Redesigning the Chowndolo: a Reflection-on-action Analysis to Identify Sustainable Strategies for NIMEs Design

Nicolo Merendino
University of Padova

Giacomo Lepri
Queen Mary, University of London

Raul Masu
Hong Kong University of Science and Technology (Guangzhou)

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Nicolò Merendino*
Centro di Sonologia Computazionale, Dept. of Information Engineering
University of Padova
Padova, Italy
chihauccisoilconte@gmail.com

Giacomo Lepri†
Independent Researcher/Artist
giacomolepri.com

Antonio Rodà‡
Centro di Sonologia Computazionale, Dept. of Information Engineering
University of Padova
Padova, Italy
roda@dei.unipd.it

Raul Masu§
Institute of Music, Science and Engineering.
King Mongkut's Institute of Technology Ladkrabang
Bangkok, Thailand
raul@raulmasu.org

ABSTRACT

The sustainability of Digital Musical Instruments (DMIs) is a crucial concern within the NIME community, not only in the design of the instruments but also in terms of sustaining the instrument over a prolonged period, promoting longevity, and minimizing obsolescence. The risk of designing advanced instruments becoming debris quickly is real if longevity is not actively considered. In this paper, we present the process of redesigning a crafted DMI to fit a small-scale production process while considering strategies that render the final design more sustainable and maximize the object's lifespan. We present the results of a critical analysis of this process through a sustainability lens. From this analysis, we distilled a number of reflections that could help similar design processes or NIME crafting activities. The most innovative reflections are related to inscribing sustainability into the practice of using the instruments. From this perspective, we suggest considering the future user as a designer capable of fixing, adjusting, redesigning, or hacking the DMI and actively provide possible solutions that can significantly extend the lifespan of a DMI and, consequently, its sustainability.

*Redesign of the instrument, data collection and analysis, discussion and sustainability strategies development

†Original instrument design, and contribution to the redesign process.

‡Overall design process supervision

§Data analysis, theoretical frame, discussion and sustainability strategies development

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Author Keywords

NIME, Sustainability, Longevity, Redesign

CCS Concepts

•**Applied computing** → **Sound and music computing;** Performing arts; •**Social and professional topics** → **Sustainability;** Governmental regulations;

1. INTRODUCTION

In the last few years, NIME started to pay increasing attention to sustainability related to building new musical tools development (e.g., [33, 29, 8]). Parallely, the community also addressed the longevity of Digital Musical Instruments (DMIs) (e.g., [36, 7, 31]), which is essential to preserve design knowledge and transform in practice. These two aspects are related, mainly if we focus on DMIs disposals [29]. Indeed, the risk of designing outstanding instruments that become debris in nothing but a few years is real if we do not actively consider longevity.

In this paper, we present the process of redesigning a crafted DMI - the Chowndolo - to fit a small-scale productive process. During the process, we specifically focused on strategies that could render the final design sustainable and maximize the object's lifespan. Additionally, we endeavored to mutate strategies from the Human-Computer Ineraction (HCI) discourse [24, 4, 2, 9], design justice [6], and Free/Libre and Open Source Software (FLOSS) debate [41, 12].

By retrospectively analyzing our work - using the Reflection-on-Action methodology [46] - and reading it through the lenses of sustainability *in* and *through* design [24], we distilled several strategies which could help similar design processes or arguably even more traditionally NIME crafting activities. Some strategies directly relate to the production process (e.g., rounding the edges, optimizing the production phases). Furthermore, we develop some reflections on future uses of the instruments, which we referred to as *inscribing sustainability in the practice.* We suggest considering the *user as a future designer* capable of fixing, adjusting, and even redesigning or hacking the DMI. We propose a list of solutions in support of this approach.

2. BACKGROUND

One of the most relevant issues related to the sustainability of DMIs is the longevity of musical instruments. For this reason, the first subsection is dedicated to this topic. Afterward, we scrutinize ideas that emerged in the Sustainable Human-Computer Interaction (SusHCI) debate and the discourse on Free Software and Open Hardware concerning sustainability.

2.1 Longevity (and Sustainability) of NIMEs

The debate on the longevity of new music technology has a relatively long life [36, 7, 26]. In 2017, Morreale and colleagues surveyed authors of new DMIs presented at NIME between 2010 and 2014 [36]. Results highlighted that most of the instruments were used in public performances less than four times by one or two artists. McPherson suggested that "design decisions that promote a successful first performance will not necessarily translate to broader uptake" [40]. To address the problem of longevity and sustainability of new DMIs, Marquez-Borbon and Martinez-Avila [26] supported the need to develop non-traditional pedagogical systems in support of artistic practices.

The T-Stick, a family of instruments originally presented at NIME paper in 2007 [23], has been the protagonist of several research projects developed to prolong its life span. In 2018, several copies of successive generations of the T-Sticks were developed to overcome "issues related to the aging of components, changes in external software, lack of documentation, and in general, the problem of technical maintenance" [39]. Additionally, several composition commissions were made to expand the community around the instrument [14]. Finally, Kirby et al. [19] developed the t-Tree to overcome obsolescence derived from the evolving changing of protocols and standards [19].

The T-stick represents one of the few examples where a large number of research projects aimed at keeping one DMI alive. Other examples include the Feral Cello [7], the Electrumpet [22], Click::RAND [10], AirStick [51], and AIterity [50], which have been updated in accordance to artistic needs derived by the practice or to prevent technical obsolescence.

All these examples represent attempts to prolong an instrument's lifespan, although some do not directly address the issue of longevity. However, the vast majority tends to be used only a few times [36]. Recently, disposal-related issues have been discussed concerning sustainable music technology design [29, 8].

In line with the studies presented here, we describe an updated version of a DMI. The novelty of this study is the explicit focus on sustainable strategies connected to the longevity of the DMI.

2.2 Sustainability In and Through Design: Ideas from HCI

Environmental sustainability has been addressed by a subfield of HCI which is labeled as Sustainable HCI (SusHCI) (e.g., [48, 4, 24]). At an early stage of the SusHCI, Blevis' [4] introduced how digital tools can impact environmental sustainability in two distinctive manners. Mankoff and colleagues [24] systematized them by proposing the categories of sustainability *in* and *through* design. While sustainability in design addresses reducing the environmental costs of the design and the components of an artifact, sustainability through design aims at promoting the awakening of environmentally-friendly practices. This second approach focuses on "[...] ways of living and processes of social change."

More recently, Hansson et al. [16] highlighted how the SusHCI discourse has primarily focused on individual resource consumption (e.g., aiming at decreasing or shifting individual choices). This *through design* approach tends to primarily focus on supporting informed choice or via persuasive systems based on strategies such as feedback, visualization, or gamification. A debate overly focused on persuasive systems has been openly critiqued by Dourish [9], who argues that such an approach conceives environmental concerns merely in terms of personal (individualistic) moral choices. In continuity with these considerations, in the last few years, several authors (e.g., [16, 20, 48, 3, 47]) pointed out the very need of broadening the vision of sustainability by addressing the social system, supporting local communities, and social justice. The need to balance multiple aspects of sustainability also represents the underlying principle that grounds the 17 United Nations goals for sustainable development [1]. We align with the need to consider sustainability from a broad perspective. In line with the design justice vision [6], we embrace the idea that open culture can address sustainability in a dimension that creates a continuity between individual behaviors and cultural change. In this sense, Free/Libre and Open Source Software (FLOSS) and open hardware can be particularly relevant. On the one hand, the use of FLOSS is often an individual choice; on the other hand, FLOSSs are developed and supported by communities [41].

2.3 FLOSS and Sustainability

Blevis has discussed ten actions, ranging from the greatest to the least negative environmental impact of the residual components of a piece of technology, that range from *Disposal* (when the design causes the disposal of physical or digital material) to *Active repair* of misuse (when the design aims at repairing the harmful effects of unsustainable use) [4]. Open hardware and free software minimize the risk of obsolescence and promote interoperability and repairing, reducing hardware waste.

In the last years, different actors pointed out how free software and open hardware can facilitate generative upcycling and prolong hardware lifespan, with examples ranging from non-profit organizations such as Free Software Foundation Europe [2] to institutional EU reports [12]. The relevance of open solutions concerning sustainability has also emerged in digital music literature (e.g., [29, 8, 15, 30]). Free software and open hardware solutions generally focus on the possibility of replicating [13] or re-using the same resource in different contexts, with a tendency to collective (social) contributions to its improvement [12, 21]. This attitude was established in the free software communities over multiple decades [41] and more recently spread to other technologies such as 3D printing and Open Hardware [38, 32]. Focusing on replicating, re-using, and improving supports prolonging the longevity of the digital tools by supporting re-use and active repair and contrasting obsolescence. Overall open standards and open culture can contribute to the sustainability of a DMI. At the same time, an

[1] `https://sdgs.un.org/`
[2] `https://fsfe.org/freesoftware/sustainability`

Open Source DMI can promote open culture, fostering and exposing a sharing and re-using attitude toward technology. In the rest of this paper, we will analyze several choices we performed in our project to try to maximize such potential within the scope of a scalable production.

3. METHODOLOGY

This paper analyzes the design process of the second version of a digital musical instrument named Chowndolo. This new version is the result of a collaboration between the first author (with a background in industrial design who acted as the main designer in the process described in this paper—from now on *the designer*) and the second author (with a background in music technology, composition, and performance, he is the creator of the original instrument and contacted the first author for redesigning the instrument—from now on *the musician*). The overall arc of the project aims to bring the instrument from the state of an advanced prototype to a product that can be produced in small stocks and sold to the public. The research combined autobiographical and idiographical design approaches (similarly to [27, 28]).

The project itself followed an idiographic process [17], as the redesign was primarily conducted by the first author (the designer) tailored to the needs of the second author (the musician), with the core aim to produce on a small-scale, and increase its sustainability. The focus of the sustainability of musical systems was introduced by the first author, who is developing his Ph.D. thesis on this topic. The reflections developed at the end of this paper are, therefore, primarily derived from the autobiographical account of the designer on his own practice within the development of the DMI.

Throughout the entire process, the designer noted the evolution of the work in a diary, including the main elements that emerged and the activities developed at each step. A step could be a discussion with the musician or a design session in CAD. The entire process lasted six months and was articulated in 13 steps. The diary served as a basis for a Reflection-on-action [46], developed by the designer on its practice. Reflection-on-action is a research activity that "takes place after the activity and enables the exploration of what happened and why in order to develop questions, ideas, and examples about the activities and practices in focus" [49]. Therefore, the core contribution of this research is based on an autoethnographic process of the designer [11] (as it has been adapted to HCI research [42]) that aims to consider our design choices in relation to sustainability critically.

To initiate such a reflexivity process, we analyzed the diary using thematic analysis [18, 5]: we inductively coded (using open coding) the diary and recursively clustered the codes to identify strategies for a sustainable development of NIMEs. This analysis identified three main themes, each composed of several subthemes. At the end of this process, we realized that the first two themes correspond to the approaches of sustainability *in* and *through* design proposed by Mankoff [24], thus we renamed them. The third theme, on the contrary, highlights a novel approach [3]. This analysis of the diary, combined observation of the final design and schematics, served as the basis to propose a set of design strategies. Before presenting these strategies, we provide an overview of the entire process and the final design.

[3]the themes and subthemes with the quotes from the diary are available at `https://github.com/chihauccisoilconte/chowndolo-V2/tree/main/chowndolo-research-materials`

4. THE (RE)DESIGN PROCESS

The original version of the Chowndolo was created by the second author and has been presented in many venues, including IRCAM Forum (Paris), Ars Electronica (Linz), Guildhall School of Music & Drama (London), Sonorities Festival (Belfast), NIME 2019 Art Installation (Porto Alegre) and received an international award: Guthman Musical Instrument Competition 2022 (3rd prize). The second author (original author of the DMI) contacted the first author to adapt the instrument's design to fit a small-scale production. This section describes the process we underwent to create the design projects and schematics to create a new version of the Chowndolo, focusing on the design choices adopted to improve its sustainability and longevity.

4.1 Original Design

The instrument relies on a pendant movement to create sounds (figure 1. The design consists of four main components (visible in figure 2): a base, a magnet attached to a pendant, a set of magnets placed on the base, and two Printed Circuit Boards (PCBs) that amplify and map movement into sound parameters. To interact with the instrument, the performer places the magnets on the base, thus inducing the pendant to oscillate. The resulting magnetic field reacts with the coil and the magnet (using a technology presented in [35] and converts the oscillations into an analog signal, which is afterward mapped into sound.

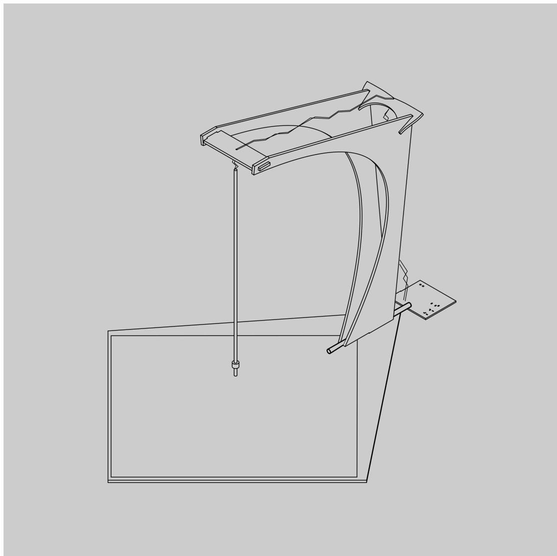

Figure 1: Isometric axonometry of the initial instrument

The base is made of a metal plate encased in a laser-cut wooden frame, and the pendant is an arc-shaped structure of four laser-cut pieces.

The arc structure is attached to the base on the upper side and to the pendant on the lower. The pendant is made from a thin iron tube connected to a magnet and a manually wrapped coil.

The magnets are encased in small wooden laser-cut tiles that can be assembled in tangram-like compositions. The magnets are made with laser-cut wood based on the Penrose Tiling pattern. The polarity of the magnet is marked by the color of the face of the element, which is hand-painted with acrylic paint.

The PCBs are a basic squared PCB that works as an amplifier and are encased in two laser-cut acrylic panels, also containing the Bela platform. The original design also included a Bela platform, enclosed in a separate case, receiving the amplified signal from the PCB. Incoming data are then used to control the parameters of an FM synth coded in Pure Data.

Before starting the redesign of the instrument, the second author shared basic documentation, including pictures and PDF files containing the laser-cut plans with annotations on the various design elements.

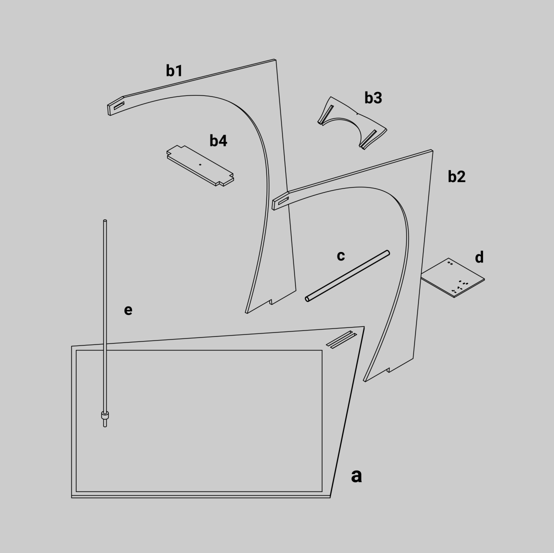

Figure 2: Exploded diagram of the initial instrument: a - base; b - arc structure; c - separator; d - PCB; e - pendant

4.2 Redesign Objective

The goal of the (re)design process was to turn the instrument into a commercially viable product that could be sold as a Do It Yourself kit. The instrument was then to be improved without deviating significantly from the original design. In addition, we focused on the sustainability and longevity of the project at various levels (this paper primarily accounts for this aspect).

An essential aspect of the design process was that the instrument could be produced in an accessible space, such as a maker space, so it could be produced autonomously.

The development process was carried out through a series of steps, alternating CAD design sessions with meetings where ideas and feedback were exchanged as the design progressed.

4.3 The Final Version

The design process of the Chowndolo led to the development of the complete set of CAD files and schematics to create a new version of the instrument (figure 3), which does not deviate significantly from the original instrument[4]. The fundamental structure was not changed, but several optimizations were made to improve its functionality and durability (figure 4).

The base is still made of a metal plate framed by a laser-cut wooden frame. However, unlike the original version, the corners have been rounded to reduce the risk of breakage.

The arc structure remains largely unchanged. We replaced the component responsible for creating tension with a new version made of two laser-cut "V-shaped" elements that support a new PCB, designed by Andrew McPherson, positioned perpendicular to the instrument's base. Additionally, the inner side of the two arc elements is now tangent to the base, which improves its overall durability. In addition, we implemented several improvements: a series of chamfers that smooth out the previously sharp corners and make it easier to insert the two elements that keep the two arcs separated and support the pendant. The pendant maintains its original form, but it is now held in place by a string rather than by electrical wires. Additionally, the hand-wrapped coil has been swapped out for a commercially available alternative.

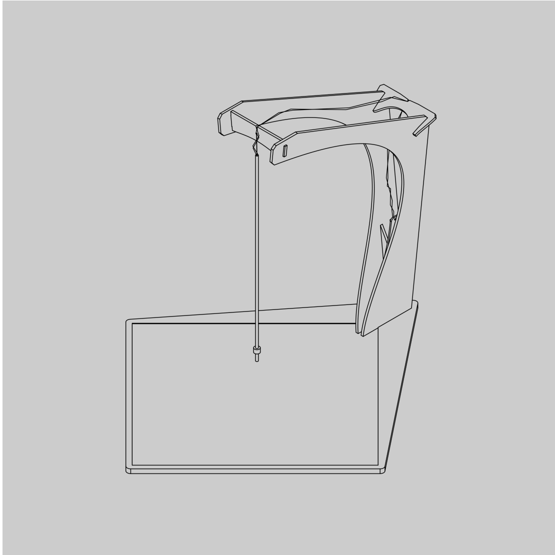

Figure 3: Isometric axonometry of the final version

The magnets maintained their original form, but we replaced the hand painting with a laser engraving process. In this way, we achieve three advantages 1) we do not need the painting (reducing the unnecessary materials), 2) we prevent the risk of paint fading, 3) we cut one phase in the production process.

The PCB, designed with the collaboration of Andrew McPherson, is specifically tailored to this updated version of the Chowndolo. It features standard connectors such as USBC for power supply and a mini jack socket for audio output.

Finally, the designer also produced a repository [5] containing all the documentation necessary to reproduce the device, including 2D drawings, 3D models, PCB diagrams and schematics, and an instruction manual that illustrates the assembly of the Chowndolo.

5. SUSTAINABILITY STRATEGIES

Based on, our reflection-on-action process, supported by the thematic analysis of the diary[6] combined with the observation of the final design and schematics, we propose here three main design strategies, each characterized by diverse points, corresponding to the themes and subthemes identified in the thematic analysis.

[4] the CAD filed and schematics can be downloaded here `https://github.com/chihauccisoilconte/chowndolo-V2/tree/main/chowndolo-CAD`

[5] `https://github.com/chihauccisoilconte/chowndolo-V2`

[6] available at `https://github.com/chihauccisoilconte/chowndolo-V2/tree/main/chowndolo-research-materials`

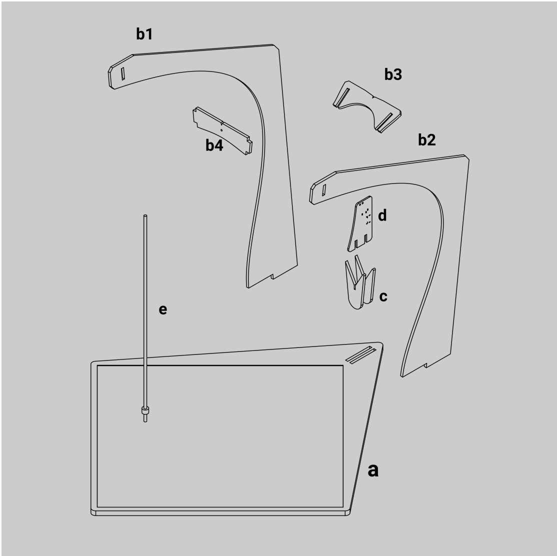

Figure 4: Exploded diagram of the final version: a - base; b - arc structure; c - "V-shape" element; d - PCB; e - pendant

5.1 In Design

5.1.1 Open Standards and Interoperability

Concerning the PCB, common standards have been adopted: Chowndolo's embedded amplifier is powered via a USBC port, and the audio output is a 3mm mini jack. These decisions were made to ensure the instrument met specific shared standards, guaranteeing reparability, flexibility, and ease of use. Additionally, the team decided to include some publicly available parts, such as the Bela platform and the ESP32 board in the design of the device to reduce the risk of technical obsolescence and improve the overall reliability of the product as well to expand its potential to IoT capabilities [45].

5.1.2 Hardware Optimization and Durability

The team aimed to optimize the instrument's shape while keeping it similar to the original version. The only changes in the shapes were focused on: 1) eliminating weak points that the original shape presented (i.e., reducing the angles); and 2) optimizing the fabrication process by reducing the number of materials and components that are needed to build the instrument (i.e., no screws needed).

5.2 Through Design

We identified only one strategy explicitly related to through design, which is Exposing the circuits.

During the design process, the musician provided the designer with reference images of PCB art products, such as the Bare Conductive Touch Board[7]. This reference material inspired the designer to incorporate a visible PCB into the design, held in place by three laser-cut ribs that slide directly into the PCB itself. These ribs are designed with slits to make it easy for the user to insert them without needing screws. This solution reduces the number of materials required to produce the object and makes assembly much simpler. Furthermore, the visible and fully accessible PCB contributes to an aesthetic that suggests a conceptual gradient between a closed object and a hackable product.

[7] `https://www.bareconductive.com/collections/touch-board`

5.3 Process Based

We proposed *process-based* as a category that encompasses aspects from *in* and *through* design approach. When the team designed the new Chowndolo, they anticipated a future where users might want to hack or modify the instrument, extending the design process and, ultimately, the durability and longevity of the DMI.

5.3.1 Digital Fabrication

The team decided that the whole Chowndolo should be designed to be fabricated using Fablab or maker space digital fabrication technologies. In particular, after considering different techniques (i.e., 3D printing), we decided to use only laser cutting technologies. We decided to use only one technique to minimize the need for a complex infrastructure to (re)build the components.

5.3.2 Customizable Circuits

The team decided that the amplifier circuit would be embedded within the instrument and connected to a control panel that could be customized to the customer's needs. This control panel could include a Bela platform-powered digital synthesizer or an ESP32-powered IoT device that could live stream the signal produced by the pendant. The team also considered the possibility of not having a panel and connecting the amplified movement of the pendant directly to a modular synthesizer.

5.3.3 Documentation and Repository

As part of the design process outcomes, the designer produced a repository containing all the documentation necessary to reproduce and/or hack the new design of the Chowndolo. The repository contains FreeCAD Standard file format (.FCStd) files, SVG and PDF, KiCAD and GBR files of the circuits, and detailed instructions explaining the instrument's assembly process. In parallel with the repository mentioned above, the design process was documented and shared via social networks such as Mastodon, Twitter, and Instagram, showing many work-in-progress pictures and screenshots.

5.3.4 Open Source

The designer's first consideration was minimizing early obsolescence risk. To achieve this, the team decided to consider a scenario where the design process outcomes would be open-source, following the business model of companies such as Arduino and Creality. In line with this principle, the new design's development happened through open-source CAD software.

6. DISCUSSION

In this section, we further discuss our strategies, strengthening the connection between our proposal and the debate on sustainability with the aim of offering a contribution on the sustainable design of an instrument/interface.

6.1 Traditional Sustainability Strategies

Firstly, we focus on the "*in design*" [24] aspect of the new instrument: the structure of the instrument minimized the number of fragile elements (e.g., sharp corners). It optimized the number of materials and fabrication techniques necessary to make the instrument.

Those strategies are not particularly novel *per se*, as for instance, were discussed by Margolin in the late 90' [25]. Additionally, they resonate with European policies established more than ten years ago: the European recycling code, also known as European Waste Catalog (EWC), established by the European Union (EU) in the Waste Framework Directive (2008 - 98 - EC)[8]; and the European Union's Waste Electrical and Electronic Equipment (WEEE) Directive (2012 - 19 - EU) [9].

However, these strategies are still quite absent in the NIME discourse. For instance, in a systematic analysis of all the NIME preceding performed in 2021, Masu et al. identified only 12 papers since the first edition of the conference accounts for sustainable instances [29]. With this work, we offer an example of how these strategies can be implemented in a NIME design process.

6.2 Designer as User of the Future

In addition to the suggestions discussed above, we propose to **inject sustainability in the future practice of a DMI**. To the end, we propose to consider the **designer as the user of the future**, fostering his possibility to repair and update the system.

The adoption of **open standards and open source software**, along with the production of documentation and manuals, allows the user to easily and actively engage with re-designing and re-developing the instrument. This possibility is further exposed in the PCB design, which is fully visible, offering the user the chance to easily fix or hack the circuit, an idea that has been discussed in relation to sustainability and circuit bending [8]. This characteristic suggests a circular relation between user and developer, which is quite known among FLOSS communities [41], that subverts the traditional approach where user and developer have two distinct and separated roles. We, therefore, underline the importance of the use of open source software and culture in general that promotes a strategy where a project is reusable and adaptable to future needs [2].

By taking into consideration these strategies, sustainability is not only focused on reducing wasted materials and the disposal of instruments themselves but also a practice-based approach that makes a **project truly available for the community**, eliminating barriers such as copyright-related costs. Our reflection here takes into consideration the uniqueness of the NIME as a community of makers (makers are by definition designers-developers-users), which represents a very fertile environment to broaden the approach mentioned above. A recent notable music example is the case of the Bela platform, which starting from a hackable product, relying on an open approach built a wide community decreasing chances of early obsolescence [37].

Taking into account the considerations above, we hypothesize that it is possible to advance a design strategy for sustainability in the use of the instrument itself, a vision that involves not only a single user but a whole community. This perspective resonates with Dourish's open critique on product-based sustainable strategies, which according to the author, is an expression of neoliberal thinking and tends to conceive environmental concerns merely in terms of personal (individualistic) moral choices [9]. The strategy envisioned by the research team rather embraces a social and community vision, which considers accessibility as a necessary asset to promote sustainability, as recently suggested in the design justice framework [6]. We argue to avoid inaccessible circuits and components so that the instrument is easily hackable and fixable, rather to promote practices such as *circuit bending*[8] and *critical making* [43]
.

This perspective opens a deeper and more important point to discuss: approaching the **user not as a passive actor of the design object, but as an active human who can partake in future re-design and active appropriations of the instrument**. The approach adopted can be labeled as *Designer as user of the future*: when designing an interface, the designer empathizes with its user and provides all the means to hack and/or redesign the outcome of the design process. This approach is based on a non-task-oriented approach [44], subverting the classic vision of the *user* [1].

Masu et al. [29] highlighted how the issue of disposal is a critical aspect of NIMEs sustainability. The authors proposed a model in which disposal is considered at the end of the process of *making, testing, using*, and *disposing*. By considering the designer as a user of the future, we promote the idea of *(re)making-using* loops that can postpone a *disposing* phase.

This approach resonates with recent European actions such as the Indice de réparabilité (reparation index[10]) introduced as a mandatory element in France in 2021, and could possibly be extended to other counties in the future; or the right to repair claiming for the right to repair electronic devices easily started out in 2019 [11].

6.3 Redesign and Longevity

A final consideration in relation to sustainability can emerge by looking at the core aim of the project: redesigning a prototype into a small-scale production. Many DMIs prototypes are designed only for the NIME conference or are tailored for a specific goal so that their life is more likely to go beyond the experimentation phase [7].

In this sense, the work presented here is aligned to the many examples that propose an updated version of a NIME described in section 2.1 (e.g. [10, 51, 50])

The case observed suggests how the life of a prototype can be extended and transformed into a longer-term salable instrument. In such a case, also the waste produced during the initial trial and error phase required to produce a prototype is amortized by a longer use of the project.

6.4 Limitation

This work describes the entire design project that led to building the complete schematics of the new version of the Chowndolo that can be produced in a small stack. However, the production phase is still to be fully developed. In the future, we will test the strategies we proposed here by analyzing the case of production. We also hope to get feedback from musicians who will be interested in remaking or hack the Chowndolo.

7. CONCLUSION

Overall our research contributes to the NIME debate on sustainable practice by proposing to consider strategies that can prolong the life of a NIME, both in terms of material and in terms of practice. With the rhetoric suggestion to 'consider designers as users of the future', we aim at inscribing sustainability into practice.

[8] https://www.eea.europa.eu/help/glossary/eea-glossary/european-waste-catalogue-1

[9] https://environment.ec.europa.eu/topics/waste-and-recycling/waste-electrical-and-electronic-equipment-weee_en

[10] https://www.ecologie.gouv.fr/indice-reparabilite

[11] https://repair.eu/about/

Some in design strategies include the production of manuals, adoption of open standards, open sourcing of hardware, and using FLOSS CAD tools, which are all crucial elements of the design process.

Furthermore, in line with the documentation guidelines of the NIME community [12], our approach also encourages the active participation of the users in the (re)design process, facilitating loops between using and future re-makings such as the integration of the instrument into an IoMusT [52] system, which is crucial to ensure long-term sustainability of NIMEs.

All these elements together render our suggestion a comprehensive and effective approach towards sustainable instrument design. The work presented in this paper has potential for further development by the proposed strategies to the wide range of projects within the NIME community. The strategies proposed here are grounded in a long-lasting debate from other areas, such as HCI [24, 4, 2] and FLOSS [41], and policies. However, we call for further research given that sustainability is relatively new as a topic within the NIME debate.

8. ACKNOWLEDGMENTS

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9. ETHICAL STANDARDS

This paper complies with the ethical standard of the NIME conference [34]. As the project followed an autobiographical approach, data are based on the experience of the authors.

This work does not present any conflict of interest, the software used during the project is all open source, additionally, the project has been released with an open license and with broad documentation. Furthermore, this paper directly addresses sustainability, one of the topics mentioned in the NIME code.

Authors contribution. The first author redesigned the instrument, collected the data (diary), contributed to the analysis, and developed with the fourth author the discussion and the sustainability strategies

The second author designed the original instrument and contributed to the redesign.

The third author supervised the overall design process.

The fourth author contributed to analyze the data, proposed the idea of "designer as user of the future", and developed with the first author the discussion and the sustainability strategies.

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