at the studied bicycle repair studios. These studios have the potential to create multiple socio-economic and environmental benefits to their users and society. However, the institutional contexts governing upcycling activities in cities need to be fully understood to enhance their sustainability profile. Based on this study, a framework for evaluating and governing the overall sustainability impacts of upcycling is proposed. There are four steps in this framework:

1. Exploring, conceptualizing, and defining the broad socio-economic and environmental interactions;
2. Evaluating the sustainability impacts;
3. Setting goals and agendas for the upcycling activities;
4. Identifying and implementing the management strategies.

The first step involves conceptualizing the major socio-economic and environmental interactions created by the upcycling activities, including the direct and indirect impacts. This involves expanding the system boundaries to include a broad set of such interactions. As discussed above, it is important to consider the institutional contexts of the upcycling activities since they can influence the nature and scale of the impacts. Various data collection methods can be employed. This study employed literature study, interviews, and participant observation. The social, economic, and environmental impacts are clearly identified and defined.

In the second step, measurable indicators are developed for the identified social, economic, and environmental aspects of the upcycling activities. These indicators can be qualitative as well as quantitative in nature. Multiple indicators can be employed to measure a single social or economic or environmental aspect. For instance, in this study, the indicated social impacts were social cohesion and empowerment. However, several other indicators can also be employed to measure social impacts, such as inclusivity, social justice, and trust, as identified by Curtis and colleagues [30]. Qualitative and quantitative data were collected accordingly.

In the third step, a particular set of goals can be set for the upcycling activities, such as increasing the user activity levels, enhancing the positive social impacts, or implementing an economically viable business model for upcycling activities. This study highlighted how the social, economic, and environmental impacts differ based on their institutional contexts. In the fourth step, a variety of business model scenarios under varying institutional contexts can be simulated to explore efficient management strategies governing the sustainability profile of upcycling activities.

5. Conclusions

The study examined the direct and indirect sustainability impacts of upcycling activities at the bicycle repair studios in Sweden and Switzerland. The study concludes that the direct sustainability impacts of upcycling include (1) material resource recovery through the reuse of spare parts and avoided purchase of new spare parts, (2) economic benefits to the users, and (3) social benefits due to the socialization of the users. Due to the changes in the users' individual time-use and behavioral patterns, upcycling activities could indirectly contribute to reducing material consumption activities. Based on this study, a stepwise framework is proposed to (i) explore, conceptualize, and define the broad socio-economic and environmental interactions, (ii) evaluate the sustainability impacts, (iii) set goals and

agendas for the upcycling activities, and (iv) identify and implement the management strategies to enhance the sustainability profile of upcycling initiatives.

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