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Tracing Design's Value in Distributed Manufacturing

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Today, much of the "innovative" design tackles with 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 which 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 monetisation 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 subscribe-based distribution of creative works. Beyond simple economic concepts, each of these scenarios operate on a different metaphor, require a different kind of digital infrastructure, and offer a different kind of incentive to attract designers and their efforts. The contribution hopes to help identifying possible strategies that might lead to sustainable business models of design for Distributed Manufacturing.

***Keywords**: digital fabrication; open source; business model; platforms; sharing*

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Introduction

Despite recent developments, today 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 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, 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 realised in an uncontrollable situation: this 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 with the substantial shift in tracing and compensating the designer's achievements, discussing possibilities according to the business models that were already experimented in other creative industries, such as music or film, that already 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 the "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.

Already today there are 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 incentivise the diffusion of high-quality designs on these platforms? This is the central question of the paper.

- Should designers donate their designs for free? If so, how to recognise their achievements?
- 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 platform – these are the three scenarios we will discuss in the following sections. Such a financially focused approach might seem too simplistic and superficial at the first glance, but each of these scenarios have deep implications on the kind of designers these might attract and on 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 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, while the third scenario seems a particularly interesting one, albeit with some caveats.

Scenario 1: creative works free

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 also designers 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 towards specific category of people in need. Why would any person or organisation decide to produce something completely for free? Naturally, free service to the 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 the society, leveraging on competences or resources possessed by a person or an organisation.

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 free availability of free web services, some of them maintained by non-profit enthusiasm, but most of them fueled by advertisement revenues. Another popular model is "freemium", whereby users are "lured" into the service by the 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 is an effort which is often just not worthwhile.

Even if not directly monetary, the success of free offerings is often valuable also for the giver. In case of genuinely free sharing, the sense of accomplishment in the community and towards the world can be enough motivation, e.g. in 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 a more positive image of the organisation. But there also 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, Cabral, 2019).

The success of these models is heavily dependent on the online infrastructure, which must establish the right incentives for the contributors, especially in case of truly free models. The devotion to ideals (such as free knowledge) certainly play a role, but the successful platforms also ensure a fair recognition of personal achievement, for example 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: while many authors are glad to share their work for free, conditions often apply regarding re-use. In case of the widespread Creative Commons licencing 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 be valid also for Open Design for Distributed Manufacturing? In general, we can assess that compared to open source software and hardware (engineering), the various branches of Design (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, while 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 educational background in Design. This latter is definitely in disadvantage, reasons might include aspects such as Designer's major focus on specificities of the user, of the enterprise, on 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 to get adequate retribution on their services. Nonetheless, there are various initiatives working on the diffusion of free designs, such as the Distributed Design Market Platform (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 privates, DIY techniques are applied to help 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 comes in help of this deficiency through a fairly new research area in which many questions are still open, such as the contribution of non-certified experts (makers) are able to generate non-certified, but nonetheless useful, tools. (Baudisch and Müeller, 2016)

It becomes interesting to explore how producers act in a crisis situation. How individuals contribute and take care on civic responsibility, since the access they have to it. The 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 the solutions. The amount of information and data related to DIY projects and third-party product, if not properly tested, could lead to put the customer in serious hazard. There are two areas of action that are taken into consideration: public sanitarian environment and private use. In Italy, engineer Christian Fracassi has started a production of 3D printed valves for certified medical respirators. The first prototype landed on social networks was actually printed with an FDM, and wrongly convinced numerous makers, moved the by best of intentions, to start a massive distributed production.

From the private side, Chilean company Copper3D has launched the platform copper3d.com/hackthepandemic with a patented open source air mask that can be printed via FDM desktop printers. It provides tips and instructions on how to print, post-process 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 (Association de Fabricantes por la Emergencia Sanitaria in Chile) on the effectiveness of the mask and the danger it could bring to people who can suddenly feel safe with it.

Scenario 2: pay-per-download of creative works

As we have seen the in the previous scenario of "free design", distributing high quality creative works online can happen for various intrinsic or indirect motivations and for certain causes worth of volunteering. However, designers still need to earn a living, preferably through practicing their profession. This second scenario we discuss is about (physical) products designs which 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 for 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 and downloading an album seems rather similar to buying a CD or vinyl; however, the possibility to copy digitally without loss of quality had deep (at first negative) impact on the music industry. If such model could become widespread (and by now superseded), is because of an industrial powerhouse like Apple enforced it in lack of better alternatives to fight illegal downloads. In any case, it transformed the way songs are created, as they didn't need to fit an album but 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: as simple as getting a pre-set 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 tends to fall into this category. Less consumer-facing creative works, such as 3D model assets for videogames, 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, while minimising 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 – 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 behaviour. 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., 2012). In the era of the 'Commons' and 'Openness' this vulnerability is amplified by the response of new producers who are distributed, digital and, precisely because they are also distributed physically on the territory, more sensitive to the needs of the prosumer.

To handle massive amounts of contents, users, payments and reviews, a complex IT infrastructure is necessary in pay-per-download systems.

Such infrastructure is further complicated by the need of protection (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 (iTunes music) trusting the user's fair behaviour, while 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 from platform to platform. Another way is to apply a watermark on the file, using a platform such as watermark3d.com, that consist in a free online retopology procedure that codify 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 on a 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 a usual capitalistic competition and reluctance to freely disclose those designs.

Zwick and Denegri-knott (2017) states that in this space and in this historical moment is the property of what surrounds us and which we believe to own that gives power to the market. A market that they define such as a 'fence' that instead of extending the consumer's potential to a wider range of products, it got confined into 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 such as ITunes or Kindle, works as 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 case of pay-per-download design, the distribution needs to consider two main kinds of potential buyers: those who print it alone will have a 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 different impact when it is related to the price paid for.

Usually, models for Distributed Manufacturing are uploaded along with tips and steps of production, often reporting the designers' di direct experience with the fabrication tools available to them. However, given the variety of digital fabrication technologies and materials available at services, fablabs and 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 the 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 is about compensating Open Design through subscription-based models. By today, accessing creative works through subscriptions is an increasingly normal consumer behaviour, at least in case of audio-visual contents. Most notable are the music and video streaming services which have largely disrupted the traditional business models based on selling physical copies of the media (from vinyl to blue-ray). Such shift was forced on by the digital environment, as free access to information became a hard-to-renounce norm on the internet fuelled by advertisement revenues, and people started to upload their personal copies on illegal file sharing services already before widespread e-commerce. By now, consumers got accustomed to paying digital for purely digital contents, and they seem to be happier to pay for unlimited access to a vast library though 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 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 doesn't 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, while it was easy to calculate percentages on CDs or iTunes songs sold, streaming services such as Spotify need to employ an algorithm, which 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).

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 in consumer there need to be many artists onboard, and to sustain many artists there need to be a large mass of subscribers.

A sustainable service needs a robust infrastructure, not only to handle massive amounts of contents, 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 made so that ever more consumers prefer to engage with the genuinely user-friendly platforms rather than shady pirate websites.

Going beyond personalised mass media, the subscription-based model is relevant also to the Design field, especially in the digital environment. Similarly to streaming platforms, the creative building blocks such as stock photo, 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 upfront 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 driver a of democratisation of "fair quality" designs. It must be recognised 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 "oldschool" 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

So, 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 a 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 an attempt to do so: while 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 programme, 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 contents makes competition hard and not particularly transparent. Besides, the Spotify model works for a variety of reasons which have not yet been imitated any of the present 3D model sharing platforms:

a) a large base collection of creative works which has already proved commercially successful before, therefore users have a reason to opt in;
b) artists actively promote their works also outside of the platform, e.g. live events, critics' reviews, therefore user search for specific artists;
c) an algorithm curates the contents which gets recommended to the 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:

a) blueprints of successful products are jealously guarded and hardly suitable for Distributed Manufacturing;
b) product design can is appreciated when it's manifested physically, there is no performative dimension comparable to concerts or celebrity appearances;
c) 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 is far less available.

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

a) 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, people who could then have a wide range of products with that style;
b) promote the brand focusing on its specific identity (product category or style), rather than a universal container, thus building a habitual "fanbase" rather than occasional visitors;
c) if efforts are focused, navigating between the options becomes easier and reduces the burden of choice to a manageable level, thus helping makers and consumer 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. While 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 (Philips, 2017).

The essential issue that must be tackled is not technological, which constitutes the simplest part of a path towards a true industrial revolution, but 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, nor to a dead end system of sale and purchase, but to insert themselves in an open framework that allows the traceability, participation and identification of individual participants in their actions (creation, sale, acquisition, modification, resale, and so on).

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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