

# Tracing Design's Value in Distributed Manufacturing



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Today, much of “innovative” design tackles purely digital products or physical products extended by digital functionalities or connectivity. Meanwhile, the digital environment of the web deeply impacts the marketing—and increasingly the design process—of purely physical objects that surround our everyday life. The increasing technological maturity of digital fabrication tools has already established the conditions for a wider diffusion of distributed manufacturing, an ever more valid alternative to conventional manufacturing in many product categories. Distributed manufacturing promises a more direct connection between designer and consumer/maker. On the other hand, new challenges emerge around the management and monetization of the work done for an unforeseeable mass of consumers rather than a single business client. Observing recent trends in other creative industries, this paper outlines three possible scenarios for a stimulating compensation of designers: free, pay-per-download, and subscription-based distribution of creative works. Beyond simple economic concepts, each of these scenarios operates on a different metaphor, requires a different kind of digital infrastructure, and offers a different kind of incentive to attract designers and their efforts. The contribution hopes to help identify possible strategies that might lead to sustainable business models of design for distributed manufacturing.

*Key words:* business model, digital fabrication, open source, platforms, sharing

## Introduction

Despite recent developments, digital fabrication is still rather marginal in the material culture. Additive manufacturing promises less waste by “adding only what is necessary,” but today it tends to cost far more than conventional manufacturing, so we are still far from the desirable vision of the “zero marginal cost society” (Rifkin, 2014), where every new physical copy of the same information tends to cost zero. But even more importantly, additive manufacturing and its “products” suffer from a problem of misunderstanding on a commercial level and still struggle to be recognized as products of everyday use, rather than prototypes or low-quality gadgets. This limits the creative potential of designers, who could (ideally) access a global market through a

worldwide network of equivalent production tools and spaces, from digital artisans (or “makers”) to fab labs, which are still seeking their ideal economic model (Holman, 2015).

In order to benefit from distributed manufacturing, designers must manage and monetize their work in a completely different way compared to the traditional model of designer–client relation, and a very different way even from the “artisanal” designer who directly manages production and sales. For industrial/product design professionals, this is a radically new scenario. On one hand, mass manufacturing requires a close connection to the client enterprise and a deep understanding of the end users, as well as the (possibly) in-person knowledge of the specific manufacturing resources. Distributed manufacturing severs this connection, relying on comparable but never fully trustable digital manufacturing tools, at a distance.

A physical product design that is created and distributed purely in the digital environment, but must be physically realized in an uncontrollable situation, presents new challenges in terms of retribution possibilities, measures of success, intellectual property protection, and digital infrastructure necessities—all these imply different metaphors of operation. We will tackle the substantial shift in tracing and compensating the designer’s achievements, discussing possibilities according to business models that have already been experimented with in other creative industries, such as music or

film, that have largely moved away from physical sales.

### Open design and three scenarios

A fundamental attribute of all designs for distributed manufacturing is openness, as the designer must release control to a certain degree. Open design has been present in design’s disciplinary discourse for many years with various approaches, ranging from open-source design inspired by software development, to open design as a collaborative (co-design) practice, as far as the facilitated access to creative resources and capabilities (e.g., mass customization or open manufacturing; Gasparotto, 2019). Indeed, we are most interested in this last interpretation.

Today there are already countless open (source) designs suitable for distributed manufacturing, available on 3D model-sharing platforms (e.g., Thingiverse), but these are rather dominated by models of dubious functional-aesthetic quality, sometimes unpractical even for digital manufacturing. Only a few niche platforms maintain a curated selection of feasible and useful product designs for distributed manufacturing (e.g., Opendesk, Distributed Design Market Platform), and some major online service bureaus offer their open marketplaces, which can provide revenues for designers.

What could incentivize the diffusion of high-quality designs on these platforms? This is the central question of the paper.

- Should designers donate their designs? If so, how should their achievements be recognized?
- Should designers sell their design files for distributed manufacturing, as if these were just physical products?
- Should designers adopt some kind of subscription model, like many other creative industries, from music-streaming platforms to template-based graphic design software?

Free, pay-per-download, and subscription platforms—these are the three scenarios we will discuss in the following sections. Such a financially focused approach might seem too simplistic and superficial at first glance, but each of these scenarios has deep implications regarding the kind of designers these might attract and the level of effort designers might invest—for highly uncertain outcomes, in all cases. All of the scenarios will be described using examples from other creative fields and following a common structure based on the following criteria:

- Metaphor: Is this scenario comparable to some common everyday situation?
- Retribution: What do designers get out of this scenario, in economic or psychological terms?
- Success: What are the signs and implications of a successful design scenario?
- Infrastructure: What kind of infrastructure is necessary for this scenario?

- Protection: How (or whether) to safeguard intellectual property?
- How do all of the above criteria apply to open design for distributed manufacturing?

The first two of the discussed scenarios—free and pay-per-download—are somewhat obvious but worth exploring better, whereas the third scenario seems a particularly interesting one, albeit with some caveats.

### Scenario 1: free creative works

The first scenario we discuss is about “free” designs for distributed manufacturing. Most of what we call “work” is some activity carried out for the benefit of unrelated people with the expectation of money in exchange, but on the margin of “normal” economic activities, there are plenty of examples of work happily done for free. Sometimes designers also offer their services for free, although they might not be a leading force in the world of volunteering.

This scenario is based on the metaphor of donation: a free gift to the world, or an act of charity geared toward a specific category of people in need. Why would any person or organization decide to produce something completely for free? Naturally, free service to society is part of the mission of academic research, especially if publicly funded. From private actors, free stuff may be a by-product of regular activities, such as a piece of software developed for internal purposes; if it seems useful to

others without “damaging” the developers, they can share it with the world. Other times, free things can come from a conscious pursuit to produce something useful for society, leveraging on competences or resources possessed by a person or an organization.

In any case, giving away valuable things for free does not mean a complete lack of retribution. As an obvious example, the world is accustomed to the availability of free web services, some of them maintained by nonprofit enthusiasm, but most fueled by advertisement revenues. Another popular model is “freemium,” whereby users are “lured” into the service by free access, but advanced features do require payment. Many of these “gifts” of the digital environment are valuable for someone but hard to monetize for the giver because marketing and responsible maintenance are an effort that is often just not worthwhile.

Even if not directly monetary, the success of free offerings is also often valuable for the giver. In the case of genuinely free sharing, the sense of accomplishment in the community and toward the world can be enough motivation (e.g., in the case of a Wikipedia author; Antin, 2011). Moreover, givers “in the circle” can expect early access to their peer’s free offerings. Acts of corporate responsibility also result in a more positive image of the organization. But there are more tangible, indirect advantages: Sharing high-quality work (e.g., open-source software) or serving a community with knowledge

(e.g., StackExchange Q&A platform) can yield profitable jobs in today’s so-called reputation economy (Xu, Nian, and Cabral, 2020).

The success of these models is heavily dependent on the online infrastructure, which must establish the right incentives for the contributors, especially in the case of truly free models. The devotion to ideals (e.g., free knowledge) certainly plays a role, but the successful platforms also ensure a fair recognition of personal achievement, such as in terms of number of edits or articles created (Wikipedia) or “reputation score” gained by “upvoted” answers on StackExchange.

When it comes to distributing free creative works (anything from software to visual art), the issue of protection is, as always, a delicate one: Although many authors are glad to share their work for free, conditions often apply regarding reuse. In case of the widespread Creative Commons licensing framework, authors can choose between various levels, and often commercial use is prohibited or at least a clear attribution (“BY”) is required.

### *Free and open design for distributed manufacturing*

So can the same metaphors, retribution mechanisms, and success measures also be valid for open design for distributed manufacturing? In general, we can assess that compared to open-source software and hardware (e.g., engineering), the various branches of design (e.g., product, graphic, service) are less practiced in

the distribution of valuable contributions. The open-source software community has produced extremely complex products, from jQuery to Linux, which have a significant role in the activities of millions of people, whereas the open design of physical products is still in its infancy, even compared to free music, photos, or graphics—albeit these are forms of creativity that can be fully appreciated in their immaterial form.

Within the open design for distributed/digital manufacturing, we should also distinguish between open design done by engineers and by designers with an educational background in design. The latter is definitely at a disadvantage; reasons might include aspects such as the designer's major focus on specificities of the user or of the enterprise, creativity, subjective aesthetics, or cultural meaning; on the other hand, we might also blame design's permanent identity crisis (Jonas, 2007) or designers' general difficulty getting adequate retribution for their services. Nonetheless, there are various initiatives working on the diffusion of free designs, such as the Distributed Design Market Platform ([distributeddesign.eu](http://distributeddesign.eu)).

#### ***A present example: design volunteering for COVID-19***

The field of additive manufacturing across different channels is intensively discussing how distributed production processes can contribute to face the global COVID-19 pandemic of 2020. The announcement of the state of emergency has immediately

revealed in the health facilities, as in the distribution of public activities, a serious shortage of technical devices. During this lack of medical supplies for private entities, DIY techniques have been applied to help advance personal fabrication solutions. So far, several items have been designed and produced in response to this crisis, and the scientific community is collecting and medically evaluating dozens of open-source medical device designs. Rapid manufacturing has come in to help resolve this deficiency through a fairly new research area in which many questions are still open, such as the contribution from non-certified experts (i.e., makers) who are able to generate noncertified, but nonetheless useful, tools (Baudisch and Müeller, 2016).

It becomes interesting to explore how producers act in a crisis situation, as well as how individuals contribute and take on civic responsibility since they have access to materials and machinery necessary for the supplies manufacturing that (in an emergency) becomes medical equipment in an accelerated bureaucratic process of certification. In this situation, what responsibility does the manufacturer have? What is the customers' responsibility?

There are discussions about the models that can even bring more problems than solutions. Consider the amount of information and data related to DIY projects and third-party products that, if not properly tested, could lead to serious hazards for the customer. There are two areas of action that are taken into

consideration: the public sanitarian environment and private use. In Italy, engineer Christian Fracassi has started production of 3D-printed valves for certified medical respirators. The first prototype that landed on social networks was actually printed with an FDM, and wrongly convinced numerous makers, moved by the best of intentions, to start a massive distributed production.

From the private side, Chilean company Copper3D has launched the platform [copper3d.com/hack-the-pandemic](http://copper3d.com/hack-the-pandemic) with a patented open-source air mask that can be printed via FDM desktop printers. It provides tips and instructions on how to print, postprocess, and assemble the product. On the other hand, it is possible to see that on most of those platforms, companies protect themselves behind disclaimers stating that they are not responsible for any hazard the use of their design could cause. There are numerous complaints and counterparties, such as the AFES (Asociación de Fabricantes por la Emergencia Sanitaria in Chile), on the effectiveness of the mask and the danger it could bring to people who may suddenly feel safe with it.

#### ***Scenario 2: pay-per-download of creative works***

As we have seen in the previous scenario of "free design," distributing high-quality creative works online can happen due to various intrinsic or indirect motivations and for certain causes worthy of volunteering.

However, designers still need to earn a living, preferably through practicing their profession. This second scenario we discuss is about (physical) product designs that are sold as digital files. We can call this “pay-per-download,” a mechanism that allows businesses (and even single creatives) to monetize downloads directly.

The simplest way of getting compensated for work done online is doing “business as usual,” following the metaphor of the traditional marketplace, exchanging one product (a file) for a given price. Conceptually, paying for and downloading an album seems rather similar to buying a CD or vinyl; however, the possibility of digitally copying without loss of quality had a deep (at first negative) impact on the music industry. The pay-per-download model became widespread, in great part due to the fact that an industrial powerhouse like Apple enforced it, in a time when there were no better alternatives to fight illegal downloads. In any case, it transformed the way songs are created, as they did not need to fit an album but only to appeal immediately on their own. The example of iTunes songs (since 2003) illustrates that even an apparently simple transposition can have important implications on the contents—much more can be expected when moving designs from physical to digital.

Retributing the creator of a digitally sold item is very straightforward: it is as simple as getting a preset percentage of the revenues coming from their works. Such

revenue depends on download count and pricing strategy. Some platforms impose a specific price or range for the products, either by rule or by convention—songs or books tend to fall into this category. Less consumer-facing creative works, such as 3D model assets for video games, have prices that are highly dependent on complexity and quality (e.g., Turbosquid, CGTrader). Setting the right price point is a delicate question, even more so than for physical products: The highest possible price might seem advantageous but limit purchases, whereas minimizing the price might raise volume by putting the digital product into the “impulse purchase” category.

Therefore, success can be measured simply through the number of downloads, which is directly proportional to the creator’s revenues. To signal quality and reputation, all platforms offer some kind of review and rating system, essential to inform consumer behavior. According to MacKinnon (2012), consumers’ feedback is more reliable, as it is disinterested regarding the profit that the product itself generates for the manufacturer. The online review is an increasingly present and valid threat to traditional production and distribution systems (Berman et al., 2009). In the era of the “Commons” and “Openness,” this vulnerability is amplified by the response of new producers who are distributed digitally and, precisely because they are also distributed physically, are more sensitive to the needs of the consumer.

To handle massive amounts of content, users, payments, and reviews, a complex IT infrastructure is necessary in pay-per-download systems. Such infrastructure is further complicated by the need for protection (digital rights management [DRM]) that is often embedded in the downloaded file to limit usage to specific devices, usually complicating the legitimate user’s life as well. Therefore, some fields abandoned DRM (e.g., iTunes music), trusting the user’s fair behavior, whereas other fields maintained DRM (e.g., Kindle books).

#### ***Pay-per-download for open design***

The issue of intellectual property protection is a particularly interesting one. With 3D files usually distributed in stereolithography format (.stl), there are numerous ways to maintain the paternity of the design. The first one is to physically apply a brand logo or a name on the model. It is also useful for communication purposes when the files start to land on various platforms. Another way is to apply a watermark on the file, using a platform such as watermark3d.com, which consists of a free online retopology procedure that codifies the mesh surface in order to read a recognition mark on it (although it can be circumvented with some effort).

These methods could be considered sneaky approaches to prevent misappropriation of digital models, but at first sight on the most popular platforms among makers, it could be possible to say that there is more a

sense of mutual respect and trust, rather than the usual capitalistic competition and reluctance to freely disclose those designs.

Zwick and Denegri-Knott (2018) state that in this space and in this historical moment, it is the property of what surrounds us and what we believe we own that gives power to the market. This market is defined as a “fence” that, instead of extending the consumer’s potential to a wider range of products, confined it to a space in which it is basically “fed” with digital goods that remain, however, rented and never really and totally possessed. The pay-per-download system, applied by digital platforms such as CGTrader, Cults3d, or more popular ones such as iTunes or Kindle, works as a monetization and data collection strategy. This mechanism activates a series of processes that harness the user to the network that offers a specific product or service.

Beyond the issues of protection, in the case of pay-per-download design, the distribution needs to consider two main kinds of potential buyers: those who only print it will have critical feedback directly with the product, and those who request it will have a critical response directly with the service.

An ambiguity is put in place: If the pay-per-download purchase model puts us in a position to obtain products with a purchasing system similar to the traditional market mechanism as it is, the result—the transition from an ideal and idealized digital world—must then account for

the print definitions and the final effects. If this feedback is always true for all 3D printed design, it certainly has a different impact when it is related to the price paid for it.

Usually, models for distributed manufacturing are uploaded along with tips and steps of production, often reporting the designers’ direct experience with the fabrication tools available to them. However, given the variety of digital fabrication technologies and materials available via services, at fab labs, and for makers at home, it is practically impossible to foresee all variants that could be obtained from the same file. The designer is not directly responsible for the finishing and quality of the end product, so the impact on the end user is rather unforeseeable. User expectations might be betrayed, and there is even a risk of compromising mechanical performance.

### **Scenario 3: subscribe for unlimited creative works**

The third scenario we discuss concerns compensating open design through subscription-based models. Accessing creative works through subscriptions is an increasingly normal consumer behavior, at least in the case of audiovisual content. Most notable are music- and video-streaming services, which have largely disrupted the traditional business models based on selling physical copies of the media (from vinyl to Blu-ray). Such a shift was forced by the digital environment, as free access to information became a hard-to-

renounce norm on the Internet, fueled by advertisement revenues, and before widespread e-commerce, people started to upload their personal copies on illegal file-sharing services. Consumers have become accustomed to paying for purely digital content, and they seem to be happier to pay for unlimited access to a vast library through subscription, rather than for single songs or movies through occasional purchase.

Therefore, the metaphor of online subscription-based distribution of creative works is neither the sale of physical goods (pay-per-copy, pay-per-use) nor the free gift as we have seen in the previous section, but more like a library subscription, a flat-rate utility bill, a travel card, or a buffet dinner. Consumers get more than they could ever consume from a large selection that does not feel too limited, thus obtaining a sense of abundance and convenience, while subscriptions also eliminate the risk of disappointing purchases.

Conversely, the retribution of creative professionals gets trickier in this scenario. For example, although it was easy to calculate percentages on CDs or iTunes songs sold, streaming services such as Spotify need to employ an algorithm that divides up revenue among artists proportionally, either summing up all revenues (so-called pro rata system) or dividing fees user by user (so everyone’s subscription goes only to the artists they listen to).

In any case, successful creative works, which capture the most attention, also get the most economic

benefits—something that feels immediately comprehensible and inherently fair. For the business model to work, scale is crucial: To lure consumers, there needs to be many artists onboard, and to sustain many artists, there needs to be a large mass of subscribers.

A sustainable service needs a robust infrastructure, not only to handle massive amounts of content, but also to manage relations with creators and copyright holders of legacy contents, all while mitigating risks through scale.

Protecting copyright is always a delicate issue. Ever since mainstream broadband Internet (and arguably even before), the music and film industries have struggled with pirate distribution; streaming services also have only limited means to impede low-quality copies, but fair and flat-rate pricing have made it so that increasingly consumers prefer to engage with the genuine user-friendly platforms rather than shady pirate websites.

Going beyond personalized mass media, the subscription-based model is relevant also to the design field, especially in the digital environment. Similar to streaming platforms, the creative building blocks such as stock photos, graphics, audio, and video are increasingly available through subscriptions (e.g., Storyblocks). On the software side, the dominant software house Adobe switched from perpetual software licenses to the Creative Cloud offering, which again mitigates risks and allows major flexibility, letting users try new tools without major up-front investments.

Beyond creative professionals with technical knowledge, today various simplified tools empower people to produce good-quality (albeit not original) template-based graphics, videos, or even websites (e.g., Canva.com, Adobe Spark, Squarespace). Such empowerment can be viewed as a driver of democratization of “fair-quality” designs. It must be recognized that tailored, high-quality solutions require, by definition, the exceptional care of talented creative professionals, but such attention is not affordable for all. For many of the “modest” design tasks, templates can be a good-enough solution, especially if these are prepared by high-quality design talent, which would likely be out of the reach of many small businesses. Just as it happens with “old-school” industrial design, the masses can afford top-quality design effort if the related costs are distributed among a mass of subscribers.

***Subscription for open design for distributed manufacturing***

Can the same mechanism apply to open design for distributed manufacturing? As previously noted, there is a large amount of freely available 3D models through platforms like Thingiverse, Cults3D, Pinshape, or Myminifactory. “Free” means not only the freedom to download or to upload, but also a general lack of curation; hence, good models need to compete among many more subpar ones. With such competition, even if retribution is possible through paid models or voluntary “tips,” the incentives are not particularly

reassuring compared to the low but guaranteed return on streaming services.

We suggest that for the diffusion of open design for distributed manufacturing, a subscription-based streaming design could be beneficial, or at least worth trying. Actually, MyMiniFactory has attempted to do so: Although free models of uncontrolled quality still dominate the platform, designers can also sell their models in a personal store or apply to the Studio Designer program, where revenues are shared based on the downloads and traffic they drive, hence attempting to retribute creative achievement proportionally, similar to Spotify.

Could this become a similarly relevant way to trace the value of design and adequately compensate designers? Arguably, the contemporary availability of free and paid content makes competition hard and not particularly transparent. Besides, the Spotify model works for a variety of reasons that have not yet been imitated on any of the present 3D model-sharing platforms:

- A large base collection of creative works exists that has already proved commercially successful; therefore, users have a reason to opt in.
- Artists actively promote their works outside of the platform (e.g., live events, critics’ reviews); therefore, users search for specific artists.
- An algorithm curates the contents that are recommended to

users; therefore, they have an illusion of having all the things they like.

Emulating these characteristics with open design for distributed manufacturing is hard because:

- Blueprints of successful products are jealously guarded and hardly suitable for distributed manufacturing.
- Product design is appreciated when it is manifested physically, but there is no performative dimension comparable to concerts or celebrity appearances.
- The pace of consuming media is far higher than the pace of new product needs, so the statistical data for learning the user's taste are far less available.

What could a subscription-based design platform do to mitigate these difficulties?

- Focus efforts on a product area and collect all relevant alternatives (e.g., HeroForge: all kinds of figurines) or focus on a design approach (style) that would appeal to a kind of person, who could then have a wide range of products with that style.
- Promote the brand focusing on its specific identity (product category or style), rather than a universal container, thus building a habitual "fan base" rather than occasional visitors.
- If efforts are focused, navigating between the options becomes easier and reduces the burden of choice to a manageable level, thus

helping makers and consumers to be happier with their choices (Schwartz, 2004).

Following such guidelines might mean that the circle of users is smaller, at least initially, but building the "smallest viable audience" and "doing work that matters for people who care" is often the best strategy to grow a business that ultimately scales (Godin, 2018).

### Conclusions

We have outlined three different ways of tracing and compensating the designer's efforts. Although the first two are already established (and present their advantages and limitations), the third one is purely hypothetical at this point. The feasibility of this direction will be further explored in future steps of a work-in-progress research.

Naturally, beyond connecting designer and consumer needs, the wide implementation of open design for distributed manufacturing depends also on other factors, such as compliance. Regulatory requirements are still obscure regarding the objective validation of project blueprints, albeit there are efforts to improve this shortage (Phillips et al., 2016).

The essential issue that must be tackled is not technological, which constitutes the simplest part of a path toward a true industrial revolution, but an economical one (Greenfield, 2017). The challenge is still to develop an economic model able to let the technology effectively generate a value that is always shared and

accessible for everyone. For digital manufacturing to become as valuable as mass production, generating a real radical revolution, it is necessary that a lasting and concrete system of sustenance and development is set behind it.

In this sense, it becomes of fundamental importance to understand the meaning of the products that float in the system and to understand how the practice of open design shifts not only the creative context, but also the distribution context. The methods and channels of creation are as open as those of distribution. Therefore, they cannot refer to a traditional system or to a dead-end system of sale and purchase but must insert themselves in an open framework that allows the traceability, participation, and identification of individual participants in their actions (e.g., creation, sale, acquisition, modification, and resale). Hopefully the contribution helped to identify possible strategies that might lead to sustainable business models of design for Distributed Manufacturing, with the implication of stimulating the more fruitful use of existing digital manufacturing infrastructures, and towards the universal accessibility of a future material culture that adopts to the exact user needs, rather than the other way around.

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framing (introduction and conclusions) and for Scenario 3, while Luca D'Elia focused on Scenario 1 and Scenario 2.

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