Assisi, Italy. April 7-9, 2016

16th CIRIAF National Congress

Sustainable Development, Human Health and Environmental Protection

Collaborative product development and peer production as an innovative integrated approach to deliver sustainable marketable products: a case study

Francesco Cappa [1,2], Fausto Del Sette [3], Darren Hayes[3,4] and Federica Rosso[5,]*

[1] LUISS Guido Carli University Department of Business and Management, Viale Pola 12, 00198 Roma, Italy
[2] Tuscia University School of Engineering (DEIM), Via S. Camillo de Lellis, 01100 Viterbo, Italy,
[3] Sapienza Università di Roma Dipartimento di Ingegneria Meccanica e Aereonautica, Piazzale Aldo Moro 5, 00185 Roma, Italy
[4] Pace University Seidenberg School of Computer Science, 1 Pace Plaza, 10038 New York, USA
[5] Sapienza Università di Roma Dipartimento di Ingegneria Civile e Architettura, Piazzale Aldo Moro 5, 00185 Roma, Italy

* Author to whom correspondence should be addressed. E-Mail: federica.rosso@uniroma1.it

---

Abstract: The purpose of this research is to provide empirical support for the adoption of an integrated approach, based on collaborative product development and peer production combined with 3D printing, to deliver more sustainable, cheaper but competitive marketable products. In particular, the experimental study is conducted in the context of mobile forensics, an emerging market where few expensive incumbents' products are present and alternatives solutions are needed. The technical viability and economic feasibility of the prototype developed in this research validate the proposed integrated approach, which could be a game changer in the mobile forensics as well as in other sectors, offering start-upping opportunities and promoting an innovative and sustainable methodology to develop and deliver marketable products, towards the paradigm of Open Sustainable Innovation. While the device developed and tested in this research has similar features to existing products, the methodology, implementation and motivation are original.

Keywords: Peer production; collaborative product development; open innovation; 3D printing; sustainability; investment analysis.

---

1. Introduction

The recent trend of producing small quantities of custom designed and low cost finished goods comes from the model of mass customization, as postulated in the “think global and produce local” concept [1]. To better respond to this novel trend, an (i) open approach for hardware and software development, (ii) peer production and (iii) distributed 3D printing manufacturing are increasingly used [2,3].

The open innovation concept changed the traditional vertically integrated mode for internally developed outputs, to achieve a new paradigm of innovation based on collaborations among several participants involved in the final productions [4–10]. An open innovation approach is more effective with the detailed division of labor during the idea generation, R&D and production phases [11]. This approach can be applied to the design of the product, the software development and production layers that are the pillars of the commons design economy [12-14]: the benefit is the possibility to use the “crowd wisdom”, created by social aggregations of individuals [15]. Collaborations among different researchers to develop a final product make the distinction between manufacturer and customer disappearing, building new collaborative networks [16,17]. Actually, these cooperations are understood to be effective mechanisms to increase innovation efficiency and creativity [4,18]. In this vein, hardware design and software development can be realized and continuously updated thanks to the work of researchers and online volunteers [19].

Peer production is intended as a collaborative activity aimed at sharing productive goals [20]. This productive methodology is based on self-organized communities, which easily interact thanks to information technology advancements, cooperating for realizing a final product. Towards this view, the recent advances in 3D printing technology made the production of components possible with commercially available desktop 3D printers [21], which are able to fabricate goods with custom shape and color [22]. Thus, people can interact online not only for the ideation and the design of the product, but also for sharing the final product specifications for the fabrication with 3D printers. This practice also provides a more sustainable, i.e. less harmful for the planet, production and distribution [1]: the product design is developed around the globe, while printed locally. Therefore, transportation and inventory costs and time, wasted materials and energy costs are almost non-existent or are significantly reduced, because only the essential raw materials are used locally [23]. In greater details, 3D printing allows the design and fabrication of a product directly from a computer connected to a printer, by following successive steps. First, the design is developed by mean of a Computer Aided Design (CAD) 3D model; subsequently it is converted to Standard Triangulation Language (STL) format; then the file is transferred to a prototyping system, generally referred to as Computer Aided Manufacturing (CAM), where the structure is divided into layers; and, finally, it is sent for fabrication to a desktop 3D printer. This profound shift in manufacturing, from remote factories to local 3D printing, would not only be economically and environmentally viable, but may also enable new capabilities in customization. In addition, 3D printing is able to unlock “latent entrepreneurship” as new opportunities are emerging for ambitious entrepreneurs to bypass barriers to enter in the market: the initial capital investment, mass production requirements, prototyping costs, and distribution organization [24]. Even if initially used for prototyping, 3D printing is nowadays extensively employed for final product realization. Markets show that the annual sales growth rate of

3D printing manufacturing sector was +24% in 2010, and that 20% of the products were not prototypes but real products [25]. Therefore, the approach here described is able to achieve sustainability, as the “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [26], exploiting open innovation and peer production towards the achievement of the Open Sustainable Innovation (OSI) [27].

The adoption of open innovation approach for product development and peer production methodology powered by 3D printing technology, is transforming traditional manufacturing methods towards a “third industrial revolution” [28]. Actually, customization at low costs for everyone is enabled by this technology, and will provide enormous value to the “commons” [29]. The benefits brought about by peer production coupled with 3D printing and collaborative design can foster the development of products able to compete in the market.

In order to evidence empirically the feasibility of the above mentioned approach, which is lacking in the literature, we experimentally validated the development of a prototype, called *CellIntel*, for professional mobile forensics, i.e. a tool for extracting private information from mobile devices during investigations, able to compete with market competitors. Mobile forensics is the examination of evidence created by a mobile device during private and public investigation [30]. Thus, the aim of these research is to demonstrate how, in the peculiar case study of mobile forensics, the use of peer production and collaborative design approaches permit to obtain a product which is cheaper and available for a larger audience, more portable for a better usage, sustainable and, last but not least, at the same time economically profitable for start-upping a new venture.

The remainder of the paper is structured as follows. In Section II, we introduce the field in which we tested the product development and where it has to operate. In Section III we provide an overview of the developed prototype, with details about collaborative development, peer production and 3D fabrication techniques. Section IV provides an economic analysis of the product’s feasibility. In Section V, we report field-testing results for the prototype. Section VI details the limitations of the research and, finally, Section VII addresses final thoughts and conclusions about the research and possible future developments.

2. Mobile forensics: state of the art

The last twenty years have experienced exponential growth in mobile communications, and the number of mobile phone subscribers has been recently estimated to be in excess of five billion with a notable increase in sales in developing countries [31,32]. Mobile technologies have become an integral and pervasive part of common life, thanks to the increasing power, functionality and capability to collect and share information on small size devices [30].

Unfortunately, the propensity for criminals to use mobile phones for their nefarious activities has also increased dramatically and therefore these devices have become even more valuable sources of evidence due to the incredible amount of information stored internally [33]. Thereafter, traditional computer crimes, including hacking and intrusions, are invading the mobile world [34]. In particular, with the integration of highly developed communication features and with the increasing capacity in data storage and functionality, the distinction between mobile phones and personal computers has become blurred. For these reasons the mobile forensic activities, as intrusions into mobile devices of criminals, have raised. In recent years, researchers and practitioners alike understood the importance of mobile devices as a fundamental source of digital evidences, which can be essential in capturing critical information to prosecute a suspect [35,36].

This approach lies in the so-called digital forensics sector defined as: “The use of scientifically derived and proven methods toward the preservation, collection, validation, identification, analysis, interpretation, documentation and presentation of digital evidence derived from digital sources for the purpose of facilitating or furthering the reconstruction of events found to be criminal, or helping to anticipate unauthorized actions shown to be disruptive to planned operations” [37]. The concept of mobile forensics involves forensic imaging, which is the creation of a bit-for-bit copy of mobile device memory during an investigation.

There are numerous investigative solutions, which are commercially available for mobile forensics, based on heterogeneous design criteria. Some of the most notable solutions include Paraben’s Device seizure [38], Oxygen Forensics Suite [39] and Cellebrite’s UFED [40], which extract data from digital devices. The initial price, subsequent maintenance costs, large dimensions and sizeable weight are common with all these forensic technologies. Among them, the main competitor in terms of product maturity and market share is Cellebrite’s UFED, offered for around $ 20,000 and implying approximately $ 3,000 in annual maintenance costs. Despite these high costs, the product can be found in several organizations. The unit is portable, but still heavy and cumbersome to be considered portable for professional activities. The limited selection of mobile forensics solutions means that prices are expected to remain high for the foreseeable future.

3. A new approach for product development

The possibility to develop and offer a state of the art device for mobile forensics, at a lower price and smaller dimension, is attractive. Offering a cheaper device is an objective not just for economic reasons to challenge existing competitors, but also to address the needs of private investigators and smaller institutions. In addition, an easy and fast production process will facilitate the worldwide distribution of these devices. Finally, to make field investigations easier, the device must be easy to use and hand portable. Therefore, in this study we tried to develop a mobile forensics toolbox with improved field usability and customer accessibility, economically viable to startup a new venture.

In order to achieve these objectives, the following steps have been undertaken: (i) offering a new “open” approach to software development and hardware design, inviting other entities to collaborate with the researchers; (ii) developing a new way for production and assembly, i.e. peer production with 3D printing; (iii) allow more people to have access to these products by reducing costs; and, finally, (iv) designing a compact, hand portable device.

To accomplish these aims, we decided to select off the shelf electronic components, open approach for product development and 3D printer for the production [41], enabling peer production and open innovation. Therefore, the prototype described in this paper represents an example of OSI [27], as it can be easily manufactured and assembled worldwide, (i) eliminating the inventory, transportation and delivery costs, (ii) reducing the production costs and time and, finally, (iii) decreasing pollutants emission by lowering energy consumptions. The contribution of this study is to offer empirical evidence of the successful implementation of this new integrated approach in the field of mobile forensics, which could be further generalized and could represent a game changer in other sectors.

3.1. *Hardware prototype*

In this section, the hardware design is described and electronic components listed, in order to get a comprehensive overview of the final product. The prototype, developed for commercial usage, is an electronic portable device to acquire and store forensics evidences. The device can image both Android and iOS devices, thus covering the 95% of United States market share and 90% of European Economic Community market share [42]. An open approach is used for both hardware and software components, in order to involve external entities in the product development [19].

The components used are chosen among those readily available on the market, while the external case of the imager is produced with a 3D printer to achieve the objectives of low cost and peer production. In the following subsections, the prototype components are described, although the in depth details were not disclosed as the aim of this research is to provide evidence of the possibility to enter the market with this new approach and, therefore, we are looking to effectively start up and sell the product in the following months.

3.1.1. Prototype electronics

The electronic parts are housed in the casing, produced with the 3D printing methodology. To keep costs low, the device is built around off the shelf components that are cheap and easily available on the market. The average prices of the electronics components are listed in Table 1.

Table 1. Costs for the 3D printed casing components for the *CellIntel* prototype.

Components	Mass	Production time	Cost
Electronic box	17 g	4h, 12 m	$ 3.40
LCD Screen box	21.8 g	2h, 38m	$ 2.56
Top of the box	16.4 g	2h, 10m	$ 2.14
TOTAL	55.2 g	9h	$ 8.1

3.1.2. Case design and realization

The imaging device is designed having in mind several key characteristics of the final product, which are namely: (i) low cost; (ii) touch screen; (iii) smaller than competitors; (iv) lighter than competitors; (v) easy to assemble; (vi) ability to connect to different mobile devices; and (vii) manually assembled.

The decision to use 3D printing technology to produce the device allows a minimal initial investment for the production equipment, low unit cost, and custom design.

The project started with the acquisition of two desktop 3D printers not excessively expensive, whose cost lies in the range of $ 3,000 and $ 10,000. As the precision and the surface finishing of a 3D printer increase, the price rises too, but for project’s needs the above mentioned price range is good enough. The design of the casing was realized with 3D CAD (Figure 1).

Figure 1. CAD rendering of the *CellIntel* prototype connected to a mobile device.

Given the peer production aim, screws and bolts are avoided and the assembly of the different parts is planned to be done with manual interlocking, by applying a small force. The parts constituting the prototype case are three: (i) a case to house electronic components and batteries, with openings designed specifically for connectors and board; (ii) the second 3D printed part is mounted on top of the previous part and it is used to house the LDC; and (iii) the third part locks the screen in place.

The desktop software Solidworks (release 2013, Dassault Systems) created the file used by the 3D printer. The software was also able to provide information regarding the price and the timing to complete each unit. In Table 2, the specific cost for each component is listed. The casing material is acrylonitrile butadiene styrene (ABS), a thermoplastic polymer used for the production of components via 3D objects, and the printer used for the first casing was a low-cost, $ 3,000, commercially available desktop solution (Makerbot Replicator 5th, US). For the second casing prototype another more expensive ($ 10,000) commercial 3D printer (S250 Tiertime, China) was used. This printer system uses the fuse deposition modeling (FDM) [43], an additive manufacturing process that works by laying down the plastic filament in layers, unwound from a coil and hot-extruded [44]. The printing outputs are the same in terms of functionality between the two solutions, but the second printer provides a superior precision level and smoother surface finishing, more suitable for entering the market and for competing with the incumbents.

Table 2. Costs of the off the shelf electronic components.

Components	Cost
LCD screen	$ 56
SSD 2.5”	$ 86
Motherboard	$ 50
3D printed casing	$ 8.1
TOTAL	$ 200

3.2. Software prototype

The here proposed novel device operates using a Debian Linux build operating system (kernel 3.4.90). An interface written in Java programming language runs on top of the operating system, providing the user a simple one-click method to execute programs and scripts installed in the device, which automates the process of evidence acquisition. The choice of Linux as operating system facilitates the open innovation approach also for the software side. The in-house developed software here described was developed by a community of volunteers working together with the researchers, a cooperation that facilitates the implementation of future updates. With the support derived from an open source software community, it is possible to create a collaborative group of experts working on the software updates for the mobile forensics device.

The starting point for the prototype's software was the in house developed software to extract data from Android and iOS devices, to which external participants contribute to generate updates for the new releases. The user interface, realized with Java, was developed to be user friendly allowing the usage for a wider range of final users: it is designed for the use of the touch screen, crucial for the user friendliness and the ability to use the device in mobility.

4. Economic analysis

The realized prototype demonstrated the feasibility of the proposed integrated approach, consisting of open innovation and 3D printed enhanced peer production, to deliver the same features of the main competitors. However, the objective of this research is not only the validation of a state-of-the-art mobile forensics imager device, but also to demonstrate its economic viability by offering it at a drastically lower price than competitors, but having a reasonable margin to start-up in the market. In order to assess the economic feasibility of this new product on the market, a Net Present Value (NPV) analysis is conducted [45]. The inputs needed to perform a NPV analysis are: (i) duration of the project; (ii) free cash flows; (iii) cost of capital; and (iv) tax rate. In this work, the information used to calculate the free cash flow for each year of operation are: (i) revenues; (ii) costs of units sold; (iii) employees' wages; (iv) initial capital investment for the equipment and its (v) amortization.

The usage of peer producing implies the vanishing of national and international transportation and delivery that generally accounts for almost 10-15% of the overall costs [23]. This is made possible by the capability of producing the final product with commercial parts readily available in the market, a common desktop 3D printer that produces the components locally, and an easy manual assembly. Therefore, while the design of the hardware and software takes place online through the collaboration of loosely affiliated collaborators through open innovation approach, i.e. crowdsourcing [46], the production of the final product can be achieved by local branches worldwide.

In our testing, we developed a durable and resilient prototype with both the Makerbot printer [47] and the S250 Tiertime printer [48], although differences in the surface finishing are noticeable and the latter one has to be preferred for the final production. The time required for the production of an imager 3D printed toolbox is nine hours plus one hour for the final assembly. Therefore, with one 3D printer, each day it is possible to realize two finished products, and approximately 40 per month. The raw material for the 3D printer estimated cost amounts to \$ 8, while the components costs are equal to \$ 192, for a total cost of \$ 200 for the final product. In this research, we evidenced that it is possible to sell the product for a much lower unit price than competitors' one, which is $ 999 instead of $ 10,000 on average. This price is significantly less than competitors' prices but it also allows a reasonable markup, which is the difference among revenues and costs, for start-upping a new venture.

Deciding to buy the most expensive 3D printer used for the better surface finishing outcomes ($ 10,000), we estimated the break-even point of units sold with our suggested price, which tells us for which amount of produced good sets the NPV equal to zero. The lifetime of the printer is supposed to be 3 years, which is a conservative span of time for the printer working full time considering that the warranty period offered in Europe for this product is equal to 2 years. Thus, the initial investment is equal to $ 10,000 with an annual straight-line depreciation of $ 3,333.

An appropriate cost of capital must be apportioned for the evaluation of the project with the NPV methodology, as described in [49,50]. From [51], we individualize that the cost of capital for the computer service sector nowadays, updated to September 2015, in USA, which represents the first and the biggest market to enter for our product, is equal to 7.64% and the tax rate is equal to 40%.

Performing a simulation, it is possible to assess the number of units to be produced and sold that allows the achievement of the break-even point. In the present case, without considering employee's wages and hypothesizing that the creators can run the project without remuneration, the break-even is reached by selling at least seven units per year. Thereby, to be profitable the company must be able to sell more units than that, and from the 8th unit sold each year, the money will be available to generate remuneration for the software and hardware developers and, after that, profits for the company. In a second simulation, having three persons working full time in this project and covering all the functions for the startup, earning a yearly salary of $ 50,000, the break-even point will instead be equal to 68 units (Table 3), thus from the 69th unit the company will be able to generate profits. According to [52], the 3-D printing is cost effective on production runs of 50 to 5,000 units, and our study confirms this result. This is a reasonable annual amount to be sold in the USA, or even worldwide, as nowadays the market size of this sector, although not publicly available, is exponentially expanding, considering that these devices can be used both by public and private law enforcement organizations. Moreover, a further lowering of the price will increase potential users and purchases, and the production approach allows scalability in reaching worldwide dispersed customers.

Table 3. Net present value analysis for the commercialization of *CellIntel*, in the hypothesis of waged employees (reported is the break-even condition).

Units	68			
Cost of capital	7.64%			
Taxes	40%			
Price	$ 999			
Cost	$ 200			
Year	0	1st	2nd	3rd
Revenues		$ 67,932	$ 6,7932	$ 67,932
Cost of unit sold		$ (13,600)	$ (13,600)	$ (13,600)
Salary costs		$ (50,000)	$ (50,000)	$ (50,000)
Depreciation		$ (3,333.33)	$ (3,333.33)	$ (3,333.33)
Earnings Before taxes		$ 998.66	$ 998.66	$ 998.66
Taxes		$ (399.33)	$ (399.33)	$ (399.33)
Depreciation added back		$ 3,333.33	$ 3,333.33	$ 3,333.33
Initial capital expenditure	($ 10,000)			
Free cash flow to operations	($ 10,000)	$ 3,932.53	$ 3,932.53	$ 3,932.53
Net Present Value	$ 200.71			

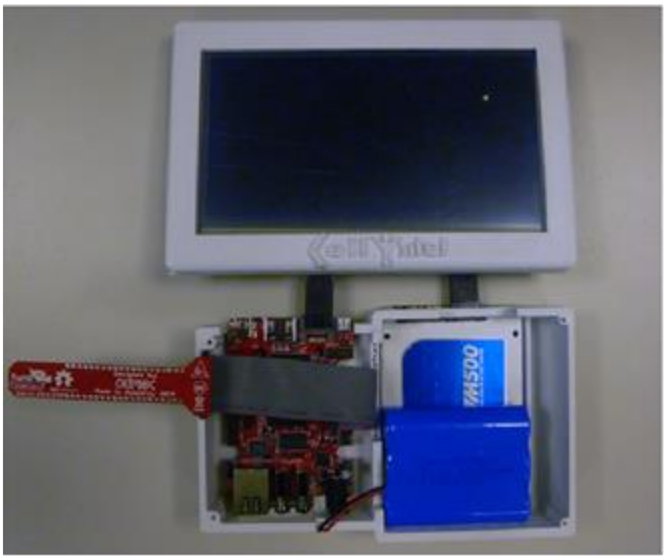
5. Empirical testing

The experimental testing performed in these months was successful in the realization of the prototype with the above mentioned techniques, in terms of lower cost, same functionalities and improved usability. After a detailed design of the imaging device developed by people interacting worldwide, the *CellIntel* prototype was produced with a Stratatsys 3D printer and manual assembled. The user interface was developed and installed in the mobile forensics imager (Figure 2), and the final product prototype was successfully tested in the field.

Figure 2. *CellIntel* prototype user interface during data extraction of a Samsung Galaxy S1 smartphone.

The assembled prototype reported in Figure 3, consisting of an in house produced 3D printed case and commercially available components manually assembled, was tested in the field.

Figure 3. *CellIntel* prototype’s components during the manual assembly: LCD screen, 3D printed screen case, battery, SSD hard disk drive, printed circuit board, cables for connections among components and 3D printed base case.



Finally, data extractions performed with the prototype were successful on both Android and iOS devices for forensics investigations use (Figure 4).

Figure 4. *CellIntel* assembled prototype in function: touch screen user interface during the choice of the device to be imaged.

6. Limitations

With the above described integrated approach, we evaluated the economic and practical feasibility of a low cost mobile forensics device which is able to enter successfully the market for general consumption. However, some limitations affect the here described prototype. Actually, the *CellIntel* prototype realized for this research cannot support all the cheaper phones, running niches and obsolete mobile OS; this is a limitation that characterizes also other well-known mobile device imagers. Additionally, there is still no support for Blackberry or Blackphones, although their market share is decreasing, and for Windows smartphones that cannot be imaged using traditional methods [53–55].

Moreover, the community of researchers and students working on this project appointed to maintain the device extraction capabilities with new software releases and to improve product’s design, must be tested to check if it proves to be a reliable solution in the long run.

Finally, as this study represents a first empirical evidence of a successful application of this approach for marketable products, the application to other sector is needed to increase the generalizability of the outcomes.

7. Conclusions

The purpose of this paper is to provide an empirical evidence of the technical viability and economic feasibility of a product developed and realized throughout the application of an integrated sustainable approach based on open innovation and peer production aided by 3D printing. The use of a 3D printer means that the product could easily be reproduced domestically, with a peer production system, thereby eliminating transportation and inventory costs. The open approach is applied to the design of hardware and software components, so that volunteers and entities on the web can assist in the development and advancements of the product. The results support the evidence of a sustainable approach and an entrepreneurial opportunity that should be exploited, towards the OSI paradigm [27]. The adoption of OSI permits to reach both firms’ economic objectives and sustainability goals, benefiting all the stakeholders [56].

The prototype described in this case study offers evidence of a feasible and collaborative-based device for making mobile forensics investigations viable for smaller law enforcement agencies in need of a cost-effective, portable solution. In particular, in this research we identified with the NPV methodology the number of required units to be sold annually to reach the break-even point. Thus, it is assessed that the device developed with the examined approach, is economically feasible.

Mobile forensics tools are gaining growing interest in the field of both private and public investigations. Thanks to the above mentioned methodologies, the prototype described in this research offers the same features as competitors in the field, but with improved portability and for a significantly lower price, thereby allowing a wider range of additional possible buyers and users, and representing a business opportunity that can be exploited. Devices with similar features already exists, therefore the contribution of this study is the implementation of a new approach, as methodology and motivation are original and innovative: the objective is not only to reply to the growing need of cheaper and more portable mobile forensics imaging device, especially for smaller law enforcement agencies and private investigations, but to represent a test bed for the validation of this new integrated approach for start-upping new ventures that could represent a game-changing concept.

Further research will be focused on small batch production of devices and field-testing by practitioners in everyday life, to improve the design, the software and the hardware and to verify the robustness and the reliability of the forensics imager. Moreover, the benefits and startup possibilities described in this case study could be applied and tested in other existing sectors, as a new standard to deliver cheaper products in a more sustainable way, able to beat the market incumbents.

References

1. Gershenfeld N. How to Make Almost Anything. Foreign Affairs 2012; 91(6): 43–57.
2. Parvin A. Architecture (and the other 99%): Open-Source Architecture and Design Commons. Architectural Design 2013; 83(6): 90–95. DOI: 10.1002/ad.1680.
3. Wittbrodt BT, Glover AG, Laureto J, et al. Life-cycle economic analysis of distributed manufacturing with open-source 3-D printers. Mechatronics 2013; 23(6): 713–726. DOI: 10.1016/j.mechatronics.2013.06.002.
4. Antikainen M, Mäkipää M, Ahonen M. Motivating and supporting collaboration in open innovationnull. European Journal of Innovation Management 2010; 13(1): 100–119. DOI: 10.1108/14601061011013258.
5. Carlsson S, Corvello V, Schroll A, Mild A. Open innovation modes and the role of internal R&D: An empirical study on open innovation adoption in Europe. European Journal of Innovation Management 2011; 14(4): 475–495.
6. Enkel E, Gassmann O, Chesbrough H. Open R&D and open innovation: exploring the phenomenon. R&d Management 2009; 39(4): 311–316.
7. Helfat CE. Open Innovation: The New Imperative for Creating and Profiting from Technology. Academy of Management Perspectives 2006; 20(2): 86–88. DOI: 10.5465/AMP.2006.20591014.
8. Chesbrough HW. The Era of Open Innovation. MIT Sloan Management Review 2003; 44(3): 35–41. DOI: 10.1371/journal.pone.0015090.
9. Schwerdtner W, Siebert R, Busse M, Freisinger U. Regional Open Innovation Roadmapping: A New Framework for Innovation-Based Regional Development. Sustainability 2015; 7(3): 2301–2321. DOI: 10.3390/su7032301.
10. Michelino F, Cammarano A, Lamberti E, Caputo M. Knowledge Domains, Technological Strategies and Open Innovation. Journal of technology management & innovation 2015; 10(2): 50–78.
11. West J, Salter A, Vanhaverbeke W, Chesbrough H. Open innovation: The next decade. Research Policy 2014; 43(5): 805–811. DOI: 10.1016/j.respol.2014.03.001.
12. Moilanen J. 3-D Printing. Statistical studies of peer production 2012; (December): 1–18.
13. Von Hippel E. Democratizing innovation. Journal für Betriebswirtschaft 2005; 55(1): 63–78. DOI: 10.1111/j.1540-5885.2006.00192_2.x.
14. Von Hippel E. Open user innovation., 2010. DOI: 10.1016/S0169-7218(10)01009-9.
15. Felin T. Cosmologies of capability, markets and wisdom of crowds: Introduction and comparative agenda. Managerial and Decision Economics 2012; 33(5-6): 283–294.
16. Koch C. Innovation networking between stability and political dynamics. Technovation 2004; 24(9): 729–739. DOI: 10.1016/S0166-4972(02)00154-2.
17. Vujovic S, Ulhøi JP. Online innovation: the case of open source software development. European Journal of Innovation Management 2008; 11(1): 142–156. DOI: 10.1108/14601060810845268.
18. Grimaldi M, Cricelli L, Rogo F. A methodology to assess value creation in communities of innovation. Journal of Intellectual Capital 2012; 13(3): 305–330. DOI: 10.1108/14691931211248882.
19. Bonaccorsi A, Rossi C. Why Open Source software can succeed. Research Policy 2003; 32(7): 1243–1258. DOI: 10.1016/S0048-7333(03)00051-9.

20. Benkler Y, Nissenbaum H. Commons-based peer production and virtue. Journal of Political Philosophy 2006; 14(4): 394–419. DOI: 10.1111/j.1467-9760.2006.00235.x.
21. Kostakis V, Papachristou M. Commons-based peer production and digital fabrication: The case of a RepRap-based, Lego-built 3D printing-milling machine. Telematics and Informatics 2014; 31(3): 434–443. DOI: 10.1016/j.tele.2013.09.006.
22. Espalin D, Muse DW, MacDonald E, Wicker RB. 3D Printing multifunctionality: structures with electronics. The International Journal of Advanced Manufacturing Technology 2014; 72(5-8): 963–978. DOI: 10.1007/s00170-014-5717-7.
23. Nozick LK, Turnquist MA. Inventory, transportation, service quality and the location of distribution centers. European Journal of Operational Research 2001; 129(2): 362–371.
24. Ratto M, Ree R. Materializing information: 3D printing and social change. First Monday 2012; 17(7). DOI: 10.5210/fm.v17i7.3968.
25. Wohlers T. Wohlers Report 2014. 3D Printing and Additive Manufacturing State of the Industry., 2014. DOI: ISBN 978-0-9913332-0-2.
26. Bruntland G. Our common future: The world commission on environment and development., 1987. DOI: 10.2307/2621529.
27. Arcese G, Flammini S, Lucchetti MC, Martucci O. Open Sustainability Innovation in the Food Sector. World Sustainability Forum 2014 2014: 8067–8090. DOI: 10.3390/su7078067.
28. Berman B. 3-D printing: The new industrial revolution. Business Horizons 2012; 55(2): 155–162. DOI: 10.1016/j.bushor.2011.11.003.
29. Pearce JM. Quantifying the Value of Open Source Hard-ware Development. Modern Economy 2015; 06(01): 1–11. DOI: 10.4236/me.2015.61001.
30. Hayes D. A Practical Guide to Computer Forensics Investigations. Pearson, 2015.
31. Arthur C. Smartphone explosion in 2014 will see ownership in India pass US. The Guardian 2014.
32. eMarketer. Smartphone Users Worldwide. eMarketer 2014: 4–5.
33. Farjamfar A, Abdullah MT, Mahmod R, Udzir NI. A Review on Mobile Device's Digital Forensic Process Models. 2014; 8(3): 358–366.
34. Ghosh A. Guidelines for the Management of IT Evidence. 2004; (March): 0–26.
35. Jang Y-J, Kwak J. Digital forensics investigation methodology applicable for social network services. Multimedia Tools and Applications 2015; 74(14): 5029–5040. DOI: 10.1007/s11042-014-2061-8.
36. Ferrara E, De Meo P, Catanese S, Fiumara G. Detecting criminal organizations in mobile phone networks. 2014. DOI: 10.1016/j.eswa.2014.03.024.
37. Palmer G. A Road Map for Digital Forensic Research. Proceedings of the 2001 Digital Forensics Research Workshop (DFRWS 2004) 2001: 1–42. DOI: 10.1111/j.1365-2656.2005.01025.x.
38. Paraben. Paraben. 2015.
39. Oxygen. Oxygen Forensics. Mobile forensics solutions: software and hardware 2015.
40. Cellebrite. Mobile foresics - delivering mobile expertise. Cellebrite 2015.
41. Mertz L. New World of 3-D Printing Offers "Completely New Ways of Thinking." IEEE Pulse 2013; (December): 12–14. DOI: 10.1109/MPUL.2013.2279615.
42. Kantar. Smarphone OS market share. World panel 2015.
43. Stratasys. FDM Technology, About Fused Deposition Modeling | Stratasys. 2015.

44. Masood SH. Intelligent rapid prototyping with fused deposition modelling. Rapid Prototyping Journal 1996; 2(1): 24–33.
45. Remer DS, Nieto AP. A compendium and comparison of 25 project evaluation techniques. Part 1: Net present value and rate of return methods. International Journal of Production Economics 1995; 42(1): 79–96.
46. Howe J. The rise of crowdsourcing. Wired magazine 2006; 14(6): 1–4.
47. Makerbot. 3D Printing Resources and Tools | MakerBot. Makerbot Industries 2015.
48. TierTime. TierTime. 2015.
49. Cappa F, Facci AL, Ubertini S. Proton exchange membrane fuel cell for cooperating households: A convenient combined heat and power solution for residential applications. Energy 2015; 90: 1229–1238.
50. Zadeh S, Hunt D, Lombardi D, Rogers C. Shared Urban Greywater Recycling Systems: Water Resource Savings and Economic Investment. Sustainability 2013; 5(7): 2887–2912. DOI: 10.3390/su5072887.
51. Damodaran A. Investment valuation: Tools and techniques for determining the value of any asset. John Wiley & Sons, 2012.
52. Sedacca B. Hand built by lasers [additive layer manufacturing]. Engineering & Technology (17509637) 2011; 6(1): 58–60. DOI: 10.1049/et.2011.0110.
53. Willassen S. Forensic analysis of mobile phone internal memory. In Advances in Digital Forensics, Springer, 2005; 191–204.
54. Chun W-S, Park D-W. A study on the forensic data extraction method for sms, photo and mobile image of google android and windows mobile smart phone. In Convergence and Hybrid Information Technology, Springer, 2012; 654–663.
55. Grispos G, Storer T, Glisson WB. A comparison of forensic evidence recovery techniques for a windows mobile smart phone. Digital Investigation 2011; 8(1): 23–36.
56. Arcese G, Lucchetti M, Merli R. Social Life Cycle Assessment as a Management Tool: Methodology for Application in Tourism. Sustainability 2013; 5(8): 3275–3287. DOI: 10.3390/su5083275.