DiDIY
DIGITAL
DO IT YOURSELF

D3.3 ETHICAL ISSUES AND WORK

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Executive summary

Deliverable 3.3, "Ethical issues and work", considers some of the ethical issues arising from the spread of DiDIY in the context of work. Our analysis is partly guided by the Research Model presented in D3.1. We begin (in section 2) with some clarifications about the main technical terms and acronyms to be used in this deliverable, and about the concept of DiDIY as we will be discussing it. In section 3, we focus on *lawful* forms of DiDIY (at the level of both individuals and groups) and their potential transformative impact on the work context, with particular attention to the contribution they might make to technological unemployment. We offer some thoughts as to how the impact of DiDIY might compare in this regard with that of emerging and disruptive technological developments like machine intelligence and automation. Section 4 examines the foreseeable impact of forms of DiDIY that would violate intellectual property rights, which we shall refer to as DiDIY counterfeiting and piracy. Both sections 3 and 4 lay out a wealth of empirical data, data that are needed to determine what sorts of ethical issues are at stake as a result of the introduction of DiDIY in the work context. Building on those data, section 5 then highlights the relevant ethical issues, and offers some suggestions about the type of measures that might help address them. Finally, section 6 summarizes our main findings, which can be characterized as expressing cautious optimism about the impact of DiDIY on work.

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1. Introduction

The rise of DiDIY promises to disrupt the *status quo* in a number of contexts, including work. This deliverable will, as its name indicates, consider some of the ethical issues that arise from the spread of DiDIY in that context. Our analysis will partly be guided by the Research Model presented in deliverable D3.1, although we will be concentrating on examples that appear to us to raise clear ethical issues. We have found these to be chiefly found among forms of DiDIY that involve digital fabrication, such as 3D printing. In fact, most of the examples we will be discussing will concern that particular technology, for the simple reason that the vast majority of the available literature on our topic deals with 3D printing. Nevertheless, our main conclusions will equally apply to other forms of DiDIY. Let us emphasize that this deliverable does not pretend to provide an exhaustive picture of the various ethical issues that DiDIY might raise in the context of work. Various extensions of the present work might be worth considering for the purpose of tackling the issues that we did not have the space to address here.

The structure of the present deliverable is as follows. We begin (in section 2) with some clarifications about the main technical terms and acronyms to be used in this deliverable, and about the concept of DiDIY as we will be discussing it. In section 3, we focus on *lawful* forms of DiDIY (at the level of both individuals and groups) and their potential transformative impact on the work context, with particular attention to the contribution they might make to technological unemployment. We offer some thoughts as to how the impact of DiDIY might compare in this regard with that of emerging and disruptive technological developments like machine intelligence and automation. Section 4 examines the foreseeable impact of forms of DiDIY that would violate intellectual property rights, which we shall refer to as DiDIY counterfeiting and piracy. Both sections 3 and 4 lay out a wealth of empirical data, data that are needed to determine what sorts of ethical issues are at stake as a result of the introduction of DiDIY in the work context. Building on those data, section 5 then highlights the relevant ethical issues, and offers some suggestions about the type of measures that might help address them. Finally, section 6 summarizes our main findings, which can be characterized as expressing cautious optimism about the impact of DiDIY on work.

2. Some basic conceptual clarifications

2.1 Technical terms and acronyms

Term	**Meaning**
ABC	Atoms-Bits Convergence
CAD	Computer-Aided Design
CNC	Computer Numerical Control
DIY	Do-It-Yourself
DIYer	individual or organisation (formal or informal) that engages in DIY
DiDIY	Digital Do-It-Yourself
DiDIYer	DIYer that engage in DiDIY
DiDIY design	(1) process of designing an object by a DiDIYer, usually by means of CAD software (2) digital blueprint resulting from a process of designing an object by a DiDIYer
DiDIY manufacturing	manufacturing of a product by a DiDIYer using DiDIY tools
DiDIY product	product created by a DiDIYer using one or more DiDIY tools
DiDIY tool	DiDIY resource as physical or virtual tool or machine directly used in physical or design work for the purpose of engaging in DiDIY
Fab Lab	small-scale non-profit workshop that makes its equipment, including digital fabrication devices, available to the public
GA	Grant Agreement
IoT	Internet of Things
IPR	Intellectual Property Right
KF	Knowledge Framework
Prosumer	a person who combines the roles of producer and consumer with regard to one and the same product
STEM	Science, Technology, Engineering, and Mathematics
SV	Shared Vocabulary

2.2 How to understand DiDIY: reminders from the Knowledge Framework

Before we start discussing the ethical issues that DiDIY raises in the context of work, it is crucial to clarify how we will understand the concept of DiDIY in this deliverable. On this issue, we will rely on the explanation of the concept presented in three foundational documents: first, the Grant Agreement for this project (abbreviated GA); secondly, the DiDIY-related shared vocabulary (abbreviated SV); and thirdly, the revised version of the Knowledge Framework (abbreviated KF; deliverable D2.4), dated from 31 March 2016. We can begin by highlighting the presence of “DIY” in DiDIY. The GA gives the following characterization of DIY, or Do-It-Yourself:

> What is customarily called **"do it yourself" (DIY)** is more a (long standing) social phenomenon than a (brand new) technology, and as such its scope is not well delimited: it customarily denotes activities performed by individuals, outside companies and without the support of professionals, in such diverse fields as mechanics and electronics but also gardening, pottery, sewing, etc. (GA, p. 4; emphasis in original).

The core ideas in that extract are summarized in the definition of DIY given in the SV:

> **Do It Yourself, DIY**
>
> social phenomenon of personally building or customizing physical or informational objects or services not as one's main professional activity.

These characterizations of DIY in turn suggest a few key features of DiDIY: it refers to a certain type of activity or practice, but also to a social phenomenon (the KF adds that it is also a certain type of cognitive process: see KF, p. 7). The type of activity in question is typically performed by individuals who are not thereby engaged in a professional endeavour[1] and are unassisted by professionals – at least, this applies to DiDIY narrowly understood; we will see shortly that there can also be broader understandings of the concept that do not rule out the presence of professionalism. Also, the KF mentions that while the "yourself" in DiDIY will standardly be an individual, it could also, at least in a broader understanding, refer to "group, a class, a community of practice, a company" or "an industrial cluster" (p. 8). Furthermore, the novelty brought by DiDIY as compared to DIY in general (which, as the KF reminds us, is a phenomenon that goes way back in history) is clearly the "digital" element: the DIY activities it enables are now performed with the help of new digital tools, from 3D printers to Arduino boards.

Let us also note that the KF defines DiDIY as being both an *objective* and a *subjective* phenomenon. To quote the formulation of the KF, DiDIY is simultaneously something that someone:

- *does*: an activity for the creation, modification or maintenance of objects or services; in this sense DIY and DiDIY are *objective* phenomena, that can be studied from the analysis of tools, products, structure of collaborations, etc; and
- *has*: a mindset, and then a producing and consuming culture; in this sense DIY and DiDIY are *subjective* phenomena, that can be studied from the analysis of motivations, competences, social contexts, etc. (KF, p. 8)

In this deliverable, our focus will mostly be on the objective facet of DiDIY, even though we will also take the subjective component into account. Understood as an activity, DiDIY involves, among other things, the use of technologies like 3D printing, CNC milling, laser cutters, and other digital manufacturing devices, by hobbyists rather than professionals, as illustrated by the rise of the contemporary "maker" movement. As the definition just quoted from the KF indicates, however, DiDIY goes beyond this to also incorporate, for instance, the modification of existing objects (which can for instance be made "smart" with the help of devices such as Arduino boards). On an even broader understanding of the concept, DiDIY could even go beyond the realm of physical

1This does not mean, of course, that the person in question cannot be a professional in a certain field, but simply that she is not acting as a professional when engaging in DiDIY.

objects and include all uses of digital technology in a DIY manner: e.g., the writing of articles on a personal blog or the design of web content for non-professional purposes.

This brings us to the distinction, again drawn in the KF, between *narrow* and *broader* conceptions of DiDIY:

- in a narrow conception, DiDIY, as we have seen, is only practised by non-professionals and without the assistance of professionals. Furthermore, it also involves what the KF calls "atoms-bits convergence" (ABC), that is, the integration of physical and informational components, resulting in the production of a physical artefact (KF, p. 18);
- in a broader view, by contrast, DiDIY "is also for professionals who maintain their DIY mindset" (p. 25), and "is also aimed at creating intangibles and performing services" (p. 18).

In this document, we will overall adopt the latter understanding of DiDIY, although we will mostly be focusing on cases where people do not engage in the relevant activities as professionals. (One exception will be cases where someone engages in a professional endeavour involving the use of digital tools, but does everything or almost everything she needs herself, without the assistance of others; we will treat this as a limiting case of DiDIY.)

We will, however, confine our analysis to cases where a person (the "DiDIYer") can clearly be said to have *made* or created something herself in more than a minimal sense, even if the thing she made is not a physical artefact. We will be leaving out, for instance, most cases of online piracy, where a person simply shares copyrighted content without permission with the rest of the world, using digital tools such as file-sharing websites (whether lawful like YouTube, or illegal like the Pirate Bay). We acknowledge that such a way of drawing the line regarding what counts as DiDIY could be the object of controversy, especially as we will include into the category of DiDIY cases that might look very similar to typical online piracy. One example would be a case in which a person (a non-professional) obtains the digital blueprint for some printable artefact and uses it to print the item on her home 3D printer. We take the view that this person is engaging in DiDIY, insofar as (s)he is manufacturing the item herself using her own tools and basic materials, rather than merely copying the contents of a DVD onto the internet, for instance – even though the person who engages in such copying can arguably also be said to have made or created something (the copy) in the most basic sense. There is no doubt some degree of arbitrariness in the choice to draw the line at exactly that point on the "making" continuum, but we do think that drawing such a line is necessary, in order to keep the scope of this deliverable within manageable limits.

A crucial related notion for our purposes is that of *DiDIY product.* As referred to in the SV, we will understand a DiDIY product to be "a product created by a DiDIYer using one or more DiDIY tools", which could be designing tools (CAD software) or manufacturing tools (e.g., 3D printing). A paradigm case of such a product would be one (say, a coffee mug) that gets designed by a DiDIYer on her computer and then manufactured by that same person on her home 3D printer. However, the definition just given allows that an item designed by a DiDIYer that then gets printed by a professional 3D printing service like Shapeways (shapeways.com), or conversely, one designed by professional designers that a DiDIYer then prints on her own 3D printer, also count as DiDIY products.[2] Items that were both designed by professionals and then printed at a 3D printing bureau would, on the other hand, fall outside the category of DiDIY products.

As we have mentioned at the outset, the majority of the upcoming discussion will be dealing with the expected impact of DiDIY *manufacturing* (the form of DiDIY that involves ABC) on the work context, even though we will also have some things to say about other forms of DiDIY. We do not thereby wish to minimize the significance of those other forms; our decision was chiefly guided by the fact that DiDIY manufacturing seemed to be the clearest source of relevant ethical issues for the purpose of this deliverable.

2In both of these scenarios, the DiDIYer in question could either be the end user of the product, or a third party (such as a hobbyist making her 3D printer available for use by others, whether for free or against a small fee). The former type of case is arguably a "purer" case of DiDIY than the latter.

3. Impact of DiDIY on the supply chain and technological unemployment

3.1 Introduction

In this section, we will look at the expected impact of the rise of DiDIY in its *lawful* forms (contrary to the forms we will consider in section 4, where we will focus on types of DiDIY that violate IPRs) on the world of work. Issues that have been mentioned in the existing literature on this topic include the following: assuming DiDIY leads to a society in which almost anyone can make almost anything, will it become the norm for people to obtain digital blueprints for the items they want and to make them at home, leading to many job losses in the sectors made superfluous by this development, such as those in the stores where people would previously have bought the said items? Similarly, if professionals start using DiDIY to make certain things locally that before they would have had to order from elsewhere, e.g., abroad, or to create things by themselves that they previously would have needed the help of a professional to create, will this again lead to a harmful impact on jobs? Is the rise of DiDIY part of what some see as the rising threat of technological unemployment, and if so, what is its contribution, as compared in particular with the rise of automation and artificial intelligence?

Before proceeding, let us stress that while we will chiefly be focusing in what follows on the possible negative consequences that the rise of DiDIY might bring about in the work context, and on possible strategies to avoid or mitigate those consequences, we certainly do not wish to deny the many advantages that might also spring from that development, some of which we shall mention, and many of which have been described in other deliverables for this project (see e.g., deliverable D3.1). In fact, one of the main points we will be emphasizing is that policy-makers and society as a whole should look for ways of counteracting any harms that DiDIY might cause without compromising its benefits.

3.2 DiDIY and work: individual level

A number of authors in the recent literature on this topic have raised the prospect that the way consumer goods are made and sold today may get shaken up by the rise of DiDIY, which might have a significant impact on jobs – whether in creating or destroying them, or both. The main technologies being cited as conducive to such a development are 3D printing and CAD software. (We certainly do not want to deny the relevance in this context of other DiDIY tools such as Arduino, but they are rarely if ever mentioned in the literature as having a similar transformative potential when it comes to how consumer goods will be made in the future.) In this subsection, we will focus on their prospective use by *individuals*, as opposed to groups (which as we have mentioned are another candidate for the “yourself” in DiDIY, and which we will discuss in the next subsection). As Deven Desai and Gerard Magliocca put it, with the advent of 3D printing, “almost anything may soon be made by large numbers of people” (Desai and Magliocca, 2014, p. 1703; see also Hornick, 2015, p. 802). In his science-fiction novel Makers, Cory Doctorow dramatizes a future of precisely that kind (Doctorow, 2009). The general vision being suggested here is that people will no longer want to purchase ready-made goods the traditional way, whether in physical shops or online, but will prefer to either design the things that they want themselves, or to get such designs from other people with the relevant skills (e.g., via websites such as Thingiverse), because this will allow them to have products that are specifically tailored to their own needs – what has been referred to as “mass customization”. They will then manufacture, e.g., 3D print, the goods associated with those designs, either on their home DiDIY tools, or using those provided by professional services like Shapeways, or by amateur hobbyists (e.g., using a website like 3dhubs.com, where both professionals and hobbyists make their 3D printers available for use by others). As John Hornick puts it:

> As demand for physical products drops and customers 3D print their own products, the data needed to make such products becomes more valuable, or at least a tradable commodity: digital blueprints of products replace the products themselves. Unlike physical products, digital blueprints are infinitely malleable. So as digital blueprints become the currency of commerce, mass customization may replace mass production. (Hornick, 2015, pp. 803-4)

The advent of CAD software and the rise of the “Maker” movement mean that more people today than ever can design their own items. Furthermore, platforms like Thingiverse allow hobbyists to share the designs they have created with others. It is also anticipated that an increasing number of brands will start offering 3D printed products that can be customized prior to order and then printed locally, leading to “on-demand” and “distributed” manufacturing; the shoe industry is a case in point (Zaleski, 2015). It is unclear, however, that this latter type of customization would truly count as DiDIY. For it to count as such, the customer ought arguably to have made a sufficiently substantial contribution to the final design using some form of CAD software, even if this only meant modifying an existing design. To treat as DiDIY design the act of setting a few parameters such as colour, size, or outer decoration before ordering a branded product, a practice that has already been commonplace for many years, would seem to overstretch the meaning of the concept – unless perhaps future customers were given the chance to control many more parameters than they can today, a prospect the likelihood of which is not very clear (among other things, because asking customers to make many choices before being able to order a product might render such customization burdensome and therefore less appealing).

This development might actually provide a buffer for industries in the face of competition from DiDIY. If most people can obtain the level of customization that they are looking for from commercial brands, they would not need to turn to DiDIY to get it. Of course, some people are motivated enough to learn how to design objects using CAD software, but we expect them to remain a relatively small proportion of the global population (barring new social developments that would involve making the learning of CAD part of compulsory education). Nevertheless, DiDIY designs can easily be obtained from the Internet, and their appeal would be strengthened if they could be used to create items of sufficient quality at lower prices than those of commercial products. The expected quality of DiDIY products in the future is a crucial piece of the puzzle when it comes to estimating the threat they represent for various industries and jobs, and about this there remains a question mark.[3]

3Some argue that technologies like home 3D printing might actually help make objects more durable and avoid planned obsolescence by facilitating repair: people will be able to manufacture a suitable spare part whenever needed rather than having to replace a whole device, which they might previously have had to do (Bella, 2015).

Admittedly, even if an adequate level of quality could be achieved, people might still be prepared to pay more to get branded products because of the cachet associated with ownership of such products from prestigious brands. Still, much of the appeal of branded goods lies in the guarantee of quality that such brands offer to their customers, and this appeal would be seriously diminished if DiDIY products could compete with commercial, branded goods. Furthermore, even among those who are attracted to branded goods mainly because of their prestige, a certain number of people might be content to own convincing replicas of such goods, which will likely become much easier to produce thanks to DiDIY (and associated technologies such as 3D scanning). Some such replicas will get sold to other people and will on that account constitute illegal DiDIY counterfeits; we will discuss these in section 4. However, as we will explain in more detail in subsection 4.1, this need not apply to all DiDIY replicas of branded goods. Those that are created for personal, non-commercial use will likely not be infringing IPRs, at least according to current EU regulations, and to that extent are relevant to the present section (Caddy, 2013).

Another relevant factor when it comes to estimating the impact of DiDIY – as practised by individuals – on existing jobs and industries is the extent to which *home manufacturing* will become the norm in the developed world over the coming decades. Indeed, home manufacturing is, by its very essence, a form of DiDIY. In recent years, there has been much talk about the prospect of people starting to print all of the items they need directly at home, thereby rendering much conventional manufacturing obsolete. However, fewer people now expect such a development to be imminent than was the case three to four years ago. MakerBot, one of the main companies making 3D printers today, recently acknowledged that they had expected home manufacturing to achieve greater popularity than it actually did, and that they had now shifted their focus to the education and professional space (Lee, 2016). People, it turns out, are more likely – at least for now – to make use of an online 3D printing service like Shapeways or Sculpteo than to buy a personal 3D printer when they wish to 3D print an item (*ibid.*). True, the latter practice will also sometimes count as DiDIY – i.e., when the digital blueprint being used is the result of DiDIY design. This might even be the case most of the time, given that, as we will discuss later, professionally designed CAD files that were sold commercially would be very vulnerable to piracy. Still, from the perspective of the present deliverable, the use of services such as professional printing bureaus is of slightly lesser relevance (even though it is definitely relevant) than is home manufacturing, since the latter will always constitute DiDIY, whereas the former might not.

There is no doubt that home manufacturing is currently nowhere nearly as widespread as home computers or even inkjet printers. Yet as the technology evolves and improves, should we not foresee that it will eventually become the norm, perhaps even in the near future? Experts are divided on this issue. Some still make enthusiastic predictions, particularly in relation to home 3D printing, others are downright sceptical, and still others take an intermediate position. Sceptics argue for instance that 3D printers suitable for the home are limited in the size, strength, surface finish, and cost of the items that they can ever make, as well as in terms of their speed and in the range of materials that they can use (Allen, 2013; Lee, 2016). To this enthusiasts might retort that this is only an accurate description of the *current* state of home 3D printing, but that the technology is steadily improving and will continue to improve over the coming years and decades. Consider for instance that people are currently not 3D printing metal items, jewellery for instance, on their home printers; items currently printed in the home are usually made of plastic. But the progress of technology leads some to foresee that the home manufacturing of items made of metal should become reality in the near future. The website all3dp.com thus writes:

> There's no way you'll gonna 3D print pure metal at home this decade. And you probably won't have a dedicated metal 3D printer standing in your home until 2020. But in some years, as nanotechnology evolves, we are going to see an incredible number of new applications. Like conductive 3D printable silver that can be ink jetted using a system very similar to the 2D graphic printer, you have at home. Even mixing different materials, like plastics and metals into the same object, is going to be possible. (All3DP, 2016)

That said, this is a prediction from enthusiasts. Peter Basiliere, the research vice-president of American research and advisory firm Gartner, who can be described as a moderate optimist in the context of this debate, takes a different view: according to him, "if you wanted to make a replacement metal part, that's a printer that costs hundreds of thousands of dollars, and that's never going to be in the home" (quoted in Dowling, 2016). Basiliere's more pessimistic prediction may or may not prove correct. Still, there is reason to regard the sceptical claim that home 3D printers will, for the foreseeable future, be limited to making plastic objects (not a claim that Basiliere makes) as overly pessimistic. For instance, American company Voxel8, founded by Harvard Professor Jennifer A. Lewis, has created a 3D printer that allows to print electronic circuit boards, which has recently started shipping (Anonymous, 2016). At the moment, its pre-order price is of $8,999, which does not yet make it suitable for the consumer market. However, some expect that, "as the technology matures, it should come down in price, eventually making it possible for anyone to print functional electronics in a single go right at home" (Hale, 2015).

Optimists about the future of home manufacturing can cite various other examples in support of their predictions. One is the MultiFab, a 3D printer conceived by researchers at the Massachusetts Institute of Technology, which can print in up to 10 different materials at a time (Barrett, 2015). Again, it is currently not available to home users, but some will argue that this will change soon as the technology gets better (*ibid.*). Another example is the technology called Continuous Liquid Interface Production (CLIP), developed by researchers at a company named Carbon 3D. They argue that CLIP technology allows 3D printing to reach speeds 25 to 100 times higher than was possible just a few years ago, and that it also allows for a smoother surface finish and can help create materials of superior strength (DeSimone, 2015; Tumbleston et al., 2015). That said, at the moment this form of additive manufacturing can only print items from certain types of photopolymer resin mostly useful for prototyping, and not just any material one might want. It is also, to the best of our knowledge, again not yet available for home use (even though 3D printing company Sculpteo is already allowing the general public to try it out via its CLIP pilot program: see Sculpteo, 2016).

Coming back to specific items, there are already a variety of prototypes of 3D printed shoes, including sports shoes and fashion ones (though mostly for women in the latter case), and the Chief Operating Officer of Nike has suggested last year that home printing of some Nike shoes (which are made of multiple materials) may not be far off (Matisons, 2015). Similarly, when it comes to 3D printed clothes, few people today are wearing any outside of fashion shows, but some anticipate again that 3D printing high-fashion clothing at home is the future (Tarmy, 2016). 3D printing drugs at home has been described as an upcoming development, one that would help open up the way for personalized medicine (Holmes, 2012). This is expected to be done by purchasing the blueprint and the “ink” for the right drug from an online pharmacy.

When it comes to food, a Barcelona based company called Natural Machines has developed Foodini, a 3D food printer. The printer works with capsules that users fill with their own ingredients. At the moment, Foodini is priced at about $2,000 and is primarily used by high-end kitchens and restaurants, but the people behind it expect it (or an improved version of it) to become part of a typical household within the next ten years. They believe that it will eventually be able to communicate with other smart devices, thereby allowing it for instance to print food with the exact number of calories that the user needs (Fussell, 2016).

A final example to which optimists about home manufacturing might point today is 3D printed toys. Toy giant Mattel thus announced this year the imminent launch (in the United States) of the ThingMaker, a family-friendly 3D printer that makes it easy for children to design and print their own personalized toys with an associated design app and the help of some templates. While this tool does not yet allow to print equivalents of Mattel’s iconic products such as Barbie or Hot Wheels, the company’s representatives have suggested that this was ultimately part of their longer term strategy (Baig, 2016).

Insofar as most of the developments we have described in relation to home manufacturing still lie in the future and are, to that extent, speculative to some degree, it is always possible to doubt that they will actually materialize, at least within the next decade. It is conceivable that optimists might be underestimating the technical challenges lying ahead, and that some of the companies talking about their future 3D printed products might not be able to deliver on their promise any time soon. And even if we assume that the technical challenges will be overcome in any particular case, one might still question whether the prospect of making a certain product at home will truly appeal to people. The costs of the whole procedure will need to drop sufficiently to make it competitive when compared to alternative methods of acquiring that product, which may or may not turn out to be the case. Moreover, home manufacturing also needs to be sufficiently convenient for users. If it adds extra steps compared to a more traditional procedure, it might not hold much appeal. Some authors cite this as their reason for believing that food printers, at least as we know them today, are unlikely to become mainstream (Barnatt, 2014; Grunewald, 2016b).[4]

Nonetheless, commentators on the future of home manufacturing (again, especially 3D printing) tend to express at least cautious optimism about it rather than downright scepticism. In 2014, Pete Basiliere from Gartner was thus quoted as stating that “consumer 3D printing is around five to 10 years away from mainstream adoption” (Gartner, 2014). The same year, futurist Christopher Barnatt suggested in his book on 3D printing that “while by 2030 home produced items may no longer be that novel, most if fewer things will continue to be commercially manufactured” (Barnatt, 2014). More recently, Davide Sher wrote, even more optimistically, that “the dream [about consumer 3D printing promptly becoming mainstream] may have faded, but the reality remains, and it says that

4Barnatt also mentions that “the things we will be able to 3D print at home will be somewhat different to most of the products that clutter our houses and apartments today... Building objects in layers is a very different process to traditional casting or molding, and hence unlikely to ever produce quite the same results” (Barnatt, 2014). This is most likely correct, yet need not necessarily reduce the appeal of home printed goods. As long as such goods meet their needs, people may well adapt to their difference from traditional items.

there was no possible way that every home could have a 3D printer within a few months, but market data says that it is very likely to happen within a few (say 15) years" (Sher, 2015).

In light of these expert predictions, together with the interest shown by many companies in developing some aspect of home manufacturing (as we have detailed above), and the fact that the possibility of creating DiDIY replicas of branded items might also increase the appeal of devices for home manufacturing among certain people, it seems that the sceptical position is not very plausible. Sceptics are certainly right that home 3D printing has been over-hyped, yet their assumption that it will never become an interesting proposition relies on an overly static view of the technology. Looking at the next two decades, the spread of home manufacturing using digital devices appears to be a possibility worth taking seriously, although not a certainty.

In addition to this, we should remember that DiDIY products need not always be the outcome of home manufacturing. They can also result from other forms of DiDIY manufacturing, such as cases where a person uses the facilities provided at a Fab Lab, or by a hobbyist, to manufacture the item they want; or from the use of a professional service like a 3D printing bureau (in that latter case, provided as we said that the CAD file that serves as the model for the manufacturing process is the result of DiDIY design). In fact, a number of authors expect these alternative forms of DiDIY to become more widespread than home manufacturing. Barnatt, for instance, writes:

> Some 3D printing enthusiasts still apparently believe that the 3D Printing Revolution will involve most people having a personal 3D printer in their own home. But I and many other industry commentators would hazard a very strong guess that far more people will use 3D printing bureaus than will ever purchase personal hardware. (Barnatt, 2014)

Such remarks are echoed by, among others, Shipley, 2013, and Lee, 2016. Besides 3D printing bureaus, initiatives like FirstBuild are worth mentioning. As an article in the *Wall Street Journal* puts it, FirstBuild is an American company focused on open innovation, and it is "set up to mine ideas for appliances from amateur inventors, students and appliance users and produce small batches of new products for sale to test their appeal with consumers" (Tita, 2016). Members of the FirstBuild community vote on the ideas thus submitted. Those that prove the most popular are then built, manufactured (first in small quantities) at the company's "microfactory", and finally sold online (Kavilanz, 2016). If we are willing to be quite liberal in our use of the concept, we may regard this process as involving a form of DiDIY, insofar as non-professionals are using a digital tool (the internet) to propose ideas for certain products, which will ultimately get realized if they turn out to have sufficient market potential. They can therefore legitimately claim to have contributed to the making of the relevant product. In cases where a particular person submits an idea, we can speak of individual-level DiDIY; if there were cases where several people collaboratively developed an idea for a product, we would have group-level DiDIY.[5]

Of course, some of the roadblocks to the spread of home manufacturing might also apply to some of those alternative forms of DiDIY. For example, even the more sophisticated 3D printers owned by companies like Shapeways might not be able to make a very broad range of consumer goods in the

5Similarly, some manufacturing companies like Local Motors and GE are relying, to a greater or lesser extent, on the practice of "crowdsourcing" to create designs: "Anyone can suggest an idea, people vote and the most popular ones get "co-designed," with collaboration from engineers and non-engineers all over the world" (Roopinder, 2015).

near future due to technical challenges (though this is less likely to apply to initiatives like FirstBuild, which boasts a broad range of devices for digital fabrication), or 3D printed goods might not always be able to compete with those produced via traditional methods (like injection moulding) in terms of price. Still, the evidence we have reviewed so far does suggest that the disruptive potential of DiDIY design and manufacturing in the foreseeable future is real indeed, even though there is some uncertainty as to how much progress we can expect with the relevant technologies, and within what time frame.

Up to this point, we have focused in this section on the practices of DiDIY design and manufacturing. There are, however, other forms of individual-level DiDIY that we haven't touched on yet. Deliverable D3.1 describes a few possible relevant examples:

- operation department head, carrying out prototyping activities without asking support to engineering firms, using 3D printers;
- quality managers in a production plant who deal with quality control without support from IT specialist (employees or consultants), by setting up an IoT system along the production line;
- marketing specialists who create advertising campaigns without the support of IT specialists (employees or consultants) by creating a dedicated web site and using social networking platforms (DiDIY D3.1, p. 11).

These various examples all involve professionals engaging in DiDIY insofar as they carry out, all by themselves (and using digital technologies), certain activities for which they would normally have requested the assistance of other qualified professionals. And we might think that variants of these examples could also provide illustrations of group-level DiDIY – if for instance we were dealing with a group of marketing specialists, rather than a single one, creating a particular advertising campaign. We will address this issue in the next subsection. At any rate, the cases just described are also relevant to our upcoming discussion of the ethical issues raised by the impact of DiDIY on work.

Another possible example of individual-level DiDIY, at least in the broad sense (since it does not involve ABC) would be the creation of free, and perhaps also open-source software, to the extent that it is not done by people acting in a professional capacity (even though they might be IT professionals); see for instance deliverable D6.1, titled "Dominant Legal Challenges and Solutions Practised". Finally, yet another relevant example might be what is referred to as "user-generated content", a category that encompasses a wide range of activities from personal weblogs to YouTube videos. User-generated content has experienced an impressive rise over the past decade, notably in the field of entertainment. We are now familiar with YouTube celebrities like Jenna Marbles and others who post highly popular videos on the website, whom countless others try to emulate with varying degrees of success (some YouTubers manage to make a living from their activities on the site, e.g., via ad revenue, even if they do not strike it rich, but most do not even get that far). We also know that some (if very few) successful bloggers make millions of dollars every year from the blogs that they created.

In the narrow sense of DiDIY, it is the obscure majority of those content creators, those who create such material as a hobby, that count as DiDIYers, and not the few extremely successful ones, who usually have turned their activity into a profession, and now run full-fledged businesses with paid staff to assist them. Nonetheless, quite a few of these stars initially started as hobbyists and

DiDIYers in the narrow sense: this applies for instance to Pete Cashmore, the multimillionaire founder of tech website Mashable, who started it as a blog that he wrote when he was 19 years old, living with his parents in Scotland (Beier, 2012); or to Jenna Marbles, who was catapulted to fame by uploading a video of herself to YouTube while she was still working odd jobs to support herself. Furthermore, in the broad sense of DiDIY, even those who make a living (and even a lot of money) by creating online content can count as DiDIYers, if they still create and upload their content mostly on their own, e.g., without the assistance of a professional video team or a whole cast of actors – this is for instance Marble's case, on account of which she has been characterized in the media as a "D.I.Y. digital entertainer" (O'Leary, 2013). This last category of cases might be less relevant than those we have discussed previously when it comes to the expected impact of DiDIY on work and employment, but we did want to mention it for the sake of completeness.

3.3 DiDIY and work: group level

So far we have focused on forms of DiDIY occurring at the individual level. Nevertheless, we have seen in section 2 that the "yourself" in DiDIY could also, within the context of this research project, be understood as referring to *groups* of people, such as companies or industrial clusters. Can we find possible cases of group-level DiDIY that would have an ethically relevant impact on the work environment?

We have already encountered some possible examples when considering D3.1's list of hypothetical cases above: these examples would involve groups of workers within a company who start to perform certain task themselves with the help of DiDIY tools, when they would previously have solicited the help of a third party (whose services might henceforth no longer be as much in demand). The same holds for initiatives like FirstBuild, in cases where groups of amateurs, rather than single individuals, proposed an idea for a new product.

To the extent that, as was mentioned in section 2, the "yourself" in DiDIY could also refer to an entity like a company, another potential candidate example of group-level DiDIY that some might cite in this context would be companies starting to make certain items (e.g., spare parts) themselves, locally, thanks to digital manufacturing technologies like 3D printing, rather than ordering them from other (possibly foreign) companies as they did before. According to Hornick:

> 3D printing may result in widespread copying, especially of consumer products. Perhaps more importantly, though, companies that formerly bought replacement or spare parts may start making or repairing the parts themselves. According to an IBM 3D printing study: "The competitive advantage from both proprietary design and parts production is expected to erode as basic design blueprints become widely available via open source... And the service parts business will lead the digital transformation, leaving companies unable to generate profits from selling spares." (Hornick, 2015, p. 803)

There is no doubt that such a phenomenon can be expected to have a significant impact on the work context. Many expect it to bring manufacturing jobs back from abroad (e.g., Desai and Magliocca, 2014) and give a boost to local production. Nonetheless, we believe that there is room for debate about the legitimacy of extending the concept of DiDIY to such cases. Consider for instance that there might be very similar scenarios in which a company that initially owned manufacturing plants abroad closes them down in favour of making the parts it needs locally. Such a scenario would seem almost identical to the previous one (including in its impact on jobs), and yet we would presumably have to exclude it from the category of DiDIY, because in the present scenario, the company would not have taken over any tasks that it used to delegate to another one.

Perhaps one could retort that even in this second scenario, the company would count as engaging in DiDIY, because by hypothesis it would be making certain items by itself, using digital technology. However, such a line of argument would seem to overstretch the concept of DiDIY, since it would imply for instance that companies like Microsoft have been engaging in DiDIY since the day they started making their own software products. One way of trying to rescue this line of argument would be to postulate that the company will count as practising DiDIY only on the condition that it now performs ("itself") a task that it used to delegate to someone else. This may be an adequate response, though it still faces some challenges. Suppose an automobile manufacturer used to order certain spare parts from another company 10 years ago, but has since been making them itself with the help of 3D printers and CNC machines. Does it still count as engaging in DiDIY? If yes, is there a certain time limit beyond which it would no longer count as such, and again why should we treat such a scenario as fundamentally different from one in which the company had always been making the spare parts itself? We do not claim that these difficulties cannot be satisfactorily resolved, yet in light of their existence, this deliverable will maintain agnosticism about the applicability of the concept of DiDIY to companies shifting to local manufacturing.

3.4 Expected impact of DiDIY (both individual- and group-level) on employment

What does the disruptive potential of DiDIY, at both the individual and group level, mean for its impact on the work context? A widely shared worry is that these practices might lead to significant job loss in various industries. If they were to become the norm, it seems that this would put many people out of work, for instance in the fields of design (as people now tended to use items designed by hobbyists), manufacturing (as manufacturing plants and assembly lines became obsolete) and retail (since people would no longer purchase the products they needed from physical retail stores).

The authors who have addressed this worry in the literature can again be grouped into three different groups: optimists, pessimists, and those who are uncertain.

Members of the first group usually agree that the rise of DiDIY design and manufacturing will cause some jobs to be lost, but add that they will also lead to the creation of an even greater number of new jobs. Some also take the view that the disruptive impact of these developments will not be large enough to cause very large job losses. Barnatt thus argues that:

> for a very, very long time to come, domestic fabrication and local manufacture-on-demand are going to be limited to high-value, customized objects and the production of industrial tooling and spare parts... 3D printing will be a revolutionary technology if it alters how 20 per cent of things are manufactured, and that will leave 80 per cent of manufacturing practice and employment untouched. This is not to say that 3D printing will not cause jobs to be lost in some companies, sectors and nations. But, as the 3D printing industry flourishes, it will also create new employment... I... suspect that 3D printing will prove far more of a springboard for industrial rejuvenation and economic recovery than a catalyst for unemployment. (Barnatt, 2014)

Brian Krassenstein also leans towards the optimist side. He does concede that "many millions of jobs will be lost" as DiDIY design and manufacturing spread through society, and adds that these lost jobs will most likely be "for relatively unskilled labor, while any jobs being created by new technology will be for managing and skilled labor", which will create "a further gap of income inequality in America" (Krassenstein, 2014a). Nevertheless, he expects that "within the next decade the cost of a higher education will likely drop substantially" thanks to initiatives for free education like Khan Academy or MOOCs from respected universities, thereby making it easy to upgrade one's education in order to adapt to the new work context. (If something like this were to happen, it might constitute an interesting example of one form of DiDIY helping counteract the harmful effects of another form of DiDIY, assuming we count MOOCs as an instance of DiDIY.) Furthermore,

> for every job lost there is a fairly good possibility that more than one job will be created. As employees are laid off by retailers and manufacturers, actual costs to the companies are decreasing substantially. This can then be passed on to the consumer, allowing for a lower cost of living nationwide. This may lead to a stronger economy as more money is available to spark new business, new innovation, and eventually millions of new jobs. While the jobs to GDP ratio will decrease, the overall economy and thus GDP may increase substantially. This means that the actual employment numbers will also rise. (*ibid.*; for a suggestion along similar lines, see also Hamermesh, 2014)

After all, greater reliance on DiDIY manufacturing would still require people who design, build, sell, and maintain the DiDIY tools used by consumers (or "prosumers"), and who manage the companies in charge of those activities. Furthermore, if services like 3D printing bureaus become popular, new jobs will be created in that context – and these bureaus might compete with similar printing locations set up by official brands to sell customized versions of their products (which again will need employees). Krassenstein adds that "there are new types of artists who rely on 3D modelling, and the CAD software market is heating up, meaning we need more programmers to write the scripts" (*ibid.*). We will also need people who provide the raw materials with which DiDIY products will be made, such as the filaments used by 3D printers; and possibly other occupations that cannot yet be foreseen. If Krassenstein's optimistic scenario were to come to pass, we would, all in all, end up not with massive unemployment but rather with a massive *transfer* of existing workers from existing jobs to new ones, and to *more* rather than fewer people being employed.[6]

The question, of course, is whether everything will indeed go as smoothly as he foresees: will enough new jobs be created to compensate for those that are lost? And will those who have lost their jobs in manufacturing or retail be able to acquire the skills required for the newly created jobs without problem? These are precisely the questions that those who are more uncertain about the impact of DiDIY design and manufacturing are asking. David Shipley thus writes, on behalf of the editorial board of *Bloomberg View*: "we suspect that 3-D printing will eventually create many jobs, much as transformative technologies in the past have done. But there's no guarantee that it will, and the transition could be a painful one for workers. In any case, the jobs it creates will almost certainly look very different from the ones we know today" (Shipley, 2013).

6A more general argument in favour of optimism on this issue would simply involve extrapolating from past, historical trends into the future: a 1998 report from the National Academy of Sciences thus concluded that "[h]istorically, technological change and productivity growth have been associated with expanding rather than contracting total employment and rising earnings" (National Academy of Sciences, 1998, p. 5; quoted in Marchant et al., 2014).

Coming now to the pessimists, a few commentators envisage doomsday scenarios, such as the authors of an article for the blog Investment Watch, according to which 3D printing "could easily destroy China's economy" and even lead to the "total destruction of worldwide manufacturing, and the crippling job losses that will go with it" (Anonymous, 2013). Somewhat more nuanced and focusing on a narrower domain, Lindsey Frick explains in the magazine *Machine Design* that consumer-driven (as opposed to industry-driven) 3D printing services like Shapeways or i.materialise (https://i.materialise.com) operate largely via their websites, where they offer a variety of automated processes, including design apps and error-correcting software, that make it easy for anyone to prepare a printable file. And these technologies, she says, "remove most, if not all, interaction with an engineer... Pairing these design apps with publicly available engineering advice and the endless amount of open-source 3D files, and it's easy to imagine a world that needs only one engineer for every 10 employed today" (Frick, 2013). If Frick is correct, this is an interesting example of DiDIY being facilitated by the spread of automation (a phenomenon we will discuss in subsection 3.4), with a potentially harmful impact on some jobs.

On a similar note, in an article for news website *Truthout*, Anne Elizabeth Moore argues that the home manufacturing of clothes (she too focuses on 3D printing) "jeopardizes jobs for around 50 million women, spread across every continent, and in most countries of the world", a number equivalent to one woman in seven (Moore, 2013). "Eliminating the fashion manufacturing and retail industries", she writes, "might benefit affluent shoppers in the US and the EU, but it would be devastating to women's economic vitality around the globe", particularly in developing countries like Bangladesh (*ibid.*). Moore acknowledges that such a development would likely create new job opportunities as well (in the very countries affected by the job losses, and not just in developed countries), particularly in the field of technology.[7] Yet she worries that these new jobs are unlikely to be filled by women – she cites a 2013 White House report according to which "women make up only 24 per cent of US science and technology fields" and adds that the situation is likely to be even worse in countries like Cambodia (*ibid.*).[8] She does mention that many of the women employed in low-wage jobs that DiDIY might threaten find them unfulfilling, and might not mind losing them so much. Still, the destruction of those jobs would only be a true bounty for the women concerned if it led to a better state of affairs for them. Having such a job might still be preferable to no job at all, if the latter situation meant starvation, dire poverty, or having to find another, potentially even more undesirable occupation to meet one's basic needs.

Of course, even if one shares Moore's concerns, there will still be room for debate regarding how to best address this issue (as we will discuss in section 5): one might for instance argue that the solution lies in improving the educational prospects of women in STEM fields, rather than trying to prevent the spread of home manufacturing through restrictive legislation. And optimists will retort to Frick that the engineers who might get displaced by the availability of DiDIY tools should have

7Focusing again on 3D printing, Fredrick Ishengoma and Adam Mtaho thus write on this issue that "[3D printing] is guaranteed to give everybody in the developing countries the power to manufacture or just create virtually whatsoever for their own uses. For example, developing countries can use [3D printing] technology to manufacture local equipment such as toys, farming tools, domestic tool etc. This will help create new jobs and empower people economically" (Ishengoma and Mtaho, 2014).

8Gebler et al., 2014, also raise the worry that the shift to localized production enabled by 3D printing will lead to more job creation in the developed world than in the developing world. However, their discussion is about 3D printing considered as a whole, and not just its DiDIY uses.

no trouble transitioning, given their professional background, to the new jobs that will be created in parallel.

While it seems to us that one-sided views that ignored the potential of DiDIY for either destroying some existing jobs or creating new ones, we think that there is room for reasonable disagreement about its net effect on employment. It is very tricky to make estimates of that effect over a specific time period, say the next ten years, especially as we would have to rule out the influence of practices similar to DiDIY that nevertheless do not count as DiDIY, such as non-DiDIY localized manufacturing (e.g., 3D printing customized goods purchased from a commercial brand at a printing bureau or at that brand's official store). And to our knowledge, no one has yet offered such estimates. In 2013, Gartner predicted that "by 2020, the labor reduction effect of digitization will cause social unrest and a quest for new economic models in several mature economies...A larger scale version of an "Occupy Wall Street"-type movement will begin by the end of 2014, indicating that social unrest will start to foster political debate" (Gartner, 2013). Leaving aside the fact that the social movement in question has, to our knowledge, failed to materialize, not only does Gartner's prediction avoid specificity when it comes to the magnitude of that labour reduction, it also bears on "digitization" at work in general, of which DiDIY is only one aspect.

More recently, the World Economic Forum (WEF) released a report in January 2016 in which its authors consider the impact of the so-called "Fourth Industrial Revolution" on the future of jobs up to the year 2020. [9] The Fourth Industrial Revolution refers to "developments in genetics, artificial intelligence, robotics, nanotechnology, 3D printing and biotechnology" that are all "building on and amplifying one another" (World Economic Forum, 2016, p. v). The WEF's report does offer specific estimates regarding the expected magnitude of the disruption to be caused by those developments:

> current trends could lead to a net employment impact of more than 5.1 million jobs lost to disruptive labour market changes over the period 2015–2020, with a total loss of 7.1 million jobs— two thirds of which are concentrated in the Office and Administrative job family—and a total gain of 2 million jobs, in several smaller job families. (*Ibid*., p. 13)

The authors view "administrative and routine white-collar office functions" as being most at risk, with manufacturing and production roles being in a slightly better position, and expecting "strong growth in Computer and Mathematical and Architecture and Engineering related fields" (*ibid*., pp. 13-14). However, the following two worrying expected developments are worth highlighting:

- as indicated by the figures just quoted, the anticipated net impact of the Fourth Industrial Revolution on jobs is clearly negative, with more than five million jobs expected to be lost. The authors of the report write that "employment growth is expected to derive disproportionately from smaller, generally high-skilled job families that will be unable to absorb job losses coming from other parts of the labour market. Even if they could, significant reskilling would be needed" (*ibid*., p. 14);
- these job losses might disproportionately affect women, as "in absolute terms, men will face nearly 4 million job losses and 1.4 million gains, approximately one job gained for every

9Others speak of a "Second Machine Age": e.g., Brynjolfsson and McAfee, 2014, and BSR, 2015.

> three jobs lost, whereas women will face 3 million job losses and only 0.55 million gains, more than five jobs lost for every job gained" (*ibid*., p. 39). This is partly linked to the low representation of women in STEM fields, where much of the expected job creation over the coming years is expected to occur.

Here again, however, the predictions being made do not bear specifically on DiDIY, even though they arguably include its expected impact. The authors of the WEF report not only consider 3D printing in all its anticipated uses (both DiDIY and non-DiDIY), but various other technologies expected to be disruptive, such as robotics, nanotechnology and artificial intelligence.

While estimates of the contribution of DiDIY to future job disruption seem to be lacking in the current literature, are there nevertheless indirect ways of reaching such an estimate, in order to assess how it compares with the contribution from those other technologies?

3.5 Comparison with other recent disruptive trends

One such indirect way would consist in finding individual estimates for each and every type of DiDIY practice that we can think of (DiDIY design, manufacturing, free and open source software, etc.), and then adding up the numbers to get a global estimate of the expected impact of DiDIY. The problem with such a solution is that such individual, more specific estimates are also, for the most part, lacking. While we have seen that some raise a general concern about the greater role of amateur designers potentially destroying jobs, those who express that concern rarely offer quantitative estimates of the net result. While Frick ventures an estimate of 90% of current engineering jobs being under threat, and Moore worries about the jobs of 50 million women in fashion manufacturing and retail, neither of them suggests a timeline for such losses, nor do they estimate how many new jobs might get created in parallel (and as we have said, it seems implausible to assume that DiDIY might solely destroy jobs without generating any new ones). Offering a quantitative estimate of the net impact of DiDIY on employment over the next decade or two is therefore an interesting avenue for future research on the topic.

It is worth noting here that even when it comes to other disruptive trends, the anticipated impact of which has been estimated by various experts, we often find wide variance between different estimates. The best illustration of this might be machine intelligence, robotics, and the process of automation that they allow. A widely cited 2013 study by Oxford researchers Carl Benedikt Frey and Michael Osborne thus estimated the probability of computerisation for 702 different occupations, and concluded that 47% of US workers had jobs that were at high risk of becoming automated over the next decade or two (Frey and Osborne, 2013). This would correspond to the astounding figure of around 60 million American jobs being at risk from automation – Frey and Osborne highlight, as most likely to be substituted for by computerization, "most workers in transportation and logistics occupations, together with the bulk of office and administrative support workers, and labour in production occupations" together with "office and administrative support occupations" (*ibid*., p. 38).

In more recent work, the same authors report even more alarming estimates for other countries: the OECD average for susceptibility to automation is estimated at 57% of the workforce by the World Bank, while the figures rise to 77% for China, and 85% for Ethiopia (Frey et al., 2016, p. 18). On the other hand, a report published this year by research and advisory firm Forrester reaches a more optimistic (though still overall pessimistic) prediction regarding the impact of automation on US jobs by 2025, anticipating a net loss of 7% of those jobs (Le Clair and Gownder, 2016) – though it should be noted that the Forrester report goes beyond merely talking about *susceptibility* to automation, and makes the stronger claim that these jobs *will* (most likely) be lost.

The studies just cited all come from reputable institutions, and reach more or less pessimistic conclusions. Nevertheless, many other experts would disagree with them. For instance, in 2014, Pew Research and Elon University released a report in which the authors conducted an expert opinion survey of about 1,900 economists, management scientists, industry analysts, and policy thinkers. The question they asked was: “Will networked, automated, artificial intelligence applications and robotic devices have displaced more jobs than they have created by 2025?”. As it turned out, about half of the experts (48 %) gave a positive answer to that question, and the other half (52%) gave a negative one (Smith and Anderson, 2014).[10] We may conjecture that if estimates were available about the impact of DiDIY on employment levels, we should again expect a significant degree of disagreement between experts, due to the simple fact that predicting the future is a contentious, difficult business.

However that may be, even if we assume that both automation and DiDIY will result in net job loss over the coming decades, it seems reasonable to suppose that the impact of DiDIY will be of lesser magnitude. Indeed, DiDIY still depends on the work of a number of people for its very existence: for example, people (non-DiDIYers) creating, selling and possibly delivering raw materials to DiDIYers, or designing, producing, selling and maintaining DiDIY tools.[11] Automation, by contrast, has no limit in principle: ultimately, machines may become able to repair and maintain other machines, simply taking humans out of the loop altogether and leading to a state of affairs in which, in the words of Rice University Professor Moshe Vardi, “machines are capable of doing almost any work humans can do” (quoted in Cookson, 2016).

To sum up, the impact of DiDIY on employment over the coming years is largely uncertain and open to debate. Nevertheless, the possibility of it contributing to technological unemployment and job transformation, even to a significant degree (though presumably less than developments like robotics, artificial intelligence, and automation), cannot be ignored, or dismissed as an irrational “Luddite” fear.

10It is worth noting that some forms of DiDIY may actually be viewed as contributing to automation too: for instance, to take an example previously cited, a quality manager at a production plant that set up an IoT system as a substitute for IT specialists for the purpose of quality control could be said to have “automated” the work formerly done by these IT specialists. That said, studies dealing with the impact of automation on jobs, such as those we have just cited, tend to focus on developments like artificial intelligence and robotics, and generally don’t pay much attention to DiDIY processes.

11Of course, it is conceivable that these processes could themselves ultimately be automated, thereby leading to uncompensated job loss. However, this would then be the consequence of automation, rather than of the practice of DiDIY itself.

4. DiDIY, work, and intellectual property (IP)

4.1 Introduction: some conceptual clarifications about IP rights

In this section, we move on to discuss the ethical issues raised by uses of DiDIY that can be expected to impact the work domain insofar as they challenge intellectual property rights (IPRs). As mentioned in D3.1 (p. 28), there are growing concerns about a potential rise in violations of IP that could be enabled by the growing availability of DiDIY-enabling technologies like 3D printing and 3D scanning; violations that could have a harmful impact on various industries. It is already known that the rise of the Internet has, besides its many benefits, significantly facilitated IPR infringement. Think of the rise of illegal file sharing since the beginning of this millennium. Starting with websites like Napster, the practice of illegally sharing digital content such as music and films has steadily gained momentum over the years. Today, websites like the Pirate Bay have taken over as platforms for the illegal distribution of copyrighted material in digital form, and have proven surprisingly resilient to the many legal challenges that they have faced since their very beginnings.

The numbers relating to illegal file-sharing are rather astounding: for instance, according to a report by the International Federation of the Phonographic Industry (IFPI), an estimated *40 billion* music files were illegally shared in 2008 (International Federation of the Phonographic Industry, 2009),[12] to which we should of course add the other giant numbers of illegally circulated files featuring other content, such as movies or video games. The practices reflected in those numbers have clearly had an impact on the industries that originally produce the content in question. Many worry that DiDIY-enabling technologies might have an impact similar to that of illegal file-sharing, this time affecting the realm of physical objects and not just that of digital data.

Before we can start addressing the relevant ethical issues, however, we need to briefly explain IPRs and the various associated concepts the violation of which is relevant to the theme of the present deliverable.

In this section, we will be talking mostly about *counterfeit goods*. Counterfeit goods are unauthorized imitations, typically created for commercial purposes, and designed to resemble an original branded product as closely as possible, to the point that they will feature a brand's official logo and signature symbols. Counterfeit goods in this strict sense should be distinguished from *knockoffs*, which by contrast merely resemble the original item but do not bear the company's trademark, as a result of which their legal status can be more ambiguous than that of counterfeits (though this is more true in places like the United States with weak protection for design rights, than in Europe; see Zaczkiewicz, 2016). Our discussion in this section will focus mostly on counterfeits in the strict sense, although we will also take knockoffs into account.

It is also worth noting that while the distinction between counterfeits and knockoffs does overlap with that between deceitful and non-deceitful illegal copies of an original item, the overlap is not perfect. As Ahuvia and colleagues note:

12Admittedly a figure to be taken with some degree of caution, given the interest that the IFPI might have in representing the illegal sharing of music files as a serious problem. Leaving aside what the precise figure happens to be, however, it does remain plausible to assume that it is very large indeed.

> Grossman and Shapiro (1988) introduced the terminology of deceptive and non-deceptive counterfeits, in which non-deceptive counterfeits are products whose consumers know they are buying fakes.

They then add that:

> Conventional wisdom dictates that most fake BLGs [i.e., branded luxury goods] are sold as non-deceptive counterfeits. Buyers are presumed to know they are fakes because they are very low priced, purchased through a non-authorized outlet, and of noticeably low quality. (Ahuvia et al., 2013, p. 4)

However, Ahuvia and colleagues go on to challenge this conventional wisdom, presenting evidence that in fact many people purchase fake luxury goods while thinking that they are real. This, they say, is partly explained by the frequent purchase of goods via the Internet, and websites like eBay (pp. 4-5). Similarly, in a report on the cost of counterfeiting published in 2015, British company NetNames (which provides online brand protection) writes that “one in six online shoppers is duped by counterfeit goods, and 28 consumers unknowingly buy lower-cost counterfeit goods online for every one that does so intentionally” (NetNames, 2015, p. 22).

A second relevant point made in this context by Ahuvia and colleagues is that while counterfeit goods are typically of lower quality than the originals they are copying, they nevertheless vary quite significantly in their quality. They cite research suggesting that “the quality of counterfeits has in some instances become ‘so good that even manufacturers themselves cannot tell the difference without the help of laboratory analysis’” (*ibid.*, p. 10).

Thirdly, Ahuvia and colleagues also distinguish between two types of scenario: “cannibalization”, in which the sale of a counterfeit of brand X substitutes for the sale of an original brand X product, and “collateral damage”, in which the sale of a fake brand X product substitutes for the sale of an original brand Y product (*ibid.*, p. 8). An example of collateral damage in that sense would be a person of limited means who purchased for $200 USD a fake Louis Vuitton handbag that would normally cost around $3,000 USD. This person, it may be assumed, would be unlikely to have purchased the original Louis Vuitton handbag – given its price tag – if the counterfeit had not been available. However, (s)he may well have purchased instead an original handbag from a less prestigious and costly brand such as Coach. In such a case, it is not Louis Vuitton, but Coach that fails to sell another handbag because of the counterfeit – despite it being a Louis Vuitton counterfeit (see Ahuvia et al., pp. 8-9).

Another important distinction for the sake of this deliverable is that between counterfeit goods and *pirated* goods – and correspondingly, between counterfeiting and piracy. In a 2010 memo, the European Commission states that “piracy consists in making an unauthorised exact copy – not a simple imitation – of an item covered by an intellectual property right” (European Commission, 2010). A paradigm example of a pirated good would be a piece of music or a film made illegally available in the form of a digital file for download on a file-sharing website like the Pirate Bay. The standard view is that pirated goods typically infringe copyright, whereas counterfeit goods, while they may also infringe copyright, tend to violate other types of IPRs such as trademark, design rights, and patent rights (Toma, 2015).

However, as we will discuss later in more detail, the advent of the new technologies enabling DiDIY challenges some of these traditional assumptions. For instance, 3D printing, 3D scanning and the sharing of CAD files democratize the ability to make exact (physical) copies of branded products. The question then arises whether such copies should be regarded as counterfeits or as pirated goods. If we take the latter view (as Sonmez, 2014, does when she talks about "cottage piracy"), we should conclude that pirated goods can also infringe trademark or design rights. In what follows, we will be speaking of "DiDIY counterfeiting" and "DiDIY piracy" to refer to forms of counterfeiting and piracy that constitute DiDIY given their reliance on digital procedures and their non-professional nature. In line with this, and with the DiDIY-related SV collaboratively produced by our Project, we will refer to those who engage in DiDIY counterfeiting and piracy as, respectively, "DiDIY counterfeiters" and "DiDIY pirates", and to the products of such activities as "DiDIY counterfeits" and "DiDIY pirated goods".

Let us now briefly describe the IPRs – just cited – that DiDIY counterfeits and pirated goods can be expected to infringe, with some indications of the impact that such infringement using traditional counterfeiting methods already has on the world of work. We confine ourselves to a relatively brief reminder of such notions, as they have already been explained in D6.1.

a) *Trademark*. "A trade mark is a sign aimed at distinguishing the goods and services of a party from those of its competitors (the party may refer to its trade mark as its "brand")" (DiDIY D6.1, p. 17). The famous "swoosh" under the Nike symbol, or the superimposed L and V letters forming the Louis Vuitton logo are paradigm examples of trademarks. The purpose of trademarks, as Elif Sonmez puts it, is two-fold: "to prevent consumer confusion when searching for goods in the marketplace, and to protect and encourage property ownership and quality control by the maker of the goods to which the trademark is attached" (Sonmez, 2014, p. 757). And as she adds later:

> if consumers existed in a cottage industry market without trademarks, where quality would vary between each maker, then the consumer would have to examine every good purchased as a matter of course and not have the short-cut communication of source and attendant quality which a trademark provides. (*ibid*., p. 761)

Counterfeit goods that violate trademark – such as fake Louis Vuitton and Nike items sold commercially – promote, on the contrary, confusion among consumers by misleading them into the assumption that the goods have a certain origin, when in fact they do not. This erroneous assumption means that they are unlikely to get the quality that they expected from the product they bought, thereby undermining the purpose of the trademark as epistemic shortcut. Furthermore, counterfeit goods illegitimately benefit from an established company's reputation while contributing to harming that reputation, and if not actively discouraged by the law, can decrease the incentive to develop and maintain distinct trademarks connected to quality goods (*ibid*., p. 758).

Trademark protection can be geographically limited, and, depending on the laws of each individual country, may or may not involve registration (OECD/EUIPO, 2016, p. 18). However, companies requiring protection throughout the European Union can also makes use of its "unified trade mark registration system...whereby one registration provides protection in all member states of the EU" (DiDIY D6.1, p. 18).

While it is uncontroversial that counterfeit goods sold commercially will be infringing trademark according to the laws of virtually any country within the EU, a somewhat trickier issue is whether making a copy of a trademarked good for *personal*, non-commercial use would also count as infringing trademark. One of our legal advisers for this project opined that this would likely not be the case: the EU's Trade Marks Directive (2008/95/EC) thus explicitly intends to protect trademark owners from uses of their products that would create "a likelihood of confusion on the part of the public" (European Parliament and Council of the European Union, 2008, p. 29). Yet someone who, for instance, 3D prints a copy of a trademarked item at home will not be confused as to its origin. Caddy, 2013, and Webb, 2014, agree with this view, and in what follows we will assume that it is correct. Therefore, in this section we will primarily be focusing on the DiDIY manufacturing of copies of trademarked items for commercial purposes (the DiDIY manufacturing of such items for personal use has already been addressed in section 3).

That said, some authors have noted that, on certain interpretations of the law, one might make the case that merely wearing or using such a copy in public might cause confusion among the public regarding its origin, in which case the practice might then infringe trademark (and thus be relevant to the present section) even in the absence of monetary gain. Even then, however, it might be challenging for trademark owners to prove that someone actually wore or used a copy of one their products in public (Osborn, 2014, p. 553).

In addition to that, the question arises whether the sale of a digital blueprint for manufacturing the copy of an item protected by trademark (or design or patent rights), as contrasted with the sale of the actual physical copy made from that blueprint, will count as infringing the relevant IPR. Lucas Osborn, focusing on the US context, suggests that this might be the case (Osborn, 2014, p. 597).[13] One of our legal advisors confirmed that suggestion in relation to the European context, but added that the distribution of such files for non-commercial purposes would be permitted by current EU laws such as the Design Directive of 1998 (European Parliament and Council of the European Union, 1998).

b) *Design rights*. Such rights protect "the outside appearance of a product. The design may consist of three-dimensional features, such as the shape or surface of a product, or of two-dimensional features, such as patterns, lines or colour" (OECD/EUIPO, 2016, p. 19). To deserve such protection, a design normally has to be novel, in the sense that no identical or very similar design is known to have existed before. Furthermore, design rights do not protect technical functions of the relevant products (*ibid.*).

Two major documents governing design rights in the European Union are the 1998 Directive on the legal protection of designs (98/71/EC), and the 2002 Regulation on Community designs. The latter offers both a registered option and an unregistered one (DiDIY D6.1, p. 17). The so-called TRIPS Agreement (World Trade Organisation Agreement on Trade-Related Aspects of Intellectual Property Rights) requires that the duration of protection should be at least 10 years (OECD/EUIPO, 2016, p. 19). European laws offer companies greater protection for their designs than countries like the United States, for instance (Dwell and Gillin, 2012). It is also worth mentioning that in some European countries including France, the UK, and Italy, design rights can also be protected by national copyrights laws – a relevant example is fashion designs (Montalvo, 2014). In the words of William Landes and Richard Posner, the rationale for a ban on imitating a protected design for a

13In relation specifically to patented items, Osborn and Timothy Holbrook have also argued that this *ought* to be the case if the file gets sold – though not if one merely owns it or distributes it for non-commercial purposes (Holbrook and Osborn, 2015).

certain period is that it "enables people to reap where they have sown. Without that prospect the incentive to sow is diminished" (Landes and Posner, 2003, p. 13, quoted in Fischer, 2008).

Counterfeit goods, to the extent that they purport to resemble originals as much as possible, are very likely to violate design rights as well as trademark. As for knockoffs, while they do not infringe on the latter, they may well illegally replicate certain designs in the European context. An example of this would be design furniture: Chinese knockoffs of Hans J. Wegner chairs were thus destroyed last year after being seized by Norwegian customs (Anonymous, 2015). Other examples include copies of designs for fashion items, watches, or jewellery.

Let us add here again that, as in the case of trademark, creating a DiDIY-manufactured copy of an item protected by design rights will presumably not break current EU laws if it is done purely for personal, non-commercial use (Caddy, 2013; Webb, 2014).

c) *Patent rights*. "A patent enables the patent holder to exclude unauthorised parties from making, using, offering for sale, selling or importing the protected inventive subject matter" (OECD/EUIPO, 2016, p. 18). Patents protect inventions, whether products or processes, that provide a new solution to specific problems in the field of technology, broadly understood. Patents are geographically bound, but a centralised application procedure is available through the Patent Cooperation Treaty (PCT) process, to avoid the need to file multiple patent applications for protection in various parts of the world. The protection conferred by the patent is usually for a period of 20 years from the date when the application is filed (*ibid*., pp. 18-19; DiDIY D6.1, p. 16). In Europe, patent rights are governed by a wide of legislations, including the European Patent Convention, in the case of Western Europe (Jackson, 2010). Items that could infringe patent rights and would be relevant to the present deliverable include counterfeit medicines (Mara, 2010), or some industrial parts (and as we have seen, also under certain circumstances the CAD files used to make such things). Finally, the requirement of monetary gain for infringement should apply to the DiDIY replication of patented items as well (Caddy, 2013; Webb, 2014).

d) *Copyright*. Copyright is a set of rights related to the original creative works of authors. It grants authors exclusive control over, among other things, the reproduction, distribution, translation and adaptation of their work. The rights in question, however, are subject to limitations, such as Fair Use.[14] Works protected by copyright include literary works, musical works, films, or works of visual art (and in some countries, as we have mentioned, fashion designs). In most legislations, copyright is granted automatically, with no need for registration, from the moment a work is created. It is also limited in time: with some exceptions such as films and photographic works, the international minimum standard for copyright protection is the life of the author plus 50 years (OECD/EUIPO, 2016, pp.17-18; DiDIY D6.1, p. 16).

Violation of copyright is typically associated with *piracy*, rather than counterfeiting. As we have mentioned in section 2, we will treat most forms of piracy as falling outside the category of DiDIY proper, and therefore outside the scope of this deliverable. Nonetheless, the category of DiDIY piracy is not empty. For instance, some forms of so-called "user-generated content" might fall into that category, and raise concerns about copyright infringement. We will discuss this issue in subsection 4.6. Furthermore, if some companies were to start selling "official" CAD files for the

14Fair Use "is the exception to copyright law that allows content creators to use the otherwise protected works of others – without the copyright holder's permission — if that use is for education, criticism, parody, news reporting, or research, among other similar uses" (Gabriel, 2016).

manufacture of particular products, or to use such files to allow consumers to manufacture objects at home based on data sent directly from the internet to their DiDIY device,[15] without downloading the design itself, these files would also be protected by copyright. Copyright protection differs from that afforded to the previous types of IPRs in that the possession or distribution of copies of such CAD files that had not been authorized by the copyright holder would be infringing that particular right even if the person who acquired and distributed the files did not benefit financially from doing so.

4.2 Relevance of IPRs to the work context

Why are IPRs as we have just described them, and infringements on IPRs, important for the work context? One argument frequently put forward is that if such rights are not sufficiently protected, creative professions will get stifled as those who would otherwise practise them won't be able to expect adequate financial compensation for their efforts, thereby undermining a crucial incentive to engage in such pursuits. As Robert Merges and colleagues put it:

> Intellectual property protection is necessary to encourage inventors, authors, and artists to invest in the process of creation. Without such protection, other could copy or otherwise imitate the intellectual work without incurring the costs and efforts of creation, thereby inhibiting the original creators from reaping a reasonable return on their investment. (Merges et al., 2010, p. 733; quoted in Sonmez, 2014, p. 783 n181)

In what follows, we will assume that this argument is misguided, based on the position stated in D6.1, according to which DiDIY practices (think for instance of websites like Thingiverse or of the phenomena of free and open source software) "show that creativity can thrive even without the need for exclusive protection of ideas, industrial designs and creative works" (p. 7). Even if we leave out concerns about protecting the incentive to create, however, IPR violations that might be facilitated by DiDIY do not automatically become ethically irrelevant. Entire industries rely heavily on IPRs for their activities (from manufacturers of power-driven hand tools to book publishers). This means that there is more at stake than one might think if one were to confine oneself to the debate about IPRs and economic incentives towards innovation. In 2013, the European Patent Office (EPO) and the Office for Internalization in the Internal Market (OHIM), the European Union's intellectual property agency, published a joint report assessing the economic significance of IP rights and the need for their protection. One of their findings was that "IPR-intensive industries account for more than 56 million jobs, or 26% of total employment, in the EU" (EPO and OHIM, 2013, p. 59). To this they add that "another 20 million jobs in the EU economy are generated in non-IPR intensive industries that supply goods and services to them", which means that, on the whole, "76.6 million jobs, or more than 35% of all jobs in the EU, are directly or indirectly contributed by IPR-intensive industries" (*ibid.*, p. 60). Two years later, another report by OHIM found that "businesses that own Intellectual Property Rights generate more revenue per employee than those that do not, have more employees and pay higher salaries to their workers and that this relationship is particularly strong for SMEs" (OHIM, 2015b). In short, many jobs and many people's salaries (and not just those of authors, inventors and artists) could stand to suffer from IPR violations.

15Or perhaps to an intermediary device that did not allow users to tinker with the data.

We also have estimates regarding the number of jobs that actually get destroyed by counterfeiting, both in the European Union and worldwide. A study released last year by the Office for Internalization in the Internal Market (OHIM), the EU's intellectual property agency, thus reports:

> It is estimated that legitimate industry loses approximately €26.3 billion of revenue annually due to the presence of counterfeit clothing, footwear and accessories in the EU marketplace, corresponding to 9.7% of the sector's sales. These lost sales translate into direct employment losses of approximately 363,000 jobs...If we add the knock-on effects on other industries and on government revenue, when both direct and indirect effects are considered, counterfeiting in this sector causes approximately €43.3 billion of lost sales to the EU economy, which in turn leads to employment losses of 518,281 and a loss of €8.1 billion in government revenue. (OHIM, 2015a, p. 7)

Moving on from counterfeiting to piracy, a 2010 study by Paris-based consultancy firm Tera Consultants reported that "in 2008 the European Union's creative industries most impacted by piracy (film, TV series, recorded music and software) experienced retail revenue losses of €10 billion and losses of more than 185 000 jobs due to piracy, largely digital piracy" (Tera Consultants, 2010, p. 5). The report adds that, "based on current projections and assuming no significant policy changes, the European Union's creative industries could expect to see cumulative retail revenue losses of as much as €240 billion by 2015, resulting in 1.2 million jobs lost by 2015" (*ibid*.). More recently, another report by the European Union Intellectual Property Office (EUIPO), focused specifically on IPR infringements in the recorded music industry, found that:

> in 2014, the recorded music industry lost approximately €170 million of sales revenue in the EU as a consequence of the consumption of recorded music from illegal sources. This total corresponds to 5.2% of the sector's revenues from physical and digital sales. These lost sales are estimated to result in direct employment losses of 829 jobs. If the knock-on effects on other industries and on government revenue are added... infringement of IPR in this sector causes approximately €336 million of lost sales to the EU economy, which in turn leads to employment losses of 2,155 jobs and a loss of €63 million in government revenue. (EUIPO, 2016)

If we look at the whole world, a recent study by the Organisation for Economic Co-operation and Development mentions that trade in counterfeit and pirated goods has grown from US$250 billion annually in 2008 to as much as US$461 billion in 2013. This means that "as much as 2.5% of total world trade in 2013 was in counterfeit and pirated products" (OECD/EUIPO, 2016, p. 68), including around 5% of all EU imports that year (ibid., p. 76). And in 2014, the International Organization for Standardization (ISO) reported that "2.5 million jobs have been lost as a result of fake products" in developed countries (ISO, 2014). Finally, the organization NetNames, in a report released in 2015, mentions that the risks of counterfeiting to customers "are not just financial, but also physical. G20 countries now see an estimated 3,000 deaths annually due to counterfeit consumer goods alone" (NetNames, 2015, p. 5). While the various figures we have quoted so far should be taken with some caution and while the methodology that led to them in any individual case could be disputed (as has been done with similar figures in the American context: see Raustiala and Sprigman, 2012a), they nevertheless represent the best data we know of on which to build our discussion of IPR violations enabled by DiDIY, and their impact on the work context.

Given that it is established that counterfeiting and piracy cause significant job loss (and have other negative effects), it seems reasonable to worry that DiDIY counterfeiting and piracy might have similar effects, and thus potentially aggravate the existing situation – though this partly depends on whether they will *add* to professional forms of counterfeiting and piracy, or rather compete with them and ultimately *replace* them. Is there, on the other hand, any potential upside to these phenomena? One possible suggestion would precisely be that DiDIY counterfeiting could, by competing with professional counterfeiting, contribute to reducing its prevalence, thereby causing some exploitative jobs to disappear, insofar as counterfeit goods "are often produced by child laborers in third-world countries" (Sonmez, p. 758). Yet here again, this will only count as a positive outcome on the assumption that the children who were previously exploited in the counterfeiting industry will then be given better options, such as going back to school to complete their education. If instead they were simply moved to a different kind of exploitative situation, or if they no longer had to work, but now faced aggravated poverty – as did their whole family – due to the loss of the income that their work in the sweatshop used to provide, then no good would have been achieved. It is therefore unclear that DiDIY counterfeiting would have beneficial effects in this context.

That said, how seriously we should take the threat to jobs posed by DiDIY counterfeiting and piracy also depends on a number of controversial empirical factors. First, how many extra jobs can we expect to be lost due to the advent of DiDIY counterfeiting and piracy? And secondly, what will happen to the people who lose those jobs? Will they simply take up other jobs, perhaps new jobs that advances in technology will create? Or will they mostly remain unemployed? If the former, will their new jobs bring them an income comparable to that of the jobs they originally had? As we will suggest in subsection 4.7, it is difficult, in light of the evidence currently available, to offer any confident answer to those questions. Before saying more about that, however, we will look more closely at the forms that DiDIY counterfeiting and piracy can be expected to take.

4.3 The advent of DiDIY counterfeiting and piracy

The arrival of the digital era and of DiDIY has important implications for the practices of counterfeiting and piracy. Considering what it describes as the recent "explosive growth" of counterfeiting, NetNames writes that "there is little doubt as to the crucial role played by the digital world in this meteoric rise, with a 15% increase in sales of counterfeit goods online last year (NetNames, 2015, p. 4)". They go on to explain that:

> Counterfeiters have been quick to exploit the high-growth potential of the digital world. The internet allows them to refine approaches, increase reach, and target the lucrative world of e-commerce via rogue websites and content that mimics those of genuine brands. Equally, the rise of auction sites has allowed criminals to sell huge volumes of goods directly to the B2B [business to business] or B2C [business to consumer] market with ease. Online piracy has also exploded, with digital content proving so straightforward to copy, distribute and monetize that pirates can outmaneuver global brands. (*Ibid*., p. 9).

The vast industry of counterfeit goods, from clothing to banknotes, has a long history. Piracy, too, did not begin with the advent of digital files, but already existed before in the form illegal copies of commercial VHS tapes, for instance. Nevertheless, physical artefacts have so far still proven trickier to exactly reproduce than digital files. This is because reproducing the latter can be done easily and automatically just by using a computer, whereas replicating the former used to require some greater or lesser degree of manual skill, and/or access to specialized manufacturing equipment that very few individuals, as opposed to professional businesses, could afford. The advent of DiDIY-enabling technologies is changing the game in that domain. People can now make a copy of a number of objects by scanning the original with a 3D scanner, turning the information into a CAD file, and then 3D printing a copy of that item on the basis of that file. Discussing the expected impact of the democratization of 3D printing on IPR infringement, Ben Depoorter writes that “as with peer-to-peer file sharing and music copyright before it, counterfeit piracy becomes a mainstream, non-commercial activity in a world of 3D printing” (Depoorter, 2014, p. 1495). His remark might be extended to DiDIY-enabling technologies more generally.

That said, it should be noted that the procedure of 3D scanning can only capture the surface properties of objects, not their internal structure. This might not matter for simple objects, but it does matter for more complex ones. For objects of the latter type, a more detailed digital blueprint would need to be created, either with the help of CAD software (which would require both CAD skills and at least rough knowledge of the internal structure of the object in question), or, in cases of items that have been originally designed to be 3D printed, by illegally obtaining the “official” digital blueprint for an object. Once one had such a detailed blueprint, however, anyone with the right kind of digital equipment and basic materials (again, for complex objects, one would need to determine exactly which ones are needed) could in theory make as many copies of the original object as they wished, and potentially sell them to others. This possibility would represent another setback for companies fighting counterfeiting and piracy, and might aggravate an already difficult situation for them. American research and advisory firm Gartner thus predicted in 2013 that “by 2018, 3D printing will result in the loss of at least $100 billion per year in intellectual property globally” (Gartner, 2013).

As we have alluded to in subsection 4.1, the arrival of DiDIY-enabling technologies raises a challenge for the standard way of distinguishing between counterfeiting and piracy. Counterfeiting is commonly associated with violations of trademark and with imitations, of noticeably lower quality, of an original branded product, while piracy is associated with copyright infringement and with the exact replication of a song, movie or video game. However, some scenarios involving the use of DiDIY manufacturing present us with hard cases. Suppose that a retailer of jewellery and accessories chose to allow its customers to purchase the right to print some of their items on their home 3D printers, using data sent directly from the company’s online store. If a hacker gained access to those data and was able to make copies of the original digital blueprints for the printable items, any unauthorized copies of those items that the hacker, or anyone else who gained access to the blueprints, was able to print would presumably count as pirated goods. Indeed, they would be exact copies of the original item, made from the original digital blueprint – only from an unauthorized copy of that blueprint.

Yet what if the scenario were slightly different, and rather than being designed to be printed on the customers’ home printers, the original items were meant to be manufactured on the company’s own 3D printers, and then sold in actual physical stores? Suppose that the digital blueprints for those items were again stolen, and that a year or two later, with the progress of technology, one could print those items on a home printer using the stolen blueprints and get a result of exactly the same quality as the company could have achieved two years earlier?

In such a scenario, assuming the eventual printed copies were sold as originals, should we regard them as counterfeits, on the grounds that they bore the company's trademark and therefore sent a misleading message about their origin (i.e., that they had been made, and possibly that they were also being sold, by the company itself)? Or should we rather view them as pirated goods, insofar as they constituted "unauthorised exact copies" of the original items (European Commission, 2010)? Choosing the former answer means abandoning the common assumption that counterfeits are inferior imitations of original products, rather than exact copies. Choosing the latter means accepting that pirated goods can violate trademark, as well as copyright. Neither of these two notions strikes us as being clearly more compelling than the other. Ultimately, it might be for the courts to decide what stance to take on these issues. In what follows, we will take the first path and treat the scenarios just described as resulting in counterfeits rather than in pirated goods,[16] because of the traditional association between counterfeiting and trademark violations, but we certainly do not wish to claim that this is the only reasonably stance to take on this.

It is important to remember here that not all acts of illegally reproducing a physical object using a 3D printer (or other form of digital technology) will count as DiDIY.[17] A private individual who, using her own digital tools, made copies of particular commercial items for her own use and occasionally sold some of them, would clearly be engaging in DiDIY. On the other hand, counterfeiters who were very well organized, worked in groups, and made a living out of 3D printing illegal replicas of designer accessories (or other items), would not constitute a case of DiDIY. These people would be professional counterfeiters, involved in a business activity. In this deliverable, we are interested in the expected impact of the first type of counterfeiters. There is, of course, room for a whole spectrum of intermediary cases between the two examples just given: we can imagine various kinds of semi-professional counterfeiters, all equipped with digital technology and more or less well-organized.

We can also imagine alternative variants of our first scenario, in which either:

(a) the counterfeiter does not print the replicas at home, using her own tools, but rather sends the digital blueprints that (s)he created for those items to a 3D printing service like Shapeways; or

(b) the counterfeiter actually operates professionally, but takes care of the manufacturing and sale (perhaps even design) of her products all by herself, as opposed to being part of an organized group.

In this deliverable, we treat cases of both the (a) and (b) type as instances of DiDIY counterfeiting in the broad sense. Yet it is worth emphasizing that the line between DiDIY counterfeiting and professional counterfeiting (relying on similar devices) is a blurry one, and that the status of cases at the margin will unavoidably be controversial.

In what follows, we will consider some major examples of items where counterfeiting and piracy could occur in a DiDIY context.

16Though we agree that the act of illegally copying an original CAD file for a printable item would constitute piracy – a charge that could not be avoided by arguing that one intended to print the item for personal use only.

17And the Gartner prediction cited above, it is worth stressing, concerns all uses of 3D printing, not necessarily just DiDIY ones.

4.4 Candidates for DiDIY counterfeiting: consumer goods from desirable brands

Let us begin by considering what kind of items would be the most likely candidates for DiDIY counterfeiting.

A domain that quickly comes to mind is that of personal consumer goods from brands whose trademark has a certain "aura", making them desirable to consumers. These include – but are not limited to – personal luxury goods, a category that encompasses things like jewellery, leather goods, watches and fashion items. Besides these, we have brands whose "cachet" makes them attractive targets for counterfeiting, including potentially DiDIY counterfeiting, but do not belong to the luxury sector. Think for instance of brands like Adidas, whose sneakers are one of the world's most counterfeited items.[18] In what follows, we will group these different types of brands (both luxury and non-luxury ones) under the label of "desirable brands".

Sonmez addresses this very topic in her article on "cottage piracy". She writes:

> The concern for owners of luxury trademarks is that as 3D scanning and printing capabilities advance, unlike current building-from-scratch counterfeiting techniques, a counterfeiter would need only one original authentic trademark-bearing object to scan, once, anywhere in the world creating a CAD file. The CAD file can then be uploaded, shared or transferred, and the counterfeit object can be printed in any material available from an intermediary printer, creating an almost exact replica. (Sonmez, 2014, p. 782)

If DiDIY counterfeiting (as well, of course, as lawful DiDIY copying for non-commercial purposes) of personal items from desirable brands did prove as straightforward to achieve as Sonmez suggests, it would clearly represent a threat to those brands. Counterfeiters would still need to procure the basic materials required to make the replicas they wanted to make, and depending on the nature of the replica to be made (faithful one vs. cheap one), these materials could be costly. However, provided that they could sell the counterfeit goods for a price high enough to still earn them a substantial profit (while still sufficiently lower than the official retail price to make it appealing to enough potential buyers), this might not be a real problem for them. As Sonmez mentions, the ease with which a digital blueprint for such an item could be circulated around the world once it had been created would make it very difficult for the companies concerned to prevent the democratization of the ability to make counterfeit versions of their products. The huge volume of digital files that are illegally shared across the internet today, to which we have previously referred in relation to the illegal distribution of music files, suggests that preventing a similar dissemination of digital blueprints for purposes of DiDIY counterfeiting would be a largely futile enterprise.

Does this mean that DiDIY counterfeiting, in combination with lawful DiDIY copying for personal use and with professional counterfeiters now armed with digital manufacturing devices, poses a threat to the very existence of these desirable brands, and perhaps to the entire personal luxury goods sector, and the many jobs that depend on it? Before we start answering that question, we need to consider the prior issue whether, even if the answer were yes, this would really constitute an ethical problem. In particular, why should we care about the interests of companies that produce and sell luxury goods, and which represent a significant proportion of "desirable" brands as we have

18See https://www.msn.com/en-us/money/companies/the-worlds-most-counterfeited-brands/ss-BBsVVXu#image=21.

defined them (or more radically, why care about the fate of desirable brands at all)? After all, we are dealing with goods that some – including some prominent ethicists – might argue should not be made and purchased anyway, at least in the current global situation where the money spent on luxury goods could instead be used to save children dying of preventable diseases, or to fight hunger and poverty, in the developing world (see e.g., Singer, 1972 and 1999).

While this is a fair challenge to raise, we believe the answer is as follows. Even assuming that the consumption of personal luxury goods is as ethically dubious a practice as some ethicists think it is, it remains the case that if the industry providing those goods were to collapse due to competition from counterfeiting, a large number of jobs would be lost and the economy might take a hit at both the local and global level,[19] all because of people (counterfeiters) who are unlawfully appropriating someone else's product, and can afford to make and sell counterfeit items without needing to employ large numbers of people, if any, other than themselves. This does look like an ethically problematic social development, first and foremost because of the harm done to the people who thereby lost their jobs. And secondly, it is not so clear that a severe negative impact on the personal luxury goods sector from counterfeiting would have no relevance whatever to those in the world who are worst off, and to our obligations towards them. The world is a complex place with many interconnected parts, and disruptions to the economy of a developed country may have adverse consequences not only for its citizens, but also for others beyond it, including people in developing countries that depend on income (in the form of aid donations or in other forms such as tourism) from the developed country in question.

Based on that fact, some authors have thus criticized philosophers like Peter Singer, who has become famous for arguing that citizens of developed countries should stop purchasing any "luxuries" and should instead give away all the money not required to meet their essential needs to charitable organizations that will help the poorest people in the developing world.[20] Philosopher Bas Van der Vossen thus writes:

> Singer's solution will likely mean that standards of living in the West dramatically decline. When we give away the money we would otherwise have used for our expensive jewelry, we do not just lose that jewelry. The jewelry stores lose business. And when stores lose business, employees lose their jobs. Similarly, suppliers to jewelry stores lose their business, and their employees will lose their jobs as well. And the people providing the things on which all these people would normally spend their money, will lose their business, income, and jobs as well. This is not a recipe for helping people escape poverty. It is a recipe for making the entire world poor. (Van der Vossen, 2014, p. 72)

We certainly do not wish to suggest that current patterns of consumption of luxury goods in the developed world are optimal for the purpose of fulfilling our obligations to the worst off in developing countries. Neither do we wish to argue for the necessity of the existence of any single branch of that sector for the economic prosperity of a country (which in turn is a precondition of the ability to send substantial aid abroad), or to maintain that nobody should ever choose to completely

19To put some numbers on this, the personal luxury goods market was estimated to be worth more than €250 billion in 2015 (D'Arpizio et al., 2015).

20Singer, 1972, 1999. In his more recent work for a general audience, Singer has toned down his initial claim (Singer, 2010).

forfeit luxury goods in order to have more money to give away to charity, as recommended by Singer. Rather, we simply wish to point out that the complete disappearance of the luxury industry as a result of a boost to counterfeiting from DiDIY (and digital fabrication more generally) might not be as obviously ethically irrelevant, even from a global ethics perspective, as one might initially have thought.

If we assume the ease of creation and dissemination suggested by Sonmez, it seems that DiDIY counterfeits could aggravate the problems – already posed by "traditional" counterfeiting – of cannibalization and collateral damage, by increasing the availability of substitutes for original products from desirable brands. Deceit may or may not be an issue with DiDIY counterfeiting, depending on the nature of the case under consideration. Some DiDIY counterfeits might be sold as such explicitly enough to avoid any confusion as to their nature. However, there is also the possibility for a DiDIY counterfeiter to present some of his or her items as originals, for instance online, on websites like eBay. The risk of people mistakenly buying counterfeits when they thought they were getting the real article may therefore increase with the advent of DiDIY counterfeits.[21] Having said that, even assuming this were the case, the extent to which special protective regulatory measures would be called for to forestall such a risk is debatable. One might argue that adult consumers can reasonably be expected to inform themselves about the sort of goods they can expect to get from online platforms like eBay, and to know that luxury items sold on such platforms, especially at a significantly lower price than the original, are most likely fakes. That does not mean, of course, that they should be left without any legal recourse should they unknowingly purchase a counterfeit item. But it is unclear that the advent of DiDIY counterfeits requires any addition to the legal avenues that are already available to people in that situation. eBay's "Money Back Guarantee" thus states that "If a buyer suspects that an item is counterfeit, and there are strong indicators that the item is counterfeit... we refund the buyer for the full cost of the item and original shipping, and the seller reimburses us for the refund".[22]

The DiDIY counterfeits with the greatest potential for deception would presumably be ones that were close in both price and quality to the originals, and were sold in contexts that lent plausibility to the belief that they were in fact originals. At this early stage in the development of DiDIY counterfeiting, it is difficult to evaluate the expected quality of its products. In principle, it seems that it could be high enough to approach that of original branded items, even luxury ones – especially considering that DiDIY, by its very nature, removes most challenges related to manual skill, the quality of the basic materials and that of the digital manufacturing device being the main relevant parameters, together with design skills, in cases where the digital blueprint for a counterfeit needs to be tinkered with. But this will of course depend on how the technology will develop in the future, which is difficult to predict with accuracy. Still, the potential for deceit of DiDIY counterfeits may therefore be relatively significant.

Nevertheless, we should remember that these potential risks from DiDIY counterfeits are all premised on the assumption that producing and distributing such counterfeits will prove relatively straightforward. While this assumption certainly seems plausible with regard to certain items, with regard to others it might be more debatable. Sonmez thus writes that "there is little, if anything,

21This might not apply to the sale of digital blueprints, unless they were sold via websites that successfully gave the impression of having been licensed to sell such blueprints by the brands concerned.

22See http://pages.ebay.com/help/policies/money-back-guarantee.html#refunds [accessed 13/8/2016].

about an original object that could foil an attempt to 3D scan it for counterfeiting purposes, unless the material cannot be printed or the shape lacks the requisite structural integrity for 3D printing" (Sonmez, 2014, p. 783). Here one might wonder whether these last two caveats really have as little relevance as Sonmez seems to think. Clearly, it is not currently possible to print just any item, or to print from just any material, especially if we are talking about home printing (as opposed to industrial printing using much more sophisticated and expensive equipment).

However, as we have mentioned in subsection 3.2, 3D printing techniques have been steadily improving over the past few years and are continuing to improve. Shapeways, for instance, boast on their website about being able to print in all kinds of materials "from metals to porcelain, plastic to sandstone, and everything in-between" (http://www.shapeways.com/materials), and they already offer various kinds of jewellery (made of various kinds of metal including gold and silver) as part of their online catalogue. It is therefore already possible, in principle, that someone in possession of a copy of the digital blueprint for an original item from a desirable brand could send it to a company like Shapeways for printing (as we mentioned earlier, we would count this as an instance of DiDIY in the broad sense, especially if the possessor of the blueprint had created it herself, say via 3D scanning, or had at least significantly modified it). We have also already talked about the prospects for the development of home manufacturing. It is true that different kinds of personal items will be more or less amenable to digital fabrication, such as 3D printing, at least in the near future. Relatively simple items such as leather wallets and belts may well become available for 3D printing very soon: an American company called Modern Meadow is thus working to develop animal-friendly, printable leather (Krassenstein, 2014b). 3D printed handbags are currently more speculative, although we may note that Italian company XYZbag already produces commercially available 3D printed bags (Millsaps, 2015) and that Nike introduced a 3D printed sports bag during the World Football Cup in 2014 (Rhodes, 2014), though it was reserved for a few elite players. We have already discussed printed shoes and clothes in subsection 3.2. Items like watches probably present the greatest challenge to DiDIY counterfeiting, even though a Swiss maker has recently presented a prototype for a watch that is almost completely 3D printed (Branwyn, 2016).[23]

We should remember, of course, that being able to fabricate a certain kind of item using digital manufacturing tools like high-end 3D printers does not automatically entail the ability to make that item on a home device. Also, some exclusive items feature precious stones like emeralds or diamonds that are not suitable for digital fabrication, at least for the foreseeable future.

Still, the above remarks suggest that the inability to print from a certain material, or to print structurally unsuitable items, need not be decisive obstacles to DiDIY counterfeiting, especially as the relevant technologies improve over the coming decades. Nonetheless, there are other considerations that might present a challenge and are worth mentioning. First, there is the question of the digital designs to be used to produce the relevant counterfeits. How would one obtain such a design? A first option, as we have said, would be to scan an original item with a 3D scanner. For some simple objects, such as a leather belt for instance, this may well suffice to produce an adequate digital blueprint. But for more complex objects, such as a handbag or even more so, a watch or a piece of audiovisual equipment, capturing the surface properties of the object will not be enough. For objects of the latter type, two courses of action are conceivable: one would either need to use CAD software to complete oneself the digital blueprint that one had created by scanning, or

23At this point, however, the watch can only keep running for about 30 minutes.

one would need to obtain an "official" digital blueprint (created by the manufacturer) for the object one was trying to counterfeit. We will now look at both possibilities, though we will suggest that the former is more likely than the latter.

When it comes to the first possibility, it seems to us that the majority of people who seek to acquire counterfeits would have little motivation to invest the time and effort to learn how to use CAD software and create their own digital blueprints (even with the help of 3D scanning), when they already have the much easier option of purchasing a counterfeit of the item they are interested in using "traditional" channels.[24] Of course, designing the object oneself allows for greater control and customization, but it seems unlikely to serve as a sufficient selling point with most potential customers. Still, there are people who possess CAD design skills (or are willing to acquire them), and among those some might indeed choose to create designs for counterfeits by scanning items from desirable brands and then filling the gaps in the resulting digital blueprint. They might either strive to mimic the actual inner structure of the original object (i.e., reverse engineer it), or they might instead use a simpler, less "fancy" but more convenient structure. They could then either sell their design at an appropriate price to anyone who wanted to print the resulting counterfeit, or of course manufacture and sell the actual item themselves. (Admittedly, they should not turn this into a full-fledged business, or it would become less clear that they still fell within the scope of DiDIY.) Designs that were more faithful to the original item, regarding both the inside and the outside, would presumably command higher prices.

If the second possibility were ever to become reality, it would certainly give a great boost to DiDIY counterfeiting. If a would-be counterfeiter were somehow to get hold of a manufacturer's CAD file for the digital creation (e.g., printing) of a personal branded good, not only could (s)he easily make copies of the item for herself, her social circle, or for illegal sale to others, but (s)he could give or sell the file to another counterfeiter, whether a DiDIY or professional one, who could then engage in similar activities. And the chain might go on from there. Even if the original CAD file had a built-in protection system that would only allow it to be used once, or on specific devices owned by the original manufacturer, it seems exceedingly likely that people with the right knowledge and skills would soon find ways to remove such protection. The question then becomes, how likely is it that someone might get hold of such an official digital blueprint. While 3D printed prototypes are seen in various contexts including fashion shows (as we have alluded to), it is still unclear at this point to what extent desirable brands will want to create commercial products that are specifically designed to be digitally manufactured.

Even assuming there were a number of such products, not just anybody could presumably get hold of the digital blueprints for making them; one would need to have insider access to such files, or to get such access through theft or computer hacking skills.[25] Such an act might be treated in a similar manner as the misappropriation of a trade secret, which would carry heavy penalties for the offender. Indeed, in a world where ownership of devices for DiDIY manufacturing were

24Admittedly, this would no longer apply if CAD literacy became the norm in compulsory education.

25It seems unlikely that desirable brands would make such blueprints available for purchase on their websites for home manufacturing, precisely because they could expect them to soon get widely disseminated illegally. Instead, we would expect a system to be set up involving e.g., information being directly sent to a 3D printer from a brand's website after purchase, ruling out (except perhaps for people with advanced hacking skills) the possibility of making additional copies of the item at will without further payment.

widespread, preventing unauthorized actors from accessing the official digital blueprints for their products would seem just as important for desirable brands as it is for brands like Coca-Cola or Mars to keep the original recipes for their products secret – something they seem to have been quite successful at doing overall, by limiting knowledge of those recipes to as few people as possible, allowing very few visitors to their factories, and requiring those who are allowed in to sign stringent confidentiality agreements (Okediji and Bagley, 2014, p. 309).

It is not inconceivable that a person with access to such digital blueprints might at some point choose to illegally share them with others. If this were to happen, however, barring a scenario in which a massive number of branded goods had already been designed for digital manufacturing and their blueprints were all "leaked" at the same time, it seems that such an incident might dissuade desirable brands from creating any further such items, if they could expect them to be even easier to counterfeit than traditional ones. This second method of getting digital blueprints for branded goods would then soon become unavailable again. It therefore seems more plausible to assume that DiDIY counterfeiting will also involve some form of DiDIY design.

So far, we have emphasized the harm that the existence of counterfeits might inflict on desirable brands through cannibalization and collateral damage. However, some – it is worth noting – have argued that it could also *benefit* those brands in at least two ways. First, it could serve as a "gateway" to the purchase of the original article: people who initially purchase a counterfeit might develop a growing interest in the original product while deploring the lower quality of the counterfeit and the possible embarrassment of having to admit to others that they own a fake, ultimately leading them to buy the "real thing" (Gosline, 2010). Secondly, counterfeits might help increase the aura of prestigious brands, insofar as people's interest in owning articles that look just like the original items from those brands is a testimony to their desirability (Raustiala and Sprigman, 2012b). That said, Ahuvia and colleagues mention that we have better evidence of buyers of counterfeits *perceiving* them as gateway products (which could potentially be a rationalization serving to justify their purchase) than we have of them *actually* functioning as such (Ahuvia et al., pp. 11-12). Moreover, they also highlight the possibility that counterfeits could hurt a brand's image by decreasing the perception of rarity of its products, or by hurting their reputation for quality in cases where people unknowingly purchase a counterfeit of lower quality (pp. 9-10).

While DiDIY counterfeiting of personal goods from desirable brands may be a more realistic prospect in relation to certain branded items than others, its rise in that context does appear to be a real possibility. We now turn to considering other types of goods that might become targets for DiDIY counterfeiting.

4.5 Candidates for DiDIY counterfeiting: other types of goods

A first potential example of such other goods that comes to mind would be counterfeit medication. We have already mentioned the prospect of 3D printing drugs at home after purchasing the necessary blueprint and "ink" for the right drug from an online pharmacy. One might wonder whether this new system might make it easier for would-be counterfeiters to create their own counterfeit drugs at home, by making their own digital blueprints and/or their own "ink". If they could, this would again amplify a phenomenon that is already a worldwide problem: the World Health Organization, for instance, has estimated that counterfeits comprised 10% of the global market for pharmaceuticals (Lybecker, 2016). And counterfeits drugs do involve a form of intellectual property theft – though this may not be the most serious problem with them, since, more importantly, they also present a health hazard for the patients who use them, including death in some cases. NetNames thus writes that “while counterfeiting is a major challenge for every industry, pharma is the worst affected sector by any metric. Counterfeiters have claimed around a third of the entire market – worth some $200 billion – and are implicated in the deaths of up to one million people each year due to toxic or ineffective drugs” (NetNames, 2015, p. 4).

However, some researchers who are themselves involved in the development of those drugs have expressed scepticism about their potential to be used for DiDIY counterfeiting. Lee Cronin, from Glasgow University, thus suggests that:

> we could make sure the ink is so simple that any attempt to split it open and do things would not work. The amount made and the way it would be deployed would be on such a small scale that it would not be usable for other things. (Holmes, 2012)

Not having the relevant scientific expertise in this field, we are unable to confidently assess whether Cronin’s statement is empirically sound, or whether he might be downplaying the actual potential of his technology for counterfeiting purposes in order to help safeguard its image. However, there does seem to be some plausibility to his suggestion that 3D printed drugs would in fact help *reduce* the number of counterfeit medications available on the market, if “the blueprint could be encrypted to ensure that drugs are only produced according to a validated blueprint” (Robinson, 2015). If people could print the drugs they need at home directly from a trusted source, this would reduce the risk of getting a counterfeit that is associated with a drug’s having to go through a long and complicated distribution network before reaching the consumer (Blackstone et al., 2014).

Besides medication, a number of other potential targets for counterfeiting using digital tools (including DiDIY counterfeiting) have been cited. For instance, Gartner predicted in a report, again in 2013 and in relation to 3D printing (of all kinds, not just DiDIY): “The global automotive aftermarket parts, toy, IT and consumer product industries will report intellectual property theft worth at least $15 billion in 2016 due to 3D printing” (cited by Molitch-Hou, 2014). The toy industry would seem like a rather straightforward target, insofar as the items it sells are plastic objects that can already be replicated easily by existing digital manufacturing technology. Some CAD files for the printing of toys inspired by famous cartoons like Tintin have already been taken down websites like Thingiverse at the request of the copyright owners (Kurman and Lipson, 2014).

When it comes to industrial parts, including automobile parts, which are already frequently counterfeited by professionals, it seems less clear that many people will be interested in engaging in DiDIY counterfeiting with regards to such items. Contrary to items from desirable brands, it is mostly functionality, rather than the property of belonging to such a brand (or at least the appearance of belonging to it) that people care about in this context, in which case knockoffs or simply functionally similar parts will do the trick. Still, it is possible that in some cases one would have to violate IP rights by exactly reproducing an existing design for a replacement part, or by infringing a patent, because doing otherwise would result in a functionally inadequate part. Although the paramount ethical concern in such cases will presumably be the risk posed to users if the parts do not meet the relevant safety standards, rather than the breach of IP rights and the economic harm for the industry, the latter effect will be most relevant to this deliverable if it means that jobs will be significantly affected (e.g., lost).

Similar remarks would seem to apply to other domains like food. For instance, it is already possible to 3D print chocolate bars (Stevenson, 2016). But it is unclear what the potential is for DiDIY counterfeiting of branded chocolate bars, e.g., Mars bars. While professional counterfeiters might perhaps find it of interest to make and sell such counterfeit bars, this seems less likely to be the case of private individuals. The main way in which such bars might violate IP rights would be by having a wrapping that mimicked the original, which would infringe trademark and copyright or design rights. Perhaps someone could choose to engage in small-scale, non-professional counterfeiting of Mars bars in this way. But here again, it is unclear how much of a target audience they would have, since people who wanted to buy original bars would typically get them from shops and supermarkets, while those who simply wanted a cheaper equivalent could make it at home fully lawfully. DiDIY counterfeits of Mars bars might admittedly hold greater appeal if they were much closer to the originals than home made ones. In an extreme case, making such counterfeit bars could involve the misappropriation of a trade secret, in addition to trademark and copyright violations, assuming they were based on the brand’s stolen secret recipe. Yet as we have mentioned previously, the likelihood of such a scenario is debatable.

4.6 User-generated content, IP, and work

Besides digital fabrication, are there also cases of DiDIY that do not involve ABC, and yet infringe IP rights in a way that could have a significant impact on some professional domains? We will now briefly consider some possible candidates, and argue that they are most likely not relevant for the foreseeable future. One practice that would clearly be relevant if it were to count as DiDIY would be online piracy in all of its forms, which clearly does result in a loss of revenue and jobs for the industries that it affects. We have previously mentioned some figures pertaining to this in relation to music piracy (while indicating that they need to be taken with some caution). Websites like YouTube have been accused of facilitating this practice and of diminishing artists’ earnings, most recently in an open letter signed by various music celebrities (Holmes, 2016). However, as we have mentioned in section 2 of this deliverable, we have chosen to leave paradigmatic cases of online piracy, where someone takes an existing piece of copyrighted material such as a movie, song or video game, and illegally shares it online without otherwise modifying it, outside the scope of the present deliverable.

That said, there are also cases where original online content is actually created, not just shared, that can raise concerns about IP rights, and that also seem to count as DiDIY in more than a minimalist sense. User-generated content is one such case, and some of it does raise interesting ethical issues about IP, as illustrated by the recent controversy relating to YouTube and their policy on Fair Use: some content creators, including the owners of channels featuring humorous movie reviews that include extracts from the films they are reviewing, have launched a campaign to draw attention to what they consider an abuse of copyright claims, e.g., by large film studios, targeting their own creations, with no proper consideration for the concept of Fair Use (Gabriel, 2016).[26] However, whether or not one thinks that the concept applies to DiDIY creations of that kind, it seems unlikely that they threaten revenue and jobs in the movie industry. On the contrary, creations like user-generated videos that sarcastically comment on certain reputedly bad movies have arguably helped

26Somewhat surprisingly, an analogous controversy has also recently arisen in relation to “parodies” of Louis Vuitton handbags: see Masnick, 2016.

increase the visibility and fame of the said movies. Therefore, while there is certainly an interesting debate to be had about IP and what constitutes Fair Use, that debate does not seem to have much relevance to the impact of DiDIY on work.

Darker potential examples of DiDIY piracy include the creation of fake websites via which to sell counterfeit products (or engage in other criminal activities such as phishing), or of bogus product reviews and mobile apps. The first example is a case where piracy and counterfeiting can mutually support one another. These various activities will count as DiDIY if those engaged in them only do so occasionally and do not make a true business out of it, or if we imagine a single individual making a living by engaging in such piracy (and any related activities) entirely on his or her own. All of these are already existing facets of contemporary piracy, and as such they contribute to the piracy-related job losses that we have described in subsection 4.2.

4.7 Expected impact of DiDIY counterfeiting and piracy on the world of work

There is no doubt that the use of digital manufacturing devices by professional counterfeiters cooperating with one another, as part of organized crime networks, constitutes a large part of the additional threat that the spread of these devices poses to the industries that they target. However, we have seen that there was a real possibility that individual counterfeiters might also avail themselves of such devices by sharing digital blueprints once these had been created, and their impact on the market should not be underestimated. With regard specifically to the luxury goods industry, Sonmez writes that:

> owners of famous luxury marks must become vigilant against cottage piracy, because unlike overseas mass counterfeiting, it has an air of legitimacy, cannot be regulated by the usual borders-and-ports customs controls, is more responsive to the cottage pirate’s domestic market, and is connected globally via the borderless internet. (Sonmez, 2014, p. 762)

DiDIY counterfeiting thus does enjoy some advantages over professional counterfeiting. That said, its expected output, as compared in size with professional counterfeiting, is a matter of uncertainty. On the one hand, professional counterfeiters have more time to devote to that activity than DiDIY counterfeiters, and are also likely to have at their disposal more digital manufacturing equipment, and of superior quality. On that basis, one might expect them to be able to create counterfeits at a much faster pace and therefore in much larger quantities than DiDIYers could. However, while this will usually be true of any particular group of professional counterfeiters as compared with any single DiDIYer, it is less clear that it must also be true of professional counterfeiting compared with DiDIY counterfeiting *as a whole*. Indeed, while the output of the average individual DiDIY counterfeiter might not be particularly sizeable, the aggregate output of all DiDIY counterfeiters could be very sizeable indeed, and even surpass that of professional counterfeiters, if there were enough DiDIY counterfeiters around. In fact, the threat from “casual” counterfeiters, as opposed to professional ones, was already recognized at the end of the previous Century with the advent of two-dimensional scanners and colour laser printers, which made it easier for a broader range of people to produce counterfeit money. In 1997, a group of experts on the topic thus wrote that:

> the number of people worldwide with access to this new technology has increased dramatically. The threat posed by these casual counterfeiters is large, even assuming that each person who counterfeits makes only a small number of notes per year, simply because the number of potential offenders is very large. (Murphy et al., 1997, p. 295)

Similar remarks could apply equally to the context of counterfeiting using the new generation of digital manufacturing devices. Whether or not this will be the case depends, first, as we have said, on whether digital blueprints for commercial products will get created and illegally obtained. We have seen that no technical obstacles seemed to rule out that possibility. Secondly, it also depends on the number of items that end up falling within the scope of home manufacturing as the relevant technologies improve. If this range becomes broad enough, then it is quite possible that DiDIY counterfeiting might overtake professional counterfeiting, just as most copyright violations on the Internet are presumably committed by individual users rather than organized groups of pirates. If the range of items suitable for home manufacturing remains rather narrow, by contrast, this expectation may no longer be warranted. True, people might still have alternative avenues for manufacturing counterfeits, such as 3D printing bureaus. However, it might be easier in such a context to monitor the legal status of the files brought by customers, and to refuse them access to the equipment if they cannot prove that their file isn't the result of theft or piracy. Thirdly, there is the question whether DiDIY counterfeiting will simply complement professional counterfeiting and add to its toll on jobs (the worst-case scenario), or whether it will rather tend to take the place of the latter, in which case it might at least not make things significantly worse in this regard. This will depend on the future evolution of the demand for counterfeit goods.

We have already mentioned the existence of disagreement between experts as to the potential for home manufacturing to become mainstream in the relatively near future. It may be that the prospect of being able to easily make counterfeit goods at home will increase the appeal of devices for home manufacturing among some parts of the population. Also, if DiDIY counterfeits could compete in quality with original products, and cost less, this would clearly deal a fatal blow to many industries and to the jobs that depend on them, especially in a context where most people had the ability to make such items themselves, away from control.

On the other hand, if DiDIY counterfeiting rather turned out to be mostly similar to traditional counterfeiting, which tends to offer items at reduced prices but also of inferior quality, then it is unclear that DiDIY counterfeiting would present a greater threat to the relevant industries and jobs than current counterfeiting methods. People who sought the best quality would then still prefer to purchase original branded goods, which offered the guarantees that they wanted (Desai and Magliocca, 2014, p. 1705). True, as we have mentioned, some people will buy DiDIY counterfeits unknowingly, mistakenly assuming they are getting the real article at a bargain price. It is thus possible that DiDIY counterfeiting will increase the number of such mistaken purchases, which would also contribute to the phenomena of cannibalization and collateral damage (and ultimately to harmful effects on jobs). Nevertheless, those who really wish to avoid purchasing counterfeits will still retain the "safe" option of buying their items from a trusted website or authorized retailer.

What can we say about how the expected impact of DiDIY counterfeiting and piracy on jobs compares with that of lawful DiDIY (as discussed previously)?

- One difference is that people can in principle purchase DiDIY counterfeits without knowing that they are doing so, whereas it is unclear that this could happen with lawful DiDIY products. In other words, DiDIY counterfeiting can lead some consumers to end up unwittingly supporting a practice that they know to be harmful to employment, whereas lawful forms of DiDIY are unlikely to have that effect (as long as consumers are made aware of the negative impact of DiDIY on jobs – assuming it does have such an impact). To this we should add, first, that by definition, it is easier to control lawful forms of DiDIY than illegal ones using regulation.

- Secondly, new services like Shapeways will still employ a certain number of people (though possibly fewer than traditional retail stores and manufacturers), whereas a DiDIY counterfeiter could in principle operate alone. And even if (s)he were to collaborate with others, these people would be hobbyist counterfeiters (or pirates) and would not be doing this as a "job".
- In addition, the home manufacturing of counterfeits might also threaten more jobs than lawful home manufacturing, insofar as some forms of the latter might still require, for instance, someone to manage the websites from which the relevant goods were purchased for home manufacturing. Since this would presumably not create many jobs, however, the difference in impact might not be very significant. Similarly, the home manufacturing of objects from lawful and freely available designs need not differ significantly from home counterfeiting in its impact on jobs.

When it comes to their impact on jobs, DiDIY counterfeiting and piracy thus present certain threats that lawful forms of DiDIY do not. This does not automatically entail, however, that *overall*, DiDIY counterfeiting and piracy present a greater threat to jobs than lawful DiDIY. This will crucially depend on how widespread each of these practices turns out to become over the coming years, and on the potential of DiDIY to help create new jobs (or not). Regarding the first point, we have previously noted the studies suggesting that about 10% of the sales of clothing, footwear and accessories in the EU marketplace were counterfeits, and that as much as 2.5% of total world trade in 2013 was in counterfeit and pirated products (OHIM, 2015a, and OECD/EUIPO, 2016). It is difficult to know whether these proportions will be found again in the DiDIY context.

In light of what we have said, it is challenging to put specific numbers on the threat posed by DiDIY counterfeiting and piracy to industry revenue and jobs. We have seen in previous subsections that current counterfeiting and piracy practices, which already incorporate digital technologies to some degree, are costing thousands of jobs in European countries, based on the estimations that have been made by experts. And contrary to lawful uses of disruptive technologies, counterfeiting and piracy tend to destroy jobs without creating new ones in parallel (except for "jobs" in professional counterfeiting, which are both ethically problematic and usually unsustainable over the long term, so that no one can reasonably be expected to transition into such a "job"). We suspect that the spread of DiDIY-enabling technologies might aggravate that problem.

However, as we have tried to show in this section, the magnitude of that extra burden depends on a number of contingencies. In conclusion, while it seems reasonable to worry about the potential negative impact of DiDIY counterfeiting and piracy on jobs, it is difficult to make confident claims about the magnitude of that impact. We can say, however, that these practices are unlikely to wreck entire industries in the near future. The technologies enabling DiDIY would still need to improve before anything of the kind can happen. But the possibility of such a scenario obtaining in the longer run should be borne in mind. In the next section, we will discuss what might be ethically problematic about the possible impact of DiDIY counterfeiting and piracy on work, and what solutions would be desirable to address those potential problems.

5. Ethical issues raised by the expected impact of DiDIY on work

5.1 Is the disruptive potential of DiDIY for jobs ethically problematic?

In sections 3 and 4 we have highlighted the disruptive potential of DiDIY, in both its lawful and illegal forms, for the world of work. While, as we have noted, the predictions of different experts disagree on this issue, we see reason to take seriously the prospect that the rise of DiDIY might contribute (alongside other factors) to the disappearance of a significant number of existing jobs. In the present subsection, we will consider whether such a development should be viewed as ethically problematic, if it were to materialize.

At first sight, it might seem cynical, even unreasonable, to ask such a question. Isn't it obvious that the loss of many jobs would be a cause for ethical concern, calling for action to remedy it? However, we should remember that there is a difference between DiDIY causing some jobs to disappear, and it resulting in a *net* reduction in the total number of jobs available. Indeed, the former effect is compatible with DiDIY *promoting* job growth overall, if it simultaneously leads to the creation of a greater number of new jobs than it destroyed. And while we should certainly feel sympathy for the hardships faced by people, if there are any, who might lose their jobs and be unable to find a new one (in cases where, say, new jobs went to other, previously unemployed people, rather than to those who had been made redundant by DiDIY), and while such people should certainly be offered appropriate assistance (financial and otherwise), there is no plausible ethical justification for privileging the interests of a currently employed worker who might get harmed by DiDIY, over those of a currently unemployed person who might benefit from it. On that basis, it seems to us that the impact of DiDIY will clearly be of concern only assuming that its net effect is harmful to workers. The most straightforward way this could be the case would be if the spread of DiDIY resulted in a higher level of unemployment, and if this effect were durable (and not just a minor blip followed by significant job growth). Such a development could bring more people into economic hardship, and even foster social unrest.

Another way in which DiDIY could have an overall negative impact on workers would be if it resulted in reduced earnings for certain people without any compensating beneficial effect. This would for instance be the case if the popularity of DiDIY design and manufacturing led some engineers to lose their jobs and forced them to move into new occupations that paid less, without causing anybody else (say, in a lower-income occupation) to now earn more. It is not simple to cash out what counts as a "compensating beneficial effect". Indeed, this will arguably depend on one's particular views about distributive justice. A classical utilitarian, for instance, will judge that DiDIY does have such a compensating effect if it leads to a higher *total* amount of earnings in a given country, regardless of the *distribution* of those earnings, i.e., even if this means that the rich have gotten richer and the poor poorer (provided that the gain for the rich is larger than the loss for the poor). However, many of us would find this objectionable, because we believe that the way earnings are distributed does in fact matter. For instance, we might think that if employees working in retail stores see their wages reduced, while Fortune 500 CEOs increase their own earnings to an even greater degree, the benefit to the latter will not count as adequately compensating the loss to the former, because those who get harmed in this scenario are much worse off financially than those who benefit. By contrast, we might view even a significant reduction in the wages of Fortune 500 CEOs as adequately compensated, from the perspective of distributive justice, by a sufficiently significant rise in the earnings of workers in lower-income jobs. Of course, there might be further complications, insofar as a reduction in the earnings of "top dogs" might indirectly harm less privileged workers (e.g., if it diminished the incentive to innovate and create new jobs). We do not wish to delve more into such complications here, but simply hope to have thrown some light on this notion of a compensating beneficial effect.

Let us note, however, that even if we could foresee that DiDIY could lead to reduced earnings for some workers without such a compensating beneficial effect, it is not clear that it would automatically justify the adoption of political measures to either prevent that harm from occurring, or to compensate those who would suffer it (despite the fact that the harm would certainly count as a socially undesirable consequence). If some people become chronically unemployed due to the evolution of work and society, it is commonly assumed that something needs to be done to help them – whether by assisting them in finding a new job, possibly by providing them with further training, or otherwise by securing (at least temporarily) an unconditional income that will allow them to meet their core needs, as illustrated by the recent proposals for a guaranteed minimum income in response to growing impact of digital technology and automation. Yet if some people simply see a reduction in their earnings, then the societal response will usually be: "too bad for you, but that's just life. The world changes as technology advances, and these changes always create winners and losers – the latter simply need to suck it up and adapt".

We believe that such a response is inadequate in the case of low wage workers, for whom a loss of earnings might have really serious consequences that would warrant remedying action, but that it does seem adequate if applied to workers who were making a comfortable (or more than comfortable) income to begin with, provided that their loss of income were not so large as to end up leaving them in a difficult financial situation. By way of illustration, we can presume that the members of the management of Lycos, the company that produced one of the most popular search engines and web portals of the 1990s, earned higher salaries when the company was at its peak at the turn of the millennium than they do now, with the rapid transformation of the internet and the dominance of Google. Nevertheless, few would argue that society ought to have taken steps to prevent this transformation, to ensure that nobody who was doing well in the late 1990s would ever lose out, or that the current management of Lycos deserves some form of financial compensation from society for the diminution in their income over the past few years.

Could the sheer fact of having to *transfer* to a new job be harmful to some workers, in a way that would warrant our concern? The answer seems to be yes, if we are talking about workers who find such a transfer challenging and cannot complete it successfully without extra assistance. On the other hand, if we are talking about people who, say, simply preferred their initial job, even though it didn't pay more, it is less clear that we are then dealing with a matter of ethical concern that would call for political action. Even though we can again sympathize with the discomfort experienced by workers who, while remaining consistently employed, no longer enjoy job and skills stability, perhaps it is nevertheless reasonable to expect them to show the flexibility that the modern world requires. In this deliverable, we will confine our discussion to less controversial cases of harm to workers (involving either job loss or reduced earnings).

As we have seen in section 3, certain groups of workers are particularly at risk from the harms we have just described, and the fact that these are vulnerable social groups, with a history of disadvantages in various areas, does seem to make this of particular ethical concern. The first of these groups is women: recall Moore's concerns about women in the fashion manufacturing and retail industries across the world, and the WEF's report, whose authors expect women to be affected by the job losses resulting from the Fourth Industrial Revolution to a greater degree than men (even though the developments they discuss go beyond DiDIY). The crucial issue here is that women are still underrepresented in STEM fields, where as we have said many if not most of the new jobs created by these disruptive developments are likely to be found. The second at-risk group includes the citizens of developing countries, where many jobs in manufacturing and shipping could be lost if DiDIY contributes, as it is expected to do, to a shift to local manufacturing. China is reported to have lost 16 million manufacturing jobs (a decline of 15%) between 1995 and 2002, due to the influence of automation (Worstall, 2012), and DiDIY could reinforce that trend.

So far, we have focused on the potential negative impact of DiDIY on employment as a relevant ethical concern. However, it is necessary to recall the various benefits that DiDIY could also bring, including some that would not only be the fruits of DiDIY, but of its actual impact on the work context. One example of such a benefit would be environmental: a shift towards local manufacturing, while posing a threat for a certain number of jobs, would also eliminate or at least reduce the need to transport goods from distant countries, thereby helping limit greenhouse gas emissions (a crucial goal for most societies today given the current threat of global climate change). A second potential example would be available if DiDIY were actually to help create more jobs than it destroyed. A third example is provided by one of the main results in WP3, namely the fact that DiDIYers can be occupied individuals, who exploit a DiDIY mindset in at least two ways:

- to improve their job by enriching their job description with activities normally performed by specialists (inside or outside their own company): this is the case of workers in manufacturing firms, able to create prototypes of products innovation; and the case of clinical professionals, using 3D printed bones to improve the diagnostic process;
- to create a second job, in parallel with their main activity: this is the case of networkers, who almost always begin to carry out network marketing as a source of extra-wage, but then this activity can become the prevalent one.

To this should be added the various other potential benefits of DiDIY that are not fundamentally tied to its transformative impact on work: these include a greater ability to customize products and possibly lower prices for consumers, various benefits for developing countries such as the ability to create prosthetic limbs and basic medical supplies faster and at a lesser cost (Ishengoma and Mtaho, 2014), and all the other advantages that have been detailed in other deliverables for this project, such as D3.1. When seeking to forestall the potential negative effects of DiDIY on employment, we therefore need to balance them against its possible benefits, and seek solutions that will, as much as possible, prevent the former while still allowing the latter to obtain. We will now take a look at what such solutions might be.

5.2 Possible measures to try and stave off the negative impact of lawful DiDIY on jobs

The main potential threat from DiDIY in the context of work that we have highlighted in this deliverable is its contribution to technological unemployment. We have mentioned the empirical uncertainty surrounding that contribution. From this, it would be natural to infer that the possible measures we will consider in what follows (some of which we will endorse, while rejecting others as misguided) will be conditional upon specific, and contentious, empirical assumptions. This is true, but only to a degree. As we will see, while some of the ideas we will discuss will indeed become irrelevant if DiDIY turns out not to have detrimental effects on employment, others will remain desirable regardless of how things turn out in this regard – we will be stressing when that is the case. In what follows we take as our basis existing ideas regarding how to address the problem of technological unemployment, including the interesting analysis by Gary E. Marchant and colleagues in their 2014 paper “Technology, Unemployment, & Policy Options: Navigating the Transition to a Better World” (Marchant et al., 2014), and bring them to bear on the issue of *lawful* DiDIY and employment (we save the discussion of how to deal with *illegal* forms of DiDIY for the next subsection).

(1) First, if we feared that DiDIY would have an overall harmful impact on jobs, we could try to limit its spread. One way of doing this would be to enforce policies restricting technological innovation, e.g., to prevent or delay the arrival of DiDIY tools like 3D printers that allowed people to make many of the goods they needed at home. This option strikes us as highly undesirable. Indeed, it would involve simply forfeiting the many potential future benefits of DiDIY, rather than looking for ways to secure them at an acceptable cost, as we have suggested we should do. Furthermore, for that strategy to work, it would have to be implemented in advance, before clear evidence emerged of the harmful impact of DiDIY on jobs, which means that it might actually end up countering a purely imaginary threat. And finally, the sheer political feasibility of stifling the research and development activities of technology firms is questionable. Not only would full compliance by those firms be difficult to secure, but politicians would be unlikely to support policies that might cause their nation to fall behind on the global marketplace.

(2) Another way of trying to limit the spread of DiDIY would involve allowing technological innovation to proceed, but discouraging the use of DiDIY tools or of services like 3D printing bureaus by taxing them more or less heavily (we will leave out the idea of an outright ban, which seems both excessive and politically unrealistic). Another possible disincentive would involve outlawing *all* acts of copying a commercial product using DiDIY techniques like 3D scanning and digital fabrication, even for personal, non-commercial purposes. This general proposal is admittedly more defensible than the previous one. It would be possible to wait until clear signs that DiDIY was destroying jobs became available, before implementing it, thereby avoiding the risk of an overreaction. Also, the advantage of a taxation scheme of the kind just alluded to would be that it would help support those who had lost their jobs (and whom society arguably has an ethical duty to support), either via unemployment benefits or retraining programs (or both). However, this solution would still share the disadvantage of stifling, to a greater or lesser degree (depending on how heavy the putative taxes would be) the potential benefits of DiDIY for the sake of artificially preserving certain professional sectors. Alternative solutions that allowed to secure those benefits without imposing excessive costs therefore seem preferable, assuming any are available. And the political feasibility of such a proposal is still questionable, for instance because it would often require a given country to impose financial disincentives on DiDIY tools and services for the sake of preserving manufacturing jobs in *another* country. Given that the respective interests of the two countries involved might not necessarily coincide, we cannot automatically assume that different countries would be willing to cooperate to implement such a solution. Finally, the prohibition of the DiDIY copying of commercial products for personal use would seem difficult to enforce. Still, this general approach should be kept in mind in case alternative measures did not prove sufficient.

A different type of option considered by Marchant and colleagues involves sharing work: instances of this include having a shorter work week, or more vacation time (Marchant et al., 2014). Yet it seems that such solutions would be most suitable for workers in the highest income brackets, who are least at risk of losing their jobs due to phenomena like DiDIY. The workers most at risk will, on the contrary, tend to be found in much lower-earning occupations, which means that this type of solution might not be workable for them in the absence of additional financial support.

The introduction of such financial support is precisely a growing object of debate today, with more and more people supporting the idea of a guaranteed basic income as an answer to the rising tide of automation created by improvements in machine intelligence (see e.g., Dubner, 2016; Kim, 2016). While the time to implement such an idea has arguably not yet come, it nevertheless seems to be one of the most promising proposals for dealing with technological unemployment, whether DiDIY-related or not, and could be used in conjunction with some of the other measures that we have already cited.

(3) Finally, as we have previously mentioned, the disruptive impact of DiDIY could also harm some workers not by resulting in fewer jobs being available, but rather by forcing those workers to effect a transition to other jobs that they might not be able to effect, at least not without assistance. The main preventive measure that has been proposed to address this issue in relation to automation involves promoting education, particularly in STEM fields (Brynjolfsson and Macafee, 2014; Marchant et al., 2014). As we have said, this might be of special importance with regards to certain groups like women – and in our deliverable on DiDIY in education and research, we will consider how the introduction of DiDIY into the school curriculum might potentially help get more women interested in STEM subjects.[27] If it can, this means that DiDIY has the potential to pre-empt some of its own potential negative effects on the workforce. The main advantage of such a solution is that it appears desirable regardless of the presence or absence of those negative effects, because even if DiDIY (and automation) end up creating more jobs than they destroy, many future jobs are expected to require advanced STEM literacy. Facilitating lifelong education and skills upgrading among workers who need to transition into a new occupation will also be crucial.

5.3 Possible measures to try and stave off the negative impact of DiDIY counterfeiting and piracy on jobs

When it comes to the prevention of DiDIY counterfeiting and piracy (which would in turn prevent their harmful impact on jobs), a variety of suggestions have already been made by experts in relation – again! – to 3D printing, and most of them are also relevant to other DiDIY tools.

(1) A first option that might come to mind would be for companies selling digital designs for printable goods (or goods otherwise suitable for DiDIY manufacturing) to impose some form of digital rights management (DRM) protection scheme on their files, as has often been done with music files and e-books sold online. A few years ago, US company Intellectual Ventures thus patented a system allowing a 3D printer "to assess whether a computer design file it's reading has an authorisation code appended that grants access for printing" (Marks, 2012). We are not persuaded that such an option holds much appeal, however, insofar as DRM has so far been largely ineffective at preventing piracy (Wiens, 2015). For that reason, as we have previously indicated, we

27Marchant and colleagues also suggest the possibility of greater educational experimentation, which includes some forms of DiDIY such as MOOCs (Marchant et al., 2014).

are inclined to think that companies which are not prepared to let their digital designs be widely shared online are unlikely to ever allow their customers to download such designs on their own computers – unless some new, much more secure form of DRM could be created. A more likely scenario would for instance involve data being sent directly from a company's website to a DiDIY tool like a 3D printer after purchase.

(2) We have also mentioned that "official" digital blueprints could also be obtained through theft, e.g., by a company's employee or by a hacker. In response to that possibility, David Martinez and colleagues suggest "securing CAD files behind industry-standard security measures such as comprehensive firewalls, up-to-date antivirus and monitoring software, penetration testing, limiting access to certain employees, and strict vetting of employees with access" (Martinez et al., 2016). While such measures seem perfectly appropriate in that context, they nevertheless cannot deal with DiDIY counterfeits produced by scanning existing branded products. For that purpose, other solutions are needed.

(3) Martinez and colleagues mention that "E-commerce companies [eBay, Shapeways or Etsy would be relevant examples] should also make sure they have robust takedown procedures that allow brand owners to report counterfeit listings" (*ibid.*). To some degree, this is already the case – even though it might be argued that improvements are still needed. For instance, Sonmez explains that Shapeways, "like most internet intermediaries dealing with potentially copyright-infringing work, implements a Notice and Take Down Policy modeled on the DMCA". Yet:

> exactly like Etsy... Shapeways's notification system follows the DMCA's reporting steps exactly, and requires that the owner of the intellectual property being infringed sign or authorizes the notification. This leaves the would-be independent reporter with no direct means to alert the company to infringing items it is hosting on its site. (Sonmez, 2014, p. 785)

Another potential challenge here concerns how to identify IPR-infringing items. Such items could either be CAD files or completed products. Taking CAD files first, Martinez and colleagues suggest that:

> E-commerce companies can proactively work with brand owners to monitor online communities that share CAD blueprints and incorporate the relevant data into existing algorithms used to flag suspicious listings. For example, a blueprint that has been downloaded many times may prompt the marketplace to flag for review the corresponding product on the marketplace. (Martinez et al., 2016)

The relevant online communities could either be ones where CAD blueprints were sold commercially, or where they were shared for free (like Thingiverse). Based on what we said before, it seems that blueprints that were being distributed for free would only infringe IPRs if they had been stolen from their rightful owners, of if they were unauthorized copies of copyright-protected files. Monitoring such large communities, however, would seem like a rather challenging task: Thingiverse alone boasts more than one million uploads since 2015 (Lelinwalla, 2015), and this number is only set to rise in the coming years. Singling out all popular blueprints for special review would still leave a large number of files to examine. That said, some technological tools might help with this task. For instance, perhaps it might be possible to create software that would scan the

CAD files on those online platforms, and then compare each of them against a database of copyrighted files – and which would include both files that had previously been identified online as violating IPRs, and files that had been sent preventively by copyright holders. If an uploaded file matched one of those in the database, a takedown notice could be issued automatically. Perhaps the software could even prevent incriminating files from being uploaded in the first place, by subjecting them to a check prior to approval.

Of course, what particular files would end up in that database would be an ethically important issue. Such a file-checking system might be legitimate if it confined itself to identifying copyright-infringing CAD files, but it would no longer be so if it got abused – for instance, if copyright holders used it to block the distribution of files that infringed no IPRs but that they found inconvenient for any reason, or if legally unproblematic files were included into the "protected" database on the grounds that someone had incorrectly reported them for IPR infringement, and this claim had not been properly checked before inclusion. Monitoring of the use of that database by an independent watchdog to ensure that it was not abused would therefore be crucial.

Clearly, such measures cannot be expected to provide a foolproof protection against the illegal distribution of CAD files online. Among other things, while it might be possible to get websites like eBay or Thingiverse to adopt such a scanning system, sites like the Pirate Bay, which are known to host a significant number of copyright-infringing files, might be less likely to cooperate. Still, a system of the sort just described would at least help contain DiDIY piracy to some degree.

Physical DiDIY counterfeits also present a challenge when it comes to identification, since as we have said, they could replicate the original goods after which they were modelled even more closely than existing counterfeits tend to do. In addition to people having the option to purchase goods from trusted sources like official retail or online stores, technology offers again potential means of telling original items from DiDIY counterfeits. In particular, it has been suggested that original products suitable for digital fabrication could be *marked* using new, high precision methods that would authenticate them in a manner that would be virtually impossible for counterfeiters to imitate. The methods in question are varied. One example is chemical tagging, which involves adding a small, subsurface "chemical fingerprint" when making a particular item, an identifier that could then be detected using a handheld spectrometer (Molitch-Hou, 2015; Grunewald, 2016a). Another, somewhat similar example is DNA marking: as John Hornick describes it, "this technology, developed by a Stony Brook, New York company called Applied DNA Sciences, uses plant DNA to mark genuine products with visible or invisible signatures that, when screened, identify the product as genuine". He adds that "products could be screened by authorized fabricators (or licensed verifiers) to verify their authenticity, or maybe by consumers with a smart phone app" (Hornick, 2014). Other, analogous marking methods have been proposed.

Again, no matter how interesting such possible technological solutions might be, it would be unreasonable to expect them to keep DiDIY counterfeiting and piracy completely at bay, if only because some people knowingly choose to purchase counterfeit and pirated goods, and would therefore not be deterred by the discovery that some item lacked the relevant mark of authenticity. Still, adopting such solutions might be warranted if it allows to significantly curb the extent of DiDIY counterfeiting and piracy, and thereby protect the jobs that would come under threat if we didn't implement them.

6. Conclusion

As we have highlighted at the beginning, the present deliverable has been focusing primarily on the anticipated impact on work from DiDIY in the narrower sense entailing ABC and the manufacturing of physical objects. This is partly because of the need to limit the scope of this deliverable, and partly because that aspect of DiDIY was the one that struck us as presenting the most salient ethical issues. Nonetheless, we do not mean to imply here that forms of DiDIY that do not involve ABC and digital fabrication do not raise interesting issues in relation to their impact on work. We have touched on some of them, but we do not rule out the possibility that there might be much more to say on this other facet of DiDIY, which might represent a promising avenue of future work for those interested in these issues.

When it comes to the aspect of DiDIY that we have been focusing on, our view is that this technological and social development, in both its lawful and illegal forms and at both the individual and group level, does raise legitimate concerns about the way it might reshape jobs, including the threat of technological unemployment. However, its potential harmful effects on work are still mostly speculative at the present stage. Whether or not they will materialize depends on a number of contingent factors, including the pace of technological development, the breadth of adoption of home DiDIY manufacturing, the quality and cost of future DiDIY products, and the effectiveness of the strategies that might be implemented to protect IPRs. Depending on how things pan out, it is possible that the net effect of DiDIY on employment might actually be a positive one. There is therefore a significant amount of uncertainty regarding the future impact of DiDIY in this context, and as we have mentioned, we are not aware of any quantitative expert estimates of that impact (as distinct from that of related disruptive developments, such as machine intelligence and automation).

In light of that uncertainty, we think it is important to avoid overreacting to any potential risks when crafting public policy about DiDIY. While this phenomenon does appear set to significantly transform work, this transformation need not be an undesirable one. We have mentioned some of the various benefits that the introduction of (lawful) DiDIY in the work context could bring, including environmental ones. For the time being, these prospective benefits give us a reason to encourage, rather than contain or thwart, that development. Furthermore, promoting STEM literacy, including among members of under-represented groups like women, is arguably a policy measure worth implementing right now, given the expected contours of the job landscape as described by experts for the coming decades. We have seen that the introduction of DiDIY activities in the school curriculum constitutes one tool worth considering for that purpose (an issue discussed in greater detail in other deliverables for this project, including D4.6). We have also described some of the other measures that might be adopted to counter any negative effects of DiDIY on employment. The key will be not to adopt such measures prematurely, but only after ascertaining that the latest available evidence, as well as a careful analysis of the foreseeable costs and benefits, warrant doing so.

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