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Making (in) the Smart City: Urban Makerspaces for Commons-Based Peer Production in Innovation, Education and Community-Building

VASILEIOS NIAROS

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TALLINN UNIVERSITY OF TECHNOLOGY
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Ragnar Nurkse School of Innovation and Governance
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Supervisors: Professor Dr. Dr. h.c. Wolfgang Drechsler, Tallinn University of Technology, Estonia

Dr. Vasilis Kostakis, Tallinn University of Technology, Estonia

Opponents: Professor Dr. Tere Vadén, University of Tampere, Finland

Dr. Panayotis Antoniadis, ETH Zurich / NetHood, Switzerland

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Declaration:

Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology has not been submitted for any other degree or examination.

/Vasileios Niaros/

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PREFACE

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INTRODUCTION

1. Scope and Aim

1.1. Critique on the "smart city"

Urbanization is a trend of our times that is beyond dispute, with the largest share of the human population globally already living in cities; a trend that is only increasing (United Nations, 2014). Cities are economic centers that through the consumption of massive resources lead to heavy environmental impact (Glaeser, 2011) as well as to social contestations and conflicts (Foster & Iaione, 2016). This creates the need for new conceptualizations for a city that will be able to deal with the current issues in more imaginative, inclusive and sustainable ways.

In this context, the term "smart city" has emerged. This concept, however, is vague to say the least, since there is neither a single template of framing it nor a one-size-fits-all definition (for a discussion on the definitions, see Albino et al., 2015). The dominant narrative hails from those private enterprises which produce advanced information and communication technologies (ICTs); it has largely been embraced by local governments and advocates of technology solutionism (**I**). The "smart city" idea has crystallized into an image of a technology-led urban utopia permeated with centrally controlled technological infrastructures, with the aim to improve the urban environment in terms of efficiency, security and sustainability (**I**, **V**).

By employing an often linear, overly techno-deterministic approach to the uses of ICTs, governments have been looking into how cities might improve urban economies and quality of life (**I**). This has led to a growing role of commercial activities through firms, such as Cisco Systems, IBM and Siemens, which promote themselves as "stakeholders" in the public consultation processes (Hollands, 2015; **I**). These large ICT powerhouses, having made massive investments, are the major companies involved in the smart city and the Internet of Things (IoT) cluster of technology. For example, in 2015 IBM announced an investment of US$3 billion over the next four years to establish a new IoT unit (Shumaker, 2015). Of course, their goal is not just to stumble upon the needs of "actually existing smart cities" but, rather, to create a new market and shape it in certain ways (Shelton et al., 2015; **I**).

Popular examples of smart cities are Songdo (South Korea), Masdar (United Arab Emirates) and PlanIT Valley (Portugal). These cities have been built from scratch through public-private partnerships in places with no former residency or infrastructure (Carvalho, 2015). Amongst others, IBM and Cisco Systems have been involved in these initiatives on a large scale by providing their products and services. Through the installation of countless wireless sensors and the utilization of the IoT, the networked technologies installed usually target better energy and garbage management; reduced water consumption; improvements to citizen mobility; and crime prevention (Albino et al., 2015). Such developments have been pursued elsewhere as well by many ICT corporations, and it is highly probable to see them expanding in the years to come.

Nevertheless, the aforementioned practices have drawn some serious criticism during the last few years. For instance, it has been argued that the notion of problem-solving ICTs does not acknowledge the needs and desires of actual city-dwellers, mainly because they are not attuned to the ways that people use technology (Sassen, 2012; **V**). Also, issues related to privacy and citizen participation are often raised (Carvalho, 2015; Kitchin, 2014). Further, Hollands (2015) claims that the unrestrained deployment of these technologies is shaped around the motives of suppliers, i.e. the commodification of their existing products and services. Therefore, an environmentally harmful consumption of ICTs increases without serving the true needs of the citizens or even addressing actual problems (**I**). It is therefore evident that this standard conceptualization of the smart city is troublesome, primarily due to issues embedded in the design and implementation of the technological infrastructure (**I**, **V**).

From the perspective of critical theory, as will later be explained in more detail, the social scientist should not only address the problematic nature of the current social reality, but also identify transformative actors and present practical goals for social change (Held, 1980/2004). Hence, in this thesis, the criticism on the smart city is used as a point of departure to highlight the potential of an emerging form of social organization in relation to urban developments. The mode of choice is that of commons-based peer production (CBPP) which, it is hoped, will enable human beings to become "producers of their own historical form of life" (Horkheimer, 1993, p. 21).

1.2. Commons-based peer production in a nutshell

To begin with, plenty of attention has been gathering around the commons, a term that refers to shared resources where each stakeholder has an equal interest (Ostrom, 1990). The commons sphere can include natural gifts, such as air, water, the oceans and wildlife, and shared "assets" or creative work, like the Internet, the airwaves, languages, our cultural heritage and public knowledge, which have been accumulating since time immemorial (Bollier, 2005, 2009). Also, the commons might simultaneously refer to shared resources, a discourse, a new/old property framework, social processes and relations or an ethic (Bollier, 2014).

During the last two decades, the rapid reduction of transaction and coordination costs through modern ICTs has created conditions for a commons-oriented form of value creation based on the collaborative efforts of physically dispersed but digitally interconnected individuals (**II**, **III**). Initiatives such as the free encyclopaedia Wikipedia and a myriad of free/open-source software projects exemplify such an emerging mode of grassroots production, named "commons-based peer production" (Benkler, 2006). In CBPP, open technological infrastructures allow individuals to communicate, self-organize, and therefore, to create value together without obtaining permissions (Bauwens, 2005; Benkler, 2006; **III**). Furthermore, there are several cases of open-hardware initiatives, such as the Open Source Ecology, the RepRap and the Wikispeed projects, which are indicative of the potential of CBPP movement for manufacturing (**III**).

In a nutshell, CBPP has three key characteristics that distinguish it from traditional capitalist practices: (a) the decentralization of the conception of problems and the execution of solutions; (b) the diversity of participants' motivations; and (c) the decoupling of governance from private property and contract (Benkler, 2015; **III**). These characteristics make CBPP agile enough to adapt to complex environments (Benkler, 2015) and provide the capacity to deliver innovative software and hardware artefacts, while participants in such projects are being intrinsically motivated (Benkler, 2006; **I**, **III**).

Of course, there might be several negative aspects of CBPP (Kostakis et al., 2013), but altogether, this proto-mode of social production arguably pushes for a political economy where economic efficiency, profit and competitiveness assume secondary and, ultimately, no role (Moore & Karatzogianni, 2009), and civil society is uplifted by bringing the commons back into the center of the economy (Orsi, 2009). Therefore, the commons could be seen as a legitimate vehicle of citizenship, through which citizens mobilize and express their interests while protecting and enhancing their rights (MacKinnon, 2012).

1.3. The right to the city and makerspaces

In light of the new information space created with the help of ICTs in urban environments (Antoniadis & Apostol, 2014), this thesis will argue that CBPP could also be viewed as a creative manifestation of the "right to the city" concept. This phrase was introduced by Lefebvre (1968), and since then it has become quite popular, taking on a variety of meanings in the process (Gorgens & van Donk, 2011; de Souza, 2010). The current research project is in line with Harvey's description of the concept, which could be summarized within the following passage:

> The right to the city is far more than the individual liberty to access urban resources: it is a right to change ourselves by changing the city. It is, moreover, a common rather than an individual right since this transformation inevitably depends upon the exercise of a collective power to reshape the processes of urbanization. The freedom to make and remake our cities and ourselves is, I want to argue, one of the most precious yet most neglected of our human rights (Harvey, 2008, p. 23).

The struggle for this freedom can be observed not only in a myriad of citizen-driven efforts to reclaim, protect and revitalize physical urban commons (squares, parks, vacant lots, cultural institutions etc) which are often threatened by privatization, but also in urban grassroots initiatives which are protecting, promoting and creating new commons, such as do-it-yourself or do-it-with-others communities (Antoniadis & Apostol, 2014; Garrett & Catlow, 2012), hackerspaces, co-working spaces etc (**II**, **III**).

This thesis discusses the right to the city by focusing on the concept of urban "makerspaces", i.e., community-led, open spaces where individuals meet on a regular basis to collaboratively engage in creative commons-based projects, usually utilizing open-source software and hardware technologies (**II**, **III**). Through the intersection of digital technologies and urban life, several initiatives have emerged that attempt to circumvent the dependence on private firms or governments to provide solutions. They produce their own solutions in co-working places, which may go by various names like microfactories, hackerspaces, fablabs or media labs and others (**III**). In this thesis, some of these terms will be employed at several stages, but the term "makerspace" will be used as an umbrella for all of them.

Individuals of varying backgrounds and goals have access to prototyping tools in makerspaces, allowing them to collaborate in order to produce small-scale solutions for problems of daily life (**I**). Hence, this thesis will attempt to demonstrate how in the context of the makerspace the city can become a commons-based "living lab" (Bergvall-Kareborn & Stahlbrost, 2009; von Hippel, 1986), where social value is produced that is geared towards addressing problems of citizens by using citizens who engage in the research, design and testing of solutions (Hardt & Negri, 2011; Hemment & Townsend, 2013; **II**). In other words, it will be described how citizens, nowadays, creatively exercise their right for a human-centric, inclusive, responsive and sustainable smart city. The next section discusses in more detail the perspective, objective, methodology and structure of the thesis.

1.4. Approach: Perspective, objective, methodology and structure

When conducting research in the social sciences, it is important to have an unambiguous and robust philosophical underpinning to support the validity of the work and provide ethical guidance for the researcher. According to Max Horkheimer (1937a/2002a), a leading figure of the Frankfurt school and a key proponent of critical theory, knowledge is not only capable of altering society but it also ought to do so. To put it in his own eloquent terms: "When an active individual of sound common sense perceives the sordid state of the world, desire to change it becomes the guiding principle by which he organizes given facts and shapes them into a theory" (Horkheimer, 1937b/2002b, p. 162).

Therefore, theory (and research) should be critical and work towards the liberation of society (Held, 1980/2004). According to this line of thought, the role of research is to accommodate change in social relations in order to eliminate oppression, and knowledge can alter both the researcher and the subject of research in the empirical world (Orlikowski & Baroudi, 1991). Research that is conducted through the lens of critical theory has critique as its basis, aiming to alter power structures in society and enhance awareness (Patton, 2008). Critique examines both what action is being taken, but also what are the reasons for action (Budd, 2008). So in other words, critical theory makes political research possible by connecting theory and action through the appropriate philosophy and methodology (Patton, 2008).

Based on this perception, this thesis is undertaken within the critical-theory paradigm, since it is clearly political and its ultimate goal is not to preserve the current societal structure, but rather to contribute to its transformation. This project will attempt to bring to the fore issues of current social reality; to identify practices that might be able to change it; and to engage in critique that could potentially lead to social transformation in a practical way. In essence, this research project will attempt to dialectically study the intersection of urban developments, technology and society. The main research objective is thus to explore the community-building, innovation and learning potential of makerspaces, i.e. an emerging civic infrastructure, towards a commons-oriented smart city. It should be emphasized that this thesis looks for insights, and the connection to improvement is crucial in the framework chosen.

Critical research can utilize all available research methods, since it is how the knowledge and research results are interpreted within the paradigm that makes it critical, and not the methods used (Carspecken, 2008). This research project will follow a social-science approach carefully informed and cautioned by Bent Flyvbjerg's methodological views. Flyvbjerg (2001), in his seminal book *Making Social Science Matter*, demands a mode of social inquiry which would try to bridge theory and practice in a way that unites philosophical and empirical subdivisions in the social sciences. The methodology of the thesis is thus rooted in qualitative research methodologies, namely the case study as well as the participatory-action research approaches informed by both primary (i.e. conduct field research) and secondary (i.e. literature review) research. It is expected from such a study to develop our partial answers to the research questions, which would be "input to the ongoing social dialogue about the problems and risks we face and how things may be done differently" (Flyvbjerg, 2001, p. 61).

The thesis comprises five original articles which shed light on a micro, meso and macro level of the "makerspace". **I**, **III** and **V** are desk-research papers which, by involving a summary of existing literature, offer a synthetic overview of four different types of the smart city dependent on the dominant technology-governance model (macro level: networks of makerspaces). In particular, **III** discusses in more detail commons-oriented models of social organization which involve the makerspace concept. **II** employs the case-study method and examines selected cases of makerspaces with the aim to better understand their community-driven governance models (meso level: the makerspace as a unit). **IV** reports a participatory-action research project which took place in the context of a Greek-based makerspace (micro level: a project of a makerspace).

The remaining introductory part of the thesis develops as follows. Section 2 discusses the concept of makerspace by providing a short historical account and discussing its role as a "third place" (Oldenburg, 1989, 1991). Section 3 is then set to explore the community-building, innovation and learning potential of makerspaces, considering them as hubs and vehicles for citizen-driven transformation. Section 4, finally, summarizes the main findings and arguments of the thesis.

2. A Historical Account of Makerspaces

Makerspaces, hackerspaces, fablabs are in flux: there is no single definition that perfectly captures all such spaces (Sleigh et al., 2015; Smith et al., 2015). It might be useful to keep in mind that this thesis departs from a rather simple and inclusive definition, using the term "makerspaces" as an umbrella for community-run physical places where people can utilize desktop manufacturing technologies (**II**, **III**). It should be noted that anything from three-dimensional (3D) printers or laser cutters (i.e. hi-techs) to simple cutting tools or screwdrivers (i.e. low-techs) can be considered desktop manufacturing technologies. This broad definition of the makerspace concept does not imply that, for example, every media lab or microfactory is necessarily a makerspace, because the former might not meet one of the following criteria. The makerspace term is adopted here because, normatively speaking, it is welcoming and inclusive (Smith et al., 2015) as well as related, but not limited, to manufacturing, a diverse sector that promotes innovation and productivity (Reinert, 2011). This definition introduces two basic criteria that qualify a space as a makerspace: first, to exercise community-based forms of governance; second, to utilize desktop manufacturing technologies. A bird's-eye view of the history of the concept may shed light on it and justify the choice of these two criteria, which are also addressed in sections 3 and 4.

In the beginning, there was the hacker, a controversial term that is only now entering mainstream usage (Smith et al., 2015; **II**). The connotation depends on the community still, and in general parlance the term is associated with doing something bad and/or illegal, whereas now this is changing. There are various types of hackers: the benevolent, white-hat hacker, who, in Wark's (2004, 2013) and Levy's (2001) vein, experiments, tinkers, modifies, creates and/or participates in collaborative projects. There also is the malicious, black-hat hacker (also known as cracker), who has criminal intentions, causes damage and carries out criminal acts (Kostakis, 2012). Then there is the grey-hat hacker who tends to hold a morally ambiguous role (Parker, 2005). For example, a benevolent, white-hat hacker would upgrade the functions of a wireless router's firmware with updates other than those that have been signed by the device's manufacturer; modify a sampling keyboard to create unusual sounds by doing circuit bending; or transform the plastic 500cc bottle into a spacer for asthma medications.

In this thesis, hacking is understood as a creative process, immersed in the hacker ethic of problem-solving (Erickson, 2008) as well as of producing novel artefacts (Söderberg, 2007; Wark, 2004). According to several scholars (Dafermos & Söderberg, 2009; Himanen, 2001; Levy, 2001; Maxigas, 2012; Söderberg, 2007; Thomas, 2002; Wark, 2004, 2013; **II**) who have taken a close look at the phenomenon, fundamental aspects of the hacker ethic include freedom, in the sense of autonomy as well as of free access and circulation of information; distrust of authority, that is, opposing the traditional, industrial top-down style of organization; embracing the concept of learning by doing and peer-to-peer (P2P) learning processes as opposed to formal modes of learning; sharing, solidarity and cooperation.

The hacker subculture appeared in the 1960s and took off in the 1970s from the MIT Artificial Intelligence Laboratory and other research institutes in the US, as well as from the phreaker scene through the magazine TAP (Technological American Party) (Maxigas, 2012). The hacker ethic is further considered to share some common characteristics with the hippie culture, dating back to the 1950s and 1960s and evolving over the decades through different generations (Hogge, 2011; Levy, 2001) and socio-economic transformations (Bauwens, 2005; Benkler, 2006; Castells, 2000, 2003). It is in the context of the networked society that hackers started to form online and offline communities, sharing knowledge, tools and ideas (**II**). Arguably there was a need to organize, in a more systematic way, these conversations among hackers in physical spaces, which led to the creation of communities such as the Homebrew Computer Club in the mid-1970s, the Chaos Computer Club in 1981 or the first hackerspaces, as we know them today, in Berlin (C-base) and Cologne (C4) in the mid-1990s.

During the last two decades, the wide distribution of ICTs and the dropping costs of desktop manufacturing technologies have sparked global interest and experimentation with grassroots creative possibilities. Individuals and groups immersed in a hacker ethic, as described above, have been building community-run physical places to pursue their common interests. In other words, we have been observing the emergence of makerspaces. Makerspaces have commonly been used as a local, physical platform for the mutualization of resources and the provision of desktop manufacturing technologies that are not yet as distributed as computers or Internet connectivity (**III**). For instance, there is a rapidly increasing global network of hackerspaces, which is documented in the hackerspaces.org wiki and spans all over the world; or fablabs, which began in 2001 as a research project of MIT with the aim to investigate how underserved communities could be empowered by digital technologies at the grassroots level (Mikhak et al., 2002). Another example might also be the municipality-supported media labs, such as Madrid-based MediaLab-Prado (**I**), which was established in 2002 and has been active in the production, research, and dissemination of digital culture (MediaLab-Prado, 2016).

Makerspaces may be seen as the development of a new form of "third place" (Moilanen, 2012; **II**). Oldenburg (1999) coined this term to highlight urban social settings or surroundings that provide "social experience outside of the home or workplace/school" (Lawson, 2004, p. 125). Since the introduction of the concept, different types of third places have been listed, from cafés, clubs, parks, libraries, barber shops, churches, cookouts (Jeffres et al., 2009) to virtual places and online communities (Soukup, 2006). It is argued that such places are significant for the empowerment of community ties, the establishment of a sense of place, civic engagement and, therefore, democracy (Oldenburg, 1999, 2001). Their role becomes of utmost importance when one considers Putnam's (2000) allegations of a decline in social capital within United States society during the last five decades, which has been undermining active civil engagement and thus democracy itself. Using the concept of third place and the community-building potential of the makerspaces as a point of departure, the following sections will describe how makerspaces can radically transform the idea of third place and serve as a new civic infrastructure.

3. Potential for Citizen-driven Transformation

3.1. Community-building potential

In order to provide a tentative mapping of makerspaces, we may start by addressing hackerspaces.org, perhaps the most popular virtual network of hackerspaces. It contains a wiki for anyone to share hackerspace-related stories and questions, mailing lists, a feed aggregator and many others. A central goal of this initiative is to support communication and collaboration among hackerspaces. The homepage provides an inclusive definition of hackerspace as any community-run physical place where people can meet and work on creative projects. At the time of this writing, 2,035 hackerspaces are listed in the wiki, with 1,248 of them marked as active and 353 as planned, while the rest appears to be inactive or closed. By examining the hackerspaces.org list, it becomes obvious that makerspaces are spread all over the world (Hackerspaces.org, 2016). However, the majority is placed in the United States and Western Europe. Most of the hackerspaces supply members and visitors with access to desktop manufacturing technologies, such as 3D printers and open hardware (Lindtner et al., 2014; Moilanen, 2012; Moilanen & Vadén, 2013).

In addition to this, there are two recent studies on makerspaces conducted on a national level in the United Kingdom (Sleigh et al., 2015) and China (Saunders & Kingsley, 2016). Within the scope of these reports, commissioned by NESTA (National Endowment for Science, Technology and the Arts, the globally influential British iLab), a makerspace is understood as “an open access space (free or paid), with facilities for different practices, where anyone can come and make something” (Sleigh et al., 2015, p. 2; Saunders & Kingsley, 2016, p. 12).

According to the first one, the proliferation of makerspaces in the United Kingdom has been rapidly growing from a handful to 97 during the last decade (Sleigh et al., 2015). The same report states that most UK cities have at least one makerspace; however, the density and number of makerspaces differs by region. Specifically, London, Scotland and Wales have the most makerspaces per capita, while the North East, the East of England and the East and West Midlands have the fewest (Sleigh et al., 2015). Moreover, most of them have small member communities, with 60% having 50 members or less, while 5% have over 1,000 members. In terms of visitors, 75% of makerspaces received up to 250 unique visits in November 2014, with almost 5% reporting over 5,000 visits during the same month (Sleigh et al., 2015).

In China, where “making things is a national specialism” (Saunders & Kingsley, 2016, p. 5), makerspaces have spread rapidly over the past five years, from just 1 in 2010 to over 100 in 2015. Three-quarters of them are located in large cities on the developed East Coast, such as Beijing, Shanghai, Shenzhen, while the rest are in large Northern and inland cities (Saunders & Kingsley, 2016). Moreover, the average number of members in China's makerspaces is 100.

Drawing from the above sources, it becomes evident that makerspaces are proliferating in the North-Western world, with a recent expansion to the East and South. In addition, the following image is a screenshot from the MakerMap, a platform where anyone can add a makerspace and tag it according to certain criteria. Although the platform does not provide a definition of what is considered a "makerspace", the map serves both as another (soft) indication of the globality of the phenomenon, but also of the regional bias typical for ICTs and desktop manufacturing technologies (Benkler, 2014).

Figure 1: TheMakerMap.com (last accessed 8 May 2016)

So, how are these community-driven places governed? According to **II**, which explored the governance mechanism of eight selected makerspaces (self-identified as "hackerspaces"), the latter seem to replicate governance structures and principles observed in online CBPP. Hence, the chosen case studies could be considered a manifestation of online CBPP in the physical realm but not a direct or a precise transfer due to the scarcity and the subsequent allocation problems of the material world, as opposed to the digital realm, where replication requires a near-zero marginal cost. Although the projects within a single makerspace can be very different from those of another and much more different than the CBPP ones, it is understood that most of the CBPP characteristics also permeate the makerspace phenomenon (**II**). For instance, in both online CBPP projects and makerspaces, issues of independence and autonomy arise when it comes to monetary support from an outsider (**II**). Even if the ability of the makerspace communities to develop the norms required for CBPP models is arguably put under more stress, it can be noticed that there are many instances that seem to embrace several CBPP aspects through adopting hybrid modes of governance (**II**). These modes, at least for the cases discussed in **II**, share certain elements which exemplify CBPP governance mechanisms and characteristics (Kostakis, 2010), which are, after all, historically and essentially indistinguishable from the hacker ethic. Therefore, it has been argued that makerspaces' various hybrid modes of governance are actually an unfinished artifact that follows the constant reform of social norms within the community, as happens in CBPP (Kostakis, 2010).

Nevertheless, while **II** is focused on makerspaces which are self-identified as hackerspaces (thus putting an emphasis on ideological issues, such as do-ocracy and voluntarism), Saunders and Kingsley (2016) and Sleigh et al. (2015) study a much wider array of makerspaces. The latter found out that the UK makerspaces rely on a combination of informal and paid roles to operate. Voluntary staff and informal user support are important features of many makerspaces. Approximately 40% of the examined makerspaces also employ technicians on a full- or part-time basis. This might be explained by the fact that, whereas almost 50% of makerspaces were founded by informal groups (as was the case with all the examined makerspaces in **II**), nearly 33% emerged from existing companies or organizations. In addition, the Chinese makerspaces are still experimenting with business models. One in five makerspaces is funded by a parent company, 34% have received some form of government support and 24% has no income and relies on the support of volunteers (Saunders & Kingsley, 2016).

To recapitulate, because of the perpetual transformation of makerspaces and their diverse organizational structures, it seems wise to approach them on a case-by-case basis for a more detailed account of governance (**II**). Of course one should be aware of the fact that every makerspace and its community is unique (Mikkonen et al., 2007). After all, as we saw, it is hard to say what a makerspace is exactly: "you know it when you are in one, but they are all unique because people are so unique" (**II**, p. 569). From the perspective of the concept of third place (Moilanen, 2012; Oldenburg, 1999, **II**), makerspaces can be viewed as community-run hubs that connect citizens not only of the same city but also of other cities worldwide. According to Sleigh et al. (2015), approximately 66% of the UK-based makerspaces collaborate with other UK-based or foreign makerspaces on a regular basis, while 46% contribute to commons-oriented, open-source projects which normally have a global orientation. However, Moilanen (2012) observed that individuals are more engaged and committed to one local makerspace. Further, of particular interest are the findings of Saunders and Kingsley (2016), Sleigh et al. (2015), and Moilanen (2012) that two of the top reasons people use makerspaces are socializing and learning. Hence, makerspaces can be platforms that cultivate relationships and networks, building social capital, i.e., "social networks and the attendant norms of trust and reciprocity" (Sander, 2002, p. 213). Next, we will discuss how these social networks can produce collective value in the form of learning as well as of innovation.

3.2. Learning potential

An increasing amount of literature coming from various disciplines (e.g. cognitive psychology, experiential learning, design theory, computer science, science and technology studies) explores the educational and pedagogical potential of making (Schrock, 2014). Two lines of scholarship in the field of pedagogical studies with a focus on making are of particular interest in the current context: constructionism and critical making. To begin with, the learning theory of constructionism (Papert, 1980a, 1980b, 1993, 1997; Papert & Harel, 1991) highlights the personalized production of knowledge artifacts as well as the social nature of the learning process (**IV**).

In line with many prominent scholars in the philosophy of education (e.g. Jean Piaget, Lev Vygotsky, Paulo Freire and John Dewey), constructionism maintains that the individual's intellectual growth must be rooted in his/her experience (Ackermann, 2001; Papert, 1980b; Wertsch & Tulviste, 1992). Knowledge is not seen as a commodity to be transmitted but as a personal experience that has to be constructed (Ackermann, 2001):

> constructionism – the N word as opposed to the V word – shares constructivism's connotation of learning as 'building knowledge structures' irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it is a sand castle on the beach or a theory of the universe (Papert & Harel, 1991, p. 3).

While both constructionism and constructivism consider socially embedded experience key to the learning process, the former puts an emphasis on the significance of actively making things (Ratto, 2011). So, "constructionism extends the theory of constructivism to focus explicitly on how the making of external artifacts supports learners' conceptual understanding" (Sheridan et al., 2014, p. 507).

Drawing upon constructionism, Matt Ratto, from the Faculty of Information at the University of Toronto, has been developing the concept of "critical making" (Ratto, 2011; Ratto & Boler, 2014). He defines critical making as "a mode of materially productive engagement that is intended to bridge the gap between creative physical and conceptual exploration" (Ratto, 2011, p. 252). Critical thinking is often understood as a conceptually and linguistically based process, whereas physical "making" is allegedly related to goal-based material work

(Ratto, 2011, p. 253). Through empirical examples and within the constructionism context, Ratto shows how two seemingly different modes of human engagement with the world can creatively be connected and not only deepen conceptual understandings, but also inaugurate venues for technical innovation (Ratto, 2011, p. 259). Ratto's findings are in line with the conclusions of **IV** where, through a participatory-action research project, it was shown how 3D printing and design can electrify various literacies and creative capacities of students in accordance with the spirit of the networked, interconnected, information-based world. It was also argued that the ethics of the commons-based/P2P movement, which has produced several media technologies of educational value (from free/open-source software, say Moodle or Sugar, to the free encyclopedia Wikipedia to open hardware such as the Arduino micro-controller or low-cost 3D printers), could provide a context for experimentation, communication, collaboration, sharing and learning (Ratto, 2011; Suoranta & Vadén, 2010; **IV**).

Therefore, the learning potential of making coupled with open learning environments (Hannafin et al., 2013; **IV**); project-based learning (Blumenfeld et al., 1991; **IV**); informal tinkering (Hunsinger, 2011); and peer collaboration (Moilanen, 2012; **IV**) can motivate the social learning and personalized involvement of participants (Baichtal, 2011). Makerspaces exhibit the aforementioned characteristics and, thus, show great promise as emerging learning hubs (**IV**). That is why makerspaces have recently generated much interest in diverse educational circles (Sheridan et al., 2014). For example, several libraries and museums have created spaces with the aim to empower creative activity, resource-sharing and active engagement with making, materials, processes and ideas in relation to their collections and exhibits (Britton, 2012; Honey & Kanter, 2013). Another instance is Buechley et al.'s (2013) study of making activities with learning value that take place in makerspaces, such as building circuits into textiles, or Honey's and Kanter's (2013) documentation of real-world examples of learning activities that occur in makerspaces, amongst other places.

It appears that makerspaces offer the capacity for informal community activity as well as a proper learning environment with a focus on productive processes rather than skill-set building (Sheridan et al., 2014). Varying activities may be combined (like programming and hardware building and even manufacturing-tools development), enabling an innovative transdisciplinary development process (Sheridan et al., 2014). The NESTA study claims that more than 50% of makerspaces offer support, courses and tool inductions (Sleigh et al., 2015). Sheridan et al., in their study of three makerspaces, conclude that as educational spaces they enable makers to be involved in "participating in a space with diverse tools, materials, and processes; finding problems and projects to work on; iterating through designs; becoming a member of a community; taking on leadership and teaching roles as needed; and sharing creations and skills with a wider world" (Sheridan et al., 2014, p. 529).

To summarize, making enables and blends various literacies and creative capacities. Thus, recognized as sites of community-building, creativity and learning, makerspaces could be game changers towards new forms of educational venues and (social) innovation.

3.3. Innovation potential

Makerspaces are often considered hubs that may act as incubators for both innovation and entrepreneurship. It should be noted that this thesis adopts the classic Schumpeterian understanding of innovation as the use of new ideas (inventions, discoveries or a new combination of known items or processes) that are turned into market successful products, services or organizational processes (Drechsler et al., 2006, p. 15-16; Schumpeter, 1912/1982). Several innovative entrepreneurial endeavors and start-ups have emerged through makerspaces, from more obvious areas, such as ICT and desktop manufacturing technologies, to less obvious areas, such as farming, culture and neuroscience.

To begin with, the low-cost 3D-printer producer MakerBot Industries is one of the most prominent start-ups whose history unfolded within two makerspaces: Austria-based Metalab, where the project was conceptualized, and US-based NYC Resistor, where it was prototyped (Pettis, 2011). MakerBot started as a successful open-source project to turn into a traditional closed-source company and subsidiary of Stratasys, a leading manufacturer of 3D printers. MakerBot used to dominate the market of low-cost 3D printing (<3,000€); however, according to a Fortune article (Zaleski, 2015), it is losing the market to smaller manufactures. For instance, Ultimaker BV, a company that is coming up the ranks, produces open-source 3D printers whose prototypes were first built in a Dutch makerspace (Utrecht ProtoSpace) (van Geelen, 2015). Both MakerBot and Ultimaker along with dozens of commercially successful start-ups are built upon the designs of the first open-source 3D printer, RepRap. The RepRap project began as a state-funded research endeavor which has greatly benefited from experimentation and incremental innovations occurring in makerspaces globally (de Jong & de Bruijn, 2013; **III**). Moreover, 3Doodler, one of the most successful Kickstarter projects of all times (Hurst, 2015), is a 3D printing pen which was first built by two friends in early 2012 at the US-based Artisans' Asylum makerspace (Denison, 2015).

Moving from desktop manufacturing technologies to sensors and microcontrollers, makerspaces have also served as incubators for relevant start-ups and innovations. To begin with, Arduino is the popular open-source computer-hardware and -software company as well as user community that designs and manufactures microcontroller-based kits for building senseable devices in the physical world. Arduino has extensively been used in makerspaces to create various objects, from simple toys and musical instruments to sophisticated devices and manufacturing machines. For example, the “brain” of several of the aforementioned low-cost 3D printers has often been an Arduino board. Moreover, in London Hackspace, the start-up Nanobe emerged, which, inspired by and based on Arduino, develops and sells a micro-controller which can interact with cloud-based applications and events in the online environment.

Further, the Public Lab, an open community network, collaboratively develops open-source technologies and practices that explore and address environmental issues. The project was created in the wake of the Deepwater Horizon oil spill in the gulf of Mexico in 2010 with the aim to “increase the ability of underserved communities to identify, redress, remediate, and create awareness and accountability around environmental concerns” (Publiclab.org, 2016). The network is virtually coordinated with the help of a wiki while physically participants meet in local makerspaces and workshops. The Public Lab network has collaboratively produced low-cost, open-source, community-supported products, such as the Roomba indoor air-quality monitoring system, the Riffle water monitoring system, the Dustuino monitoring system, and desktop and mobile spectrometers. These products produce meaningful, understandable and high-quality environmental data. Public Lab also has a shop where one can buy some of the do-it-yourself kits.

Another example of a novel approach to environmental data-gathering has been suggested by the Open Source Beehives project. At its beginning, the project involved a diverse network of makerspaces (Fab Lab Barcelona, the Belgium-based OKNO and the Open Tech Collaborative in Denver) which prototyped an open-source, senseable beehive that could be made with desktop manufacturing technologies (Romano, 2014). The team has now grown into a citizen-led beehive network with the ultimate goal to discover what is causing Colony Collapse Disorder (Romano, 2014). The core group behind the project has now launched a company, AKER LLC, which, in addition to the Open Source Beehive, produces and sells open-source kits for urban farming (AKER, 2016).

More diverse fields in which makerspaces have served as platforms for innovation are following. To start, the Open Access Control project began in the US-based 23b Shop makerspace to satisfy the need for a customizable and low-cost electronic access control at the makerspace (Baichtal, 2013). After a first prototype was built and successfully operated, several commercial boards were commissioned from Flashline Electronics. Recently, the ACCX Products store was created, where one can buy an up and running open-source security system (Baichtal, 2013).

Next, the KiloBaser project, self-titled the “Nespresso machine of DNA synthesis” (Kilobaser.com, 2016), emerged in the Austria-based realraum makerspace.

Kilobaser is now a product of the start-up company Briefcase Biotec GmbH, founded in 2014 and related to a biotechnology-oriented makerspace, which develops life-science equipment reduced to the bare essentials. Another commons-oriented initiative with regards to the life sciences is the Backyard Brains, which emerged in the US-based All Hands Active makerspace. This start-up company has an array of novel, open-source products including the Spikerbox, which uses invertebrates to help learn about how the cells in the brain work to communicate; the Muscle SpikerBox, which records electrical activity produced by cells in human muscles; the Completo, which is a full tabletop, portable electrophysiology rig; or RoachScope, which can turn the mobile phone into a microscope.

Some of the aforementioned projects and eco-systems, such as the RepRap- or Arduino-based eco-systems, may represent both the Schumpeterian and social-oriented understanding of innovation. They seem to create win-win situations and inaugurate commons-oriented business models which arguably go beyond the classical corporate paradigm and its extractive profit-maximizing practices (Bauwens & Kostakis, 2016). To recap, in makerspaces people innovate and learn together by making things and using the Web to globally connect and share designs, tutorials and code. They offer creative environments where innovators, potentially with diverse agendas, motives and backgrounds, can meet and interact and thus benefit from synergies and the cross-pollination of ideas (Capdevila, 2015; **II**, **III**). Moreover, in makerspaces designers can come together and collaborate in participatory explorations during the use phase by prototyping, adding small-scale interventions and, therefore, moving from a "design-in-the-studio" to a "design-in-use" strategy (Seravalli, 2012).

In all, makerspaces should not be viewed merely as experimentation sites with desktop manufacturing technologies but as places "where people are experimenting with new ideas about the relationships amongst corporations, designers, and consumers" (Lindtner et al., 2014, p. 9). The review of makerspaces-related innovation showed that they mainly produce user-led, incremental product and process innovations. However, there are numerous technological infrastructures produced in makerspaces aiming to cover certain needs of the community which might not lead to the commercial introduction of new products. Nevertheless, this process promotes the diffusion of technology among makerspaces, which in turn could outline future trajectories on innovation. Such trajectories are certainly based on ICT, the pervasive technology of the current techno-economic paradigm (Perez, 2002) and provide a new potential to transform and enable innovations in other industries (Perez, 2009). Therefore, since it is the availability of potential innovation as investment opportunities that leads to economic growth (Schumpeter, 1939/1982), makerspaces' contribution might be viewed as valuable. At the same time, by offering real solutions outside the market system, makerspaces provide fertile ground for the flourishing of CBPP.

4. Instead of Conclusions: Challenges and Opportunities for a Commons-oriented Smart City

> *Ἐρωτηθεὶς τί αὐτῷ περιγέγονεν ἐκ φιλοσοφίας, ἔφη, ‘εἰ καὶ μηδὲν ἄλλο, τὸ γοῦν πρὸς πᾶσαν τύχην παρεσκευάσθαι.’ Ἐρωτηθεὶς πόθεν εἴη, ‘κοσμοπολίτης,’ ἔφη.*
>
> *On being asked what he had gained from philosophy, he replied, ‘This at least, if nothing else – to be prepared for every fortune.’ Asked where he came from, he said, ‘I am a citizen of the world.’*
>
> Diogenes Laertius, The Lives of Eminent Philosophers, Book VI, passage 63.

Are makerspaces just a manifestation of the “new spirit of capitalism” which has incorporated and adapted several of its various critical cultures, thus overcoming its own impasses (Boltanski & Chiapello, 2005; Söderberg & Delfanti, 2015)? Or could we consider makerspaces to be sites with non-negligible post-capitalist dynamics? Both possibilities still exist. If we subscribe to the thesis that at least some makerspaces can be seen as CBPP in practice (Smith et al., 2013; **II**), then, as has been argued about the transitional dynamics of CBPP (Bauwens, 2009; Kostakis & Bauwens, 2014), makerspaces may belong to a new form of capitalism but, at the same time, also highlight ways in which this new form might be transcended. If the dominant discourse of the “smart city” project is aligned with a neoliberal, corporate vision for urban development (**I**), then the “makerspace” could simultaneously be a source of legitimacy for the project but also serve as an infrastructure and institution for citizen-driven transformation.

It is argued in this thesis that an alternative vision for the smart city may be possible through a commons-oriented approach geared towards the democratization of means of production. The basic tenant of this approach is encouraging citizens to participate in creating solutions collectively instead of merely adopting proprietary technology (**I**, **V**). Within this context, makerspaces would play a key part since they may be seen as spaces where individuals and communities can engage in urban technology development in a socially inclusive environment. In other words, they are viewed as seeds for the flourishing of a socially sustainable city that ultimately fulfill the promise of the “right to the city”.

In addition to virtual connections which made CBPP possible, makerspaces can be the physical nodes of a collaborative culture and a new production model, which has tentatively been called “design global-manufacture local” (DGML) (Kostakis et al., 2015; **III**). DGML describes the processes where design is developed, shared and improved as a global digital commons, whereas the actual customized manufacturing takes place locally with “specific local biophysical conditions in mind” (Figure 2; Kostakis et al., 2015, p. 8). In a nutshell, it follows the logic that what is light (knowledge, design) is global, and what is heavy (manufacturing) is local (**III**). The architectural structure of this model is based on three layers of infrastructure. The first layer concerns the knowledge commons and the socio-technical digital platforms which enable individuals and communities to collaborate in various projects on a global basis (**III**). The ongoing circulation of the produced commons, which promotes continuous innovation and knowledge diffusion on a global scale (**I**), is assured by the global network of makerspaces (second layer). Moreover, makerspaces provide access to a spectrum of hardware technologies, which constitute the essential means of production in this setting. Last, the third layer relates to the local society, which stresses the needs of citizens, offers ideas and participates in the design and/or the manufacturing of the technological solutions. Further, this layer includes the development of entrepreneurial coalitions and relevant funding ecologies. This activity benefits the creation of a funding infrastructure which sustains the knowledge commons, creates added value on top and markets these as products or services (**III**).

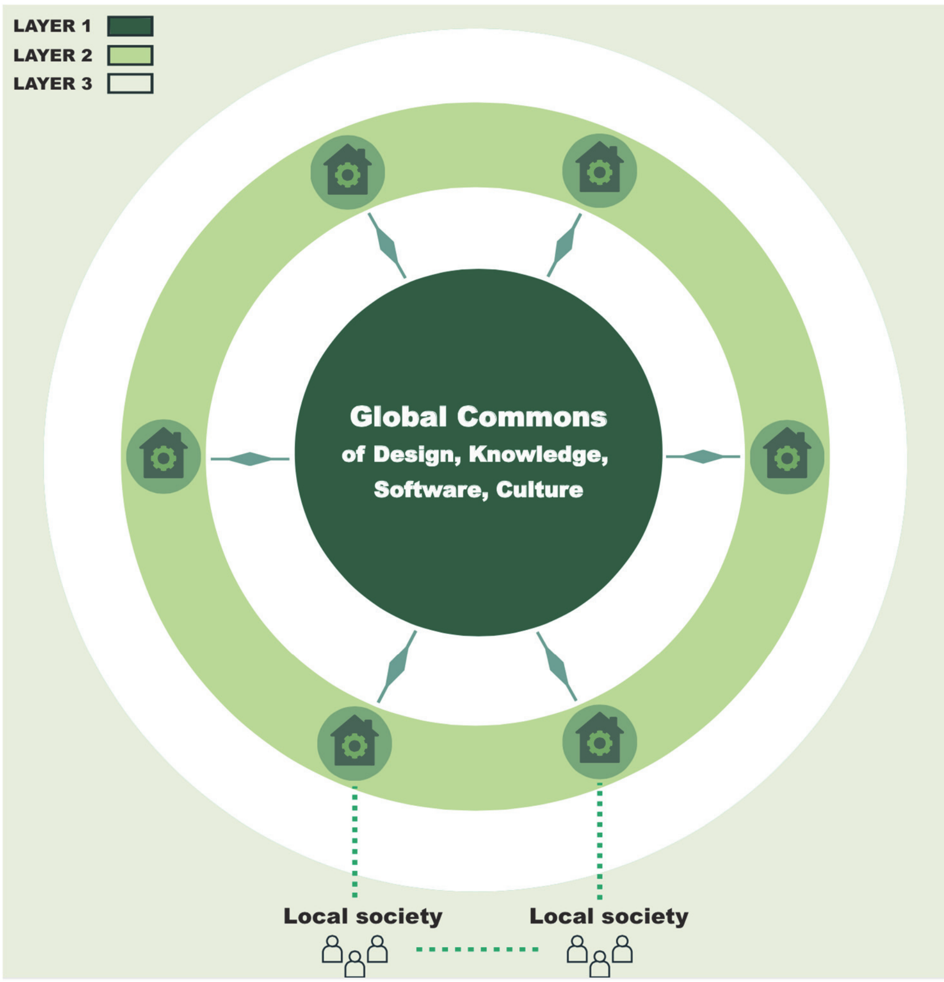

Figure 2: The three layers of DGML

As seen in many DGML cases, such as the RepRap 3D printer, the Arduino micro-controllers, the Public Lab project, the Wikispeed car or the Open Source Ecology, the role of makerspaces in the realization of this model is crucial, as they interlink the three layers. Thus, they allow for the convergence of digital commons with desktop manufacturing technologies, which could enhance the autonomy of people, transform all sectors of production in the direction of sustainability (Dafermos, 2015; Gershenfeld, 2007; **III**) and facilitate the creation of a commons-oriented smart city (**I**).

In order to enhance the functionality of this model, policy makers should make sure that ICT vendors do not have the control of the technological infrastructure in the given city and provide appropriate facilities to enable the deployment of participative ways of working. Therefore, they are advised to examine the potential of makerspaces and, ideally, promote their establishment. This development, along with a focus on a commons-oriented approach for the smart city, will allow the successful implementation of the DGML productive model, which could offer an alternative of how productive activities could be organized to enable a sustainable and socially inclusive city as well as possibly electrify the transition to a post-capitalist society.

In the spirit of Diogenes Laertius, the ultimate goal of this thesis was to modestly contribute to the preparation for any fortune, but preferably to help that fortune veer towards emancipatory social change (Horkheimer, 1937a/2002a) and human happiness (Drechsler, 2001). This is a massive undertaking, but without the patient assembly of many small stones – akin to the drilling of many thick boards (Weber, 1919) – the good city can never be made.

5. References

Ackermann, E. (2001). Piaget's constructivism, Papert's constructionism: What's the difference. *Future of learning group publication, 5*(3), 438.

AKER. (2016). Store. Retrieved from: https://aker.me/#section-store.

Albino, V., Berardi, U., & Dangelico, R. M. (2015). Smart cities: Definitions, dimensions, performance, and initiatives. *Journal of Urban Technology, 22*(1), 3-21.

Antoniadis, P., & Apostol, I. (2014). The Right(s) to the Hybrid City and the Role of DIY Networking. *The Journal of Community Informatics, 10*(3).

Baichtal, J. (2011). Mitch Altman Talks about the Hackerspace Movement. *MAKE Magazine*. Retrieved from: http://makezine.com/2011/08/19/mitch-altman-talks-about-thehackerspace-movement/.

Baichtal, J. (2013). Open Access Secures Hackerspaces. *MAKE Magazine*. Retrieved from: http://makezine.com/2013/09/25/open-access-secures-hackerspaces/.

Bauwens, M. (2005). The Political Economy of Peer Production. *CTheory Journal*. Retrieved from: http://www.ctheory.net/articles.aspx?id=499.

Bauwens, M. (2009). Class and Capital in Peer Production. *Capital & Class, 33*, 121-141.

Bauwens, M., & Kostakis, V. (2016, forthcoming). Can Hyper-neoliberalism Be Overcome by Open Cooperativism? In T. Scholz & N. Schneider (Eds.), *The Rise of Platform Cooperativism*. New York, NY: OR Books.

Benkler, Y. (2006). *The Wealth of Networks: How Social Production Transforms Markets and Freedom*. New Haven, CT: Yale University Press.

Benkler, Y. (2014). Ch@nge: Distributed Innovation and Creativity, Peer Production, and Commons in Networked Economy. *BBVA Open Mind*. Retrieved from: https://www.bbvaopenmind.com/en/article/distributed-innovation-and-creativity-peerproduction-and-commons-in-networked-economy/.

Benkler, Y. (2015). Peer Production and Cooperation. In J. Bauer & M. Latzer (Eds.), *Handbook on the economics of the internet*. Cheltenham: Edward Elgar.

Bergvall-Kareborn, B., & Stahlbrost, A. (2009). Living Lab: an open and citizen-centric approach for innovation. *International Journal of Innovation and Regional Development*, 1(4), 356-370.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational psychologist, 26*(3-4), 369-398.

Bollier, D. (2005). *Brand Name Bullies: The Quest to Own and Control Culture*. Hoboken, NJ: Wiley.

Bollier, D. (2009). *Viral Spiral: How the Commoners Built a Digital Republic of their Own*. New York, NY: New Press.

Bollier, D. (2014). The Commons as a Template for Transformation. *Great Transition Initiative*. Retrieved from : http://www.greattransition.org/document/the-commons-as-a-template-for-transformation.

Boltanski, L., & Chiapello, E. (2005). The new spirit of capitalism. *International Journal of Politics, Culture, and Society, 18*(3), 161-188.

Britton, L. (2012). The makings of maker spaces, part 1: Space for creation, not just consumption. *The Digital Shift*. Retrieved from: http://www.thedigitalshift.com/2012/10/public-services/the-makings-of-maker-spacespart-1-space-for-creation-not-just-consumption/.

Budd, J. M. (2008). Critical theory. In L. M. Given (Ed.), *The sage encyclopedia of qualitative research methods* (pp. 174–178). Thousand Oaks: Sage.

Buechley, L., Peppler, K., Eisenberg, M., & Kafai, Y. (2013). *Textile messages: Dispatches from the world of e-textiles and education*. New York, NY: Peter Lang Publishing Incorporated.

Capdevila, I. (2015). How Can City Labs Enhance the Citizens' Motivation in Different Types of Innovation Activities? *Social Informatics* (pp. 64-71): Springer.

Carspecken, P. (2008). Critical research. *The SAGE encyclopaedia of qualitative research methods*, 171-175.

Carvalho, L. (2015). Smart cities from scratch? A socio-technical perspective. *Cambridge Journal of Regions, Economy and Society, 8*(1), 43-60.

Castells, M. (2000). *The Rise of the Network Society*. Oxford: Blackwell.

Castells, M. (2003). *The Power of Identity* (2nd ed.). Oxford: Blackwell.

Dafermos, G. (2015). Transforming the productive base of the economy through the open design commons and distributed manufacturing. *Journal of Peer Production, 7*.

Dafermos, G., & Söderberg, J. (2009). The Hacker Movement as a Continuation of Labour Struggle. *Capital & Class, 33*, 53-73.

de Jong, J. P., & de Bruijn, E. (2013). Innovation lessons from 3-D printing. *MIT Sloan Management Review, 54*(2), 43.

De Souza, M. L. (2010). Which right to which city? In defence of political-strategic clarity. *Interface, 2*(1), 315-333.

Denison, D. (2015). 3Doodler Creator Shares His Experience from Makerspace to Market. *Makezine*. Retrieved from: http://makezine.com/2015/06/14/drawn-to-it/.

Drechsler, W. (2001). *Good and bad government: Ambrogio Lorenzetti's frescoes in the Siena town hall as mission statement for public administration today*. Budapest: Local Government and Public Service Reform Initiative / Open Society Institute.

Drechsler, W., Backhaus, J., Burlamaqui, L., Chang, H.-J., Kalvet, T., Kattel, R., . . . Reinert, E. (2006). Creative Destruction Management in Central and Eastern Europe: Meeting the Challenges of the Techno-Economic Paradigm Shift. In T. Kalvet & R. Kattel (Eds.), *Creative Destruction Management: Meeting the Challenges of the Techno-Economic Paradigm Shift*. Tallinn: Praxis Center for Policy Studies.

Erickson, J. (2008). *Hacking: the art of exploitation*. San Francisco, CA: No Starch Press.

Flyvbjerg, B. (2001). *Making social science matter: Why social inquiry fails and how it can succeed again*. Cambridge: Cambridge University Press.

Foster, S., & Iaione, C. (2016). The City as a Commons. *Yale Law & Policy Review, 34*(2).

Garrett, M., & Catlow, R. (2012). DIWO: Do It With Others–No Ecology without Social Ecology. *Remediating the Social*, 69-74.

Gershenfeld, N. (2007). *Fab: The coming revolution on your desktop: From personal computers to personal fabrication*. New York, NY: Basic Books.

Glaeser, E. (2011). *Triumph of the city: How our greatest invention makes us richer, smarter, greener, healthier, and happier*. New York, NY: Penguin.

Gorgens, T., & van Donk, M. (2011). From basic needs towards socio-spatial transformation: coming to grips with the 'Right to the City'for the urban poor in South Africa. *The Isandla Institute*. Retrieved from: http://isandla.org.za/publications/152/.

Hackerspaces.org. (2016). List of all hacker spaces. *Hackerspaces.org*. Retrieved from: https://wiki.hackerspaces.org/List_of_ALL_Hacker_Spaces.

Hannafin, M. J., Hill, J. R., Land, S. M., & Lee, E. (2013). Student-centered, open learning environments: research, theory, and practice. In J. M. Spector, M. D. Merrill, J. Elen & M. J. Bishop (Eds.), *Handbook of research on educational communications and technology* (pp. 641-651). New York, NY: Springer.

Hardt, M., & Negri, A. (2011). *Commonwealth*. Cambridge, MA: The Belknap Press.

Harvey, D. (2008). The right to the city. *New Left Review, 2*(53), 23-40.

Held, D. (1980/2004). *Introduction to Critical Theory: Horkheimer to Habermas*. Berkeley, CA: University of California Press.

Hemment, D., & Townsend, A. (2013). *Smart Citizens*. Manchester: FutureEverything Publication.

Himanen, P. (2001). *The hacker ethic and the spirit of the information age*. New York, NY: Random House.

Hogge, B. (2011). *Barefoot into Cyberspace: Adventures in search of techno-Utopia*. Essex: Barefoot Publishing.

Hollands, R. G. (2015). Critical interventions into the corporate smart city. *Cambridge Journal of Regions, Economy and Society, 8*(1), 61-77.

Honey, M., & Kanter, D. E. (2013). *Design, make, play: Growing the next generation of STEM innovators*: Routledge.

Horkheimer, M. (1937a/2002a). Traditional and critical theory. In M. Horkheimer (Ed.), *Critical Theory: Selected Essays* (pp. 188–243). New York, NY: Continuum.

Horkheimer, M. (1937b/2002b). The latest attack on metaphysics. In M. Horkheimer (Ed.), *Critical Theory: Selected Essays* (pp. 132-187). New York, NY: Continuum.

Horkheimer, M. (1993). *Between Philosophy and Social Science*. Cambridge, MA: MIT Press.

Hunsinger, J. (2011). The social workshop as PLE: lessons from hacklabs. Retrieved from: http://www.academia.edu/1086161/The_Social_Workshop_as_PLE_Lessons_from_Hacklabs.

Hurst, S. (2015). 3Doodler 2.0 Becomes Kickstarter's Most Successful Hardware Sequel As It Surpasses $1 Million in 10 Days. *Crowdfund Insider*. Retrieved from: http://www.crowdfundinsider.com/2015/01/61176-3doodler-2-0-surpasses-1-million-10-days-kickstarter/.

Jeffres, L. W., Bracken, C. C., Jian, G., & Casey, M. F. (2009). The impact of third places on community quality of life. *Applied Research in Quality of Life, 4*(4), 333-345.

Kilobaser.com. (2016). Kilobaser: Rapid DNA prototyper. *Briefcase Biotec*. Retrieved from: http://www.kilobaser.com/.

Kitchin, R. (2014). The real-time city? Big data and smart urbanism. *GeoJournal, 79*(1), 1-14.

Kostakis, V. (2010). Peer Governance and Wikipedia: Identifying and Understanding the Problems of Wikipedia's Governance. *First Monday, 15*. Retrieved from: http://firstmonday.org/ojs/index.php/fm/article/view/2613.

Kostakis, V. (2012). The Political Economy of Information Production in the Social Web: Chances for Reflection on Our Institutional Design. *Contemporary Social Science, 7*, 305-319.

Kostakis, V., & Bauwens, M. (2014). *Network society and future scenarios for a collaborative economy*. Basingstoke: Palgrave Macmillan.

Kostakis, V., Fountouklis, M., & Drechsler, W. (2013). Peer Production and Desktop Manufacturing: The Case of the Helix_T Wind Turbine Project. *Science, Technology & Human Values, 38*(6), 773-800.

Kostakis, V., Roos, A., & Bauwens, M. (2015). Towards a political ecology of the digital economy: Socio-environmental implications of two competing value models. *Environmental Innovation and Societal Transitions*.

Lawson, K. (2004). Libraries in the USA as traditional and virtual "third places". *New Library World, 105*(3/4), 125-130.

Lefebvre, H. (1968). *Le Droit à la ville*. Paris: Anthropos.

Levy, S. (2001). *Hackers: Heroes of the computer revolution* (Vol. 4). New York, NY: Penguin Books.

Lindtner, S., Hertz, G. D., & Dourish, P. (2014). *Emerging sites of HCI innovation: Hackerspaces, hardware startups & incubators.* Paper presented at the Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.

MacKinnon, R. (2012). *Consent of the networked*. New York: Basic Books.

Maxigas. (2012). Hacklabs and hackerspaces. *Journal of Peer Production*.

MediaLab-Prado. (2016). About. Retrieved from: http://medialab-prado.es/article/que_es.

Mikhak, B., Lyon, C., Gorton, T., Gershenfeld, N., McEnnis, C., & Taylor, J. (2002). Fab Lab: An Alternative Model of ICT for Development."development by design"(dyd02). *ThinkCycle*. Retrieved from: http://citeseerx.ist.psu.edu/viewdoc/download.

Mikkonen, T., Vadén, T., & Vainio, N. (2007). The Protestant ethic strikes back: Open source developers and the ethic of capitalism. *First Monday*. Retrieved from: http://www.ojphi.org/ojs/index.php/fm/article/view/1623.

Moilanen, J. (2012). Emerging hackerspaces–peer-production generation *Open Source Systems: Long-Term Sustainability* (pp. 94-111): Springer.

Moilanen, J., & Vadén, T. (2013). 3D printing community and emerging practices of peer production. *First Monday, 18*(8).

Moore, P., & Karatzogianni, A. (2009). Parallel visions of peer production. *Capital & Class, 33*(1), 7-11.

Oldenburg, R. (1989). *The great good place: Café, coffee shops, community centers, beauty parlors, general stores, bars, hangouts, and how they get you through the day*. New York, NY: Paragon House Publishers.

Oldenburg, R. (1991). *The Great Good Place*. New York, NY: Marlowe & Company.

Oldenburg, R. (1999). *The great good place: Cafes, coffee shops, bookstores, bars, hair salons, and other hangouts at the heart of a community*: Da Capo Press.

Oldenburg, R. (2001). *Celebrating the third place: Inspiring stories about the" great good places" at the heart of our communities*: Da Capo Press.

Orlikowski, W. J., & Baroudi, J. J. (1991). Studying information technology in organizations: Research approaches and assumptions. *Information systems research, 2*(1), 1-28.

Orsi, C. (2009). Knowledge-based society, peer production and the common good. *Capital & Class, 33*(1), 31-51.

Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge: Cambridge University Press.

Papert, S. (1980a). *Mindstorms. Children, computers and powerful ideas*. New York, NY: Basic books.

Papert, S. (1980b). Teaching children thinking. In R. P. Taylor (Ed.), *The computer in the school: Tutor, tutee, tool*. New York, NY: Teachers College Press.

Papert, S. (1993). *The children's machine: Rethinking school in the age of the computer*. New York, NY: Basic books.

Papert, S. (1997). Why school reform is impossible. *The Journal of the Learning Sciences, 6*(4), 417- 427.

Papert, S., & Harel, I. (1991). *Constructionism*. Norwood, N.J.: Ablex Publishing.

Parker, D. (2005). The different shades of hacker. Retrieved from: http://www.windowsecurity.com/articles/different-shades-hackers.html.

Patton, M. Q. (2008). Orientational perspective. In L. M. Given (Ed.), *The sage encyclopedia of qualitative research methods* (pp. 586–587). Thousand Oaks: Sage.

Perez, C. (2002). *Technological Revolutions and Financial Capital: The Dynamics of Bubbles and Golden Ages*. Cheltenham: Edward Elgar.

Perez, C. (2009). Technological Revolutions and Techno-Economic Paradigms. *Cambridge Journal of Economics, 33*, 185-202.

Pettis, B. (2011). Made in my backyard. In B. van Abel, L. Evers, R. Klaassen & P. Troxler (Eds.), *Open Design Now* (pp. 76–83). Amsterdam: BIS Publishers.

Publiclab.org. (2016). About Public Lab. Retrieved from: https://publiclab.org/about.

Putnam, R. D. (2000). *Bowling alone: The collapse and revival of American community*. New York, NY: Simon and Schuster.

Ratto, M. (2011). Critical making: Conceptual and material studies in technology and social life. *The Information Society, 27*(4), 252-260.

Ratto, M., & Boler, M. (2014). *DIY citizenship: Critical making and social media*. Cambridge, MA: MIT Press.

Reinert, E. S. (2011). Zeitgeist in Transition: An Update to How rich countries got rich and why poor countries stay poor (Vol. 37): TUT Ragnar Nurkse School of Innovation and Governance.

Romano, Z. (2014). Support Open Source Beehives and help promoting international bee recovery. *Arduino*. Retrieved from: https://blog.arduino.cc/2014/03/19/support-opensource-beehives/.

Sander, T. H. (2002). Social capital and New Urbanism: leading a civic horse to water? *National Civic Review, 91*(3), 213-234.

Sassen, S. (2012). Urbanising Technology, Urban Age Electric City Conference. *LSE Cities, London School of Economics*, 12-14.

Saunders, T., & Kingsley, J. (2016). Made in China: Makerspaces and the search for mass innovation. *Nesta*. Retrieved from: http://www.nesta.org.uk/sites/default/files/made_in_china-_makerspaces_report.pdf.

Schrock, A. R. (2014). Education in Disguise: Culture of a Hacker and Maker Space. *InterActions: UCLA Journal of Education and Information Studies, 10*(1).

Schumpeter, J. A. (1912/1982). *The theory of economic development*. New York, NY: Transaction publishers.

Schumpeter, J. A. (1939/1982). *Business Cycles*. Philadelphia, PA: Porcupine Press.

Seravalli, A. (2012). *Building Fabriken: Design for socially shaped innovation.* Paper presented at the DRS 2012 Conference proceedings.

Shelton, T., Zook, M., & Wiig, A. (2015). The 'actually existing smart city'. *Cambridge Journal of Regions, Economy and Society*, *8*, 13–25.

Sheridan, K., Halverson, E. R., Litts, B., Brahms, L., Jacobs-Priebe, L., & Owens, T. (2014). Learning in the making: A comparative case study of three makerspaces. *Harvard Educational Review, 84*(4), 505-531.

Shumaker, L. (2015). IBM Says to Invest $3 Billion in 'Internet of Things' Unit. *Reuters*. Retrieved from: http://www.reuters.com/article/2015/03/31/us-ibm-investment-idUSKBN0MR0BS20150331.

Sleigh, A., Stewart, H., & Stokes, K. (2015). Open dataset of UK makerspaces: A user's guide. *Nesta*. Retrieved from: http://www.nesta.org.uk/sites/default/files/open_dataset_of_uk_makerspaces_users_guide.pdf.

Smith, A., Hielscher, S., Dickel, S., Soderberg, J., & van Oost, E. (2013). Grassroots digital fabrication and makerspaces: Reconfiguring, relocating and recalibrating innovation?. *SPRU Working Paper Series*. Retrieved from: http://sro.sussex.ac.uk/49317/.

Smith, A., Hielscher, S., & Fressoli, M. (2015). Transformative social innovation narrative: Hackerspaces. *Project Report. TRANSIT: EU.*

Söderberg, J. (2007). *Hacking capitalism: The free and open source software movement*. New York, NY: Routledge.

Söderberg, J., & Delfanti, A. (2015). Hacking Hacked! The Life Cycles of Digital Innovation. *Science, Technology & Human Values, 40*(5), 793-798

Soukup, C. (2006). Computer-mediated communication as a virtual third place: building Oldenburg's great good places on the world wide web. *New Media & Society, 8*(3), 421-440.

Suoranta, J., & Vadén, T. (2010). *Wikiworld*. London: Pluto Press.

Thomas, D. (2002). *Hacker culture*. Minneapolis: University of Minnesota Press.

United, N. (2014). World Urbanization Prospects: The 2014 Revision. Retrieved from: http://esa.un.org/unpd/wup/highlights/wup2014-highlights.pdf.

van Geelen, S. (2015). Joris van Tubergen. *Ultimaker*. Retrieved from: https://ultimaker.com/en/blog/47-joris-van-tubergen.

von Hippel, E. (1986). Lead users: a source of novel product concepts. *Management science, 32*(7), 791-805.

Wark, M. (2004). *A Hacker Manifesto*. Cambridge, MA: Harvard University Press.

Wark, M. (2013). Considerations on a Hacker Manifesto. In T. Scholz (Ed.), *Digital Labor: The Internet as Playground and Factory*. New York, NY: Routledge.

Weber, M. (1919). *Politik als Beruf*. Lecture delivered before the Freistudentischen Bund of the University of Munich. Retrieved from: http://harpers.org/blog/2008/06/weber-on-the-political-vocation/.

Wertsch, J. V., & Tulviste, P. (1992). LS Vygotsky and contemporary developmental psychology. *Developmental psychology, 28*(4), 548.

Zaleski, A. (2015). MakerBot lays off 20% of its staff—again. *Fortune*. Retrieved from: http://fortune.com/2015/10/08/makerbot-lays-off-20-percent-of-staff-again/.

SUMMARY IN ESTONIAN

Kasutades lähtekohana targa linna kriitikat, tõstetakse uurimistöös esile avalike töötubade (*makerspaces*) poolt pakutavaid võimalusi. Avalikeks töötubadeks on sellised linnaruumid, kus osalejad rakendavad oma tegevuses kogukonnapõhiseid valitsemismudeleid ning kohalikke tootmistehnoloogiaid. Uurimistöö annab lühiülevaate avalike töötubade ajaloost, mille juured ulatuvad häkker-liikumiseni. Nii esmasele (uute empiiriliste andmete kogumine) kui teisasele (kirjanduse ülevaade) materjalile tuginevalt on arutletud avalike töötubade potentsiaali üle aidata kaasa kogukonna tugevnemisele, õppimisele ning innovatsioonile. Uurimistöö näitab, kuidas avalikud töötoad võivad osutuda kodanike poolt juhitud muutuste keskmeks ning vahendiks, mängides olulist rolli kaasava ning osalusel ja ühistegevusel baseeruva targa linna loomises.

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Introducing a Taxonomy of the "Smart City": Towards a Commons-Oriented Approach?

Vasilis Niaros

Ragnar Nurkse School of Innovation and Governance, Tallinn University of Technology, Estonia; P2P Lab, Ioannina, Greece, vasileios.niaros@ttu.ee

Abstract: The past decade has seen considerable debate over the relatively vague concept of the "smart city". Nowadays, the smart city has crystallised into an image of a city permeated with top-down and centrally controlled technological infrastructures that promise to improve the urban environment in terms of efficiency, security and sustainability. However, many scholars have criticised this perception of networked technologies for not being able to meet the needs of city-dwellers, raising privacy issues, and leading to an increase of environmentally harmful consumption of ICTs. The aim of this article is to contribute to the ongoing dialogue by providing a taxonomy of the smart city, based on certain technology governance models. After theoretically discussing the socio-environmental costs of each model, I argue for a commons-oriented approach, which could democratise the means of making and offer more environmental benefits.

Keywords: Smart city, Technology governance, Commons, Open source, Microfactories

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1. Introduction

The trend towards urbanisation is evident and well-documented. According to the United Nations (2008), the majority of the world's population is now living in urban areas. The fact that most resources are consumed in cities, contributes to their economic importance, but also to their poor environmental performance (Glaeser 2011). By 2050, it is expected that more than two-thirds of the global population will be living in urban environment. This demographic pressure, coupled with global warming and economic instability, has led to a range of new conceptualisations for the city.

Additionally, during the last two decades we have been witnessing a shift towards information- and networked-based socio-economic structures (Castells 2000). As a result, local governments have propagated a persistent interest in the concept of the "smart city". Yet, this concept is nebulous since there is neither a single template of framing it, nor a one-size-fits-all definition (for a discussion on the definitions see Albino, Berardi and Dangelico 2015). The current leading narrative arose from private corporations dealing with advanced information and communication technologies (ICTs) and was later embraced by local governments and advocates of technology solutionism. According to this view, the "smart city" idea has crystallised into an image of a technology-led urban utopia permeated with top-down and centrally controlled technological infrastructures, with the aim to improve the urban environment in terms of efficiency, security and sustainability. In short, common goals for the smart city are better energy and garbage management; reduced water consumption; improvements to citizen mobility; and crime prevention (Albino, Berardi and Dangelico 2015).

However, many scholars have criticised this view of networked technologies claiming that they do not meet the needs and desires of city-dwellers, mainly because they are not attuned to the ways that people use technology (Sassen 2012). Moreover, they raise social issues related to privacy and democracy (Carvalho 2015; Kitchin 2014). As Hollands (2015) argues, the unrestrained deployment of these technologies is shaped around the motives of the sup-

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pliers, i.e. the commodification of their existing products and services. Therefore, environmentally harmful consumption of ICTs increases without serving the true needs of the citizens or even addressing actual problems. Hence, this version of the smart city is seemingly not accomplishing its goals, primarily due to the design and implementation of the technological infrastructure.

It becomes apparent that the adoption of a certain technology governance model will partially determine the formation of the smart city. In other words, the question that arises is who will design, develop and control the technological infrastructure? Are we going to follow a proprietary-based model for designing our cities or should we explore the potential of a more citizen-engaged urban design? As Townsend (2013, 15) asks: “what do you want a smart city to be?”.

This article aims to contribute to the ongoing dialogue by theoretically discussing the social and environmental aspects of the smart city and shedding light on an alternative approach, that of commons-oriented technological infrastructures. It is argued that the urban design can no longer be addressed from a singular perspective; hence, a commons-oriented approach should be adopted in order to promote an emerging mode of production. This new mode, named commons-based peer production (Benkler 2006), could arguably democratise the means of making with more environmental benefits. I will tentatively propose the adoption of an alternative technology governance model, which enables the utilisation of existing conditions in the city and sparks the creation of small-scale, bottom-up and need-driven solutions. The latter arguably increases the active participation of citizens in the design and decision-making processes for a sustainable city.

In order to simplify possible outcomes, two axes or polarities are used which are giving rise to four distinct types of the smart city. Section 2 provides a short description of the axes and the emerging quadrants, while section 3 discusses in detail the characteristics of each of the four types. The essay concludes by drawing assumptions about which technology governance model would be ideal for a more democratic and sustainable smart city.

2. Framework

Inspired by Kostakis’ and Bauwens’ (2014) approach, I adapt their theoretical framework into this analysis as seen in the figure below. Specifically, the first axis concerns the polarity of centralised/global versus distributed/local control of the technological infrastructure, whereas the second axis relates to an orientation towards the accumulation or circulation of capital versus an orientation towards the accumulation or circulation of the commons (figure 1).

The left quadrants include the “corporate smart city” and the “sponsored smart city” where ICT firms and their ambition for profit maximisation are in the forefront. Still, the nature of the implemented technological infrastructures does not follow the same pattern in both types. On the other hand, the “resilient smart city” and the “commons-based smart city” are oriented towards the production of common value with a focus on either local or global scale. The four types of the smart city are described through prominent cases of corporations and collaborative spaces, which produce technologies that exemplify the characteristics of each quadrant. It should be noted that the positioning of the selected cases in the respective quadrants is based on the author’s view of their aims and activities.

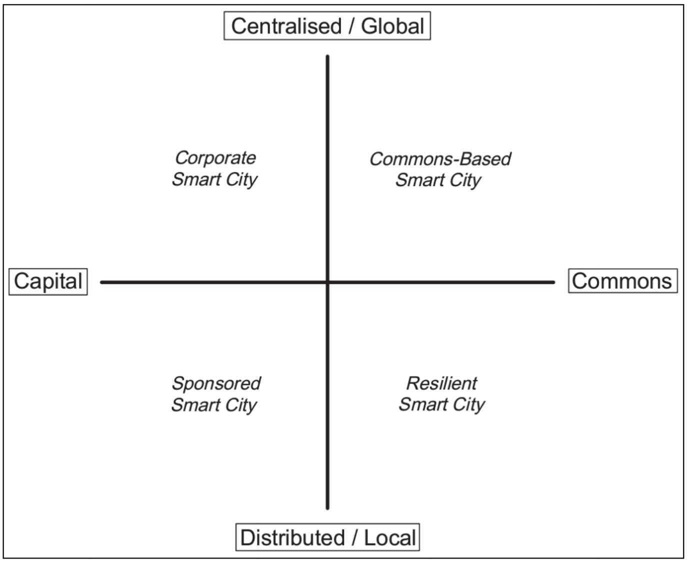

Figure 1: A taxonomy of the smart city

The comparison amongst the technology governance models adopted in each quadrant is defined by the following criteria: i) *citizen participation* during the design and implementation processes of the technological infrastructure; ii) *citizens' privacy*; and iii) *environmental impact* in terms of ICTs consumption.

It should be highlighted that this essay does not aim to offer an all-inclusive account but rather to provide a framework, which could facilitate further discussion around the concept of the smart city. Last, all of the smart city types featured here follow a techno-deterministic approach, overlooking that a non-technical solution could be a better option. However, this does not mean that technological solutions are the only viable way to solve urban problems.

3. Four Types of the Smart City

3.1. The "Corporate Smart City"

The top-left quadrant is related to the leading narrative of the smart city. By employing an often techno-deterministic approach on the uses of ICTs, governments have been looking into how cities might improve urban economies, quality of life and tackle other issues. This has led to a growing role of commercial activities through firms, such as Cisco Systems, IBM and Siemens, which promote themselves as "stakeholders" in public consultation processes (Hollands 2015). As chief executives of Cisco claim, they can provide "intelligent and efficient stewardship of growing cities" (Chambers and Elfrink 2014). These large ICT powerhouses are the major industries involved in the smart city and the Internet of Things (IoT) cluster of technology, having made massive investments. For example, IBM recently announced an investment of US$3 billion over the next four years to establish a new IoT unit (Reuters 2015). Of course, their goal is not just to stumble upon the needs of "actually existing smart cities" but, rather, to create a new market and shape it in certain ways (Shelton, Zook and Wiig 2015).

Popular examples of smart cities are Songdo (South Korea), Masdar (United Arab Emirates) and PlanIT Valley (Portugal). These cities have been built from scratch through public-private partnerships in places with no former residency or infrastructure (Carvalho 2015). Amongst others, IBM and Cisco Systems have been largely involved in these initiatives by providing their products and services. Through the installation of countless wireless sensors and the utilisation of the IoT at the city-scale, the installed networked technologies are usually targeting real-time traffic solutions, crime prevention, environmental information services etc (Hollands 2015). Such developments aim to transform cities from "dumb" to "smart". For instance, in Rio de Janeiro (Brazil), the Intelligent Operations Center for Smarter Cities was built in 2010 by IBM for hosting the World Cup 2014 and the Olympic Games 2016. The role of this big control room is to help city leaders gain insight into all aspects of the city and even predict its future performance (IBM 2014). Such optimisation centres have been created elsewhere by many ICT corporations and it is highly expected to see them expanding in the years to come.

Nevertheless, the aforementioned practices have been broadly criticised by many scholars (see Greenfield 2013; Hollands 2015; Kitchin 2014; Townsend 2013; Vanolo 2014). According to Greenfield (2013), even if the involved firms present their initiatives as being city- and citizen-orientated, what they really do is push for the adoption of market-led technological solutions to city administration in order to maximise their profits. Hence, many issues are emerging that affect both the urban environment and the citizens themselves.

To begin with, this techno-deterministic approach cannot arguably meet the true needs of the citizens, since they do not come first. Moreover, corporations propagate rhetoric of the smart city that fosters citizen participation and democratic decision-making. But, as it happens in this quadrant, control and governance in today's smart city are located within a single proprietary hierarchy, whose main motive is profit maximisation (figure 2). In this case, citizens do not participate neither in the design process of the technological infrastructure nor in its implementation. They are merely treated as another source of information. This is why newly built smart cities such as Songdo and Masdar have evidently failed. Not only are they literally ahistorical but, most importantly, their developers appear to lack any feel for the ways in which cities actually generate value for the people who live in them (Greenfield 2013). It is obvious that smart city vendors like Cisco and Siemens try to redirect the focus of some of their initiatives from being top-down to highlighting inclusivity and citizen empowerment (Greenfield 2013). Through such discursive moves, advocates seek to silence the critics while keeping their central mission of capital accumulation and technocratic governance untouched.

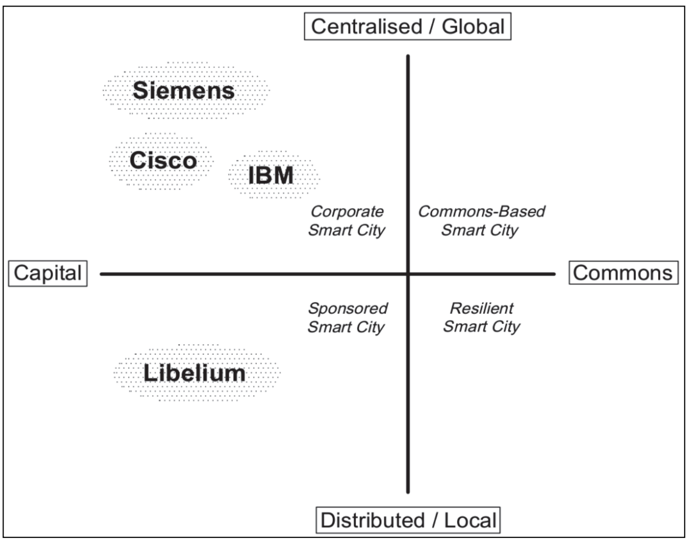

Figure 2: The profit-oriented types of the smart city

Secondly, the installation of thousands of cameras by government and corporate actors and the collection of myriads of data generated by the inhabitants, may have serious consequences with respect to citizens' freedom (Kitchin 2014). The fact that corporations have the control and ownership of the implemented ICTs, transforms the city into a highly privatised space and poses significant threats concerning privacy, surveillance, censorship, and manipulation, that should not be underestimated (Morozov 2013).

Furthermore, the "corporate smart city" does not exhibit only serious social issues. As already mentioned, one of the main reasons for the deployment of ICTs in the city is the reduction of environmental harm. However, as Viitanen and Kingston (2014) argue, the goal here is the expansion of consumerism and not the saving of energy or resources. Since the main motive is profit maximisation, these firms aim to sell as many of their products as possible. Hence, we are witnessing a huge consumption of ICTs with virtually no utilisation of the existing infrastructures. Taking into consideration the underlying material aspects of ICT infrastructures (Fuchs 2013), i.e. slave-like working conditions, class relations and undesirable environmental consequences, it is assumed that the adoption of this technology governance model will not lead to a socially and environmentally sustainable city.

3.2. The "Sponsored Smart City"

The second combination (bottom-left quadrant) matches distributed control of the technological infrastructure with a remaining focus on capital accumulation. Similar to the "corporate smart city", ICT firms are playing a key role here as well. What primarily separates the two types of smart city is the nature of the produced technologies. While in the former type proprietary technologies were in the forefront, in this quadrant the utilised technologies are open source. Yet, there are different kinds of open source projects, which have different goals and requirements. Following West and O'Mahoney (2008), the open source projects are distinguished between "sponsored" (i.e. corporate-led) and "autonomous" (i.e. community-developed). In sponsored projects, one or more corporate entities control the development of the project and employ most of the developers, whereas in community-developed projects, governance and control are shared among the community. What mainly sets apart these two types is their primary goal. On the one hand, corporations aim at maximising their profits from their investment, while an open source community would seek for improvements of the capabilities of the shared technology. Therefore, in this quadrant engages only with the "sponsored" kind of projects.

From corporations' point of view, going open source has a lot of benefits, since it allows them to reduce their development and maintenance cost, and receive greater market recognition (Widenius and Nyman 2013). Companies like Libelium are participating in the formation of the smart city by developing open source technologies. For example, Libelium designs and manufactures hardware and application programming interfaces for wireless sensor networks to establish a platform for the IoT. Recently, they released a new platform for "Precise Urban Monitoring" to enable the creation of future smart city applications and services (Libellium 2015a). But, could the utilisation of corporate-led open source technologies offer more socially acceptable solutions?

Contrary to the conventional technological infrastructures, open source technologies offer a high degree of transparency since the code or the designs of the project are shared through the use of appropriate licenses. However, accessibility to the development process is not assured since the code might not be easily forked. Although companies recognise the importance of attracting participants to the communities built around their projects, most of them provide less accessibility in order to retaining some controlling influence and to ensure that the community will remain aligned with the corporate strategy (West and O'Mahoney 2008). Thus, the distributed control of the technological infrastructures in the "sponsored smart city" entails only the implementation part. In other words, citizens are able to acquire these products and install them wherever they wish, contributing to the generation of local data, but they do not participate in the design process of the technologies, since corporations undertake it. Such practices are opposed to the collaborative way of producing solutions, which allow citizens to discuss common needs, exchange ideas and finally produce better solutions. In its place, Libelium (2015b) has " [...] a sales engineer assigned to you to ensure you choose the right and optimal configuration to your needs". Nevertheless, even if it is feasible to fork the code of an application or modify a device—which is not the most favourable scenario in the case of corporate-led technologies—great citizen engagement is not granted. In order to adjust an acquired product according to their needs, citizens need certain technological capabilities, which they do not always have. Despite the proclaimed advantages of ICTs use in cities, they can also increase inequalities and promote a digital divide (Norris 2001). Hence, certain factors should be considered when implementing ICTs with regard to inequality and the digital divide.

Similar to the "corporate smart city", privacy issues may also be a central concern. Since the design and the control of the technological infrastructure is in the hands of the "sponsors", it is really up to them to choose the degree of transparency and openness for their technologies. Driven by their motives, corporations will determine who may have access to the generated data and whether it will be freely distributed or not. In addition, anonymity for those using the technologies cannot be guaranteed. What differentiates the "sponsored smart city" from the first quadrant is the fact that, here, users might be able to see what kind of data is gathered and how. Therefore, it becomes easier for them to decide which products they should buy and where to implement them.

Last, although the sustainability of open source technologies might allow for a longer use, corporations may keep producing additional products to make more profit. As a result, a higher consumption of ICTs is possible. Still, in case users are able (both in terms of accessibility and technical capabilities) to fork the code, planned obsolescence will be more difficult to implement. Overall, it seems that environmental sustainability is not entirely linked with this type of the smart city. However, in order to speak more accurately about how these technologies affect the environment, a lifecycle assessment would be needed.

Hence, this approach might be less socially and environmentally harmful than the "corporate smart city", but there are drawbacks in exclusively adopting the technology governance model of the "sponsored smart city".

3.3. The "Resilient Smart City"

So far two types of the smart city have been described whose driving force is profit. The "resilient smart city" (bottom-right quadrant) follows a different philosophy which, instead of encouraging the use of top-down, proprietary technology, is focusing on enabling and empowering citizens for the creation of common value (figure 3). This bottom-up approach aspires to foster new forms of participatory planning and governance, where social and cultural factors are of significant importance. Contrary to the "sponsored smart city", the two right quadrants are associated with the philosophical views of the "free software" movement, which are quite different from those of "open source". As seen in section 3.2, many corporations have adopted the open source rhetoric ("sponsored" projects) due to highly practical reasons, like, for instance, it is producing affordable, powerful and reliable technology (Stallman 2015). On the other hand, the philosophy of the "autonomous" (i.e. community-developed) projects is resembling the "free software" movement, which highlights the meaning of the word "free" and respects the users' essential freedoms to run, study, change and redistribute the developed project. These freedoms are vitally important for society as a whole because they promote social solidarity, i.e. sharing and cooperation (Stallman 2015).

Through the intersection of digital technologies with urban life, several initiatives have emerged that overcome the need for firms or governments to provide solutions and are building their own. Such solutions are now being developed at co-working places, universally labelled as microfactories—alternatively they may be called makerspaces, hackerspaces, fablabs or media labs. In general, microfactories are defined as community-led spaces where individuals meet on a regular basis to engage collaboratively in the creation of meaningful, creative projects (Kostakis, Niaros and Giotitsas 2014). Activists, hackers, researchers and others may have access to prototyping tools there, allowing them to explore and produce small-scale solutions for problems of daily life. Hence, cities of this type are becoming laboratories where common value is produced and problems are addressed by citizens who engage in the research, design and testing of solutions (Hardt and Negri 2011; Hemment and Townsend 2013).

An indicative example of such places is the Metalab, which is a non-profit innovation centre based in Vienna. Like all hackerspaces, it offers a physical space for free exchange of information and collaboration between technology enthusiasts, hobbyists and hackers. Amongst others, Metalab's fields of interest include hardware hacking, free public networks and urban hacking/street art. Another initiative that could be linked with the "resilient smart city" is the Medialab-Prado. This collective innovation laboratory has been established by the Madrid city council and is mainly interested in the production, research and dissemination of cultural projects. Through the development of various collaborative projects and events, the Medialab-Prado focuses at sustaining an active community of engaged citizens.

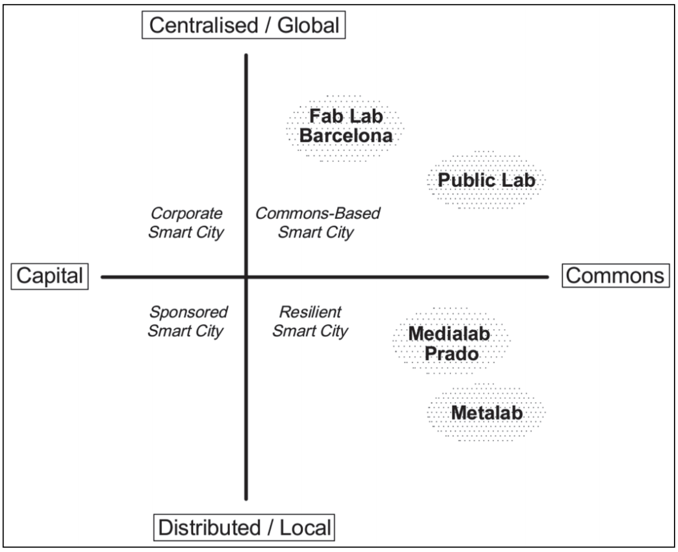

Figure 3: The commons-oriented types of the smart city

The technological infrastructures developed in the aforementioned initiatives have certain characteristics that appear to render this type more efficient than the previous ones. To begin with, they are impregnated with the Do-It-Yourself (DIY) culture which empowers non-experts to become the designers of their own technologies (Antoniadis and Apostol 2014). The threshold for participation in the design process of the technologies is as low as possible, thus we meet higher levels of social inclusiveness. Nevertheless, there are challenges related to digital divides which do not seem to be properly tackled but could be partially addressed through the technical support from the community. Moreover, the fact that citizens have a say during the design and implementation of the technological infrastructures means that almost all of the produced solutions meet existing needs. Hence, this approach is opposed to the supply-driven production system manifested in the previous types and effectively establishes a demand-driven one.

Contrary to the proprietary technologies which come with risks to users' privacy, DIY infrastructures offer a wide range of services that can be operated outside the public Internet (Antoniadis and Apostol 2014). Additionally, since the community has the ownership and the control of the infrastructure, users are able to interact privately within a local network and avoid sharing details beyond it. Also, they have the option of anonymity and can secure their private location information, such as GPS coordinates (Antoniadis and Apostol 2014).

Concerning the environmental impact, the "resilient smart city" demonstrates some more advantages. Firstly, the technologies produced in this type of smart city are designed for a long-term usage. Thus, less consumption of ICT will take place, compared to the left quadrants. Moreover, the modularity of these technologies allows for a better match between citizen's needs and produced solutions. Even if a technological solution fails to tackle a certain problem, the community's ability to adjust it might reverse the situation. Hence, there may be no need to develop new solutions from scratch and consume more materials.

Last, a fundamental characteristic of the "resilient smart city" is the rejection of the value of bigness and an opposition to the organisational tendency toward large scale. Although relations of collaboration and solidarity may well extend to the global level, the solutions are designed in a smaller scale. This includes strong pre-defined goals that can be bound with measurable results, reduced costs but also quick decision-making. On the other hand, it could be claimed that this locally-oriented approach is not utilising the existent dynamics. The knowledge produced in this case may not be widely applicable or even available for adoption elsewhere. Consequently, the scalability of produced solutions is under threat, potentially hindering the circulation of common knowledge and the subsequent diffusion of innovation.

3.4. The "Commons-Based Smart City"

The last quadrant (top-right) includes a type of the smart city, which currently is far from being mature. It exists only in a seed form but, hypothetically, could offer a sustainable alternative for the evolution of the smart city. The manifestation of the smart city in this quadrant draws the attention towards the global commons (figure 3). Advocates and builders of this approach argue that the commons should be created and fought for on a transnational global scale (Kostakis et al. 2015). The "commons-based smart city" is characterised by wide citizen engagement, while designing and implementing the technological infrastructures, and an ongoing circulation of the commons, which promotes continuous innovation and knowledge diffusion on a global scale.

As already mentioned at the "corporate smart city" (section 3.1), there is a tendency to group smart city discourses into an all-inclusive narrative and use certain examples as indicative of all cities. Unquestionably, cities share some characteristics, but they also have distinct cultures, histories and political economies that shape the urban environment and the relational dynamics. Hence, it can be argued that a globally-organised system for urban development might not be sustainable.

On the other hand, there are numerous small-scale urban commons projects emerging which might be applicable to other cities as well. Consequently, a logical next step would be to communicate the scattered knowledge produced at the local level. One way to do this is through microfactories. Such spaces are considered as essentially networked and might catalyse the up-scaling of the produced commons, not only within the city of origin but universally as well.

An initiative working towards that direction is the Public Laboratory for Open Technology and Science (Public Lab). The Public Lab is a worldwide community of local activists, educators and researchers, which develops and applies open source hardware and software tools to environmental exploration and investigation. Their goal is to grow a collaborative network which will support and enable citizens to discover, contribute and collaborate on locally important matters. Another initiative, which shares the global-orientation is the Fab Lab Barcelona. As a core member of the international fab lab network (Fab Foundation), it aims at creating opportunities to improve lives and livelihoods around the world, by providing citizens with access to the necessary tools and knowledge. Currently, the Fab Lab Barcelona is developing projects in different scales, from smart devices for data collection by individuals (Smart Citizen), to conceptualising new models for cities (Fab City).

However, there are constraints that lead us to the assumption that microfactories alone cannot accomplish the aforementioned goal. First of all, while an increasing number of people are getting involved with microfactories, there is a large part of the population who do not. Yet cities cannot afford to neglect them, since through the collaboration with commons-oriented communities, every citizen could bring to the front an interesting idea and succeed in implementing it (Kostakis, Fountouklis and Drechsler 2013). In addition, as Harvey (2012) argues, in order to address large-scale problems, such as the global warming, more "centralised" forms of organisation are needed.

It becomes evident that, in order to succeed at scale, grassroots innovation needs support from the appropriate institutions (Kostakis, Bauwens and Niaros 2015). Therefore, this type suggests that smart cities should follow a more synthetic approach which combines: i) the bottom-up innovation through which citizens seek to create a better life for themselves and their community and ii) the top-down policies and planning that seek to distribute resources fairly so that everyone has the opportunity to innovate successfully. This notion has also been articulated by Campbell (2009), an urbanist whose "Massive/Small" concept and theory of "Smart Urbanism" are based on the belief that cities need to harness the collective power of small-scale innovation to make a big difference.

In a nutshell, the adoption of the "commons-based smart city" might encompass all the advantages of the third quadrant infused with characteristics like interoperability and scalability. This could present a more viable alternative for a smart city which takes advantage of the global knowledge commons and utilises them on the local level. Of course, it is not claimed that all cities should apply the same technological solutions and disregard their peculiarities. Instead, they could follow a demand-driven approach and leverage the part of knowledge that suits best to their needs. In addition, collaborating and sharing knowledge on a global basis may inspire the communities to create new tools and solutions related to their local environments and, thus, enrich the global commons.

In order to enhance the functionality of this model, the creation of a unique culture is vital. This may be accomplished through supporting small-scale innovation, which can serve as an awakener for the local community and lead to the creation of a robust paradigm whose core value is collaboration. Towards that direction, governments and local authorities should provide appropriate facilities to enable the deployment of participative ways of working, which will help in producing social innovation outcomes. This could be done by promoting the establishment of collaboration spaces, such as microfactories, in the city and enhance the digital connectivity amongst citizens. Furthermore, governments should focus on establishing legal frameworks that offer the best opportunities to develop local sustainable solutions (for a discussion on the relationship between law and technology see Drechsler and Kostakis 2015). After ensuring the existence of the basic infrastructures, the next step would be to integrate them into every day social interaction and make all data available to citizens. This could be achieved by building digital platforms to promote open governance through the collaboration between local governments and city-dwellers. Moreover, in order for locally-produced innovations to be diffused and adopted globally, the infrastructure should comply with standards that would be designed to enhance interoperability. These standards should shape technologies that are easily accessible, transparent and open to adaptation to local conditions. At the same time, local authorities could contribute to the adoption of open standards through planning frameworks and procurement practices.

4. Conclusions

This essay argues that the formation of the smart city is partially determined by the model of technology governance they embody. The four types differ in their vision for the prime focus, either for the profit maximisation or the production of common value, and the nature of the produced technologies.

It can be articulated that without the adoption of open ICT infrastructures and platforms (i.e. free/open source software and hardware), the construction of a truly smart city will be highly unlikely. Thus, I support a commons-oriented smart city that will provide the capacity for open participation and democratic problem-solving procedures. Citizen engagement in the decision-making processes is essential to create a direct link between technology and the needs of city-dwellers. Participatory urban technologies, greater social inclusion, and a substantial shift in power from corporations to ordinary people and their communities, are crucial elements of a socially sustainable city.

Further, this essay suggests that a commons-oriented smart city exhibits less privacy issues than a corporate one, due to the citizens' motives and the openness of the deployed technologies. Nevertheless, it would be risky to make any assumptions about how scale relates to this matter. Although many researchers and activists have the tendency to presuppose that local equates with 'good' and it is preferred over non-local scales, Purcell (2006) claims that we cannot assume a priori that locally controlled structures are inherently more democratic than global ones or vice versa.

From an environmental perspective, this work argues that the demand-driven production system established in the commons-oriented smart city may offer more benefits. In fact, the reduced consumption of ICTs and the utilisation of the existing conditions in the city allow for more sustainable outcomes.

Last, it is worth noting that there is a lack of in-depth empirical research on a range of smart city developments. Until recently, there have been relatively few extensive case studies on smart cities. Most of the academic work either provides short overviews and critiques on the smart city concept or follows a more technical perspective and introduces new technologies. Thus, further investigation could focus on the empirical study of smart cities and, possibly, compare the propagandised smart city with the actual one.

References

Albino, Vito, Umberto Berardi and Rosa Maria Dangelico. 2015. Smart Cities: Definitions, Dimensions, Performance, and Initiatives. *Journal of Urban Technology* 21 (1): 3-21.

Antoniadis, Panayotis and Ileana Apostol. 2014. The Right(s) to the Hybrid City And the Role of DIY Networking. *Journal of Community Informatics* 10. Accessed June 8, 2015. http://ci-journal.net/index.php/ciej/article/view/1092.

Benkler, Yochai. 2006. *The Wealth of Networks: How Social Production Transforms Markets and Freedom*. New Haven: Yale University Press.

Campbell, Kelvin. 2009. *Massive Small: The Operating System for Smart Urbanism*. Urban Exchange.

Carvalho, Luís. 2015. Smart Cities From Scratch? A Socio-Technical Perspective. *Cambridge Journal of Regions, Economy and Society*, 8 (1): 43–60.

Castells, Manuel. 2000. *The Rise of the Network Society: The Information Age: Economy, Society, and Culture*. 2nd ed. Malden, MA: Wiley-Blackwell.

Chambers, John and Wim Elfrink. 2014. The Future of Cities: The Internet of Everything Will Change How We Live. *Foreign Affairs*. Accessed June 8, 2015 http://www.foreignaffairs.com/articles/142324/john-chambers-and-wim-elfrink/the-future-of-cities.

Drechsler, Wolfgang and Vasilis Kostakis. 2015. Should Law Keep Pace With Technology? Law as Katechon. *Bulletin of Science, Technology & Society,* 34 (5-6): 128–132.

Fuchs, Christian. 2013. Theorising and Analysing Digital Labour: From Global Value Chains to Modes of Production. *The Political Economy of Communication* 1 (2): 3-27. Accessed June 8, 2015. http://www.polecom.org/index.php/polecom/article/view/19.

Glaeser, Edward L. 2011. *Triumph of the City: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier, and Happier*. New York: Penguin Press.

Greenfield, Adam. 2013. *Against the Smart City*. New York: Do Publications.

Hardt, Michael and Antonio Negri. 2011. Commonwealth. Cambridge, MA: The Belknap Press.

Harvey, David. 2012. *Rebel Cities: From the Right to the City to the Urban Revolution*. London: Verso.

Hemment, Drew and Anthony Townsend. 2013. *Smart Citizens*. Manchester: FutureEverything Publication. Accessed June 8, 2015. http://futureeverything.org/wp-content/uploads/2014/03/smartcitizens.pdf.

Hollands, Robert. 2015. Critical Interventions Into the Corporate Smart City. *Cambridge Journal of Regions, Economy and Society* 8 (1): 61–77.

IBM. 2014. Intelligent Operations Center for Smarter Cities. Accessed June 8, 2015. http://www-03.ibm.com/software/products/en/intelligent-operations-center.

Kitchin, Rob. 2014. The Real-Time City? Big Data and Smart Urbanism. *GeoJournal* 79 (1): 1–14.

Kostakis, Vasilis and Michel Bauwens. 2014. *Network Society and Future Scenarios for a Collaborative Economy*. Basingstoke: Palgrave Macmillan.

Kostakis, Vasilis, Michail Fountouklis and Wolfgang Drechsler. 2013. Peer Production and Desktop Manufacturing: The Case of the Helix_T Wind Turbine Project. *Science, Technology & Human Values* 38 (6): 773–800.

Kostakis, Vasilis, Michel Bauwens and Vasilis Niaros. 2015. Urban Reconfiguration after the Emergence of Peer-to-Peer Infrastructures: Four Future Scenarios with an Impact on Smart Cities. In *Smart Cities as Democratic Ecologies*, edited by Daniel Araya, 116–124. New York, NY: Palgrave Macmillan.

Kostakis, Vasilis, Vasilis Niaros and Christos Giotitsas. 2014. Production and Governance in Hackerspaces: A Manifestation of Commons-Based Peer Production in the Physical Realm?. *International Journal of Cultural Studies*.

Kostakis, Vasilis, Vasilis Niaros, George Dafermos and Michel Bauwens. 2015. Design Global, Manufacture Local: Exploring the Contours of an Emerging Productive Model. *Futures* 73: 126–135.

Libelium. 2015a. Libelium Releases Smart Cities Sensor Platform for Precise Urban Monitoring. Accessed June 8, 2015. http://www.libelium.com/new-smart-cities-platform-air-quality-dust-sound-light-precision-sensors/.

Libelium. 2015b. Get Inspired: 50 Sensor Applications for a Smarter World.

Morozov, Evgeny. 2013. *To Save Everything Click Here: The Folly of Technological Solutionism*. New York: Public Affairs.

Norris, Pippa. 2001. *Digital Divide: Civic Engagement, Information Poverty, and the Internet Worldwide*. New York: Cambridge University Press.

Purcell, Mark. 2006. Urban Democracy and the Local Trap. *Urban Studies* 43 (11): 1921–1941.

Reuters, 2015. IBM Says to Invest $3 Billion in 'Internet of Things' Unit. Accessed June 8, 2015 http://www.reuters.com/article/2015/03/31/us-ibm-investment-idUSKBN0MR0BS20150331.

Sassen, Saskia. 2012. Urbanising Technology. *LSE Cities*. Accessed June 8, 2015. https://lsecities.net/media/objects/articles/urbanising-technology/en-gb/.

Shelton, Taylor, Matthew Zook and Alan Wiig. 2015. The 'actually existing smart city'. *Cambridge Journal of Regions, Economy and Society*. 8: 13-25.

Stallman, Richard. 2015. Why Open Source Misses the Point of Free Software. *GNU*. Accessed June 8, 2015. http://www.gnu.org/philosophy/open-source-misses-the-point.html..

Townsend, Anthony M. 2013. *Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia*. New York: W. W. Norton & Company.

United Nations. 2008. World Urbanization Prospects: The 2007 Revision. Accessed June 8, 2015. http://www.un.org/esa/population/publications/wup2007/2007WUP_Highlights_web.pdf.

Vanolo, Alberto. 2014. Smartmentality: The Smart City as Disciplinary Strategy. *Urban Studies* 51 (5): 883–898.

Viitanen, Jenni and Richard Kingston. 2014. Smart Cities and Green Growth: Outsourcing Democratic and Environmental Resilience to the Global Technology Sector. *Environment and Planning A* 46 (4): 803–819.

West, Joel and Siobhán O'Mahoney. 2008. The Role of Participation Architecture in Growing Sponsored Open Source Communities. *Industry & Innovation* 15 (2): 145–168.

Widenius, Michael and Linus Nyman. 2013. Introducing "Business Source": The Future of Corporate Open Source Licensing? *Technology Innovation Management Review* 3 (6): 5–12.

About the Author

Vasilis Niaros

Vasilis Niaros is an engineer/urbanist and a PhD candidate at the Ragnar Nurkse School of Innovation and Governance, Tallinn University of Technology. His research interests include open source technologies, smart cities, makerspaces and do-it-yourself culture.

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Article

Production and governance in hackerspaces: A manifestation of Commons-based peer production in the physical realm?

Vasilis Kostakis, Vasilis Niaros and Christos Giotitsas
Tallinn University of Technology, Estonia; P2P Lab, Greece

Abstract
This article deals with the phenomenon of hackerspaces and sheds light on the relationship of their underlying values, organizational structures and productive processes to those of the online communities of Commons-based peer production projects. While hackerspaces adopt hybrid modes of governance, this article attempts to identify patterns, trends and theory that can frame their production and governance mechanisms. Using a diverse amount of literature and case studies, it is argued that, in many cases, hackerspaces exemplify several aspects of peer production projects' principles and governance mechanisms.

Keywords
commons, community governance, hacker culture, hackerspaces, open source, peer production

The phenomenon of Commons-based peer production (CBPP) has recently been gathering increasing attention from scholars and practitioners. Researchers have been investigating the governance mechanisms of Commons-based online communities, such as those which participate in free/open source software (FOSS) projects or in Wikipedia,

Corresponding author:
Vasilis Kostakis, Tallinn University of Technology, Ragnar Nurkse School of Innovation and Governance, Akadeemia tee 3, Tallinn, 12618, Estonia.
Email: kostakis.b@gmail.com

arguing that hybrid modes of governance, which share certain characteristics, are exercised (see Bauwens, 2005; Bruns, 2008; Dafermos, 2001; Kostakis, 2010; O'Mahony and Ferraro, 2007; O'Neil, 2009). However, few scholarly studies have dealt with what happens when individuals, immersed in the hacker culture, meet in person and start to organize their productive activities in physical places. These communities found or form open organizations with a strong emphasis on technology and experimentation, where participants share knowledge, ideas, tools and equipment in a community-driven physical space. In this article these formal or informal organizations/communities are embraced by the term 'hackerspaces', and the relationship of their organizational structures and productive processes to those of the online communities of CBPP projects is discussed.

Therefore the aims of this article are to tentatively examine if and how CBPP translates into physical-space practices, and in particular the large number of hackerspaces around the world. Thus the question raised is whether hackerspaces do in fact, and to what extent, replicate governance structures and principles we already observe in online CBPP. To this end, first we shed light on the theoretical framework which defines the context within which the concept of hackerspace is emerging. More specifically, we consider the meaning of 'hacking' as a creative, trial-and-error, experimental, productive and problem-solving process. We then provide a bird's-eye-view of the political economy of CBPP, which is premised on the 'hacker ethic'. Next, we refer to the research methodology as well as the empirical setting on which our ensuing discussion is based. Finally, a brief summary of the argument follows, along with some recommendations for future research.

The emergence of hackerspaces

'Hacking' has been a controversial term during recent decades. It can be claimed that there are various types of hackers: the benevolent, white-hat hacker who, in Wark's (2004, 2013) and Levy's (2001) vein, experiments, tinkers, modifies, creates and/or participates in collective productive projects. There is also the grey-hat hacker who tends to hold a morally ambiguous role (Parker, 2005). Then there is the malicious, black-hat hacker who has criminal intentions, causes damage and/or steals information (Kostakis, 2012). Of course, such a broad categorization entails dangers of misinterpretation; arguably, however, it helps to exclude from our discussion hackers who carry out self-evidently criminal acts, such as overcharging citizens' credit cards.

'The pirate takes another's property', Wark (2013: 73) writes, whereas 'the hacker makes something new out of property that belongs to everyone in the first place'. Therefore, in this article 'hacking' is understood as a creative process, immersed in the 'hacker ethic' of problem-solving (Erickson, 2008) as well as of producing innovative artifacts (Söderberg, 2007; Wark, 2004). According to several scholars (Levy, 2001; Himanen, 2001; Dafermos and Söderberg, 2009; Maxigas, 2012; Söderberg, 2007; Thomas, 2002; Wark, 2004, 2013), who have taken a close look at the phenomenon, fundamental aspects of the hacker ethic include freedom, in the sense of autonomy as well as of free access and circulation of information; distrust of authority, that is, opposing the traditional, industrial top-down style of organization; embracing the concept of learning by doing and peer-to-peer learning processes as opposed to formal modes of learning; sharing, solidarity and cooperation.

However, the hacker ethic is not a solid set of norms values and practices but a heterogeneous aggregation of codes ranging from the American and Anglo-European liberal tradition to the leftist, anarchist politics critical of economic globalization that creates a wide and diverse map of practices (Coleman and Golub, 2008). It has been argued that these hacker practices are at the epicentre of the struggle for freedom, privacy and access in the realm of information technologies, or to put it in Coleman's and Golub's words:

> Through regular and shared routine practices of their ordinary, technical life … hackers come to collectively embody evaluative moral and aesthetic dispositions in which knowledge is sacred territory; access to and personal control over the means of information creation and circulation is valued as essential; and technical activity is often experienced as the vehicle for self-fashioning and creative self-expression. (2008: 271)

The hacker subculture started in the 1960s and took off in the 1970s from the MIT Artificial Intelligence Laboratory and other research institutes in the US, as well as from the phreaker scene through the magazine *TAP* (*Technological American Party*) (Maxigas, 2012). The hacker ethic is further considered to share some common characteristics with the hippie culture dating back to the 1950s and 1960s and evolving over the decades through different generations (Hogge, 2011; Levy, 2001; Lobo, 2011) and various socio-economic transformations (Benkler, 2006; Bauwens, 2005; Castells, 2000, 2003). Regarding the latter, the implications of this are discussed later; however, it is important to stress that it is in the context of the networked, information-based society that hackers started to form online and offline communities, sharing knowledge, tools and ideas. Arguably there was a need to organize, in a more systematic way, these conversations among hackers in physical spaces, which led to the creation of communities such as the Homebrew Computer Club in the mid 1970s, the Chaos Computer Club in 1981 or the first hackerspaces, as we know them today, in Berlin (C-base) and Cologne (C4) in the mid 1990s. The phenomenon is not entirely unprecedented and the surge of hackerspaces was also pre-dated by the hacklabs in the early 1990s (for a comparative analysis of hacklabs and hackerspaces see Maxigas, 2012).

Nowadays there are many different initiatives and institutions that consider themselves as 'hackerspaces' (Maxigas, 2012). Troxler (2011) and Maxigas (2012) distinguish different kinds of similar workplaces, such as hackerspaces, fablabs, hacklabs, makerspaces and media labs. In the current article, for the sake of clarity, the term 'hackerspaces' refers to the physical, community-led places where individuals, immersed in a hacker ethic, are to be met with on a regular basis engaging with meaningful, creative projects. Schneeweisz (in Lobo, 2011) argues that it is impossible to find two hackerspaces that are alike and that is why, as Moilanen (2012) points out, there is still no agreed, compact definition of hackerspaces.

Since the establishment of C-base and C4, the number of hackerspaces has grown rapidly and, at the time of writing (August 2013), there are about 896 active hackerspaces around the world and 521 soon to be founded or currently being built, according to hackerspaces.org (2013). For comparison purposes, it is interesting to note down that at the beginning of 2007 there were worldwide 30–40 active hackerspaces whereas almost 4.5 years later (July 2011) their number had risen to 480, particularly in Europe and USA (Lobo, 2011). It can be argued that the hacker ethic, through hackerspaces' public visibility and permanent contact with society as an open third space (Farr, 2009; Lobo, 2011; Oldenburg, 1997), is achieving wide dissemination in comparison to the early stereotype of hacking as a marginalized subculture.

It can be claimed that hacking, hackerspaces and the hacker ethic in general are of great interest, especially if seen through the lenses of the political economy of CBPP, in which individuals, immersed in the hacker ethic, have been playing a prominent role.

The emergence of CBPP

Plenty of attention has been gathering around the information production models enabled by the modern information and communication technologies (ICT) and brought to the forefront by collaborative projects such as the FOSS movement or the free encyclopaedia Wikipedia. On the other hand, authors such as Webster (2002a, 2002b) have argued against the idea of an (egalitarian) 'information society'. They emphasize the continuities of the current age with former capitalist-oriented social and economic arrangements (Schiller, 1981, 1984, 1996; Webster 2002a, 2002b). Kumar (1995:154) maintains that the information explosion 'has not produced a radical shift in the way industrial societies are organized' and concludes that 'the imperatives of profit, power and control seem as predominant now as they have ever been in the history of capitalist industrialism'. The widespread adoption of ICT cannot automatically produce a better world for humanity as, following Winner (1986), some technologies need the appropriate social environments to be structured in a certain way. The rise of the information society does not necessarily transcend capitalism: class relations still dominate society today, though with an apparent shift of productive forces from physical labour to cognitive labour (Fuchs, 2012). Thus changes have come to pass in the class structure with the coming of ICT, along with the first signs of an alternative society (Fuchs, 2012).

Because there have been several cases of successful networked-based collaborative projects, some see the emergence of new 'technological-economic feasibility spaces' as setting a new agenda for social practice (Benkler, 2006: 31). These feasibility spaces – we will argue that hackerspaces can be considered as such also – include different social and economic arrangements, in contrast to the claim made by Kumar and Webster, where profit, power, and control do not seem as predominant as they have been in the history of modern capitalism. In these technological-economic feasibility spaces a new social productive model, that is, CBPP, is emerging that is different from the industrial one. CBPP, exemplified by various software (GNU, the Linux kernel, KDE) and content (Wikipedia) projects, makes information sharing more important than the value of proprietary strategies and allows for large-scale information production efforts (Benkler, 2006). In this context, CBPP could be considered an early seed-form stage of a new mode of information production enabled through internet-based coordination, where decisions arise from the free engagement and cooperation of the people, who coalesce to create common value without recourse to monetary compensation as key motivating factor (Bauwens, 2005; Kostakis, 2013; Orsi, 2009).

Following Bauwens (2005, 2009), CBPP is based on processes which stand in contrast to those of the market-based business firm. More specifically, CBPP is opposed to industrial firms' hierarchical control and authority, but rather is based on communal validation and negotiated coordination as quality control is community-driven and conflicts are solved through an ongoing mediated dialogue. Further, CBPP is generally unrelated to the for-profit orientation of market-driven projects, as CBPP projects have a for-benefit orientation, creating use value for their communities. This does not mean that in CBPP projects, the profit motive is absent, but rather, that incentives such as learning, communication and experience come to the fore. According to Hess's (2005) 'private-sector symbiosis' hypothesis, the emphasis on technology and product innovation can lead 'to the articulation of social movements' goals with those of inventors, entrepreneurs, and industrial reformers. Therefore, 'a cooperative relationship emerges between advocacy organizations that support the alternative technologies/products and private sector firms that develop and market alternative technologies' (Hess, 2005: 516). The case of Linux and IBM affirms Hess's argument. Moreover, instead of the division of labour, in CBPP a distribution of modular tasks takes place, with anyone able to contribute to any module while the threshold for participation is as low as possible. And, finally, it is opposed to the rivalry (scarcity of goods) through which market profit is generated, as sharing the created goods does not diminish the value of the good, but actually enhances it (Bauwens, 2005; Benkler, 2006).

Hence, it becomes obvious that what sets CBPP apart from the industrial mode of production is its mode of governance (meritocracy with consensus-oriented governance mechanisms) and property (communal shareholding). In short, according to the literature (see Bauwens, 2005; Benkler, 2006; Bruns, 2008; Kostakis, 2012) some key aspects of CBPP consist of sharing, abundance of resources, intrinsic positive motivation, openness, collaboration, bottom-up innovation, community accountability, autonomy, communal validation, distribution of tasks, and common ownership of the results. These aspects arguably create an alternative political economy where economic efficiency, profit and competitiveness cease to be the sole guiding stars (Moore and Karatzogianni, 2009) and civil society has a more fundamental role, bringing the notion of mutual cooperation back into the very heart of economy (Orsi, 2009).

Many scholars have highlighted the original characteristics of CBPP and the Commons, considering them either as immanent (Benkler, 2006, 2011; Tapscott and Williams, 2006; von Hippel, 2005), transcendent (Hardt and Negri, 2011; Merten and Meretz, 2009; Siefkes, 2007; Rigi, 2012) or even, following an integrative approach, both immanent and transcendent (Bauwens 2005, 2009) in relation to the capitalist system. Bauwens (2005, 2009) and Kostakis (2013) maintain that CBPP simultaneously creates a new form of capitalism while pointing out how that new form can be overcome. As a hyperproductive mode, CBPP forces the for-profit entities to adapt to its characteristics, 'thereby further integrating it into the existing political economy, but not without the transformative effects of its market transcending aspects' (Bauwens 2009: 121). The take of this article concerning the potential of CBPP is in line with Bauwens' idea that this passionate mode of production (Moore and Karatzogianni, 2009) has features that 'decommodify both labor and immaterial value and institute a field of action based on peer-to-peer dynamics and a peer-to-peer value system' (Bauwens, 2013: 208). CBPP functions within the cycle of accumulation of capital but also within the cycle of the creation and circulation of the Commons (Bauwens, 2013). Therefore, with regard to the criticism (in addition see Keen, 2007; Lanier, 2010) directed against the egalitarian potential of the 'information society', which mistakenly equates proprietary-based initiatives (e.g. Facebook) with Commons-based ones (e.g. FOSS), it can be stated that the ICT 'revolution' exhibits both emancipatory/creative and exploitative/dystopic aspects (Fuchs, 2008; Kostakis, 2009).

Research methodology and empirical setting

When dealing with a group phenomenon – such as the emergence of hackerspaces – which has not been thoroughly examined, the in-depth case study may serve as an appropriate approach (Dafermos, 2001; Radloff and Helmreich, 1968). The studies of CBPP projects (see Dafermos, 2001; Kostakis, 2010; Mateos-Garcia and Steinmueller, 2008; O'Mahony and Ferraro, 2007; Shah, 2006) demonstrate clearly the penetrating insights that a longitudinal study permits by covering a time-span in which the project has grown considerably, so that the particular modes of production and governance can be examined in a rigorous manner. However, the aforementioned studies investigate the production and governance mechanisms of, mainly, online communities which collaborate and produce in a state of abundance that is a main characteristic of CBPP projects with serious implications for their governance mode (Kostakis, 2010).

Taking into consideration Schneeweisz's claim (in Lobo, 2011) that it is impossible to find two hackerspaces that are alike, this investigation should include more than one case study in the effort to document some of the basic elements and principles upon which production and governance are based in these places. To enhance the validity of the case study approach, it was decided to focus on eight distinct hackerspaces which have various differences in their date of establishment, degree of activity, legal status, projects run, number of members and guests, and city/country. Initially we contacted the members of 15 hackerspaces around the world that fitted the desired diversity. The eight that were willing to cooperate openly were chosen. This article's primary sources of data consist of the observation of hackerspaces' functions in both a physical (i.e. visiting hackerspaces) and virtual manner (through various mailing lists, foras and web sites). Thus, on the one hand we did not get involved in either the actual development process or in any conversation that took place in the various mailing lists and (virtual) discussion foras. On the other hand, however, we visited two of the hackerspaces and observed some of the activities and the projects run there, revealing our identity. Issues such as authorization to explore the particular organization and questions as to whether to reveal one's 'research identity' (Mayo, 1945; Schwartz and Jacobs, 1979) are not irrelevant when one is physically present, and we are aware of the fact that the group behaviour could have changed due to our physical presence. To reduce the possibility for bias we tried to combine both virtual (where our identity is not revealed as access is open and discussions are public) and physical observation.

This article's primary sources of data also consist of 23 semi-structured interviews by voip, email and face-to-face contact in order to establish a possible connection between CBPP and its physical manifestation in such groups of people. We contacted not only individuals who play a key role in the examined hackerspaces, and as a consequence were easier to track down from their respective websites, but also individuals who take part in hackerspaces projects either as peripheral members or guests, mainly those that appeared more active in the mailing lists and foras. Further, we use the empirical data provided by the longitudinal statistical survey of Jarkko Moilanen (2012), co-founder of 5w hackerspace at Tampere as well as investigator of hackerspace communities' ethics. Moilanen, through a random sample of 201 participants in 2010 and 250 participants in 2011, tries to document the demographics and the motivations of those who participate in the production process of hackerspaces. His survey's quantitative results are freely accessible via the open platform Statistical Studies of Peer Production (Moilanen, 2012), and have been featured in the press review of France24 (2011) as well as in an infographics format by Owni (Blanc, 2011).

Analysis and results: production and governance in hackerspaces

The discussion is organized around 11 basic characteristics of CBPP, as outlined before, with the aim of detecting their presence and applicability in the examined hackerspaces. In particular, we see what the interviews and observation evidence say about a specific number of clearly delineated characteristics of CBPP, namely, intrinsic positive motivation; openness; collaboration; sharing; common ownership; bottom-up innovation; community accountability; communal validation; autonomy; distribution of tasks; and abundance of resources. It is important to note that our discussion does not try to be exhaustive or all-inclusive but to answer our question in reference to these fundamental characteristics.

Intrinsic positive motivation

Moilanen's (2012) longitudinal survey shows that participants in hackerspaces are mainly motivated by various positive intrinsic incentives. For individuals who took part in the 2010 and 2011 survey (Moilanen, 2012) the most important factors of motivation seem to be: communication and interaction with other hackers in physical space; fun and learning; altruism; and community commitment. Also, in the vein of online CBPP (Benkler, 2006), money remains a peripheral concept only. Comparing 2010 with 2011 data it can be claimed that the attitude towards earning money as well as reputation-building has become slightly less negative. As Moilanen told us,1 the 'physical hackerspace is needed for several reasons, but I think the biggest reason is social. People want to meet others in the flesh.' All these are consistent with every single interview we took from members and guests concerning their motives for involvement in hackerspaces. In addition, all the interviewees, with one exception, replied that they are or have been contributing to online CBPP projects before their involvement in hackerspaces; however the former did not motivate the overriding majority for the latter. 'I would say that my values (which precede both activities) have motivated my involvement in peer production as well as HS [hackerspace]', Kelly Buchanan, treasurer at the San Francisco-based Noisebridge, says, reflecting the general tenor of the answers we received. Moreover, it could be claimed that hackerspace is both a social and a political experiment (as was done by M. Altman, Y. Kargiotakis, N. Brik). 'We're here to make the world a better place', Nigel Brik, co-founder of Utrecht-based Randomdata, exclaims, while Yorgos Kargiotakis from Athens-based Hackerspace articulates that: 'we are trying to change a culture of misery which permeates Greek society against openness, sharing and experimentation'.

Further, Johan Söderberg, a researcher of hacker culture and a hackerspace guest, believes that falling costs, which will make desktop manufacturing equipment (such as 3D printing) more accessible, could lead to the replacement of collective spaces with individualized, desktop workshops. This point is partially echoed by Stelios Tsampas from P-Space in Patras, who underlines that not only social interaction and peer learning but also the cost-effectiveness of hackerspaces concerning equipment was a determining factor for his participation. Although we agree with Söderberg's proposal that an explicit political agenda may provide hackerspaces with a raison d'être beyond just making tools available, we would partly disagree with his former allegation. And the reason for this is that arguably hackerspaces come into existence, as a third place (see Oldenburg, 1997), mainly to satisfy the need of people who share the hacker culture to socialize. Following Oldenburg's (1997) concept of 'third places', the spaces where individuals would gather to exchange knowledge, share tools and create common value could be considered as alternative locations to one's house (first place) and work (second place). Their role, according to Oldenburg (1997), is of a great importance for communities' social vitality because it is through third places that people socialize and satisfy some of their higher needs. Thus, the emergence of hackerspaces can be seen as an answer to the loss of the community reference (Lobo, 2011) and an effort to bring into a physical space emerging modes of social production coordinated with the aid of the internet. Hence, even if the costs, especially concerning equipment necessary for physical production, fall considerably, it could be argued that hackerspaces will not cease to exist because what mostly motivates participants is not shared tools but the social process of sharing the tools.

To conclude, it appears that the involvement in hackerspaces could arguably produce social happiness, as it seems to be based on intrinsic positive motivations similar to those of online CBPP projects (Benkler, 2006; Hertel et al., 2003; Lakhani and Wolf, 2005). Thus, according to the aforementioned discussion, hackerspaces and online CBPP communities are very similar in terms of their participants' incentives.

Openness, collaboration, sharing and common ownership

'The barrier to entry [in hackerspace projects] is to hack on stuff or to help out with whatever needs to be done.' Thus, 'that barrier isn't a door; it's a social thing' Jacob Appelbaum, Noisebridge's co-founder, postulates. The openness of hackerspaces to new members as well as to guests is also stressed in all the interviews carried out with members, founders and guests. Anyone is equally free to participate in any project: 'the only requirement is interest', Mitch Altman, Noisebridge's co-founder, states. However, G., a regular visitor at two USA-based hackerspaces, notices that some spaces are 'radically inclusive. To a fault.… I go there less frequently because they seem to allow people who are disruptive.' The degree of inclusiveness and openness differs from hackerspace to hackerspace, and being a paying member may offer some additional provisions. For instance, often it can be 24/7 access to space and tools (from traditional tools to 3D printers, laser cutters, sensors and computers); to storage space for running projects; and to consumable things (from CDs to beverages). Moreover, membership allows full participation in all the examined hackerspaces' official decision-making processes.

Further, seven out of the eight hackerspaces studied explicitly refer to 'do-ocracy' as one of the two modes of decision-making. The second relates to 'bigger decisions' (D. Fotel), such as operational ones (K. Buchanan), which are taken through weekly, biweekly or monthly meetings based on either consensus or voting. Of course, opinions are asked and topics are discussed among participants, as was observed in all the mailing lists or chat of the investigated hackerspaces prior to and/or after the arranged meetings. In addition, David Raison, co-founder of Luxemburg-based Syn2cat, mentions that they have been changing from 'where everybody present could vote to decision taking by the council by majority vote, to consensus in a steering group and back and forth'. Regarding Noisebridge, 'the grand majority of decisions made … are unofficial and do not require consensus' (K. Buchanan). In the same fashion most of the examined hackerspaces 'try to be a do-ocracy, meaning that if you do something, you are more right than somebody who just suggests something on the mailing list' (M.) or, to quote Nikos Roussos, co-founder of Athens-based Hackerspace, 'the more active participants will finally take the lead'. Some decide to do something and they simply start doing it inviting more to collaborate: 'those who dedicate more time and energy for the hackerspace are actually those who define the community's fate and not those who just vote' (Y. Kargiotakis). And after all, to quote Dimitris Tzortzis from P-Space, 'it is better to apologize [after having done something] than asking for permission [in order to do something]'. We believe that the tendency (see Kogut and Metiu, 2001; Lee and Cole, 2003; Raymond, 2001) of open source communities to operate in a meritocracy, but without a clear idea of what merit really means (O'Mahony and Ferraro, 2007), applies to hackerspaces as well. Our data suggests that merit is built upon a mix of organizational building and technical contributions, which may differ from case to case.

Further, the ownership of the infrastructure, which may have been acquired by donations (internal or open), fundraising and/or sponsorship, rests with the community in all the hackerspaces under study. People can take advantage of the infrastructure to work on either community or personal projects. Regarding the latter, it would be interesting to mention Raison's opinion, as it reflects more or less the general spirit of hackerspaces (although it is not an essential part of that spirit): 'I'd prefer people to work on common infrastructure projects … than on their own projects, but at least by working on them [i.e. personal project] at the space, they populate the space and I see that as their contribution.' Sometimes, although everyone can use the infrastructure for a personal project, hackerspaces' community collaborative projects may be prioritized (N. Brik). Also it is often appreciated if people who are running their personal projects contribute something to the community, either financially or in another creative way (D. Fotel).

Some hackerspaces have a clearly defined policy of sharing the results of the projects run using Commons-oriented licences whereas some others do not have such an explicit rule or statement, but they seem to favour Commons-oriented licences over proprietary ones. As Altman emphasizes, despite the fact that Noisebridge has only one rule (i.e. 'be excellent to each other'), all the projects are Commons-based, as far as he knows. Of course, the mode of ownership depends on the nature of the project, that is, whether it is software or hardware: 'if it is about collaboratively developing software and you seriously disagree with your team fellows, you can easily break up and continue the project on your own.… However, if we speak about, say, a robot, things become much more complicated' (T. Papatheodorou). Buchanan also notices the difference in terms of property that emerges from the nature of personal projects:

> There are plenty of projects which … are actually personal projects. I may bring in a camera that I want to hack and hack it at Noisebridge and then take it home with me. This is a very common use of Noisebridge's resources. However, none of these projects are 'Commons-based projects' really.

It is obvious that Buchanan's argument is right, but it is also true that even personal projects can benefit from collaborative assistance. Therefore it is important to distinguish personal projects from collaborative ones as, especially in terms of property, the licence/regime/status of the final results may seriously differ.

To conclude, openness, collaboration and sharing serve as the bedrock of hackerspaces' functioning more or less in the way that they define online CBPP. However, in terms of property there are arguably two levels: one in terms of infrastructure and another in terms of results produced. In online CBPP, infrastructure mainly consists of a personal computer and an internet connection –it is distributed and 'personal' – but in hackerspaces things can be more complicated as infrastructure is more expensive and, thus, 'communal' and 'centralized'. That's why the majority of the hackerspaces studied provide different degrees of access to infrastructure for members and non-members. In terms of the hackerspace-based projects, all the investigated hackerspaces are in general Commons-oriented either explicitly or implicitly. Thus, online CBPP and hackerspace projects differ as in the former the Commons-orientation is always and explicitly stated whereas in the latter it can be implicit, and there are cases where personal projects, not really Commons-based, may take place.

Cooperative bottom-up innovation

In terms of bottom-up innovation, quoting Moilanen, hackerspaces serve as a chance 'to freely test new goofy ideas that might otherwise be left alone'. 'There are no boundaries to cross,' he adds. In a reminder of the importance of sharing and collaboration as made evident in CBPP, Altman says:

> People enthusiastically share what they know and love. And people enthusiastically learn from others. We all teach and learn and share from one another. This is so incredibly different from industry, where it is important to hide useful information from one another. When we share, we all learn, and it inspires and encourages creativity. When we keep our knowledge secret, we are not helped by others who may want to help. And by keeping our knowledge secret, we discourage people from exploring their creative ways of exploring, and bettering your project.

Software development, hardware development and the organization of relevant events are the main three activities that take place in hackerspaces (Moilanen, 2012). However, there is a trend towards hacker communities focusing more and more on hardware development and building things (Maxigas, 2012; Moilanen, 2012; and interview with J. Moilanen), which is consistent with the general tenor of our interviews. They tinker and deal with cutting-edge technologies such as robotics, 3D printing, biotechnology and energy production. For instance, Makerbot, one of the best-known 3D printers, was a project initiated in NYC Resistor hackerspace (Pettis, 2011; also interview with M. Altman). One can find dozens of novel projects running worldwide, from building robots to helping in agriculture to developing FOSS for facial recognition, at hackerspaces.org (2013) project section. However, Bryan Bishop, a practitioner and investigator of desktop manufacturing, assumes that 'any transformative projects will involve people who are probably members of hackerspaces, but it won't necessarily involve the directed efforts of any single hackerspace'. Even if Bishop is right, hackerspaces along with the CBPP movement highlight the underestimated power of meaningful human cooperation and sharing that can deliver innovative results (even in a seed form) and improve existing products (Benkler, 2006; Kostakis, 2012). As Altman vividly notes: 'I am a really good engineer. But I am only one person.'

Community accountability, communal validation and autonomy

Trust is definitely a central pillar of hackerspaces' operation. Especially in smaller communities, social control seems to be enough to ensure security. In comparison to CBPP online communities, hackerspaces' face-to-face meetings trigger more trustworthy behaviour since group members like each other more when they come into face-to-face contact than when they communicate electronically (Weisband and Atwater, 1999). Members try to create a web of trust (N. Roussos) so that everybody may feel the 'space as their home' (Y. Kargiotakis). In rare cases this may not work well (P. Tiefenbacher), so communities take some measures, either beforehand or after a theft (which, however, was mentioned in only one interview, therefore it seems it might be an isolated case), such as electronic doors, surveillance cameras (R. Itapuro), alarm systems (D. Raison) and security locks (N. Brik). People say 'we don't want to monitor our members' and, thus, there is 'no means of verifying that members don't steal other than trust' (D. Raison). Further, it would be interesting to mention two clearly defined rules that were articulated in our interviews and apply in many hackerspaces: 'be excellent to each other' (Noisebridge members) and 'rule 0: do not behave in a way that makes us make more rules' (D. Fotel). It becomes obvious that building trust and solidarity among members is crucial for creating a sense of autonomy and freedom that are embedded in the hacker ethic.

The emphasis on autonomy is evident, as well, in the answers given when participants were asked whether they would run a project in the hackerspace on collaboration with a public institution or a firm. Although some are sceptical or have a negative disposition towards cooperating with a business firm, all maintain that accepting or rejecting such a proposal would depend on the project and on the independence that hackerspace members would have in the working and distribution process of the results. 'We would be honoured', says David Askirk Fotel from Copenhagen-based Labitat, as long as 'we provide the hacker view on their project' and 'there is an understanding that any result would be shared with the general public'. In addition, Altman emphasizes that if they were asked to collaborate with 'an organization such as DARPA [an agency of the US military that exists to create technology to help the US military], that has goals that are antithetical to many members of Noisebridge, then it will not happen'. Despite the fact that some hackerspaces are more open than others about running for-profit projects – as M. says, 'several start-ups were founded in/around our hackerspaces' – all the interviewees focus on the nature of the project and autonomy in production and distribution. The general feeling from the interviews is that although for-profit projects are not condemned, profit maximization is avoided, given that the results are usually shared with open licences. In other words, profit-making is acceptable in the sense that it favours the survival of the space and its members. This shows the project-based orientation of hackers, and their eagerness to work and learn through production processes based on autonomy, cooperation and sharing or, to put it differently, through a physical manifestation of CBPP practices.

However, as Buchanan claims, hackerspaces are broader in scope and goals than well-known CBPP projects 'which are inherently limited by having a specific goal (such as the development of a product or resource)'. 'Hackerspaces have an open, boundless goal of enabling learning and hacking and providing any unspecified resources necessary for those ends' (K. Buchanan), while online CBPP projects 'must, by necessity, have rules and standards and local nodes of authority … which allow them to accomplish their specific goals' (K. Buchanan). Because of the fact that online, dispersed communities of CBPP projects lack the physical contact and, after all, the specified goal is what creates them in the first place, it could be argued that a more concrete framework is necessary for CBPP to occur in the digital realm. To summarize, we argue that hackerspaces share with online CBPP the characteristics of community accountability, communal validation and autonomy, but in a much less concrete framework.

Distribution of tasks and abundance of resources

The majority of interviewees mention that, apart from a treasurer/financial manager, there is no other clearly defined role or any sort of classification. The treasurer pays the bills, collects the membership fees and in general is responsible for the financial sustainability of hackerspace. The main source of funding comes from membership fees – we should take into consideration that our interviews and Moilanen's data (2012) point to the importance of independence for the community – with donations (money and/or hardware) from individuals or firms ('without strings', as many stress) and governmental sources playing a supportive role. In addition to the treasurer, some, mostly informally, may hold other roles; for example, public relations manager (J. Moilanen), deputy secretary (D. Raison) and heavy machine tools maintainer (P. Tiefenbacher). This division of roles/tasks is often the result of a 'do-ocracy', as explained before, or a meritocracy (for instance regarding the maintenance of specific equipment that demands a certain level of knowledge or skills). When asked who defrosts the fridge participants from Noisebridge and 5W hackerspaces replied that even 'the fridge is hacked', meaning that a robot has been created for auto-defrost. In other hackerspaces defrost and in general cleaning are either carried out by a cleaning lady (M.); by participants based on a certain weekly schedule (N. Lamprianidis); or, in most cases, through 'do-ocracy'. However, several comment that some get frustrated when they have to clean up someone else's mess and that occasionally cleanliness is an issue.

Furthermore, there is a variety of boards and several hackerspaces have no boards at all. This depends on their legal status; for instance, in the USA, some hackerspaces are non-profit 501c3 (J. Appelbaum) or even limited liability companies (B. Bishop). During meetings, as mentioned before, participants discuss operational issues as well as proposals for projects. However, many projects may begin without prior discussion, as a result of 'do-ocracy'. Tsampas submits that 'although we try not to adopt any system of ranking, sometimes it is inevitable because some persons invest more time and energy on hackerspace's processes; therefore their opinion informally may have greater impact'. In a similar vein, Riku Itapuro from 5w at Tampere remarks that they 'value (still) each member despite their input to the hackerspace', but soon they 'will probably go through many common collective's arguments about who is classified to do what and by what standards'.

Appelbaum suggests the concept of 'pseudo leadership' commenting that 'we need no sacred cows; we should all rotate, certainly when it comes to positions of authority'. Pseudo leadership (Ohlig and Weiler, 2007) brings to mind the concept of benevolent dictatorship, where the community tries to keep hierarchy to a minimum, but sometimes leadership is temporarily used when it is really needed. Benevolent dictatorships are common in CBPP (Malcolm, 2008; Raymond, 2001). This concept actually highlights the tensions between hierarchy and equality as well as authority and autonomy in CBPP (Kostakis, 2012 and interview with G. Dafermos). Similarly O'Neil's (2009) three forms of authority (i.e. hacker-charisma, index-charisma and sovereign authority) identified in online tribes seem to apply here also. A mixture of talent and skill, time and effort spent, and rules imposed by the limitations of the material world constitute the wide spectrum of task distribution in hackerspaces. For instance, benevolent dictatorships can be found in the Linux project, where Linus Torvalds is the benevolent dictator (Malcolm, 2008), or in Wikipedia, where Jimmy Wales holds that role. Bruns defines benevolent dictators 'as one of several heterarchical leaders of the community, who have risen to their positions through consistent constructive contribution and stand and fall with the quality of their further performance' (interview in Kostakis, 2010). Kargiotakis, echoes Bruns, when arguing that the person who holds such a role is not an oppressor, but the person who sets the ethos and the guidelines of a certain project: 'People accept this development model because they know very well that nobody is made for everything, and some may perform better in certain tasks dependent on each project.'

Last but not least, it was understood that hackerspaces, unlike typical CBPP projects, do not operate in states of abundance since resources are scarce (from the rented place and cleaning stuff to the shared infrastructure and electricity bills). That is why a shared basis of authority, necessary for the collective groups to survive (O'Mahony and Ferraro, 2007), tends to prevail concerning the organization and execution of operational duties. Scarcity, as we saw, leads to a less distributive infrastructure, which has to be funded and maintained and, thus, arguably, stricter decision-making and control mechanisms have to be applied occasionally. Therefore, in comparison to online CBPP, apart from the more generic framework in which hackerspaces operate, scarcity of resources is another key difference that influences the governance and production mode of hackerspaces. However, for now and at least with regard to the hackerspaces studied, it seems that an imperfect mix of leadership, informal coordination mechanisms, implicit and explicit norms, along with some formal governance structures informed by the experience of CBPP are effective in managing scarcity and allocating duties and tasks. Taking into consideration the relatively small number of members (from dozens to a few hundreds) of the examined hackerspaces, forms of representative democracy have not (as yet) prevailed. Concerning CBPP, O'Neil (2009) notes that especially in large-scale projects, open participation with an increasing number of participants makes the governance of the project much more complex. It can be argued that the same may happen in large hackerspaces, which additionally have to manage scarce resources on the one hand, but on the other entail the physical contact which offers considerable compensations.

Conclusions

The aim of this article was to tentatively see whether, and to what extent, hackerspaces replicate governance structures and principles observed in online CBPP. Our answer is that hackerspaces, at least those examined here, could be considered a manifestation of online CBPP in the physical realm but not a direct or a precise transfer due to the scarcity and the subsequent allocation problems of the material world. Although a single hackerspace's projects can be very different from another's and much more different than the CBPP ones, we came to understand that most of the CBPP characteristics examined also permeate the hackerspace phenomenon. Of course, it should be highlighted that CBPP projects differ from the projects run in hackerspaces, in the sense that the former, most of the time (e.g. the Linux project), include thousands of specialized participants who operate in a relatively defined, concrete framework. Moreover, it is obvious that in both CBPP and hackerspaces, issues of independence and autonomy arise, as shown, when it comes to monetary support from an outsider. Even if the ability of the hackerspace community to develop the norms required for CBPP models is arguably put under more stress, we noticed that there are many instances that seem to embrace several CBPP aspects through adopting hybrid modes of governance. These modes, at least for the cases discussed, share certain elements which exemplify CBPP governance mechanisms and characteristics, which are, after all, historically and essentially indistinguishable from the hacker ethic. Thus it can be stated that hackerspaces' various hybrid modes of governance are actually an unfinished artifact that follows the constant reform of social norms within the community, as happens in CBPP (Kostakis, 2010).

Because of the perpetual transformation of hackerspaces and their diverse organizational structures, it seems wise to approach them on a case-by-case basis if we aim for a more detailed account of governance. What we tried to do here is to provide a bird's-eye-view of the trends and norms of eight distinct hackerspaces which are not unrelated to those of CBPP communities. They share the same roots and can be considered as interrelated strands of an alternative mode of development and production, that is, social production. Of course we should be aware of the fact that every hackerspace is unique.

After all, as Altman (2011) says in a Noisebridge introductory video, ‘it’s not easy to say what a hackerspace is exactly. You know it when you are in one, but they are all unique because people are so unique.’

It is interesting to note that understanding community forms of organizing can increase ‘the range of tools or solutions that society can bring to social problems’ (O’Mahony and Ferraro, 2007: 1079). Hence, future research could focus on the role of hackerspaces and their impact on learning, social innovation and urbanism, that is, how hackerspaces, as third places (see Oldenburg, 1997), could influence the design and development of the urban web and potentially offer opportunities for meaningful social interactions among citizens.

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Notes

1. All quotations that have no dates are from interviews; for details of participants and interviews, see the Appendix.

References

Altman M (2011) Open source creativity – hackerspaces: Science on the spot Video. Available at: http://www.youtube.com/watch?v=wamwklXWK4M (accessed 7 August 2013).

Bauwens M (2005) The political economy of peer production. *CTheory Journal*. Available at: http://www.ctheory.net/articles.aspx?id=499 (accessed 7 August 2013).

Bauwens M (2009) Class and capital in peer production. *Capital & Class* 33: 121–141.

Bauwens M (2013) Thesis on digital labor in an emerging P2P economy. In: Scholz T (ed.) *Digital Labor: The Internet as Playground and Factory*. New York: Routledge.

Benkler Y (2006) *The Wealth of Networks: How Social Production Transforms Markets and Freedom*. New Haven, CT: Yale University Press.

Benkler Y (2011) *The Penguin and the Leviathan: The Triumph of Cooperation over Self-interest*, New York: Crown Business.

Blanc S (2011) Draw me a hacker. *Owni.eu*. Available at: http://owni.eu/2011/08/11/infographic-draw-me-a-hacker/ (accessed 7 August 2013).

Bruns A (2008) *Blogs, Wikipedia, Second Life, and Beyond: From Production to Produsage*. New York: Peter Lang.

Castells M (2000) *The Rise of the Network Society*. Oxford: Blackwell.

Castells M (2003) *The Power of Identity*. Oxford: Blackwell.

Coleman EG and Golub A (2008) Hacker practice: moral genres and the cultural articulation of liberalism. *Anthropological Theory* 8: 255–277.

Dafermos G (2001) Management and virtual decentralised networks: the Linux project. *First Monday* 6. Available at: http://firstmonday.org/htbin/cgiwrap/bin/ojs/index.php/fm/article/view/1481/1396 (accessed 7 August 2013).

Dafermos G and Söderberg J (2009) The hacker movement as a continuation of labour struggle. *Capital & Class* 33: 53–73.

Erickson J (2008) *Hacking: The Art of Exploitation* San Francisco, CA: No Starch Press.

Farr N (2009) Respect the past, examine the present, build the future. Hackerspaces Flux. Weblog, 25 August. Available at: http://blog.hackerspaces.org/2009/08/25/respect-the-past-examine-the-present-build-the-future (accessed 7 August 2013).

France24 (2011) La Répression syrienne opère sur plusieurs fronts, les opposants témoignent. *France24*, 18 August. Available at: http://www.france24.com/fr/20110818–2011–08–18–0122-wb-fr-le-net (accessed 7 August 2013).

Fuchs C (2008) *Internet and Society*. London: Routledge.

Fuchs C (2012) Capitalism or information society? The fundamental question of the present structure of society. *European Journal of Social Theory* 16(4): 413–434.

Hackerspaces.org (2013) List of all hacker spaces. Hackerspaces.org, 7 August. Available at: http://hackerspaces.org/wiki/List_of_ALL_hackerspaces (accessed 7 August 2013).

Hardt M and Negri T (2011) *Commonwealth*. Cambridge, MA: Harvard University Press.

Hertel G, Niedner S and Herrmann S (2003) Motivation of software developers in open source projects: an internet-based survey of contributors to the Linux kernel. *Research Policy* 32: 1159–1177.

Hess D (2005) Technology- and product-oriented movements: approximating social movement studies and science and technology studies. *Science, Technology, & Human Values* 30(4): 515–535.

Himanen P (2001) *The Hacker Ethic, and the Spirit of the Information Age*. New York: Random House.

Hogge B (2011) *Barefoot into Cyberspace: Adventures in Search of Techno-utopia*. Essex: Barefoot Publishing.

Keen A (2007) *The Cult of the Amateur*. New York: Doubleday.

Kogut B and Metiu A (2001) Open-source software development and distributed innovation. *Oxford Review of Economic Policy* 17(2): 248–264.

Kostakis V (2009) The amateur class, or, the reserve army of the web. *Rethinking Marxism* 21: 457–461.

Kostakis V (2010) Peer governance and Wikipedia: identifying and understanding the problems of Wikipedia's governance. *First Monday* 15. Available at: http://firstmonday.org/htbin/cgiwrap/bin/ojs/index.php/fm/article/view/2613/2479 (accessed 7 August 2013).

Kostakis V (2012) The political economy of information production in the social web: chances for reflection on our institutional design. *Contemporary Social Science* 7: 305–319.

Kostakis V (2013) At the turning point of the current techno-economic paradigm: commons-based peer production, desktop manufacturing and the role of civil society in the Perezian framework. *Triple C* 11(1): 173–190.

Kumar K (1995) *From Post-industrial to Post-modern Society*, Oxford: Blackwell.

Lakhani K and Wolf R (2005) Why hackers do what they do: understanding motivation and effort in free/open source software projects. In: Feller J, Fitzgerald B, Hissam S et al, (eds) *Perspectives on Free and Open Source Software*. Cambridge, MA: MIT Press, pp. 3–22.

Lanier J (2010) *You Are Not a Gadget: A Manifesto*, New York: Knopf.

Lee GK and Cole RE (2003) From a firm-based to a community-based model of knowledge creation: the case of the Linux Kernel development. *Organization Science* 14(6): 633–649.

Levy S (2001) *Hackers: Heroes of the Computer Revolution*. New York: Penguin Books.

Lobo R (2011) Hackerspaces: from electrical to cultural resistance. International Symposium on Electronic Arts, Istanbul, September.

Malcolm J (2008) *Multi-stakeholder Governance and the Internet Governance Forum*. Perth: Terminus Press.

Mateos-Garcia J and Steinmueller E (2008) The institutions of open source software: examining the Debian community. *Information Economics and Policy* 20: 333–344.

Maxigas (2012) Hacklabs and hackerspaces. *Journal of Peer Production*. Available at: http://peer-production.net/issues/issue-2/peer-reviewed-papers/hacklabs-and-hackerspaces/ (accessed 7 August 2013).

Mayo E (1945) *The Social Problems of an Industrial Civilization*. Boston, MA: Division of Research, Graduate School of Business Administration, Harvard University.

Merten S and Meretz S (2009) Germ form theory: peer production in a historical perspective. Available at: http://en.wiki.oekonux.org/StefanMerten/Papers/CapitalAndClass/MagazineVersion (accessed 7 August 2013).

Moilanen J (2012) Peer production communities survey 2011. Statistical Studies of Peer Production. Available at: http://surveys.peerproduction.net/2012/02/peer-production-communities-survey-2011/ (accessed 7 August 2013).

Moore P and Karatzogianni A (2009) Parallel visions of peer production. *Capital & Class* 33: 7–11.

O'Mahony S and Ferraro F (2007) The emergence of governance in an open source community. *Academy of Management Journal* 50: 1079–1106.

O'Neil M (2009) *Cyberchiefs: Autonomy and Authority in Online Tribes*. London: Pluto Press.

Ohlig J and Weiler L (2007) Building a hacker space. Paper presented at: 24th Chaos Communication Congress. Berlin, December.

Oldenburg R (1997) *The Great Good Place: Cafés, Coffee Shops, Community Centers, Beauty Parlors, General Stores, Bars, Hangouts, and How They Get You Through the Day*. New York: Marlowe.

Orsi C (2009) Knowledge-based society, peer production and the common good. *Capital & Class* 33: 31–51.

Parker D (2005) The different shades of hackers. 29 December. Available at: http://www.windowsecurity.com/articles/different-shades-hackers.html (accessed 7 August 2013).

Pettis B (2011) Made in my backyard. In: van Abel B Evers L, Klaassen R and Troxler P (eds) *Open Design Now*. Amsterdam: BIS Publishers, pp. 76–83.

Radloff R and Helmreich R (1968) *Groups under Stress: Psychological Research in SEALAB II*. New York: Appleton-Century-Crofts.

Raymond ES (2001) *The Cathedral and the Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary*. Cambridge, MA: O'Reilly.

Rigi J (2012) Peer to peer production as the alternative to capitalism: a new communist horizon. *Journal of Peer Production*. Available at: http://peerproduction.net/issues/issue-1/invited-comments/a-new-communist-horizon/ (accessed 7 August 2013).

Schiller HI (1981) *Who Knows: Information in the Age of the Fortune 500*. Norwood, NJ: Ablex.

Schiller HI (1984) *Information and the Crisis Economy*, Norwood, NJ: Ablex.

Schiller HI (1996) *Information Inequality*. New York: Routledge.

Schwartz H and Jacobs J (1979) *Qualitative Sociology: A Method to the Madness*. New York: Free Press.

Shah S (2006) Motivation, governance, and the viability of hybrid forms in open source software development. *Management Science* 52: 1000–1014.

Siefkes C (2007) *From Exchange to Contributions: Generalizing Peer Production into the Physical World*. Berlin: Edition C. Siefkes.

Söderberg J (2007) *Hacking Capitalism: The Free and Open Source Software Movement*. New York: Routledge.

Tapscott D and Williams A (2006) *Wikinomics: How Mass Collaboration Changes Everything*. New York: Portfolio.

Thomas D (2002) *Hacker Culture*. Minneapolis: University of Minnesota Press.

Troxler P (2011) Libraries of the peer production era. In: Van Abel B, Evers L, Klaassen R and Troxler P (eds) *Open Design Now*. Amsterdam: BIS Publishers, pp. 86–95.

von Hippel E (2005) *Democratizing Innovation*. Cambridge, MA: MIT Press.

Wark M (2004) *A Hacker Manifesto*. Cambridge, MA: Harvard University Press.

Wark M (2013) Considerations on a Hacker Manifesto. In: Scholz T (ed.) *Digital Labor: The Internet as Playground and Factory*. New York: Routledge.

Webster F (2002a) *Theories of the Information Society*. New York: Routledge.

Webster F (2002b) The information society revisited. In: Lievrouw L and Livingstone S (eds) *The Handbook of New Media*. London: Sage.

Weisband S and Atwater L (1999) Evaluating self and others in electronic and face-to-face groups. *Journal of Applied Psychology* 84(4): 632–639.

Winner L (1986) *The Whale and the Reactor: A Search for Limits in an Age of High Technology*. Chicago: University of Chicago Press.

Author biographies

Vasilis Kostakis is a Political Economist and founder of the P2P Lab. He is a research fellow at the Tallinn University of Technology as well as at the P2P Foundation.

Vasilis Niaros (PhD student at the Tallinn University of Technology) is an Urbanist interested in investigating the relationships of technology, culture and urbanism. He is serving as a research fellow at the P2P Lab.

Christos Giotitsas is a junior research fellow at the P2P Lab and is currently pursuing postgraduate studies at the Tallinn University of Technology.

Appendix

Table 1 lists the names and roles of the interviewees, as well as the methods used for the interviews and dates when they took place.

Table 1. People interviewed for this article.

Name	Role	Method	Period/date
Altman, M.	Co-founder of Noisebridge (San Francisco)	Email	May 2012
Appelbaum, J.	Co-founder of Noisebridge	Email	May 2012
Balaskas, E.	Co-founder of Hackerspace.gr (Athens)	Face-to-face contact	23 February 2012
Bishop, B.	Investigator of desktop manufacturing and hackerspace guest	Email	April 2012
Brik, N.	Co-founder and secretary of Randomdata (Utrecht)	Email	April 2012
Buchanan, K.	Treasurer of Noisebridge	Email	May 2012
Dafermos, G.	Investigator of FOSS projects governance and hackerspace guest	Email and face-to-face contact	May 2012, 20 April 2013
Fotel, D.	Member and ex-chair of Labitat (Copenhagen)	Email	May 2012
G. (anonymity)	Guest of two USA-based hackerspaces	Email	April 2012
Georgitzikis, V.	Member of P-Space (Patras)	Email and face-to-face contact	May 2012, 12 February 2013
Itapuro, R.	Co-founder and treasurer of Hackerspace 5w (Tampere)	Email	May 2012
Kargiotakis, Y.	Member of Hackerspace.gr	Email	April 2012
Lamprianidis, N.	Member of P-Space	Email	May 2012
Lehnardt, J.	Guest of C-Base and member of Co-Up (Berlin)	Email	April 2012
M. (anonymity)	Member of one hackerspace	Email	April 2012
Moilanen, J.	Co-founder of 5w and investigator of hackerspaces communities' ethics	Email	May 2012
Papatheodorou, T.	Member of Hackerspace.gr	Voip	1 May 2012
Raison, D.	Co-founder and deputy secretary of Syn2cat hackerspace (Luxembourg)	Email	May 2012
Roussos, N.	Co-founder of Hackerspace.gr	Face-to-face contact and voip	23 February, 14 April, 25 November 2012, 15 May 2013
Söderberg, J.	Investigator of hackers' ethics	Email	May 2012
Tiefenbacher, P.	Treasurer of Metalab (Vienna)	Email	May 2012
Tsampas, S.	Member of P-Space	Email and face-to-face contact	27 March, April 2012
Tzortzis, D.	Member of P-Space	Email and face-to-face contact	April 2012, 13 February 2013

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Design global, manufacture local: Exploring the contours of an emerging productive model

Vasilis Kostakis[a,b], Vasilis Niaros[a,b,*], George Dafermos[c], Michel Bauwens[d]

[a] Ragnar Nurkse School of Innovation and Governance, Tallinn University of Technology, Akadeemia Street 3, 12618 Tallinn, Estonia
[b] P2P Lab, Kougkiou 3A, 45221 Ioannina, Greece
[c] National Institute of Higher Studies (IAEN), Av Rio Amazonas N37 -. 271 y Villalengua, Quito, Ecuador
[d] P2P Foundation, Realengracht 196, 1013AV Amsterdam, The Netherlands

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ABSTRACT

This article aims to contribute to the ongoing dialogue on post-capitalist construction by exploring the contours of a commons-oriented productive model. On the basis of this model called “design global-manufacture local”, we argue that recent techno-economic developments around the emergence of commons-based peer production and desktop manufacturing technologies, may signal new alternative paths of social organization. We conclude by arguing that all commons-oriented narratives could converge, thereby supporting the creative communities which are building the world they want within the confines of the political economy they aspire to transcend.

1. Introduction

The aim of this article is to contribute to the ongoing discussion about post-capitalist construction, and to tentatively propose, from a techno-economic perspective, how a global commons-oriented productive model could be possible. Through the aforementioned model called “design global-manufacture local” (DG-ML), we argue that the emergence of the commons-based peer production signals new alternative paths of social organization. We attempt to show how the DG-ML model, which has been enabled by the conjunction of the modern information and communication technologies (ICT) with the desktop manufacturing technologies (such as the three-dimensional (3D) printing and the computer-numerical-control machines), can offer a sustainable working alternative. Therefore, the current analysis might be a useful techno-social contribution to the research agenda of future studies.

Section 2 deals with the resilient communities approach in relation to degrowth. In short, we discuss the fetishization of localism while we claim that the ultimate goal should be to develop global-oriented productive models. We do not attempt to offer an all-inclusive account but rather to focus on the points where the DG-ML model and framework can be of value. Section 3 includes a description of the basic dynamics that gave rise to a third modality of information production, what Benkler (2006) first called commons-based peer production. It also provides a brief overview of the political economy of the global information commons which determines, as we see in Section 4, the techno-economic conditions from which the DG-ML productive model is emerging. There, we also refer to three prominent cases which exemplify seed forms of the DG-ML.

* Corresponding author at: Tallinn University of Technology, Akadeemia Street 3, 12618 Tallinn, Estonia.
E-mail address: vasileios.niaros@ttu.ee (V. Niaros).

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Next, Section 5 addresses the relation of the DG-ML model and degrowth with the criticism of the resilient communities movement, highlighting their complementarity. Moreover, it sheds light on a tentative theoretical model of the DG-ML process introducing a new agenda for action research by future studies scholars, political ecologists, policy makers and practitioners. In Section 6, we conclude arguing that all the commons-oriented narratives could converge and, thus, support the creative communities who are building the world they want, within the confines of the political economy they aspire to transcend.

2. Degrowth and resilient communities discourses

The crisis the world is facing, which is not only ecological but also economic, social, cultural and political in nature, has been the point of departure for both degrowth and resilient communities movements. Focusing on strategies for combating the crisis, it has been argued that a radical shift has to take place from growth as the main objective of the economy toward contraction and equitable downscaling (Fournier, 2008; Schneider, Kallis, & Martinez-Alier, 2010; Foster, 2011; Kallis, Demaria, & D'Alisa, 2014). Specifically, a transition to a low-carbon, sustainable economy of sharing has been advocated, in which the goal of growth is displaced by the values of social justice and the ethics of collaboration, thus liberating humanity from the yoke of "economism" (Cattaneo, D'Alisa, Kallis, & Zografos, 2012; Garcia, 2012; Lewis & Conaty, 2012). This discourse has given rise to new intellectual movements and inspired a revival of radical Green thought (Kallis et al., 2014). Moreover, it has been the catalyst for the creation of numerous eco-communities and eco-villages/urban villages around the world (for a critical discussion of the concept, see Xue, 2014), providing them with the necessary theoretical bedrock.

Indicative of this wave is the Transition Towns movement. The goal of such initiatives is the radical relocalization of politics, economics and culture to autonomous and self-sufficient communities with a view to building resilience against destabilizing forces such as peak oil and climate change. Hopkins – who, in 2006, created a working model of a Transition Town community in Totnes, UK – first introduced this concept in his 2008 book "The Transition Handbook". Nowadays, there are over a hundred transition communities around the world in various stages of development (Chamberlin, 2009; Hopkins, 2011). Despite their individual differences, all of these communities are characterized by their small size, which is intended to ensure that all community members have a strong personal influence over collective decisions (Hopkins, 2008, 2011). The Transition Towns concept is animated by the principles of permaculture, combined with resilience and relocalization. Permaculture, a term which stands for "permanent agriculture", is the design and maintenance of agricultural ecosystems with the diversity, stability, and resilience of natural ecosystems (Mollison, 1988). It is argued that a system based on the permaculture principles can evolve, self-organize and adapt to almost any change (Alexandra & Riddington, 2007; Meadows, 2008).

Hence, the argument is that in order to counter the volatility and fragility of the dominant system, building resilience locally is fundamental (Latouche, 2009; Lewis & Conaty, 2012; Trainer, 2012). It is vital to shift to a system with the capacity "to evolve without losing its core sense of identity or purpose" (Wilding, 2011, p. 19). Therefore, resilience can be seen as the degree to which the system is capable of learning, self-organizing and adapting while preserving its coherence (Carpenter, Walker, Anderies, & Abel, 2001; Folke, 2006; Walker, Abel, Anderies, & Ryan, 2009). Walker and Salt (2006) along with Lewis and Conaty (2012) highlight some key aspects of resilience: diversity, modularity, reciprocity, social capital (that is, relations of trust and solidarity among community members) and tight feedback loops. Steps and policies towards the world envisioned by resilient communities include the support of a dynamic local economy; the empowerment of local governance and control; the optimization of assets; the recognition of the value of local distinctiveness and of permaculture; the development of sustainable infrastructures (such as, for example, affordable housing, interest-free banks, community land trusts, and autonomous energy production); and the construction of a social solidarity economy (García-Olivares & Solé, 2015; Lewis & Conaty, 2012; Wilding, 2011).

According to Xue (2014, p. 131) the local focus of degrowth and resilient communities narratives is evident: "'relocalize' is considered one of the most important approaches and assumes a strategic role". "The idea of relocalization", she continues, "is not confined to economic relocalization though it is an important aspect, but also means political and ecological relocalization." It might be true that relocalization features strongly in early degrowth literature. However, today many of the key degrowth theorists examine more carefully the relationship between the local, the national and the global, and point to the need for political movements as well as institutional change at higher levels than the local (see Kallis, 2011; Kallis et al., 2014; Demaria, Schneider, Sekulova, & Martinez-Alier, 2013; who emphasize the multi-scale degrowth strategy).

In its most extreme form, the resilient community approach may include lifeboat strategies and initiatives for the protection of small communities amidst generalized chaos. This may build on the idea that we must accept the reality of considerably more expensive energy and food (Lewis & Conaty, 2012). What characterizes this discourse is the rejection of the value of bigness and an opposition to the organizational tendency toward large scale. Even though relations of collaboration and solidarity may well extend to the global level, the focus remains firmly on the local. Most often, political and social mobilization on a large scale is seen as unrealistic and doomed to failure. Resilience and vulnerability are not often used in the modern degrowth literature which is against a pure survivalist spirit (Kallis, 2014). As Kallis (2014) stresses, "a 'survivalist' take on degrowth . . . hides the fact that we are not all equally responsible or equally vulnerable . . . [and] opens the potential for authoritarian responses to save 'us' from disaster". In contrast to Romano's (2012, p. 582) idea that degrowth just offers "techniques that will allow the human species merely to 'stay alive'", Kallis et al. (2014, p. 9) write against an "apolitical, technocratic discourse of sustainable development" and set the scene for an alternative political vision, where "'sharing', 'simplicity', 'conviviality', 'care' and the 'commons' are primary significations of what this society might look like" (p. 3).

The development of resilient communities, which are squarely aimed at generating community value, is without a doubt a healthy reaction against global problems and environmental degradation. Resilient communities try to be immune to the dominant system and use peer-to-peer practices and technologies for good reasons (for example, the Transition Towns concept incorporates open source organizational practices). They try to support individuals's physical and psychological well-being by creating a positive sense of place, by localizing the economy within ecological limits, and by ensuring the entrepreneurial/community stewardship of the local commons (Wilding, 2011). They do not, however, build global structures. In our view, these structures are essential: organizing an ecumenical counter-power that is able to propose alternative models of social organization on a global scale is of paramount importance. For Sharzer (2012), localism is a type of fetishization of (small) scale, as some positive benefit is ascribed to a place precisely because it is small. He argues that communities driven by that ideal are inevitably assimilated by the broader capitalist economy, because they do not confront it, but rather try to avoid it. Initiatives like Transition Towns are gaining momentum in the context of efforts focusing on the local level. As we will point out below however, they can co-exist in harmony with the approach of the global commons. This is based on the rationale that whatever is heavy is local (for instance, desktop manufacturing technologies), and whatever is light is global (for instance, global knowledge commons).

Arguably the real issue is not how to produce and consume less, but how to develop new productive models which are capable of outperforming capitalist models, i.e., by doing things differently and better. We consider it impossible to challenge the dominant system without a working plan to transcend it. Transitioning to a post-capitalist world goes well beyond the mere regression to pre-industrial times. Echoing Fuster Morell (2014, p. 160), there are several commonalities between the digital commons and the concept of degrowth, which calls for a transition to a future of frugal innovations. We will thus attempt to discuss about new institutions, fueled by the spirit of the global commons, with the aim of providing a viable alternative based on integral perspectives, theories and narratives.

3. A new mode of information production: commons-based peer production

Plenty of attention has been gathering around the commons. But what is its concept all about? In general it is a term that refers to shared resources where each stakeholder has an equal interest (Ostrom, 1990). The commons sphere can include natural gifts such as air, water, the oceans and wildlife, and shared "assets" or creative work like the Internet, the airwaves, the languages, our cultural heritage and public knowledge which have been accumulating since time immemorial (Bollier, 2005, 2009). Also, the commons might simultaneously refer to shared resources, a discourse, a new/old property framework, social processes and relations, or an ethic (Bollier, 2014).

During the last two decades, several commons-based projects such as myriad of free/open source software projects or the free encyclopedia Wikipedia have highlighted "the emergence of technological capabilities shaped by human factors, which in turn shape the environment under which humans live and work" (Kostakis & Bauwens, 2014, p. 51). They create what Benkler (2006, p. 31) calls new "technological-economic feasibility spaces" for social practice. These feasibility spaces contain "different social and economic arrangements, where profit, power, and control do not seem as predominant as they have in the history of modern capitalism" (Kostakis & Bauwens, 2014, p. 51).

Commons-based peer production is a new collaborative and distributed form of organization emerging from this new interconnected digital and physical environment. When it comes to information, peer production is more productive than market-based or centrally-controlled systems (Benkler, 2006). It produces social well-being because it is based on people's intrinsic positive motivations and synergetic cooperation among participants and users (Benkler, 2006; Hertel, Niedner, & Herrmann, 2003; Lakhani & Wolf, 2005). According to a study of the incentives of 141 Linux kernel community participants, the former were driven "by similar motives as voluntary action within social movements such as the civil rights movement, the labor movement, or the peace movement" (Hertel et al., 2003, p. 1174).

Benkler (2006) makes two intriguing economic observations which challenge some "eternal truths" of the mainstream economic theory. Commons-based projects fundamentally challenge the assumption that in economic production, the human being solely seeks profit maximization. Volunteers contribute to information production projects, while they gain knowledge, experience, and reputation, and communicate with each other motivated by intrinsically positive incentives. This does not mean that the monetary motive is totally absent; however, it is relegated to a peripheral concept (Benkler, 2006).

The second challenge is directed against the conventional wisdom that, in Benkler's (2006, p. 463) words, "we have only two basic free transactional forms—property-based markets and hierarchically organized firms". In contrast to markets, in peer production the allocation of resources is not done through a market-pricing mechanism. Hybrid modes of governance are employed and what is generated is not commodities, but a commons. Peer production is opposed to industrial firms's hierarchical control and authority as it is based on communal validation and negotiated coordination with a community-driven quality control (see, for instance, Dafermos's (2012) study on the Free BSD project's collectivist and consensus-oriented governance system).

Instead of the division of labor, a distribution of modular tasks takes place with anyone able to contribute to any module and the threshold for participation as low as possible: modularity is vital for peer production to emerge (Bauwens, 2005;

Tapscott & Williams, 2006; Kostakis & Papachristou, 2014). Described in technical terms, modularity is a form of task decomposition. It is used to separate the work of different groups of developers, creating, in effect, related yet separate sub-projects (Dafermos & Söderberg, 2009). Torvalds (1999), the instigator of the Linux project, maintains that the Linux kernel development model requires modularity, because in that way, people can work in parallel. Empirical research shows that modular design is characteristic not just of Linux but of the free/open source software development model in general (MacCormack, Rusnak, & Baldwin, 2007).

Further, modularity leads to stigmergic collaboration. In its most generic formulation, stigmergy is the phenomenon of indirect communication among agents and actions (Marsh & Onof, 2007, p. 1). An action leaves a trace which stimulates the performance of a next action, by the same or a different agent. Therefore, in the context of peer production, stigmergic collaboration is the "collective, distributed action in which social negotiation is stigmergically mediated by Internet-based technologies" (Elliott, 2006). For example, see how free/open source software and Wikipedia entries are being produced in a distributed and ad hoc fashion through the contributions from large numbers of people.

Moreover, peer production is opposed to the notion of scarcity of goods through which market profit is generated, as the practice of sharing the created goods does not diminish their value, but actually enhances it (Benkler, 2006). To this, one might add that peer production is facilitated by the free cooperation of creative communities, which lowers the legal restrictive barriers and invents new institutionalized ways of sharing, such as the Creative Commons or the General Public Licenses (Kostakis, Fountouklis, & Drechsler, 2013). It is, however, important to highlight that contributors to peer production projects do have interests and rights concerning their work and are interested in protecting their intellectual property (O'Mahony, 2003). Thus, the commons-oriented approach to property "does not assert that sharing is an ethical absolute", but rather tries to balance the rights of innovators with the rights of the public (O'Mahony, 2003; von Hippel & von Krogh, 2003).

It becomes obvious that what sets peer production apart from proprietary models of production are three key characteristics: (a) the decentralization of the conception of problems and the execution of solutions; (b) the diversity of participants's motivations; and (c) the decoupling of governance from private property and contract (Benkler, 2015). These characteristics make peer production agile enough to adapt to complex environments (Benkler, 2015) and provide the capacity to deliver innovative results such as the Apache web server, Mozilla Firefox browser, Linux kernel, BIND, Sendmail, and a myriad of emerging open source hardware projects.

Beyond the great potential of peer production, there might be various obstacles, practical problems and negative side effects (Kostakis et al., 2013). However, taken in this idealized context, peer production is arguably a carrier of forces which create a political economy where economic efficiency, profit, and competitiveness cease to be the sole guiding stars (Moore & Karatzogianni, 2009), while civil society attains a more important role, bringing (back) the notion of the commons into the heart of the economy (Orsi, 2009). From this point of view, the commons can be seen as a legitimate vehicle of citizenship or as an equivalent of Tocqueville's (2010) civil society, through which citizens mobilize and express their interests while protecting their rights (MacKinnon, 2012). It can be central to the process of civilizing the economy, which would require a strong notion of citizenship—of membership in a global civil society (Brown, 2010).

The commons movement is arguably removing property relations as our political economy's foundation and is replacing them with civic relations that define our bonds with each other (Brown, 2010; Kostakis & Bauwens, 2014, p. 55). The commons are long-term social and material processes that cannot be created overnight: "in order to become meaningful they must exist over an extensive period of time" (Stadler, 2014, p. 31). In other words, the various spheres of the commons are products of peer-to-peer creative processes as they expand horizontally and in dense interconnections with each other. That is why we must go beyond a material understanding of the concept and approach the commons not only as a resource or as a property regime, but rather as a social process. Producing a categorization or taxonomy of the commons based on what type of resource is involved can be misleading, as Bollier (2014) warns us:

While choosing to categorize commons by the type of resource involved is tempting, a focus on the resource alone can be misleading. For example, a "knowledge commons" on the Internet is not simply about intangible resources such as software code or digital files; such a commons also requires physical resources to function (computers, electricity, food for human beings). By the same token, "natural resource commons" are not just about timber or fish or corn, because these resources, like all commons, can only be managed through social relationships and shared knowledge.

In other words, to quote Helfrich (2013), "all commons are social, and all commons are knowledge commons". Our relationships to shared goods that are managed as commons should be the focal point and, thus, we should discuss the process of commoning (i.e., do things in common).

But what alternative productive models should we experiment with in order to build sustainable, commons-oriented economies and societies? Section 4 points to three commons-based projects that share certain characteristics that could inaugurate a new proto-mode of material production, as explained in Section 5.

4. Seeds of a new mode of material production: commons-based peer production and desktop manufacturing

Contrary to the conventional industrial paradigm and its economies of scale, peer production and desktop manufacturing could arguably develop commons-based economies of scope. While the advantages of scale rest on high-capital-entry and cheap global transportation, which is facing problems due to the environmental crisis, the commons-based economies of scope share infrastructure costs in terms of intangible and tangible productive resources. They utilize the capabilities of the new fabrication tools which, up to a degree, are computerizing the manufacturing industry (Hermann, Pentek, & Otto, 2015).

There is a growing tendency for the creation of a new type of communities, which follow a global commons approach that focuses on a larger scale in relation to the resilient communities. Advocates and participants of those communities argue that the commons should be created and fought for on a transnational global scale (Kostakis & Bauwens, 2014).

The RepRap project, the Open Source Ecology and the Wikispeed car are prominent cases that build on the convergence of global commons with desktop manufacturing technologies. We consider them as seeds of an emerging mode of material production, called DG-ML. Hence, it is arguably of great importance to pinpoint the necessary conditions that will allow us to draw several proposals for a new action research agenda for political ecologists, policy makers, practitioners and future studies scholars.

To begin with, the RepRap was introduced by Adrian Bowyer in 2005. His goal was to create a 3D printer that could self-replicate by manufacturing its main components. This project was conceived as a peer production artifact, meaning that the technical specifications and its design files are open source. This has resulted in the formulation of networks of individuals which offered significant incremental innovations to the original design. Three updated versions of the RepRap were released in the years that followed. By 2010 the RepRap had a 5000-strong community which has rapidly been expanding (de Bruijn, 2010).

Further, the Open Source Ecology is an open hardware project focused on manufacturing a set of fifty industrial machines, called the "Global Village Construction Set", which it considers to be sufficient for creating a small civilization with modern comforts from locally available resources. The development of the machines is distributed across a global network of parsimoniously linked, self-managing groups of hardware hackers and hobbyists who share design information through the Internet and build prototypes, which are then tested in a farm in Missouri, USA. So, as a start, Marcin Jakubowski, a Missouri-based physicist, designed a new tractor and posted the design on the Internet under a commons-based license. This attracted the attention of the Internet community and of hardware hackers and hobbyists around the world, who soon started to contribute improvements and build prototypes. And thus, the Open Source Ecology network was born in 2003. With the help of this network of contributors, Jakubowski identified the fifty machines – from cement mixers to 3D printers and moving vehicles – which are necessary to build a sustainable modern village community and embarked on a collective effort to manufacture them. To accommodate the enlarged scope of work, the project was officially launched as a platform for coordinating the enterprise and Jakubowski's farm was repurposed into a site for building and testing the prototypes developed by project members from all over the world, many of whom would come to the farm on "dedicated project visits" to help with the work (Thomson & Jakubowski 2012, pp. 53–70).

To date, of the fifty machines that make up the Global Village Construction Set, eight have already been successfully manufactured, while development of the rest is currently underway. By tapping into the contributions of a global community of hardware hackers and afficionados, this project has achieved significant cost reductions (Dafermos, 2015). To its credit, the machines built by Open Source Ecology have a much lower cost of production than their industrial counterparts, being at least eight times cheaper to manufacture (Dafermos, 2015).

Although community contributions raised through crowdfunding campaigns have so far been Open Source Ecology's main source of financial support (Jakubowski, 2011), the aforementioned production cost savings allow the project to finance its activities by selling its machines directly to farmers. Indicatively, it estimates to make about $80 K a month by selling its tractors at a price of $10 K (Jakubowski, 2013). Also, additional revenue comes from the educational courses and workshops that Open Source Ecology offers to people who are interested in learning how to build their own machines.

However, the sustainability of the Open Source Ecology enterprise extends well beyond its business model: this project furnishes a working example of how farming and the manufacturing of agricultural machines can be carried out in a way that is not only productive but also environmentally sustainable (Dafermos, 2015). For example, the electricity that Jakubowski's farm consumes, which includes a 4000 square foot fabrication facility and a 3000 square feet living unit, comes from renewable energy resources, using methods like closed-loop manufacturing (which recycle waste materials into livestock for other production processes; for a detailed discussion, see Kelly 1994, ch. 10) and technologies that the project itself has built such as photovoltaic panels and wind turbines (Open Source Ecology, 2013). Equally important, Open Source Ecology-manufactured machines are designed with the principle of durability in mind and in such a way as to be easily repairable and modifiable by end-users (Dafermos, 2015). In that regard, the Open Source Ecology machines are paradigmatic of what is called sustainable design: they are designed to last for a lifetime, rather than throw away and replace by newer machines.

Our last case is the development process of the Wikispeed car. What makes this process unique is that fact that it is driven by a global community of volunteers who, through peer production methods, are able to manufacture cars at highly reduced time and cost compared to conventional ones. A network of semi-autonomous teams with their own garage are the main developers. Their shared activities, which are coordinated online, are made possible by the modular structure of the car. This means that individual modules of the car may be developed autonomously with minimal central coordination.

The Wikispeed car embodies the basic characteristic of peer production: all knowledge regarding its development (design, specifications) is available to the community so that everyone may be able to contribute, thus benefiting from the assistance of volunteers from around the world. Free access to information enables the core team of the project to establish a collective model of development for the car, and at the same time set the foundation for a distributed entrepreneurship model were individuals may download and utilize all the available information to develop their own car.

To sum up, the above cases as open source projects utilize the globally designed commons to assist the formulation of global communities. They basically illustrate how commons-based technology along with desktop manufacturing can provide more autonomy while at the same time transforming the productive sectors's economic and environmental aspects

(Dafermos, 2015). In essence, they imagine a novel production model that is suitable for a post-fossil fuel economy. A model whose basic principles are decentralization, resilience, smallness, on demand and locally controlled production, and most importantly global development.

5. Towards a new productive model: design global, manufacture local

The resulting distributed organizational infrastructures of the cases discussed in the previous section is arguably key to realizing significant economies of scope and flexibility. The sustainability implications of such a paradigm shift in manufacturing are arguably obvious: we see the emergence of DG-ML productive model which leverages the global design commons for local manufacturing. As said in Section 4, unlike large-scale industrial manufacturing, the DG-ML model emphasizes application that is small-scale, decentralized, resilient and locally controlled.

In other words, a model of sustainable development which recognizes the limits to growth posed by finite resources and organizes material activities accordingly. From an environmental perspective, a useful way to see this emerging productive model is through a “stack” of interlocked practices that create a positive feedback loop:

- Design for sustainability. Proprietary design in for-profit enterprises often aims to achieve planned obsolescence to maintain tension between supply and demand. Commons-oriented design communities do not have the same incentives and “generically” design for sustainability, modularity, and participatory design. This design is open and transparently available and usable by other designers, citizens and entrepreneurs, and guarantees that the rapid innovation is available everywhere.
- Distributed machinery. The second practice involves the use of desktop manufacturing technologies to create a demand-driven production system, instead of a supply-driven system, and allows relocalization of manufacturing.
- Mutualisation. The third practice is related to the mutualization of the products of industry itself, i.e., the genuine “sharing economy” in which idle resources are identified and used in mutual ways.
- Commons-oriented property regimes. The fourth practice includes adapted models of ownership and governance which facilitate generative forms for the management of productive resources.

Elements of all these practices have emerged and are present in fragmented ways, but have not yet been integrated into an organic mode of production and distribution of value. So, how could such a model be scaled-up? Are there any hints on the role of the state and the market? We attempt to provide a tentative description of such a theoretical model that builds on the convergence of the degrowth and peer production narratives, the resilient communities and the lessons taught by the emerging DG-ML projects that utilize both ICT and desktop manufacturing technologies. To do so, the following figure would help us in outlining our proposal (Fig. 1).

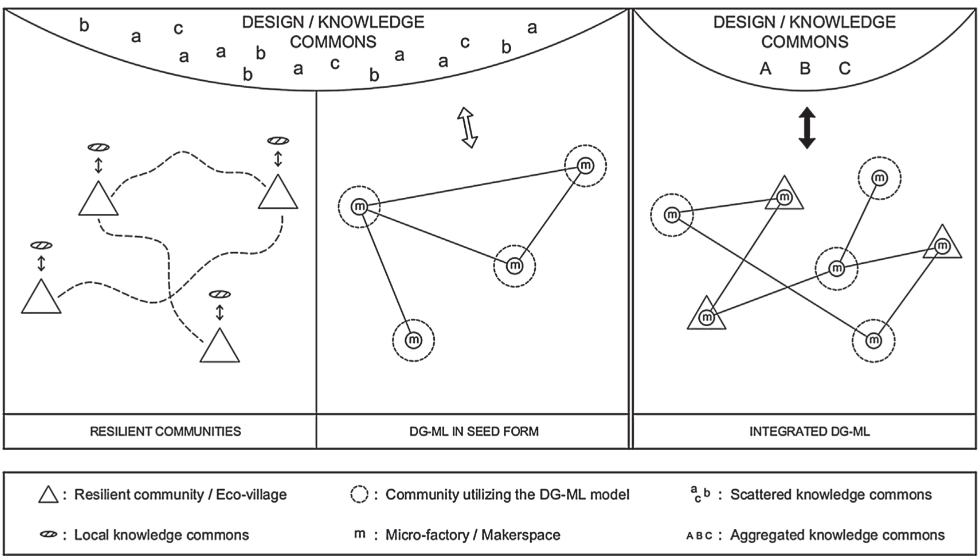

Fig. 1. A proposal for convergence: the DG-ML productive model.

1 It should be noted that the theoretical framework provided in Section 3 is a reworked excerpt from the Kostakis et al., 2013 and the Kostakis & Bauwens, 2014.

The main vein of our critique to resilient communities, as stated in Section 2, is twofold. First, many resilient communities and eco-villages are producing a design/knowledge commons while working to meet their needs, but because of their local focus: they have loose connections with each other; they do not produce a global commons; and thus they fail to contribute to the formation of a global counter-power. Second, a radical shift should take place toward contraction and downscaling, whereas we claim that there are possibilities for "doing things differently" utilizing the modern community-driven technologies and practices. In line with degrowth and resilient communities narratives, we are arguably living the endgame of neoliberal material globalization based on cheap energy, which necessitates relocalization of production. However, we have new possibilities for online, affinity-based socialization, coupled with the resulting physical interactions and community building. The value-creation communities of the global commons approach might be locally based but are globally linked. Out of that, there may come new forms of business organization, which are substantially more community-oriented. This approach sees no contradiction between global open design collaboration, and local production/manufacturing: both can occur simultaneously, so the relocalized reterritorialization will be accompanied by global networks of enterprises. The various information commons, based on shared knowledge, code and design, will be part of these new global knowledge networks, but closely linked to relocalized implementations.

It is obvious that the emergence of the community-driven development model characteristic of Wikispeed, Open Source Ecology and RepRap would have been impossible in the absence of the design/knowledge commons and the respective digital platforms of each project. So, at the most basic level, the scaling up of the DG-ML model would firstly require distributed access to enabling collaborative socio-technological digital platforms that would allow knowledge workers, farmers, hackers, engineers, scientists, hobbyists and open design communities to collaborate on joint or individual projects on a global basis. In a nutshell, it would include the state of the art of open source hardware, i.e., a stack of essential technologies in relation to each productive realm. The knowledge should be documented step-by-step in several languages, so that almost anybody may understand how a certain solution is implemented, replicated or even advanced. Moreover, it would be important to develop open assessment systems so that everyone could contribute to maturity evaluations of the projects. So, the current platforms and libraries of global design/knowledge commons should become more accessible and user-friendly. A proposal could be that the state organizes this first layer of infrastructure enriched with the design/knowledge commons produced by the universities and other research institutes which are funded by tax payers money. Further, the legal framework of the digital commons, especially concerning the open hardware, should be advanced, maybe in line with the proposal for commons-based reciprocal licenses (Bauwens & Kostakis, 2014).

Secondly, the scaling up of the DG-ML model would require distributed access to fixed capital, i.e., a spectrum of hardware technologies such as personal computers and desktop manufacturing technologies, which constitute the essential means of production in this setting. Though production is distributed and therefore facilitated at the local level, the conjunction of peer production practices and products with desktop manufacturing technologies could create sustainable business ecologies. There, the resulting micro-factories/makerspaces, essentially networked on a global scale, would profit from mutualized global cooperation, both on the design of the product and on the improvement of common machinery. "Micro-factories" is a concept that refers to small dimension, automated factories capable of greatly conserving resources like space, energy, materials and time (Okazaki, Mishima, & Ashida, 2004; Tanaka, 2001). They are likely to feature automatic machine tools, assembly systems, evaluation and control systems, a quality inspection system and waste elimination system (Koch, 2010; Kussul et al., 2002). Micro-factories can be identical to makerspaces/fablabs which can be found either in hackerspaces, media labs, and other co-working or community-driven spaces (Troxler, 2011). Community-driven micro-factories are commonly used by individuals and groups with limited financial resources as a local, physical platform for the mutualization of resources and the provision of shared access to those means of production that are not yet as distributed and generally available as personal computers and Internet connectivity. As such, they form a territorial infrastructure for the development of commons-oriented projects like RepRap and Wikispeed. Again, on the regional, national and international level, a proposal could be that the state empowers, supports and even builds micro-factories/makerspaces and intellectual hubs so that bottom-up modes of collaboration and entrepreneurship, which would build on the commons, are developed.

Any distributed enterprise could be seen in the context of transnational alliances of ethical enterprises that operate in solidarity around a particular knowledge commons (de Ugarte, 2014; P2P Foundation, 2014). As the key terrain of conflict is around the relative autonomy of the commons vis-a-vis for-profit companies, we are in favor of a preferential choice towards entrepreneurial formats which integrate the value system of the commons, rather than profit-maximization. In this context, the creation of businesses by the community, can make the commons viable and sustainable over the long run. Advocates of this scenario struggle for a shift from the current flock of community-oriented businesses towards business-enhanced communities. They believe that we need corporate entities which are sustainable from the inside out, not just via external regulation from the state, but from their own internal statutes and links to commons-oriented value systems.

Hence, the third layer relates to the local communities and the development of entrepreneurial coalitions and relevant funding ecologies. Through local hubs (private and public) and the development of a global network of micro-factories/makerspaces and commons-oriented communities, various entrepreneurial coalitions (often in the form of co-operatives) could be catalyzed. The goal should be the creation of a funding infrastructure that benefits and sustains the design/knowledge commons, creates added value on top, and markets these as products or services. Public authorities and governments could help orchestrate the public-private-commons triad in order to benefit from the local effects of the new networked "coopetition" between entrepreneurial coalitions and their linked communities.

Therefore, political and social mobilization on the regional, national and transnational scale is seen as part of the struggle for the transformation of institutions. Participating enterprises are vehicles for the commoners to sustain global commons as well as their own livelihoods. This approach does not take social regression as a given, and believes in frugal abundance for the whole of humanity. It envisions a transition to a paradigm which would include new decentralized and distributed systems of provisioning and democratic governance, escaping the pathologies of the current political economy and constructing an ecologically sustainable alternative (Bollier, 2014). To achieve such a transition, the global commons scenario, through the DG-ML productive model, suggests that we should work on building both global and local political and social infrastructures. Of course, we do not argue that peer production can instantly substitute all production processes or that centralized infrastructures (such as water supply) are useless. Peer production is a proto-mode of production and, thus, currently unable to perpetuate itself on its own outside capitalism, to an autonomous and real mode of production. It has been argued (Kostakis & Bauwens, 2014) that the state could catalyze such a transition to hybrid modes of production reconfiguring the micro-economic and macro-economic level in the spirit of certain commons-oriented policies. Central to this discussion are the concepts of the "ethical market", which would include commons-oriented enterprises, as well as the "partner state", which would enable and empower direct social-value creation by providing support for the basic infrastructures, and focus on the protection of the commons sphere (Orsi, 2009; Kostakis & Bauwens, 2014 and for a critical perspective Rigi 2012, 2013, 2014).

6. Conclusions

In this paper, we attempted to make a contribution to the discussion on degrowth and resilient communities from a techno-economic perspective. It has been claimed that techno-economic paradigm shifts are never the result of technological forces alone, but also presuppose the creation of new social institutions, of new norms and value systems (Perez, 1983, 2009). Viewed from that perspective, resilient communities, the degrowth movement and peer production are complementary components of a paradigm shift away from an economic system based on the irrational exploitation of natural resources and the ecologically destructive magnification of production and consumption, towards one characterized by a radically different definition of the content of human well-being and happiness.

The model advocated here bears a lot of resemblance and materializes ideals that are core to the degrowth imaginary, such as "autonomy" or "conviviality" (see Kallis et al., 2014 for discussions on the work of Ivan Illich and Andre Gorz in relation to degrowth). Resilient communities provide not only a blueprint for the creation of self-sufficient communities but also a fertile ground for the application and further elaboration of the degrowth movement's strategies and policies for transitioning to a sustainable economy. In the context of this experimentation with alternatives, both resilient communities and the degrowth movement would be well advised to look into the mode of peer production and focus on a larger scale by following a global commons approach. This shift, along with the embrace of desktop manufacturing technologies, will allow the implementation of the DG-ML productive model, which could offer an alternative of how productive activities could be organized during the transition period to a more sustainable post-capitalist society.

Last, of particular interest for future research will be an evidence-based documentation of the sustainability aspects of commons-based peer production's convergence with desktop manufacturing technologies, as well as to advance their integration into a coherent mode of production and value distribution in the vein of degrowth.

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References

Alexandra, J., & Riddington, C. (2007). Redreaming the rural landscape. *Futures*, *39*(2–3), 324–339.
Bauwens, M. (2005). The Political Economy of Peer Production. CTheory Journal. http://www.ctheory.net/articles.aspx?id=499 Accessed 1.09.15.
Bauwens, M., & Kostakis, V. (2014). From the communism of capital to capital for the commons: towards an open co-operativism triple C: communication. *Capitalism & Critique*, *12*(1), 356–361.
Benkler, Y. (2006). *The wealth of networks: how social production transforms markets and freedom*. New Haven, CT: Yale University Press.
Benkler, Y. (2015). Peer Production and Cooperation. In J. M. Bauer, & M. Latzer (Eds.), *Handbook on the economics of the internet*Edward Elgar.
Bollier, D. (2005). *Brand name bullies: the quest to own and control culture*. Hoboken, NJ: Wiley.
Bollier, D. (2009). *Viral spiral: how the commoners built a digital republic of their own*. New York, NY: New Press.
Bollier, D. (2014). The Commons as a Template for Transformation. Great Transition Initiative. http://www.greattransition.org/document/the-commons-as-a-template-for-transformation Accessed 1.09.15.
Brown, M. T. (2010). *Civilizing the economy: a new economics of provision*. Cambridge: Cambridge University Press.
Carpenter, S. R., Walker, B. H., Anderies, J. M., & Abel, N. (2001). From metaphor to measurement: resilience of what to what? *Ecosystems*, *4*, 765–781.
Cattaneo, C., D'Alisa, G., Kallis, G., & Zografos, C. (2012). Degrowth futures and democracy. *Futures*, *44*(6), 515–523.
Chamberlin, S. (2009). *The transition timeline: for a local, resilient future*. Cambridge: Green Books.
Dafermos, G. (2012). Authority in peer production: the emergence of governance in the free BSD project. *Journal of Peer Production*, *1*(1), 1–12.
Dafermos, G. (2015). Transforming the productive base of the economy through the open design commons and distributed manufacturing. *Journal of Peer Production*, *7*, http://peerproduction.net/issues/issue-7-policies-for-the-commons/peer-reviewed-papers/distributed-manufacturing/ Accessed 5.09.15.

Dafermos, G., & Söderberg, J. (2009). The hacker movement as a continuation of labour struggle. *Capital & Class*, *33*, 53–73.
de Bruijn, E. (2010). On the Viability of the Open Source Development Model for the Design of Physical Objects: Lessons Learned from the RepRap Project. (MSc dissertation), Tilburg University. http://thesis.erikdebruijn.nl/master/MScThesis-ErikDeBruijn-2010.pdf Accessed 1.09.15.
de Ugarte, D. (2014). Trilogía de las Redes. http://lasindias.com/de-las-naciones-a-las-redes Accessed 1.09.15.
Demaria, F., Schneider, F., Sekulova, F., & Martinez-Alier, J. (2013). What is degrowth? from an activist slogan to a social movement. *Environmental Values*, *22*(2), 191–215.
Elliott, M. (2006). Stigmergic collaboration: the evolution of group work. *M/C Journal: A Journal of Media and Culture*, *9*(2) .
Folke, C. (2006). Resilience: the emergence of a perspective for social–ecological systems analyses. *Global Environmental Change*, *16*, 253–267.
Foster, J.B. (2011). Capitalism and Degrowth: An Impossibility Theorem. Monthly Review, 62(8). https://monthlyreview.org/2011/01/01/capitalism-and-degrowth-an-impossibility-theorem Accessed 1.09.15.
Fournier, V. (2008). Escaping from the economy: the politics of degrowth. *International Journal of Sociology and Social Policy*, *28*(11/12), 528–545.
Fuster Morell, M. (2014). Digital Commons. In G. D'Alisa, F. Demaria, & G. Kallis (Eds.), *Degrowth: a vocabulary for a new era* (pp. 159–161). New York, NY: Routledge.
Garcia, E. (2012). Degrowth, the past, the future, and the human nature. *Futures*, *44*(6), 546–552.
García-Olivares, A., & Solé, J. (2015). End of growth and the structural instability of capitalism: from capitalism to a symbiotic economy. *Futures*, *68*, 31–43.
Helfrich, S. (2013). Economics and the Commons?! Towards a Commons-Creating Peer Economy. Paper presented at the Economics and the Commons Conference, Berlin. http://commonsandeconomics.org/2013/06/09/silke-helfrichs-opening-keynote-towards-a-commons-creating-peer-economy Accessed 1.09.15.
Hermann, M., Pentek, T., & Otto, B. (2015). *Design principles for industrie 4.0 scenarios: a literature review*. Dortmund: Technische Universität.
Hertel, G., Niedner, S., & Herrmann, S. (2003). Motivation of software developers in open source projects: an internet-based survey of contributors to the Linux kernel. *Research Policy*, *32*, 1159–1177.
Hopkins, R. (2008). *The transition handbook: from oil dependency to local resilience*. Cambridge: Green Books.
Hopkins, R. (2011). *The transition companion: making your community more resilient in uncertain times*. Cambridge: Green Books.
Jakubowski, M. (2011). Global Village Construction Set Kickstarter Campaign. https://www.kickstarter.com/projects/622508883/global-village-construction-set Accessed 1.09.15.
Jakubowski, M. (2013). The Open Source Economy. http://www.marioninstitute.org/videos/2013/marcin-jakubowski-open-source-economy Accessed 1.09.15.
Kallis, G. (2011). In defence of degrowth. *Ecological Economics*, *70*(5), 873–880.
Kallis, G. (2014). Response by Giorgos Kallis to Brian Davey's Review of Degrowth. Feasta. http://www.feasta.org/2014/12/22/response-by-giorgos-kallis-to-brian-daveys-review-of-degrowth/ Accessed 1.09.15.
Kallis, G., Demaria, F., & D'Alisa, G. (2014). Degrowth. In G. D'Alisa, F. Demaria, & G. Kallis (Eds.), *Degrowth: a vocabulary for a new era* (pp. 1–17). New York, NY: Routledge.
Kelly, K. (1994). *Out of control: the new biology of machines, social systems, and the economic world*. Basic Books.
Koch, M.D. (2010). Utilizing Emergent Web-Based Software Tools as an Effective Method for Increasing Collaboration and Knowledge Sharing in Collocated Student Design Teams. (MSc), Oregon State University. http://ir.library.oregonstate.edu/xmlui/handle/1957/16855 Accessed 1.09.15.
Kostakis, V., & Bauwens, M. (2014). *Network society and future scenarios for a collaborative economy*. Basingstoke, UK: Palgrave Macmillan.
Kostakis, V., Fountouklis, M., & Drechsler, W. (2013). Peer production and desktop manufacturing: the case of the Helix_T wind turbine project. *Science, Technology & Human Values*, *38*(6), 773–800.
Kostakis, V., & Papachristou, M. (2014). Commons-based peer production and digital fabrication: the case of a reprap-based, lego-built 3D printing-milling machine. *Telematics and Informatics*, *31*(3), 434–443.
Kussul, E., Baidyk, T., Ruiz-Huerta, L., Caballero-Ruiz, A., Velasco, G., & Kasatkina, L. (2002). Development of micromachine tool prototypes for microfactories. *Journal of Micromechanics and Microengineering*, *12*(6), 795–812.
Lakhani, K., & Wolf, R. (2005). Why Hackers Do What They Do: Understanding Motivation and effort in free/open source software projects. In J. Feller, B. Fitzgerald, S. Hissam, & K. Lakhani (Eds.), *Perspectives on free and open source software* (pp. 3–22). Cambridge, MA: MIT Press.
Latouche, S. (2009). *Farewell to growth*. Cambridge, MA: Polity.
Lewis, M., & Conaty, P. (2012). *The resilience imperative: cooperative transitions to a steady-state economy*. Gabriola Island: New Society Publishers.
MacCormack, A., Rusnak, J., Baldwin, C.Y. (2007). The Impact of Component Modularity on Design Evolution: Evidence from the Software Industry. Harvard Business School Technology & Operations Mgt. Unit, 08–038. http://ssrn.com/abstract=1071720 Accessed 1..09.15.
MacKinnon, R. (2012). *Consent of the networked*. New York, NY: Basic Books.
Marsh, L., & Onof, C. (2007). Stigmergic epistemology, stigmergic cognition. *Cognitive Systems Research*, *9*(1–2), 136–149.
Meadows, D. (2008). *Thinking in systems: a primer*. Vermont, VT: Chelsea Green Publishing.
Mollison, B. (1988). *Permaculture: a designers' manual*. Tyalgum: Tagari Publications.
Moore, P., & Karatzogianni, A. (2009). Parallel visions of peer production. *Capital & Class*, *33*, 7–11.
O'Mahony, S. (2003). Guarding the commons: how community managed software projects protect their work. *Research Policy*, *32*, 1179–1198.
Okazaki, Y., Mishima, N., & Ashida, K. (2004). Microfactory—concept, history, and developments. *Journal of Manufacturing Science and Engineering*, *126*(4), 837–844.
Open Source Ecology (2013). Open Source Ecology Shop 2011. http://opensourceecology.org/wiki/OSE_Shop_2011 Accessed 1.09.15.
Orsi, C. (2009). Knowledge-based society, peer production and the common good. *Capital & Class*, *33*, 31–51.
Ostrom, E. (1990). *Governing the commons: the evolution of institutions for collective action*. Cambridge: Cambridge University Press.
P2P Foundation (2014). Phyles. http://p2pfoundation.net/Phyles Accessed 1.09.15.
Perez, C. (1983). Structural change and assimilation of new technologies in the economic and social systems. *Futures*, *15*(5), 357–375.
Perez, C. (2009). Technological revolutions and techno-economic paradigms. *Cambridge Journal of Economics*, *34*(1), 185–202.
Rigi, J. (2012). Peer production as an alternative to capitalism: a new communist horizon. *Journal title Journal of Peer Production*, *1*(1) .
Rigi, J. (2013). Peer production and marxian communism: contours of a new emerging mode of production. *Capital & Class*, *37*(3), 397–416.
Rigi, J. (2014). The coming revolution of peer production and revolutionary cooperatives: a response to Michel Bauwens, Vasilis Kostakis and Stefan Meretz. *Open Access Journal for a Global Sustainable Information Society*, *12*(1), 390–404.
Romano, O. (2012). How to rebuild democracy, re-thinking degrowth. *Futures*, *44*(6), 582–589.
Schneider, F., Kallis, G., & Martinez-Alier, J. (2010). Crisis or opportunity? economic degrowth for social equity and ecological sustainability. introduction to this special issue. *Journal of Cleaner Production*, *18*(6), 511–518.
Sharzer, G. (2012). *No local: why small-scale alternatives won't change the world*. Winchester: John Hunt Publishing.
Stadler, F. (2014). *Digital solidarity*. Lüneburg: Mute & PML Books.
Tanaka, M. (2001). Development of Desktop Machining Microfactory. *Riken Review*, 34. http://pdf.aminer.org/000/353/685/development_of_a_micro_transfer_arm_for_a_microfactory.pdf Accessed 1.09.15.
Tapscott, D., & Williams, A. (2006). *Wikinomics: how mass collaboration changes everything*. New York, NY: Portfolio..
Thomson, C. C., & Jakubowski, M. (2012). Toward an open source civilization: (innovations case narrative: open source ecology) innovations: technology. *Governance, Globalization*, *7*(3), 53–70.
Tocqueville, A. D. (2010). *Democracy in America*. New York, NY: Signet Classics.
Torvalds, L. (1999). The Linux Edge. In C. DiBona, S. Ockman, & M. Stone (Eds.), *Open sources: voices from the open source revolution* (pp. 101–109). Sebastopol, CA: O'Reilly.

Trainer, T. (2012). De-Growth: Do you Realize What it Means? *Futures*, *44*(6), 590–599.
Troxler, P. (2011). Libraries of the peer production Era. In B. Van Abel, L. Evers, R. Klaassen, & P. Troxler (Eds.), *Open design now* (pp. 86–95). Amsterdam: BIS Publishers.
von Hippel, E., & von Krogh, G. (2003). Open source software and the private-collective innovation model: issues for organization science. *Organization Science*, *14*, 209–223.
Walker, B., & Salt, D. (2006). *Resilience thinking: sustaining ecosystems and people in a changing world*. Washington, DC: Island Press.
Walker, B. H., Abel, N., Anderies, J. M., & Ryan, P. (2009). Resilience, adaptability, and transformability in the goulburn-broken catchment, Australia. *Ecology and Society*, *14*(1), 12.
Wilding, N. (2011). *Exploring community resilience in times of rapid change*. Dunfermline: Fiery Spirits Community of Practice.
Xue, J. (2014). Is eco-village/urban village the future of a degrowth society? An urban planner's perspective. *Ecological Economics*, *105*, 130–138.

IV Kostakis, V., **Niaros, V.**, & Giotitsas, C. (2015). Open source 3D printing as a means of learning: An educational experiment in two high schools in Greece. *Telematics & Informatics*, *32*(1), 118-128. (1.1)

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Open source 3D printing as a means of learning: An educational experiment in two high schools in Greece

Vasilis Kostakis [1,*], Vasilis Niaros [2], Christos Giotitsas [3]

P2P Lab, Tallinn University of Technology, Akadeemia tee 3, 12618 Tallinn, Estonia

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ABSTRACT

This research project attempts to examine to what extent the technological capabilities of open source 3D printing could serve as a means of learning and communication. The learning theory of constructionism is used as a theoretical framework in creating an experimental educational scenario focused on 3D design and printing. In this paper, we document our experience and discuss our findings from a three-month project run in two high schools in Ioannina, Greece. 33 students were tasked to collaboratively design and produce, with the aid of an open source 3D printer and a 3D design platform, creative artifacts. Most of these artifacts carry messages in the Braille language. Our next goal, which defined this project's context, is to send the products to blind children inaugurating a novel way of communication and collaboration amongst blind and non-blind students. Our experience, so far, is positive arguing that 3D printing and design can electrify various literacies and creative capacities of children in accordance with the spirit of the interconnected, information-based world.

1. Introduction

Three-dimensional (3D) printing – actually a subset of additive manufacturing – is, in short, the process of joining material, layer-by-layer, to make objects from 3D model data (usually created by a computer-aided design software or a scan of an existing object), in contrast to subtractive manufacturing technologies (ASTM, 2010). This technological capability has been around for more than three decades and has been known as the "rapid prototyping machine" (Bradshaw et al., 2010; Campbell et al., 2011). It was called "rapid" because one-offs could be made more easily and quickly than by the conventional numerically-controlled machines and it was called "prototyping" because it was too slow and expensive to be used for production (Bradshaw et al., 2010). For example, an architect could print in 3D the design of a building or an automobile engineer could print a prototype of a part from the car for further refinement of the design. However, lately 3D printers have been adopted, especially by aerospace and health care industries (Bullis, 2011), to make functional products as well, whereas the rise of relatively low-cost (€500–1300), open source desktop 3D printers, such as RepRap or Ultimaker

* Corresponding author.
E-mail address: vasileios.kostakis@ttu.ee (V. Kostakis).

[1] Vasilis Kostakis (PhD, MSc, MA) is a political economist and founder of the P2P Lab. Currently he is a research fellow at the Tallinn University of Technology and a collaborator of the P2P Foundation.

[2] Vasilis Niaros (PhD student at the Tallinn University of Technology) is an urbanist interested in investigating the relationships of technology, education, culture and urbanism. He is also a research fellow at the P2P Lab.

[3] Christos Giotitsas is a junior research fellow at the P2P Lab.

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(Kalish, 2011) have given the chance to hobbyists and adopters of the do-it-yourself culture to experiment, design and produce things moving gradually from "prototyping" to "manufacturing". Moreover, it becomes evident that this Commons-oriented, open source, collaborative experimentation with 3D printing has arguably dropped the costs and improved the user-friendliness of 3D printing hardware and software making this technology more accessible than ever, even to schools and young students.

This article is part of an ongoing research project that tries to tentatively examine to what extent and degree the technological capabilities of 3D printing could serve as a means of learning as well as a way of meaningful communication amongst blind and non-blind students. This paper, which describes the first phase of this project, focuses on open source 3D printing, within the context of two high schools based in Ioannina, Greece, with particular reference to possible applications for learning. In total 33 students from one public and one private high school were called to collaboratively design and produce, with the aid of an open source 3D printer and a 3D design platform, functional artifacts of their own choice. Students were told that those artifacts, from stamps, cups and sharpeners to sophisticated toys, carrying messages in Braille language, would be sent to blind fellow students.

Within the framework of constructionism we attempted to run our experimental project, document our experience, discuss our findings and create an educational scenario in a narrative format that could be used, tested, criticized, enriched and, hopefully, improved further. This paper begins with the formulation of our research questions as well as a brief review of the relevant theoretical background. The methodological part follows with a description of our educational scenario as well as some information on the schools where the project took place. We, then, discuss our experience through students' creations concluding with recommendations for future research.

2. Research questions and theoretical framework

Nowadays students have grown up in a framework of constant connectivity and interactive culture and, thus, may have different attitudes and understandings of concepts such as creativity, collaboration, communication and sharing (see only Prensky, 2001, 2007; Rushkoff, 1996; and for a critical approach to the "digital native" concept see Bennett et al., 2008; Bennett and Maton, 2010). This behavior should have arguably led to reforming the institutions of learning and education. Since the 1980s, Seymour Papert (1980a,b, 1993, 1997), father of the LOGO programming language and key developer of constructionism, has been arguing that the social penetration of information and communication technologies (ICT) provides individuals or communities with the means to develop and to implement new educational ideas. However, as Papert (1997) points out discussing the penetration of computers in schools, learning institutions resist the reform by appropriating or assimilating it to their own structures.

The main research question that guides our inquiry could be formulated as follows: What role could 3D printing and design, along with the modern ICT, play in developing and implementing new educational ideas based on the principles of constructionism? Therefore, from the aforementioned question a few sub-questions emerge: What kind of educational environments could be created, fused with the values of collaboration and meaningful communication which are pillars of the Commons-oriented, open source movement (as it is explained later)? Could these scenarios and environments be considered as "objects-to-think-with" (Papert, 1993, p. 182), which would contribute to the social process of constructing the education of the future? And last but not least –actually this was the main concern of the teachers, Christos Bitsis and Loukianos Xaxiris, who participated in this first phase of our project– could such a media-based knowledge acquisition contribute to the solution of problems observed in these high schools, i.e., lack of students engagement (personal communication with Bitsis and Xaxiris, April, 2013); theoretical teaching and textbook based instruction (personal communication with Bitsis, Xaxiris, April, 2013); poor demonstration infrastructure available (personal communication with Bitsis, Xaxiris, April, 2013); and students' misconceptions about project-based learning (personal communication with Bitsis, Xaxiris, April, 2013). Regarding the latter point, it would be interesting to mention that although students were unanimously for a hands-on, practical mode of learning they seem to highly underestimate the project-based courses held so far in their schools (questionnaires and personal communication, 2013).

To tackle these questions we choose to develop our educational scenario based on the learning theory of constructionism developed by Papert (1980a,b, 1993, 1997), Papert and Harel, (1991) and informed by Ackermann (2001), which emphasizes the personalized production of knowledge artifacts as well as the social nature of the learning process:

> constructionism – the N word as opposed to the V word – shares constructivism's connotation of learning as "building knowledge structures" irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it is a sand castle on the beach or a theory of the universe (Papert and Harel, 1991, p. 3).

Similar to many prominent scholars in the philosophy of education (for example Jean Piaget, Lev Vygotsky, Paulo Freire or John Dewey) constructionism maintains that students' intellectual growth must be rooted in their experience (Papert, 1980b). Knowledge is not seen as a commodity to be transmitted but as a personal experience that has to be constructed

(Ackermann, 2001). Our constructionist approach is informed, though, by Ackermann's, (2001, p. 10) discussion on Papert and Piaget where she argues for both ''dwelling in'' and ''stepping back'' in ''getting such a cognitive dance going''. Echoing Kegan (1982), Ackermann (2001) highlights not only the need to become embedded but also to emerge from embeddedness for a deeper understanding of oneself and others. However, our approach remains constructionist in essence, since it focuses more on the art of ''learning to learn'' and highlights the importance of media, conversations with artifacts and context in learning (Ackermann, 2001; Papert, 1993). In our project students get the opportunity to engage in hands-on explorations that fuel the constructive process (Ackermann, 2001; Papert, 1993) and, thus, constructionism offers us the appropriate context.

Further, the ethics of the open source or Commons-oriented movement (see only Bauwens, 2005; Benkler, 2006, 2011; Bruns, 2008; Kostakis, 2012; Lakhani and Wolf, 2005; Levy, 2001; Wark, 2004), which has created several media technologies of educational value (from free/open source software, say Moodle or Sugar, to free encyclopedia Wikipedia to open hardware such as the Arduino micro-controller or low-cost 3D printers), could arguably provide a context for experimentation, communication, collaboration, sharing and learning. Based on constructionism; inspired by the general values (i.e., free collaboration, autonomy, openness, learning by doing and peer learning, sharing of resources, producing use value for society etc.) of open source/Commons-based communities' production processes; and using open source tools (such as the 3D printer Ultimaker) whose internal structure can be easily studied, we attempt to create open educational environments.

With substantive, indeed massive techno-economic changes appearing in our life world, almost anything eventually changes with them or adapts at least somehow (Perez, 2002) and this open source movement could be regarded as a manifestation of a creative culture emerged from constant connectivity and interaction (Bauwens, 2005; Benkler, 2006, 2011; Kostakis, 2012, 2013; Lessig, 2005, 2009). It has been stated that the open source movement shows ''how cooperation trumps self-interest – maybe not all the time, for everyone, but far more consistently than we have long thought'' (Benkler, 2011, p. 249). Therefore, in addition to the technical knowledge which may be gained, through such an environment students could arguably have a chance to realize that there are also possibilities for societal development based on intrinsic positive incentives and voluntary efforts beyond competition and self-interest.

3. Educational scenario and methodology

The current paper tries to document the first of the three phases of our ongoing research project. Specifically, the first phase includes a tentative effort to examine the educational sides of 3D printing and design in a small sample of high school students. At the second phase, we try to create a network of collaborators, i.e., teachers and scholars from other schools (both primary and secondary) and institutions (such as public centers of creative development) inside and outside the Greek borders who are willing to apply, test, criticize, enrich and improve further first phase's educational scenario. In that way, hopefully, we will gain more experience, knowledge and insights increasing our sample, enhancing the educational scenarios and building an open collaboration network. The third phase will contain the investigation of the communicational potential of 3D printing amongst blind and non-blind students.

Therefore, in this first, pilot phase we decided to approach two high schools, one public and one private. The main reason we chose high schools was because of the ''project course'' that students of first and second class in Greece have. That is to say, for two hours per week in students' official curriculum there is a special course in which they are supposed to run collaborative and/or individually two research-based projects in a school year. Exemplary topics could include the documentation of old, forgotten professions or a discussion of social media technologies. According to the learning theory of constructionism, when having children do their work using ICT, duration is key for students to become personally – intellectually and emotionally – involved (Papert, 1980b). So, the existence of the project course gave us enough time to implement our scenario but also covered for our inexperience with primary school students. Moreover, personal acquaintance with both the directors of the schools allowed full consensus easily as well as the appropriate cooperative environment for such a project to run smoothly. We approached several other schools of the region, whose directors, unfortunately, seemed unable to comprehend our goals and unwilling to cooperate.

The project began, on January the 23rd, 2013, with the private high school Dodonaia, based in Ioannina (a relatively small city in north-western Greece), particularly with its second year class, consisted of 15 16-years-old students. The second school was the 7th General Lyceum, a public high school, and the project took place in its first year class consisted of 18 15-years-old students. The collaborator teachers respectively were the physicist Loukianos Xaxiris and the ICT teacher Christos Bitsis responsible, amongst others, for the ''project course''. In total we were in class approximately for 700 min in each school while many students worked beyond school time as well. In addition, three open 3D printing days (April Saturdays' mornings from 11:00 to 17:00) took place in our lab where students were present, discussing about necessary adjustments and changes in their designs while watching theirs or others fellow students' artifacts printing.

To begin with, the main learning goal was that students grasp the concept of 3D design using simplified software (there are both very good, user-friendly free/open source and proprietary software available) and the basics of 3D printing as part of a living experience (Dewey, 1997; Mooney, 2000; Papert, 1993). This concerns the application and further development of skills from various fields such as engineering, design, linguistic (the software was in English and much information on the web was in English as well) or artistic skills. Bearing in mind that students learn better if they are in charge of their own learning processes (Freire, 2000, 2005; Papert, 1993), we let them explore the research procedures themselves performing their efforts, though within the framework of organized teaching. Another skill was that students should be able to use web tools (such as email, office suites, browser-based software etc.) efficiently to present and support what they have learned and share with others, as conversation plays a vital role in learning (Mooney, 2000; Papert, 1993). Therefore, students were expected to be able to explore the process through trial-and-error; to learn to function in group collaboration and decision making; and to engage in a creative way of thinking creating 3D objects.

To achieve these goals the learning activities that took place begun with an introduction of the concept of open source 3D printing along with the idea of learning and improving through experiment, re-use and sharing. In more detail, through lecture- and video-based classes students were introduced in the 3D printing technology and in the open source movement. We attempted to demonstrate how through collaboration people can achieve certain goals as well as that self-interest is not the sole purpose of society and economy. People can produce collaboratively (in contrast to competition) while satisfying their inner needs for communication and learning (in contrast to considering money as a key motivating factor). The objectives of this stage (duration 60–90 min) was students to pay attention; understand; respond; think critically; and participate in a discussion on what humans can achieve when they cooperate with each other. The necessary hardware ideally includes computers, a video-projector and a 3D printer. If available, it is desirable to download (there is a plethora of 3D models available under Commons-based licenses) and 3D print a functional object in the class for demonstration, empowering children's motivation for the project.

Afterwards, students had to get familiar with their working environment, i.e., to learn designing (and thinking) in 3D using specified, browser-based software. They had the choice to either learn the design software through special lessons the platform offers or by a learning-by-doing process. Therefore, the students, once having been introduced in the context of an open source 3D printer and got familiar with the software, were free to propose objects. On this basis, later, they formed tentative working teams (from 2 to 4 persons, and two students worked on their own). In their decision to form groups and take a final decision on the selected objects we asked them to take into consideration four points and try to cover at least three of them (the first one was mandatory). Their object should be possible to be 3D printed on a low cost 3D printer like ours (this predicates that they have understood its capabilities and limits); it should be novel, functional, and/or usable by blind children.

Monitoring how students used the software, 80% opted to learn the software experimenting and tinkering, without following the lessons (almost 70% of this 80% took at least one lesson, though, but quit afterwards). Then, most of the students who decided to design objects aimed for use by blind fellow students had to learn writing in the Braille language in order to implement it on the design of their artifacts. As was mentioned above, the students were free to choose whether they would design an object to be sent to the blind or not: 13 of the 16 objects, finally designed, were meant for use by blind people and 8 of them would carry messages in Braille, even though this was an optional condition. In this stage (400–500 min), the children were expected to think creatively; experiment; adapt and perform creatively in small-groups, pairs or even individually. It should be emphasized that since they found that there was not enough time in class, most of them continued their work at home, which, in our opinion indicates their commitment to the project.

The next learning activity contained the engagement of students in the printing process in which students had the chance to see the flaws of their design and make the necessary adjustments for it to be printable. Because of the several shortcomings the designs had, it took us more than 120 min, on average, to deal with each artifact. The 3D printing took place in our lab and three persons had to be present to address students' questions, to help them with suggestions while making the appropriate adjustments for printing a functional object as well as using the 3D printer. This process could not be facilitated at school, since it is very time consuming to print one object with our printer, let alone plenty. However most of the students (28/33) were present, spending more of their personal time to help materialize their design.

In the last learning activity students would write reports on their artifacts (for instance why they chose such an object or problems in designing and printing phases etc.) as well as provide some information on open source 3D printing (some would investigate the mechanics, others the software, the used materials or the socio-economic impact) and take part in an official school ceremony presenting in public their efforts. A general flowchart with basic steps of the project ensues (Fig. 1).

The teacher (in every class at least one of the authors was present cooperating with the teacher) was the catalyst and orchestrator of the learning process (Papert, 1980a,b, 1993). In the introductory, lecture-based classes the teacher explained the concept of open source and the operation of 3D printing and 3D design, making the relation of these particular ICT tools to general and course concepts, and triggered discussions with the whole class. Afterwards, the teacher was responsible to facilitate and monitor interaction amongst students and courseware, and direct students learning by clarifying misconceptions; providing vocabulary for concepts; giving examples of skills; modifying behaviors; suggesting further learning experiences; providing an occasion for students to cooperate on activities; discussing their current understanding; and helping them present their efforts publicly.

In the beginning of this project's phase we gave students short, anonymous questionnaires of 18 questions (see Appendix). This process took place in order to help us conceptualize the context and, therefore, transform the project into something more suitable for the students, rather than to exclude any assumptions about the research question. For that reason there was no validation required. The aim was to get an idea of how familiar and dependent students were with and on ICT (i.e., computers, Internet, social media, open source projects, 3D printing), how much they liked the way lessons are taught in school and whether they knew what the Braille language was. 73% had heard of the Braille language and the same amount had already had an idea about what profession would like to study (almost half was for technical studies).

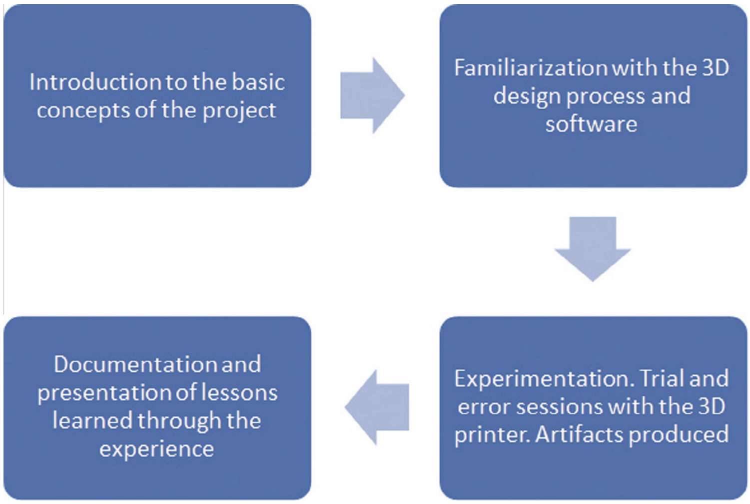

Fig. 1. Basic steps of the project at schools.

All 33 students were for a more practical, hands-on learning approach. Their favorite courses are physics and math (64% did not find bland the way these lessons are taught) but not the project course which comes last in students' preferences (2 out of 33 voted for the project course as one of their two favorites lessons). Regarding familiarity with ICT, 82% of the students had an account in, at least, one social media platform, 94% were using Wikipedia and 48% had heard, watched or read something about 3D printing. It would be interesting to note that in the private school all students owned a smart-phone or a tablet whereas in the public a 45% had one. Another discrepancy in their answers was that in the public school 95% did not consider school as a burden while in Dodonaia the respective percentage was 40%. In the long, semi-structured interviews and discussions we had – and still have – with teachers of both schools before and during the project, the crucial problems, from which the educational systems in Greece has been suffering (and recently with the deep socio-economic crisis and the cuts in education the situation has deteriorated), came to the fore as documented in the previous section.

To sum up, the process used to create and study our educational scenario and its implementation is rooted in the qualitative research methodologies, namely the case study approach informed by both primary (i.e., questionnaires to students; semi-structured interviews with teachers and students; and in situ observation) and secondary (i.e., literature review) research. It should be emphasized that on the one hand our engagement and involvement into the development and the application of the educational scenario in the two high schools might breed the possibility for biased interpretation of the

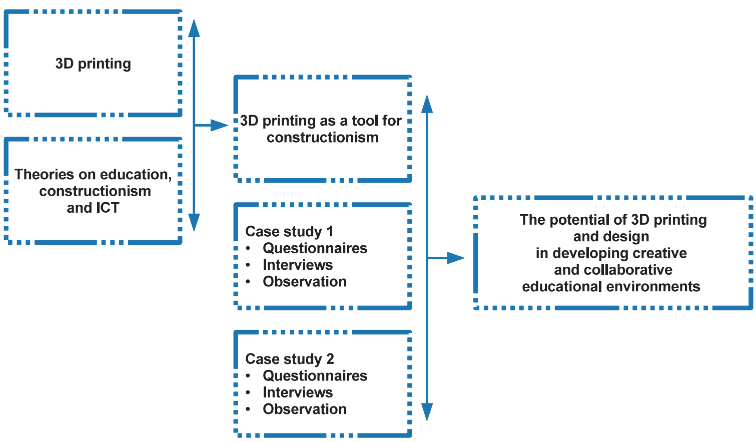

Fig. 2. Schematic representation of the research framework. The vertical arrows stand for the "confrontation" of some particular issues, from which a conclusion can be drawn (the horizontal ones).

results. On the other, as insiders we had the chance to experience the complex relations with students and the educational processes in class and, thus, arguably gain a sharpened understanding of why the instance happened as it did (Flyvbjerg, 2006). Based on Verschuren and Doorewaard (2005), a schematic representation (Fig. 2) of this paper's research framework follows so to gain a general understanding of the various steps towards the realization of our goal. Our research project is a case study and, hence, what should be expected from such a study is to develop our partial answers to the research questions, which would be "input to the ongoing social dialogue about the problems and risks we face and how things may be done differently" (Flyvbjerg, 2001, p. 61).

4. Artifacts and results

We assumed that 3D printing and design would motivate students express their ideas making them tangible and shareable (Ackermann, 2001) via processes that stimulate students to make various connections related to the under creation artifacts. Selected examples of such processes are listed below:

- Learning to design and think in 3D.
- Researching material in Greek and in English about the Braille language.
- Exploring the mechanics of the objects to be designed or the open source 3D printers.
- Studying designs of similar objects made with conventional manufacturing techniques and understanding the engineering process behind them.
- Envisioning what blind people would need that 3D printing could deliver.
- Combining ordinary hardware with their 3D printed artifacts.
- Applying knowledge from different disciplines such as geometry, physics, architecture or the arts.
- Sharing their creations with the world under Commons-based licenses.

And as Papert (1993, p. 103) maintains 'the more connections... made the more likely to be long-lasting'.

According to the teachers (personal communication with Bitsis, Xaxiris, April, 2013), who have been coordinating the project course since its introduction in 2011, greater engagement by students along with a reduced need of discipline and less disruption were observed. "My class consisted of generally uncooperative, especially concerning the project course, students who, surprisingly enough, were very willing to engage in this particular project", Xaxiris (personal communication, April, 2013) notes. "There were some fellow students that even surprised me", a Dodonaia student (personal communication, April, 2013) emphasized echoing not only his teacher but also students from both schools. As Bitsis (personal communication, April, 2013) told us, "this change is a result of children's increased connection with the world (new ideas, literacies, technologies)... followed by an increase in their self-esteem". Both teachers claimed for an increase in their esteem as well and noticed an increased involvement by parents, since many of the latter showed a great interest for the project course. In addition, through the use of open source technologies, working approaches and licenses it was stated that "a sharing culture is developed, i.e., child to child and school to society" (personal communication with Bitsis, April, 2013).

It would be arguably better to let the children's creations speak for themselves. In total 16 + 1 artifacts were designed; the plus one designed by a public high school's third-class student, G., who upon hearing about the project asked to participate despite his "hectic time and heavy workload" (G., who is dyslectic, designed a H_2O molecule, calculating the right angles, that can be studied and understood by the blind as he put Braille letters on the oxygen's and hydrogen's molecules) (Fig. 3).

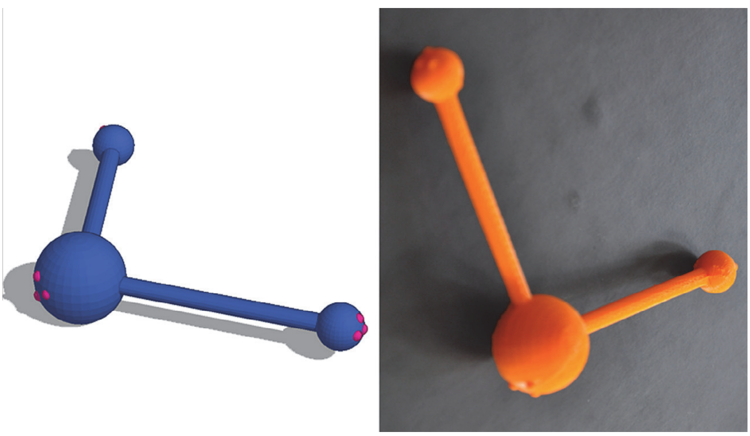

Fig. 3. The molecule was ergonomically designed specifically for the blind by the student.

As mentioned, 13 of the 16 objects were specifically designated for use by the blind although children were free to design almost whatever they want (the remaining three are an airplane, an electric guitar and a sophisticated i-phone case). It could be argued that every single artifact has a story to tell, therefore, we refer to all the 13 designs with a short description enlivening our discussion. A few figures are provided for those objects whose design or function is difficult to be effectively explained in words (all figures can be found on-line in our project's blog).

The first object, designed by two students, is a 3D comic where the hero exclaims "save the world!", written in the Braille language. The forms are on purpose kept simple because, as students found out after some research, "blind people are unable to understand complicated shapes such as windows, doors etc.; however, hopefully they can imagine the stars" (personal communication, March, 2013). Three other students discovered on-line a 3D model depicting the Parthenon of the classical ages and decided that blind fellow students need to know how Parthenon looks today. Hence, since this particular model was distributed under a Creative Commons license, they were free to build on that after studying Parthenon's current condition (and through that its history), carefully dismantling classical times' magnificent temple. Another object is a cup with the message "drink me" in the Braille on it "to make drinking more fun for the blind", as our young designers said (personal communication, February, 2013). Moreover, small-scale 3D models, which could "help the blind understand the forms of their surroundings", to put it in students' words (personal communication, March, 2013), of three, complementary touristic sites of Ioannina (a mosque and a museum which are situated in the old castle of Ioannina) as well as the largest bridge in Greece were made by three different groups. In addition, a group of four students came up with a stamp on which one can read in Braille the text "7 ΓΕΛ" (the name of their school in Greek) which is found underneath. In other words, this is an analogue "way of translating the Braille language", as one of the four highlighted (personal communication, March, 2013). In this artifact students had to make several adjustments for it to be functional since our 3D printer creates the object layer-by-layer and the design's geometry had to take into consideration the necessary support infrastructure (Fig. 4).

Furthermore, some novel ways of combining conventional hardware with 3D printing modules are manifested through the sharpener and the Rubik's cube projects. To begin with, the sharpener (Fig. 5) was created by two students with the aim to offer the blind the possibility, with special symbols, to understand sharpener's geometry and, thus, easily sharpen a pencil and make efficient management of the waste. Therefore, after 3D printing the three modules, a typical razor had to be added. Two other students attempted, and to our surprise succeeded, to create a working Rubik's cube using Braille language's letters instead of colors. They managed to set functional the printed object with synthetic rubber by carefully adding small holes diagonally in each part of the design (Fig. 6).

An informed version of the old sand-timers for use by the blind was another object produced by a group of two students. Instead of sand they used marbles to produce sound while counting the time. Their design has a few small holes scattered on its surface so as to not trap the sound (Fig. 7). Moreover, two students noticing a lack of board games for the blind decided to create a Braille-based Sudoku board. They came up with a novel way of playing the Sudoku game creating extra tiles with numbers in Braille that offer replay value (Fig. 8). And last but not least, the solar system (Fig. 9) was one of the most intriguing objects made by a student "who although extremely talented and clever – a national chess champion in his age –, never cared much about school" (personal communication with Xaxiris, April, 2013). Still we are unable to functionally 3D print it because of its complexity which seems to seriously challenge our knowledge in 3D design and printing. The student had to realistically adjust his model in scale, therefore, various complex calculations had to be made. Then, he wrote on each planet the first letter in the Braille language in order to allow the blind to experience the solar system's structure.

Most of the objects have already been 3D printed and are functional. However, even for those (like the solar system) which remain in pixels (but we are trying to turn its bits into atoms), the design phase itself was of great interest for all the participants (personal communication with Bitsis, Xaxiris, April, 2013). More important than to successfully 3D print students' creations was to have them present during the process to discuss the problems and make necessary adjustments directly and in real time. We had the chance to experience this creative interaction with most of them, and see in their eyes the disappointment, when 3D printing proved devastating, but also the exhilaration and satisfaction when, after several adjustments and much (co-)calibration, we managed to get functional objects. Overall, all have shown great engagement

Fig. 4. The stamp went through several modifications to reach its final form.

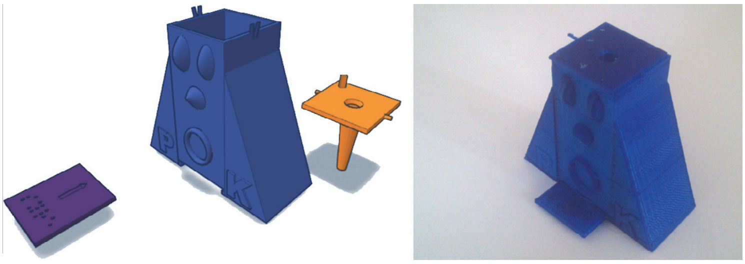

Fig. 5. A razor and some glue were needed for the sharpener to be complete.

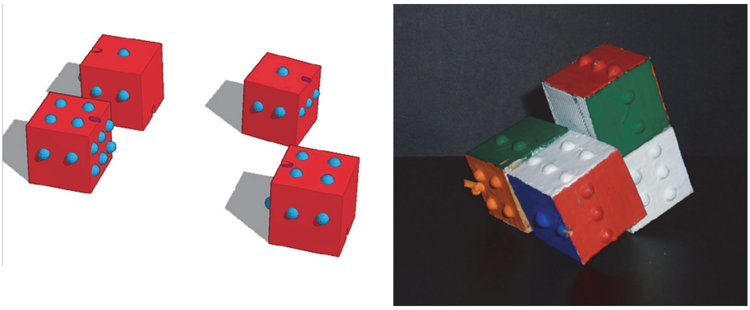

Fig. 6. The students painted the sides of the cube to make it functional for non-blind people.

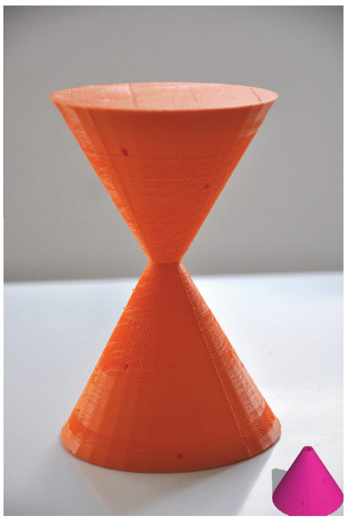

Fig. 7. Instead of sand several materials were tested to reach the desired sound effect.

and care for their design and many have contacted us or appeared on our lab after the project's end to inquire the printing processes and other future projects. This has provided us with a clear indication that 3D printing, and other open source technologies, can have a meaningful impact in a classroom by allowing students to tap in their creativity while exploring communities whose goal is the sharing of information and knowledge. Of course, this remains a subjective interpretation which was shared, at least, with students' teachers with whom we will collaborate during the next school year.

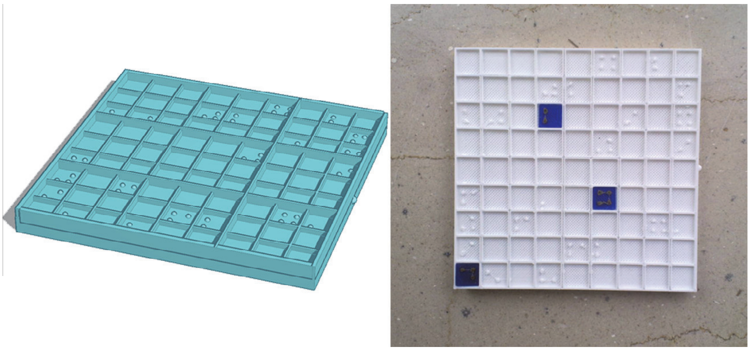

Fig. 8. This artifact required a lot of math skills both for the game itself but also for the appropriate sizes of the parts.

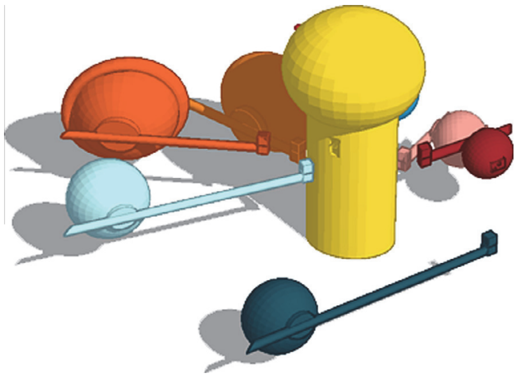

Fig. 9. This design incorporated knowledge from several principles.

5. Conclusions

Echoing Papert (1993, p. 216), this research project does not, and cannot, single-handedly invent mega-change but seeks to participate in its emergence. The case studies of the first phase were realistically modest in scale and were offered not "as exact pictures of the future but rather as an intimation of the rich potential that the future might hold" (Papert, 1993, p. 6). Through this three-month educational experiment we attempted to shed light on the effects 3D printing could have as a learning tool, helping students to become literate, i.e., to think differently than they did previously and, thus, see the world differently (Freire, 2000, 2005; Papert, 1993).

This was not a process without challenges. First of all, there are differences at the level of technological literacy among students. Despite the fact that most possess basic skills in ICT, some are more "engaged" than others, creating an uneven field in the classroom. To tackle such a challenge the teacher needs to distribute his focus accordingly so that all students achieve the same level of understanding and knowledge gained. This was further evident in our case study, since the equipment used exceeds that of standard ICT classes. It demanded first the familiarization of the teachers with the 3D printer and extra caution in the explanation of key concepts and principles, so that all students could proceed without falling behind. In addition, allowing the students to create an artifact with very few restrictions, resulted in a wide variety of objects that made it challenging to provide proper consultation on the various obstacles that occasionally appeared. However, through dialog and experimentation, but also information available on the Internet, these obstacles were overcome. Further, the cost of such equipment (3D printer) currently limits the possibility of acquiring several units for the convenience of students. Even in our case where an open source 3D printer was used, whose cost is significantly lower than the proprietary ones, the schools found it difficult to apprehend one. Also, technical issues demand further familiarization of the teachers with the hardware and their keeping up with advances in technology. These advances will eventually allow for cheaper, faster and more accurate 3D printers to find their way into schools.

Our overall experience was certainly positive arguing that 3D printing and design can electrify various literacies and creative capacities of children in accordance with the spirit of the networked, interconnected, information-based world.

We have seen that students, who were otherwise indifferent (according to them and their teachers) about their project class, when given proper stimulation and the necessary tools can choose what to learn themselves through exploration. Thus, addressing our initial question, modern ICT can help in creating a lively environment in a classroom where, as in our case, students may truly engage in the whole process by materializing an artifact out of a mere idea. Then proudly share their results with others while they acquire knowledge instead of dry information out of textbooks.

Of course, more research needs to be done in different frameworks and contexts than ours focusing not only on open source 3D printing but also on other open source hardware such as the Arduino micro-controllers. And there are three main reasons for that: first, open hardware is cheap and hi-tech; second, it is open and, thus, can be easily studied and modified to serve certain educational purposes; and third, it is a product that celebrates the power of human cooperation. In addition, as already stated in this article, the communicational aspect of 3D printing (especially in the context of the blind and non-blind) along with the global, Commons-oriented information production (for example, the ability to design globally but produce locally) will be one of our next research pathways. We would be happy to see other efforts in that or even alternative directions, sharing, however, the goal to educate children so they can creatively face a future that we may never see.

Acknowledgements

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Appendix A

Descriptive table of students’ answers.

Question	Dodonaia School				7th General Lyceum				Total			
1. How much time do you spend on the computer every day?	0–1 h	1–2 h	2–3 h	>3 h	0–1 h	1–2 h	2–3 h	>3 h	0–1 h	1–2 h	2–3 h	>3 h
	1	5	5	4	4	6	6	2	5 15%	11 33%	11 33%	6 19%
2. How much of this time do you spend for something related to school?	0 h	1/2 h	1 h	> 1 h	0 h	1/2 h	1 h	>1 h	0 h	1/2 h	1 h	>1 h
	9	1	4	1	8	4	6	0	17 52%	5 15%	10 30%	1 3%
	Yes		No		Yes		No		Yes	No		
3. Do you think that the way these two courses are taught is tedious?	6	40%	9	60%	6	33%	12	67%	12 36%	21 64%		
4. Do you consider school as a burden?	9	60%	6	40%	1	5%	17	95%	10 30%	23 70%		
5. Have you decided what kind of academic career you will follow?	10	67%	5	33%	14	78%	4	22%	24 73%	9 27%		
6. If yes, is it something related to technology?	9	60%	6	40.0%	9	50%	9	50%	18 55%	15 45%		
7. Would you prefer a more practical, hands-on learning approach?	15	100%	0	0%	18	100%	0	0%	33 100%	0 0%		
8. Do you own a smart phone or tablet?	15	100%	0	0%	8	45%	10	55%	23 70%	10 30%		
9. Do you use any social network (e.g. facebook, twitter)?	14	93%	1	7%	13	72%	5	28%	27 82%	6 18%		
10. Do you use Wikipedia?	15	100%	0	0%	16	89%	2	11%	31 94%	2 6%		

(*continued on next page*)

Appendix A (*continued*)

Question	Dodonaia School				7th General Lyceum				Total			
11. Did you know that Wikipedia is an encyclopedia created by volunteers?	13	87%	2	3%	15	83%	3	17%	28	85%	5	15%
12. Do you know what is the free software/open source software?	5	33%	10	67%	6	33%	12	67%	11	67%	22	33%
13. Have you ever used any application of the free software/open source software?	2	13%	13	87%	3	17%	15	83%	5	15%	28	85%
14. Have you ever heard of 3D printing?	9	60%	6	40%	7	39%	11	61%	16	48%	17	52%
15. Do you enjoy sharing things?	13	87%	2	3%	14	78%	4	22%	27	82%	6	18%
16. Have you ever heard of the Braille language?	12	80%	3	20%	12	67%	6	33%	24	73%	9	27%

References

Ackermann, E., 2001. Piaget's constructivism, Papert's constructionism: what's the difference? Available at: http://learning.media.mit.edu/content/publications/EA.Piaget%20_%20Papert.pdf (Accessed 23 February 2014).

ASTM (American Society for Testing and Materials), 2010. Standard terminology for additive manufacturing technologies. ASTM F2792-10. Available at: http://www.astm.org/Standards/F2792.htm (Accessed 23 February 2014).

Bauwens, M., 2005. The political economy of peer production. CTheory J. Available at: http://www.ctheory.net/articles.aspx?id=499 (Accessed 23 February 2014).

Benkler, Y., 2006. The Wealth of Networks: How Social Production Transforms Markets and Freedom. Yale University Press, New Haven/London.

Benkler, Y., 2011. The Penguin and the Leviathan. Crown Publishing Group, New York.

Bennett, S., Maton, K., 2010. Beyond the 'digital natives' debate: towards a more nuanced understanding of students' technology experiences. J. Comp. Assist. Learn. 26 (5), 321–331.

Bennett, S., Maton, K., Kervin, L., 2008. The 'digital natives' debate: a critical review of the evidence. Brit. J. Educ. Technol. 39 (5), 775–786.

Bradshaw, S., Bowyer, A., Haufe, P., 2010. The intellectual property implications of low-cost 3D printing. SCRIPTed 7, 5–31.

Bruns, A., 2008. Blogs, Wikipedia, second life, and beyond: From Production to Produsage. Peter Lang, New York.

Bullis, K., 2011. GE and EADS to print parts for airplanes. Technol. Rev. Available at: http://www.technologyreview.com/news/423950/ge-and-eads-to-print-parts-for-airplanes/ (Accessed 23 February 2014).

Campbell, T., Williams, C., Ivanova, O., Garrett, B., 2011. Could 3D Printing Change the World? Technologies, Potential, and Implications of Additive Manufacturing. Atlantic Council, Washington.

Dewey, J., 1997. Experience and education. Free Press, New York.

Flyvbjerg, B., 2001. Making Social Science Matter: Why Social Inquiry Fails and How It Can Succeed Again. Cambridge University Press, Cambridge.

Flyvbjerg, B., 2006. Five misunderstandings about case study research. Qualitat. Inq. 12 (2), 219–245.

Freire, P., 2000. Pedagogy of Freedom: Ethics, Democracy, and Civic Courage. Rowman & Littlefield Publishers, Lanham, MD.

Freire, P., 2005. Education for Critical Consciousness. Continuum International Publishing Group, New York.

Kalish, J., 2011. Ultimaker: There's a new 3D printer in town. Make. Available at: http://blog.makezine.com/2011/08/01/ultimaker-theres-a-new-3d-printer-in-town/ (Accessed 23 February 2014).

Kegan, R., 1982. The Evolving Self. Harvard University Press, Cambridge, MA.

Kostakis, V., 2012. The political economy of information production in the social web: chances for reflection on our institutional design. Contemp. Soc. Sci. 7, 305–319.

Kostakis, V., 2013. At the turning point of the current techno-economic paradigm: commons-based peer production, desktop manufacturing and the role of civil society in the Perezian framework. TripleC 11, 173–190.

Lakhani, K., Wolf, R., 2005. Why hackers do what they do: understanding motivation and effort in free/open source software projects. In: Feller, B.F.J., Hissam, S., Lakhani, K. (Eds.), Perspectives on Free and Open Source Software. MIT Press, Cambridge, MA, pp. 3–22.

Lessig, L., 2005. Free culture: The Nature and Future of Creativity. Penguin Group, New York.

Lessig, L., 2009. Code 2.0, 2nd ed. CreateSpace Independent Publishing Platform, New York.

Levy, S., 2001. Hackers: Heroes of the Computer Revolution, Updated afterword ed. Penguin Books, New York.

Mooney, C.G., 2000. Theories of childhood: An introduction to Dewey, Montessori, Erikson. Redleaf Press, St. Paul, MN, Piaget & Vygotsky.

Papert, S., 1980a. Mindstorms. Children, Computers and Powerful Ideas. Basic books, New York.

Papert, S., 1980b. Teaching children thinking. In: Taylor, R.P. (Ed.), The Computer in the School: Tutor, Tutee, Tool. Teachers College Press, New York.

Papert, S., 1993. The children's machine: rethinking school in the age of the computer. Basic Books, New York.

Papert, S., 1997. Why school reform is impossible. J. Learn. Sci. 6 (4), 417–427.

Papert, S., Harel, I., 1991. Constructionism. Ablex Publishing, Norwood, NJ.

Perez, C., 2002. Technological revolutions and financial capital: the dynamics of bubbles and golden ages. Edward Elgar Pub, Cheltenham.

Prensky, M., 2001. Digital game-based learning. McGraw-Hill, New York.

Prensky, M., 2007. Digital game-based learning. Paragon House, St. Paul, MN.

Rushkoff, D., 1996. Playing the future: How kids' culture can teach us to thrive in an age of chaos, 1st. HarperCollins, New York.

Verschuren, P., Doorewaard, H., 2005. Designing a research project. Lemma, Utrecht.

Wark, M., 2004. A Hacker Manifesto. Harvard University Press, Cambridge, MA.

V Kostakis, V., Bauwens M., & **Niaros, V.** (2015). Urban reconfiguration after the emergence of peer-to-peer infrastructures: Four future scenarios with an impact on smart cities. In D. Araya (Ed.), *Smart cities as democratic ecologies* (pp. 116-124). New York: Palgrave Macmillan. (3.1)

7

Urban Reconfiguration after the Emergence of Peer-to-Peer Infrastructure: Four Future Scenarios with an Impact on Smart Cities

Vasilis Kostakis, Michel Bauwens, and Vasilis Niaros

Introduction

Today, the majority of human beings are city dwellers. In this increasingly urbanized world, smart cities are emerging as an alternative city model to tackle several environmental, economical, and societal issues. Although there is not any compact and agreed-upon definition of smart cities, cities are generally defined as "smart" when they are infused with information and communication technologies (ICT), and a social infrastructure that promotes sustainability and active engagement of citizens (Caragliu, Del Bo, & Nijkamp, 2009). In the current environment, rapidly progressing ICT and the subsequent emergence of peer-to-peer (P2P) infrastructure are giving rise to potentially limitless innovation that can be implemented in cities to improve efficiency and connectivity.

To be more precise, P2P infrastructure is that infrastructure for communication, cooperation, and common value creation that allows for permission-less interlinking of human cooperators and their technological aids. We argue that such infrastructure is becoming the general condition of work, life, and society with the potential to reshape the idea of the "smart city." P2P relational dynamics, which epitomize the old slogan "Jeder nach seinen Fähigkeiten, jedem nach seinen Bedürfnissen!" (From each according to his ability, to each according to his need!), are based on the distribution of our productive forces.

First, the means of information, immaterial production (i.e., the networked computers) and now the means of physical, material production (i.e., machines that produce physical objects) are being distributed and interconnected. Just as networked computers democratized the means of production of information and communication, the emergent elements of networked microfactories or what some (see Kostakis, Fountouklis, & Drechsler, 2013) call desktop manufacturing, such as three-dimensional (3-D) printing, are democratizing the means of production.

Of course, this is not by any means an unproblematic process. In a period of extreme socioeconomic polarization and lacking any equilibrium regarding the global governance of the Internet (Mueller, 2010), we have been witnessing conflicts for the control and ownership of distributed infrastructure. On the one hand, commons-based peer production signals fundamental changes in value creation, especially when juxtaposed against an old order that is in decline (see Bauwens, 2005; Benkler, 2005; Kostakis, 2013). On the other hand, the proposed legislations of Anti Counterfeiting Trade Agreement (ACTA)/Stop Online Piracy Act (SOPA)/Protect IP Act (PIPA) enforce strict copyright within a regulatory regime that polices transactions beforehand instead of afterward (Boyle, 1997). Furthermore, the attempt for surveillance and censorship by both authoritarian and liberal countries, and "the growing tendency to link the Internet's security problems to the very properties that made it innovative and revolutionary in the first place" (Mueller, 2010) are only some reasons that have made scholars, like Zittrain (2008), worry that digital systems may be pushed back to the model of locked-down devices centrally controlled information appliances.

Hence, a battle is emerging among agents (several governments and corporations) that are trying to turn the Internet into a tightly controlled information medium, and user communities that are trying to keep the medium independent (Kostakis, 2013). This battle certainly affects the design processes of smart cities as well, because it has a direct relation with the involved stakeholders.

This chapter attempts to simplify possible outcomes by using two axes or polarities that give rise to four possible scenarios (see Figure 7.1) and then tries to adapt the evolution of the smart city in this context. The chapter concludes by drawing some assumptions about what should determine the ideal selection for a smart city.

The Two Axes and the Four Quadrants

The first axis concerns the polarity of centralized versus distributed control of the infrastructure; the second axis relates to an orientation

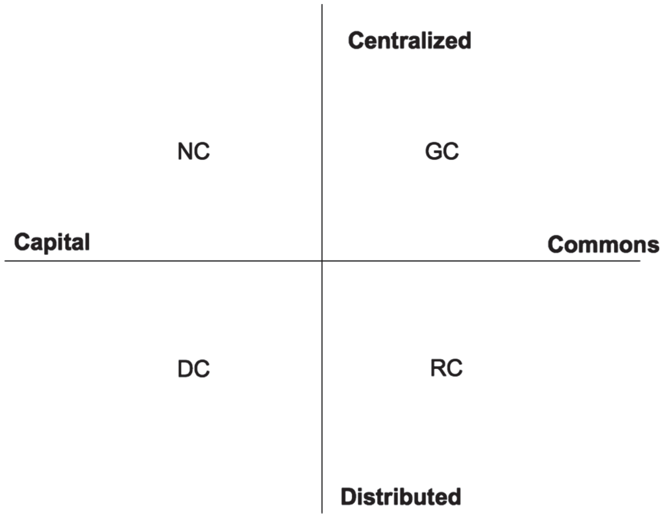

Figure 7.1 The four quadrants of future scenarios.

toward the accumulation or circulation of capital versus an orientation toward the accumulation or circulation of the commons.

First, we introduce the concepts of "netarchical" and "distributed capitalism." Before describing in detail the two forms that shape this emerging model, it is important to highlight their basic difference. Netarchical and distributed capitalism may both be profit oriented, but they are also based on various technological regimes' dependence on the structure of every project's back end. User-oriented technological systems generally have two sides. The front end is the side that users interact with, and the only side visible to them. The back end, however, is the technological underpinning that makes it all possible. This is engineered by the platform owners and is invisible to the user. Hence, a front end that enables a P2P social logic among users can often be highly centralized, controlled, and proprietary on the back end; forming an invisible technosocial system that profoundly influences the behavior of those using the front end, by setting limits on what is possible in terms of human freedom. Then, we present the remaining quadrants, that is, resilient communities and global commons whose ultimate goals are commons driven.

Netarchical Capitalism (NC)

We define "netarchical capitalism" as the first combination (upper left) that matches centralized control of a distributed infrastructure with an orientation toward the accumulation of capital. NC is that fraction of capital that enables and empowers cooperation and P2P dynamics, but through proprietary platforms under central control. While individuals will share through these platforms, they have no control, governance, or ownership over the design and the protocol of these networks/platforms (e.g., Facebook or Google). Typically under conditions of NC, sharers will directly create or share use value, but the monetized exchange value will be realized by the owners of capital. While in the short term it is in the interest of shareholders or owners, this also creates a longer-term value crisis for capital, because the value creators are not rewarded, and have no purchasing power to acquire the goods that are necessary for the functioning of the physical economy.

Distributed Capitalism (DC)

The second combination (bottom left), called "distributed capitalism," matches distributed control but with a remaining focus on capital accumulation. The development of the P2P-driven currency Bitcoin and the Kickstarter crowdfunding platform are representative of these developments. Under this model, P2P infrastructure is designed in such a way as to allow the autonomy and participation of many players, but the main focus rests on profit making. In Bitcoin, all the participating computers can produce the currency, thereby disintermediating large centralized banks. However, the focal point remains on trading and exchange through a currency designed for scarcity, and thus must be obtained through competition. Furthermore, Kickstarter functions as a reverse market with prepaid investment. Under these conditions, any commons is a by-product or an afterthought of the system, and personal motivations are driven by exchange, trade, and profit. Many P2P developments can be seen within this context, striving for a more inclusionary distributed and participative capitalism. Although they can be considered as part of, say, an antisystemic entrepreneurialism directed against the monopolies and predatory intermediaries, they retain the focus on profit making. Distribution, here, not meant locally, though, as the vision is one of a virtual economy, where small players can have a global compact, and create global aggregations of small players.

Resilient Communities (RC)

Distributed control with a focus on the commons is what we call the "resilient communities" (bottom right). The focus here is mostly on the relocalization and re-creation of local community. It is often based on an expectation for a future marked by severe shortages of energy and resources, or in any case, increased scarcity of energy and resources, and takes the form of lifeboat strategies. Initiatives like the Degrowth movement or the Transition Towns, a grassroots network of communities, can be seen in that context. In extreme forms, they are simple lifeboat strategies, aimed at the survival of small communities in the context of generalized chaos. What marks such initiatives is arguably the abandonment of the ambition of scale while the feudalization of territorial integrity is considered mostly inevitable. Even though global cooperation and web presence may exist, the focus remains on the local. Most often, political and social mobilization at scale is seen as not realistic, and doomed to fail. In the context of our profit-making versus commons axis, though, these projects are squarely aimed at generating community value.

Global Commons (GC)

This approach (upper right) is against the aforementioned focus on the local, focusing on the global commons. Advocates and builders of this scenario argue that the commons should be created for and fought for on a transnational global scale. Although production is distributed and therefore facilitated at the local level, the resulting microfactories are considered as essentially networked on a global scale, profiting from the mutualized global cooperation both on the design of the product and on the improvement of the common machinery. Any distributed enterprise is seen in the context of transnational phyles, that is, alliances of ethical enterprises that operate in solidarity around particular knowledge commons. In addition, political and social mobilization, on regional, national, and transnational scale, is seen as part of the struggle for the transformation of institutions. Participating enterprises are vehicles for the commoners to sustain global commons as well as their own livelihoods. This latter scenario does not take social regression as a given and believes in sustainable abundance for all humanity.

Discussion

These four scenarios differ in their vision for the prime focus of the accumulation of value, either for the benefit of global shareholders, for a network of small for-profit enterprises, for the local community, or for transnational commons. It can be argued that the prevalence of each scenario will have different impacts on the smart city model to be adopted.

All four scenarios take the existence of P2P-enabling infrastructure as a given, and mutualize both immaterial and material resources to obtain economies of scope. Indeed, while economies of scale are advantageous in the context of temporal eras dominated by an abundance of resources and energy—that is, producing more of a thing creates competitiveness—economies of scope become essential in periods of increased energy and resource scarcity—that is, doing more with less. Open source is mutualization of immaterial resources such as knowledge, which become operative for the whole of humankind, rather than fragmented and privatized through intellectual property. The mutualization of physical resources increases the efficiency of resource and energy use, and combats the idleness of physical resources and the waste that is inherent in fragmentation.

The new P2P production modalities are global-local (or glocal). While they enable production at the local scale through microfactories using distributed manufacturing technologies, both the knowledge work on the product and on the machinery can be global. As a general rule, one can say that the principle is this: "what is heavy is near, what is light is far"; thus we design global, but manufacture local responding to certain needs. Cooperation on the immaterial productive processes (i.e., design) is maximized, but the global transportation of material good is minimized. This new productive model should be carefully considered during policy making for urban development as it can have a profound impact on the city itself.

In our four scenarios, what differentiates the strategies are first of all, the aim of the cooperation, that is, are they aimed at capital accumulation, or at improving the circulation of the commons? And second, where is the focus of control? Is control distributed through free self-allocation by commoners who can affect the governance and design of their infrastructure of cooperation? Or is the design of the infrastructure in the hands of centralized privately owned platforms? The answer to the these questions will probably define the final form of the so-called "smart city."

If we want to locate the "smart city," as it is conventionally understood, in the context of our scenarios, we should look at the top-left quadrant of netarchical capitalism (see Figure 7.1). What we have for the time being is smart cities in terms of ICT deployment and not actual smart urbanism. Citizens are able to contribute by providing "big data," which are gathered from the utilization of an array of sensors throughout a city, to offer governments/firms solutions to their needs. But as it happens in this scenario, control and governance in today's smart cities are located within a single proprietary hierarchy, where the main motive is profit maximization. As a result, it is questionable whether citizens actually take part in the decision-making process, in order to meet their true needs, or just constitute another source of information without knowledge and influence at the back end.

The circumstances could be slightly different in the distributed capitalism scenario, where control is located in the network of participating for-profit entrepreneurs. Here, citizens may enjoy an increased capacity to influence the shaping of smart city infrastructure, leading to more transparent and democratic decision making for specific issues. However, profit maximization remains the ultimate goal for all parties involved. This can, arguably, have a negative impact on the aforementioned decision-making process and lead to unsustainable outcomes.

The further we move toward the right quadrants, those of resilient communities and global commons, the higher the potential for bottom-up civic engagement and support of citizen empowerment and user-driven innovation. In the local community model, control is located in a particular geographical territory, and depends on the governance model of the initiating community. The adoption of this scenario while planning a smart city—or even a smart town—could lead to successful practices, as designing in a smaller scale includes strong predefined goals that can be bounded with measurable results and quick decision making. Contrary to similar interventions in big cities, a small area means a smaller chance for failure. However, the knowledge and know-how produced in this case may not be widely applicable or even available for adoption elsewhere, due to the fact that it is locally oriented. This potentially hinders the circulation of the commons and the subsequent diffusion of innovation regarding smart cities.

At the grander scale of the global-local commons model, governance is located in the triarchical model of the community practicing the social self-allocation of resources, of the for-benefit associations that manage the physical infrastructure of cooperation (e.g., the multitude of Free/Libre Open Source Software Foundations) and of the entrepreneurial alliance that cooperates around the same commons. In this model, it is essential that the commons orientation is guaranteed by new governance models of the participating entrepreneurs. For example, in the case of the largely corporate Linux Commons, open source code commons are clearly integrated in the processes of capital accumulation of the participating for-profit enterprises. A countermodel would require the creation of commons-friendly, ethical enterprises, consisting of the commoners themselves, who also control their own governance and have ownership. Such enterprises would be legally structured so that theirs is an obligation to support the circulation of the commons. We suggest a plural form of ownership that combines maker ownership (i.e., a revisiting of worker ownership for the P2P age), with user ownership (i.e., a recognition that users of networks co-create value, and eventually a return for the ethical funders that support the enterprise). In this model, profit making is allowed, but profit maximization remains a taboo.

The manifestation of the smart city in this scenario is highlighted by wide citizen engagement while designing and implementing interventions and an ongoing circulation of the commons, which promotes continuous innovation and knowledge diffusion. In this case, the production of commons on a global scale will lead to a more sustainable city model, which could perform better than the current dominant model while solving a number of systemic problems.

To enhance user participation, the creation of a unique culture is vital. This can be accomplished through implementing small-scale, low-cost actions that have little bureaucratic requirements and encourage citizens to reclaim common open spaces in the urban environment. These processes should serve as a user-driven platform for the local community and lead to the creation of a robust paradigm aiming to collaboration.

Toward that direction, governments and local authorities should provide appropriate facilities to enable the deployment of participative ways of working, which will help in producing social innovation outcomes, that is, commons. This could be done by promoting the creation of collaboration spaces, such as microfactories, all over the city and creating wired and wireless networks that will enhance the connectivity between citizens. Moreover, the establishment of social enterprises should be promoted. This will certainly lead to the development of business models, but instead of seeking easy financial gains, social enterprises will be focusing on sustainability and development in the long term.

After ensuring the existence of the basic infrastructure for a commons-driven smart city, the next step would be to integrate them into everyday social interaction and make all the data available to the citizens in a format that they can use. Because several cities will deploy different infrastructure and adopt various approaches, this procedure may become quite challenging. In order for locally produced innovations to diffuse and be adopted globally, the aforementioned infrastructure should comply with some "standards" that will enhance interoperability. These "standards" should be based on open source technologies, so they would be easily accessible, transparent, and open to modification and adaptation to local conditions and individual needs.

Conclusion

One of the most fundamental characteristics of a smart city should be its direct link with the needs and concerns of urban residents. However, it has already been observed that this citizen perspective is often ignored in the smart city discussion. While technology is a powerful tool able to help improve urban infrastructure, citizen engagement is essential to make cities truly sustainable and livable.

In the discussion above, we argue that different applications of certain productive infrastructure have different impacts on urban life, depending on the model of governance and strategies of citizenship they embody. Notwithstanding the fact that community-driven, commons-driven, and distributed versus centralized for-profit–driven infrastructure coexist, smart cities will be organized differently depending on the dominance of any of the four scenarios.

What is needed, in our view, is a more commons-driven smart city that will provide the capacity for open participation and democratic problem-solving practices that can potentially lead to social, environmental, and economic sustainability.

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References

Bauwens, M. (2005). “The political economy of peer production.” *CTheory Journal*. Retrieved March 3, 2013, from http://www.ctheory.net/articles.aspx?id=499

Benkler, Y. (2005). *The wealth of networks: How social production transforms markets and freedom*. New Haven, CT: Yale University Press.

Boyle, J. (1997). “Foucault in cyberspace.” Retrieved March 3, 2013, from http://www.law.duke.edu/boylesite/foucault.htm

Caragliu, A., Del Bo, C., and Nijkamp, P. (2009). “Smart cities in europe.” Series Research Memoranda 0048, VU University Amsterdam, Faculty of Economics, Business Administration and Econometrics.

Kostakis, V. (2013). “At the turning point of the current techno-economic paradigm: Commons-based peer production, desktop manufacturing and the role of civil society in the Perezian framework.” *TripleC*, 11(1), pp. 173–190.

Kostakis, V., Fountouklis, M., and Drechsler, W. (2013). “Peer production and desktop manufacturing: The case of the Helix_T wind turbine project.” *Science, Technology & Human Values*, 38(6), pp. 773–800.

Mueller, M. (2010). *Networks and states: The global politics of Internet governance*. Cambridge, MA: MIT Press, p. 160.

Zittrain, J. (2008). *The future of the Internet – and how to stop it*. New Haven, CT: Yale University Press.

CURRICULUM VITAE

1. Personal data

Date and place of birth:	25 November 1984, Ioannina, Greece
Citizenship:	Hellenic Republic

2. Contact information

E-mail:	vasilis.niaros@gmail.com
Address:	Rizari 27, 45221, Ioannina, Greece
Skype:	vasilis.niaros

3. Education

2008 – 2009	University of Thessaly, School of Engineering, *Master of Science (MSc)* in Planning and Regional Policy. Grade: 9.01/10 (Excellence scholarship, 1st).
2002 – 2007	University of Thessaly, School of Engineering, *Bachelor of Science (BSc)* in Planning and Regional Development (5-years degree). Grade: 7.47/10.

4. Language skills

Greek	Native language
English	Proficient user

5. Professional employment

2016 – ...	P2P Foundation, Amsterdam, Netherlands, *Funding Manager*.
2012 – ...	P2P Lab, Ioannina, Greece, *Research Fellow / Project Manager.*
2011 – 2012	*Assistant* to Senior Research Fellow Dr. Vasilis Kostakis.

2009 – 2010	Mandatory service at Greek army. Mytilene, Greece, *Corporal*.
2009	'Gruppo Nikos Salingaros' for P2P urbanism, *Translator*.

6. Defended thesis

2009	'Organisations and Methodologies for Evaluation of Development Policies'.
2002 – 2007	'Strategic Plan for the Development of Ioannina Prefecture'.

7. Main areas of scientific work

Urbanism, smart city, commons, peer production, makerspaces, do-it-yourself culture, free/open source software, open hardware.

8. Publications

Niaros, V. (2016). Introducing a taxonomy of the 'smart city': Towards a commons-oriented approach? *tripleC: Journal for a Global Sustainable Information Society*, 4(1): 51-61.

Kostakis, V., Niaros, V., Dafermos, G., & Bauwens, M. (2015). Design global, manufacture local: Exploring the contours of an emerging productive model. *Futures*, 73, 126-135.

Kostakis, V, Bauwens, M., & Niaros, V. (2015). Urban reconfiguration after the emergence of peer-to-peer infrastructures: Four future scenarios with an impact on smart cities. In D. Araya (Ed.), *Smart Cities as Democratic Ecologies* (pp. 116-124). New York, NY: Palgrave Macmillan.

Kostakis, V., Niaros, V., & Giotitsas, C. (2015). Production and governance in hackerspaces: A manifestation of commons-based peer production in the physical realm?. *International Journal of Cultural Studies*, 18(5), 555-573.

Kostakis, V., Niaros, V., & Giotitsas, C. (2015). Open source 3D printing as a means of learning: An educational experiment in two high schools in Greece. *Telematics & Informatics,* 32 (1), 118-128.

ELULOOKIRJELDUS

1. Isiklikud andmed

Sünnikoht ja kuupäev:	25. november 1984, Ioannina
Kodakondsus:	Kreeka

2. Kontaktandmed

E-mail:	vasilis.niaros@gmail.com
Aadress:	Rizari 27, 45221, Ioannina, Kreeka
Skype:	vasilis.niaros

3. Hariduskäik

2008 – 2009	University of Thessaly, School of Engineering, *Master of Science (MSc)* in Planning and Regional Policy.
2002 – 2007	University of Thessaly, School of Engineering, *Bachelor of Science (BSc)* in Planning and Regional Development.

4. Keelteoskus

Kreeka	Emakeel
Inglise	Kesktase

5. Töökogemus

2016 – ...	P2P Foundation, Amsterdam, Netherlands, *Fondijuht*.
2012 – ...	P2P Lab, Ioannina, Kreeka, *Teadustöötaja / Projektijuhataja.*
2011 – 2012	*Assistent* to Senior Research Fellow Dr. Vasilis Kostakis.
2009 – 2010	Kohustuslik Sõjaväeteenistus Kreeka armees. Mytilene, Kreeka, *Kapral*.

2009	'Gruppo Nikos Salingaros' P2P linnaplaneerimiseks, *Tõlkija*.

6. Kaitstud lõputöö

2009	'Organisatsiooni ja hindamise metoodika arendamise poliitika'.
2002 – 2007	'Ioannina Prefektuuri Strateegiline Arenguplaan'.

7. Teadustöö põhisuunad

Linnaplaneerimine, nutilinn, üldkasutatavad platvormid (*commons*), *makerspaces*, tee-ise-kultuur, ühistootmine (*free/open source software*), avatud riistvara.

8. Publikatsioonid

Niaros, V. (2016). Introducing a taxonomy of the 'smart city': Towards a commons-oriented approach? *tripleC: Journal for a Global Sustainable Information Society*, 4(1): 51-61.

Kostakis, V., Niaros, V., Dafermos, G., & Bauwens, M. (2015). Design global, manufacture local: Exploring the contours of an emerging productive model. *Futures*, 73, 126-135.

Kostakis, V, Bauwens, M., & Niaros, V. (2015). Urban reconfiguration after the emergence of peer-to-peer infrastructures: Four future scenarios with an impact on smart cities. In D. Araya (Ed.), *Smart Cities as Democratic Ecologies* (pp. 116-124). New York, NY: Palgrave Macmillan.

Kostakis, V., Niaros, V., & Giotitsas, C. (2015). Production and governance in hackerspaces: A manifestation of commons-based peer production in the physical realm? *International Journal of Cultural Studies*, 18(5), 555-573.

Kostakis, V., Niaros, V., & Giotitsas, C. (2015). Open source 3D printing as a means of learning: An educational experiment in two high schools in Greece. *Telematics & Informatics,* 32 (1), 118-128.

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