architecture institutions and change

Proceedings of the
Society of Architectural Historians
Australia and New Zealand
Vol. 32

The bibliographic citation for this paper is:

de Manincor, John. "Open to Change: Is Open Source Design an Agent of Change for the Institution of Architecture?" In *Proceedings of the Society of Architectural Historians, Australia and New Zealand: 32, Architecture, Institutions and Change*, edited by Paul Hogben and Judith O'Callaghan,123-134. Sydney: SAHANZ, 2015.

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Open to Change: Is Open Source Design an Agent of Change for the Institution of Architecture?

Open source refers to free public access to design documentation via online platforms. With a pre-history in the DIY movement, early developers of the World Wide Web quickly adopted the sharing and adapting of design information – its code. Today HTML code, the backbone of the Internet, remains an open source platform. From this initial focus on software, a new movement has grown – open source design. This often involves collaborative and user-driven development combined with innovative royalty models.[1]

Through open source, designers and architects are striving to challenge the status quo for existing models of design, manufacture and consumption through the redistribution of knowledge. Claims that open source is disruptive and "revolutionises every step of the traditional building process" are ubiquitous and largely unchallenged. Alistair Parvin, Director of Architecture 00, the creators of the WikiHouse, argues that it will enable "Architecture for the people by the people." Parvin links open source architecture to the 'third industrial revolution', being closely affiliated with digital design and manufacture processes, the maker movement and the rise of the Fab-lab.

Open source should not be dismissed as a marginal enterprise, nor, however, should claims that open source design will democratise architectural knowledge be unquestionably accepted or viewed outside the history of previous attempts to share design information such as Stuart Brand's Whole Earth Catalogue *(1968), Ant Farm's* Inflatable Cookbook *(1971) and Enzo Mari's* Proposta per Un'autoprogettazione [Proposal for a Self Project] *(1974). This paper contextualises the open source phenomenon raising pertinent questions regarding the implications of OSD as an agent of change for architecture as an institution.[2]*

In an essay on open source criticism Naomi Stead writes "There was a time not so long ago when many of us, myself included, thought that a brave new world of architectural commentary and criticism was about to open, by virtue of the democratizing capacities of Web 2.0."[3] A similar excitement exists around the potential of open source design (OSD) processes for architecture. Carlo Ratti et al define Open Source Architecture (OSArc)[4] as "an emerging paradigm describing new procedures for the design, construction and operation of buildings, infrastructure and spaces … it describes an inclusive approach to spatial design, a collaborative use of design software and the transparent operation throughout the course of a building and city's life cycle."[5] OSD introduces the concept of the end-user/consumer playing a key role in the design process as 'co-designer'.[6] This utopian concept where 'everyone is a designer' challenges the role of institutionally trained designers and the profession of architecture. This paper will explore the role of the designer in the pre-history of open source in pattern books and the Do-it-Yourself (DIY) movement. Further, the extent to which OSD acts as an agent of change in shifting the institutional practices[7] of architecture will be examined.

Architecture fits accepted definitions of a profession which include; being distinct from trades, providing a service, association with a formal organisation (the numerous 'Institutes' of architects), the exclusion of unqualified (socially or otherwise) persons, expectations to undertake altruistic activities, a requirement of formal education including theoretical knowledge, and the control over relevant educational bodies.[8] The practice of architecture encompasses more than the design of buildings by professionals, it includes education and academia; together they form an institution. With jurisdiction over education, there is an inherent control of knowledge – the control of power. Francis Bacon coined the phrase 'knowledge is power', a topic explored in depth by Michel Foucault who notes that institutions are a way of fixing particular relations of power such that only a privileged number of people are advantaged.[9] Power in this instance could be said to be knowledge, and knowledge of design and design skills form a major part of the public's perception of the traditional role the professional architect thus placing the architect in a position of power.

Open Source has 'movements' in politics, computer software, product design, fashion, architecture and more. Common to each is their reliance on the ever increasing access to and dissemination of information through digital media. It is well documented that the manner in which society accesses and distributes information has long been shaped by technology, from the transition of monks painstakingly copying books by hand to the invention of the printing press, from Morse code and the electrical telegraph system, to telephone, radio, television, satellite communication, the advent of the personal computer and the smart phone. Each has changed society in providing greater access to information, thus (slowly) shifting the balance of power. Today, it is difficult to imagine any project, be it scholarly research or the design of a building that does not involve an Internet search or email communication. The very code that powers the Internet, Hyper Text Markup Language, or HTML as it is commonly known, is itself an open source computer language.[10] In the 1980s, 'Video killed the Radio Star'[11], then email killed the fax, subsequently open source websites

like Wikipedia have given birth to the Wikidemic and Wikillectual profoundly changing the (first) world's relationship to information. HTML is but one example that illustrates that perhaps all institutions, including architecture, have already changed as a direct result of open source processes.

Originating in the software industry, the fundamental premise of OSD is "the free exchange of comprehensive design information."[12] Programmers share 'source code' or 'blueprints' with minimal or no royalty fees, allowing that code to be adapted to solve a particular computing problem.[13] Licence agreements for shared code simply require the user to acknowledge the original designer in any redistribution of the modified code. Carlo Ratti et al suggest that the precursor to open source is cooking and that "vernacular architecture – producing recipes for everyday buildings – is another form of early lo-fi open-source culture."[14] In the earliest oral traditions the design information for the construction of vernacular buildings was passed on from generation to generation, each adapting and modifying the design as conditions dictate in the same way that family recipes were shared long before the advent of nana's butter stained notebooks or Nigella Lawson's websites. The design code for these vernacular buildings had neither copyright nor intellectual property rights as we understand them today and, to some degree, no specific monetary value.[15] These conversations were not recorded or transcribed nor did they rely on any form of technology for their dissemination.

There is a rich history of design information that designers, builders and consumers have adopted and adapted from books and other printed publications. Architect and open source advocate Alistair Parvin states "architecture is a discipline effectively founded as one huge 'copy' function, from the Vitruvian pattern book onwards. So for architecture to publish[16] its 'code' is actually less of a sacrifice than it is for software developers to do so."[17] This reference to Vitruvius and historic pattern books is worthy of further consideration. Vitruvius' *Ten Books on Architecture* shaped Roman cities for centuries through the designs made by others according to his principles. Whilst Palladio's *I quattro libri dell'architettura* documented classical details and illustrated the application of these through his own works. In their 2012 *Villa Rotunda Redux* project FAT (Fashion Architecture Taste) argue "Palladio's *Four Books of Architecture* for example, were explicit manuals published to be copied by other architects."[18] Much later in *A Pattern Language* Christopher Alexander sets out "the detailed patterns for towns and neighborhoods, houses, gardens and rooms."[19] Of interest to the open source movement is that the authors advocated for their 'codes' to be adapted and adopted widely, long before ⌘C and ⌘V (cut and paste) formed part of the lexicon of designers. In the cases of Vitruvius and Palladio it was master-builders rather than institutionally trained designers or architects who decoded the author's data.[20] They were only a select few members of society that could read or write – access to knowledge was indeed limited.

Technological change has long influenced the practice of architecture, not only through the dissemination of knowledge but also through the process of making and manufacture. The first industrial revolution in the mid-to-late 1800s saw radical changes for the traditions of the craftsperson and artisan. Well known for its socialist tendencies the Arts and Crafts Movement rallied against the loss of these skills and the demise of the decorative arts that

sat outside the profession of architecture, but which played a vital role in the realisation of buildings. Part of the resistance included a call to the untrained consumer to engage in these acts of making themselves, a kind of early Do-It-Yourself (DIY). Important journals of the time such as *The Studio* and *The Craftsman* provided how-to instructions for "easy-to-make furniture and homes, targeted at the inexperienced 'amateur'."[21] Whilst the craft guilds did not hold the status of the professional architect, this early model of DIY represented a resistance to new brokers of power.

Given the social imperative of OSD suggested by Rati et al it is worth contextualising it in relation to the societal ambitions of the DIY movement and the institutions they set to change. DIY, particularly in the United States of America, was seen as much an economic necessity as it was to reaction against mass production and consumer culture. In Australia, Canada and the USA design manuals for self-build homes and furniture became popular in the post-war era. Catalogues such as *Sears Homes/Sears Modern Homes* (1908-40), Gordon-Van Tine's *Ready-Cut Homes* and Australia's *Hudsons' Ready-Cut Homes* provided details and materials for low-cost user-assembled homes. Unlike earlier pattern books these kit homes came with construction details and materials schedules. Sears actively promoted modification of their 'source code' allowing purchasers to modify "houses and hardware according to buyer taste."[22] Despite sitting outside conventional project delivery, the designs were conservative and indicative of the mainstream taste.
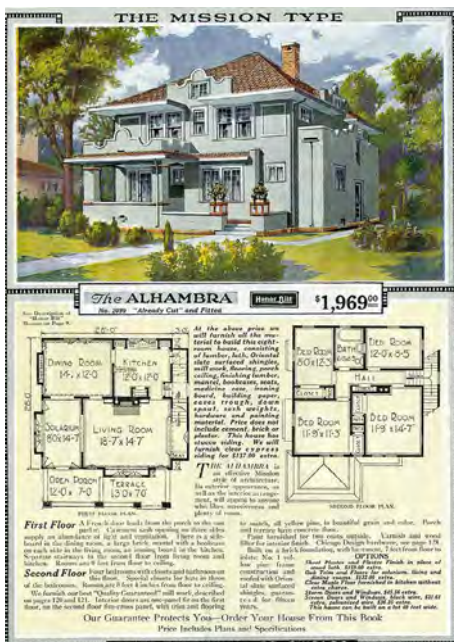

Fig. 1 "The Alhambra" (Model No. 2090). Sears Catalog home appearing in the 1919 Sears Roebuck Catalog. Wikicommons.

It is perhaps the American counterculture's philosophical position on DIY that is most aligned to the values of OSD principles. Andrew Kirk notes that DIY explored ways to circumvent "a reliance on capitalist commissioning systems"[23] whilst as Gabrielle Kennedy writes "ultimately, it (OSD) takes power away from the huge multinationals and from production

hubs like China and India and hands it back to craftspeople – those individuals rendered irrelevant by industrialization."[24] The DIY manuals associated with the era have been well documented in architectural discourse; seminal examples include Stuart Brand's *Whole Earth Catalogue* (WEC - 1968), Ant Farm's *Inflato Cookbook* (1971) – they provide valuable insight into the pre-history of the philosophy of OSD. There are interesting similarities between WEC and the Open Source Ecology (OSE) project founded by physicist-turned-inventor Marcin Jakubowski. The function of the WEC was to act as "an evaluation and access device. With it, the user should know better what is worth getting and where and how to do the getting."[25] Brand's position was that large institutions and corporations' lust for power and wealth had obscured "the power of the individual to conduct his own education, find his own inspiration, shape his own environment, and share his adventure with whoever is interested."[26] This sentiment could well be the catchcry of the open source movement. As Simon Sadler notes "Brand – who organized the first conference for computer hacking (1984) – brought something of the sensibility of open-source software to bear on architecture."[27] WEC was essentially a catalogue of 'tools' that had been vetted according to Brand and co.'s value system. Consumers could purchase Brand's pre-approved products through traditional stores or via mail order from Brand's company. Sandler referred to WEC as a "design Wiki"[28], the 1970s equivalent to a trusted online shopping site, the fundamental difference being that in the contemporary context buyers are likely to use multiple websites to review products prior to purchase, often in a very short timeframe.[29] OSE is equally opposed to the lack of choice offered by large corporations. Jakubowski set out to establish a "Global Village Construction Set (GVCS) … a modular, DIY, low-cost, high-performance platform that allows for the easy fabrication of the 50 different Industrial Machines that it takes to build a small, sustainable civilization with modern comforts."[30] Similarly the work of *Ant Farm (1968-1978)* was "an opposition to what they saw as the rampant consumerism of 1970s USA."[31] Like Ant Farm's *Inflato Cookbook* (1971), yet somewhat less humorous in its presentation, OSE has created detailed documentation of a range of 'tools' including a tractor, induction furnace, press forge, along with digital fabrication hardware that includes 3D scanner, 3D printer, CnC torch/router and an industrial robot. OSE has produced a working prototype of *LifeTrac*[32] (a tractor bulldozer hybrid) made from universally available parts that was estimated to cost in

Fig. 2 Open Source Ecology –Global Village Construction Set. Image by Aaron Makaruk. Wikicommons.

the order of €9,000, where as the equivalent product from *John Deer* may cost in the order of €35,000.[33] One might well imagine a fleet of OSE's tools servicing *Drop City*, the rural hippie commune that 'hacked' Buckminster Fuller's domes in the late 1960s.[34] Interestingly, Brand's Whole Earth network was instrumental in establishing "the Whole Earth 'Lectronic Link, or *WELL* for short: hereafter; the World Wide Web"[35] the very vehicle of OSD.

Resistance against manufacturing paradigms was not restricted to North America or Australia. Formed in 1973 by members of the Italian Radical Architecture movement Global Tools was "as a direct reaction to the political, ecological and socio-economical crises in Italy at the time." They promoted "the use of 'poor' materials and, among other forward-thinking initiatives, it proposed simplifying the design process to counter the early mass-industrial adoption of plastics."[36] A year later, celebrated Italian industrial designer Enzo Mari's *Proposta per Un'autoprogettazione* [Proposal for a Self Project] caused uproar in the design establishment. Mari, known for his communist leanings, once stating that his work was "less about pleasing the user, than the factory workers who make his products."[37] Proposta per Un'autoprogettazione was "… an elementary technique to teach anyone to look at present production with a critical eye. (Anyone, apart from factories and traders, can use these designs to make them by themselves. The author hopes the idea will last into the future and asks those who build the furniture, and in particular, variations of it, to send photos to his studio …)."[38] Joseph Grima describes the *Autoprogettazione* project as a political act, a rebellion against the institutionalisation of manufacturing.[39] What is particularly noteworthy is Mari's interest in the 'variations' of his work by the untrained designer. On face value this interest appears completely aligned to the philosophies of the OSD movement, yet it is an idea that he himself rejects. Mari suggests that open source may be an outlet for "individual, quick projects, he says, yes. Why not !?! But if a designer sits for one or two years on a real project then the designer needs to be paid."[40]

The Second Industrial Revolution saw the proliferation of electrified factories and a significant shift to mass production. Today we are in the midst of two interrelated revolutions; the Digital Revolution and associated New, or Third, Industrial Revolution.[41] The Digital Revolution is most commonly associated with changes in the communications technologies on which OSD relies and is a well-documented phenomenon. OSD is intrinsically linked to the Third Industrial Revolution, which, through OSD, purports to disrupt established modes of manufacturing.[42] Parametric software tools, robotic arms, 3D printers, laser cutters and CnC routers form the arsenal of this new revolution, driven by an army of institutionally trained designers and untrained tinkerers. These rebels, like the counter cultures before them, are eager to challenge the status quo of existing modes of design and manufacture along with the centres of power that they fuel. The Ford era was typified by mass production at mega scales, new design and fabrication tools facilitate mass customisation and the distribution of manufacturing that sees the potential for a new network of sophisticated production at scales not previously considered; the micro scale. These micro manufacturing plants are an evolution of the "Fab Lab™" (fabrication laboratory) concept. The term is credited to Neil Gershenfeld of MIT's *Fab Foundation,* an offshoot of the Centre of *Bits & Atoms.* Australian

academic William (Bill) Mitchell forecast the concept when he stated by "interfacing production machinery with computer graphics systems, a very sophisticated design/production facility can be developed".[43] For Gershenfeld and his team the term Fab Lab™ has specific philosophical and logistical characteristics; "A Fab Lab is about democratizing access to the tools for personal expression and invention. So a Fab Lab™ must be open to the public for free or in-kind service/barter at least part of the time each week."[44] This altruistic ambition promotes a bottom-up culture of innovation and shares the principles of the counterculture of the 1960s and 1970s.

Outside the nurtured environment of the Fab Lab™ is a new industry of small-scale workshops with the capacity to produce high quality products using digital hardware. These businesses are of such significance that American President Barack Obama noted in his 2013 State of the Union address "A once-shuttered warehouse (in Youngstown, Ohio) is now a state-of-the art lab where new workers are mastering the 3D printing that has the potential to revolutionise the way we make almost everything ... guarantee(ing) that the next revolution in manufacturing is Made in America."[45] For Gershenfeld and Obama the imperative to produce and innovate are both social and economic. A raft of dispersed manufacturers has sprung up in recent times for small-scale objects accessed through sites such as Shapeways, Ponoko, Thingiverse and Sculpteo. The model of dispersed, networked manufacture offers designers and makers access to tools at levels of availability and affordability never before imagined. As access to these manufacturing tools becomes more even affordable, we will see further change in the relationship between designer and maker, in some instances these boundaries may disappear completely. The proposition challenges scientific management theory, or Taylorisim, which separated 'thinking' from 'doing' – definitions that Broadbent et al see as distinctions between professions and trades.[46]

Fig. 3 Warsztaty Open Source FabLab. Photograph by Katarzyna Piądłowska. Flickr/Creative Commons ShareAlike 2.0 Generic.

As a profession, architecture expects its members to undertake altruistic activities.[47] In his impassioned 2013 TedTalk, Alistair Parvin co-creator of WikiHouse, highlights the fact "that almost everything that we call architecture today is actually the business of designing for about the richest one percent of the world's population."[48] This comment clearly aligns

Parvin to the politically charged Occupy Movement with their slogan 'We are the 99%' and resonates with the American counterculture and Arts and Crafts movements. Like Mari's *Proposta per Un'autoprogettazione,* WikiHouse is an altruistic project. "WikiHouse is an open-source construction set. The aim is to make it possible for *anyone* to design, 'print'[49] and assemble low-cost, high-performance houses that are suited to their needs."[50] Consumers are given free access to design files of a modular framing system for housing via a Creative Commons CC-BY-SA 4.0 licensing.[51] The system, launched in 2011, by Parvin and business partner Nick Ierodiaconou is widely discussed in much of the discourse on OSArc.[52] The creators invite anyone to modify their template files using "open parametric design tools" that allow designers to move "from 3-D models to cutting files in one click." The files are provided to anyone with a Gmail account in SketchUp format and are "shared without any kind of warranty or guarantee."

Fig. 4 A-Barn, Scotland by *Wikihouse.* Photograph by Hector Carde. *Wikihouse.*

The terms of use include being responsible for meeting local codes and legislation, being solely responsible for the use of the information, responsible for using information in a safe way, share improvements or adaptations royalty free and not use the name or logo of WikiHouse (the WikiHouse trademark [name and logo] are protected). Parvin suggests, "the factory of the 21st century is anywhere, it means that increasingly the *design team might be anyone*, opening the door not just to a litany of lawsuits, but also to the possibility of open products developed *by* and for the community."[53] The very premise of the project assumes that 'anyone' has access to electricity, a computer and the Internet. The World Bank reports that 89 per cent of the UK and the USA has 84 per cent have access, in the third-word the figure is substantially less with Sri Lanka at 21.9 per cent and Uganda at 16.2 per cent.[54] *The Economist* writes "computers and broadband links are not much use without a reliable electrical supply."[55] So we are faced with a dilemma, not 'anyone' in the 99 per cent can be a designer without appropriate infrastructure or training. Within the 1 per cent, there remains a divide between those with knowledge, the professions, and those without. These scenarios highlight economic and cultural divides driven global financial and existing institutional structures.

Fig. 5 Distributed Manufacture *Wikihouse. Wikihouse.*

The Wikihouse terms of use provide clues as to who Parvin's 'anyone' designers and makers might be. They may well include institutionally trained architects, along with others "capable of studying, understanding and modifying source code."[56] A key difference between earlier DIY approaches and OSD projects like Wikihouse is that the latter fundamentally relies on digital technologies for access to, and modification of, source code as well as for fabrication techniques. Vardouli and Buechley suggest this represents a "shift from traditional modes of construction where builders translated drawings into buildings [or amateurs follow DIY guides] to (a) situation where the source code produces the end product."[57] Parametric modeling and file-to-Fab Lab processes allow accurate fabrication of building elements with relative ease using hardware like laser cutters, 3D printers and CnC routers. However, these contraptions require an understanding of material properties and their relationship to terms such as offsets, margins, bit speed, plunge rates, bridging, etc. Whilst the mode of translation of design data has shifted, to realise even the most rudimentary buildings, say at the scale of the WikiHouse, requires knowledge of building physics, economics and regulatory frameworks. And although Gershenfeld promotes the Fab Lab and $100K Garage[58] as the epicentres of distributed fabrication, these micro-manufacturing plants are (currently) generally only suited to industrial design and small building components. The revolution is slow and expensive: 'Beantown Sports' is a two-part braille puzzle designed by former MIT student Edrie Ortega for the Burst Open exhibition in Brisbane, Australia, in 2014.[59] It took 14 hours to print this small toy using a MakerBot Replicator 2X. For the same exhibition, architect Andrew D'Occhio's attempted to produce an open source chair design for AUD$45 – the price of a generic chair from a large Swedish furniture supplier. As an experiment D'Occhio acted as an 'anyone' designer/consumer and issued the code files for his 'Valovi Chair 2.0' to nine fabricators to obtain a quote to have them CnC cut. Two declined due to concerns with the cut template design (equal to a Wikihouse template). Only three quotes were received, $AUD144, $AUD97 and $99 per chair.[60] In a design studio at the University of Queensland students discovered that the cost of erecting a 10sq.m 'rationalised' Wikihouse designed for Burst Open was equal or more expensive than the equivalent structure using skilled labour and traditional timber framing.[61]

Fig. 6 *UQikiHouse* by University of Queensland Master of Architecture students, 2014. Photograph by John de Manincor.

The Digital Revolution has seen changes in the world's access to information and has "brought about a mutation of the power structures around the formation of architectural cultures."[62] Simultaneously the Third Industrial Revolution is giving rise to new modes of manufacture. Vardouli and Buechley suggest literal application of open source design to architecture is "an open sharing of the digital files that encode information to build artifacts."[63] In early 2015 the WinSun Decoration Design Engineering Co claimed to have completed the world's tallest 3D printed building was erected in Suzhou, China.[64] The building is not a result of open source architecture nor entirely printed. Images of the project under construction show hand placed reinforcement and traditional wiring systems. This suggests the industry is not quite ready to fully embrace digital fabrication and reinforces the fact that multiple hands are at play in the realisation of buildings. Notwithstanding, as a result of open source, users and clients are becoming savvier and in some instances taking part in the design process as co-designers.[65] "The project of open sourcing architecture (is) inherently interdisciplinary, necessitating the collaboration of people with different skills and expertise."[66] Amongst these are change agents like Alistair Parvin and Neil Gershenfeld, those without whom there can be no shift in institutional practices of the profession.[67]

Returning to Naomi Stead's essay on criticism, Stead believes open source allows for the "possibility of building a richer and more nuanced vision of what happens to buildings beyond their architects."[68] To paraphrase Stead, open source requires of the entire profession a more nuanced mode of operation, to be more discerning to raise public standards and expectations, not only of the aesthetics and functionality of designed objects, but of their sustainability, and their upholding (or subordination) of the tenets of social justice. To do so demands a "rethinking of the discipline's theory and practice – a re-diagramming of its processes and the roles of the subjects involved in them."[69] It requires the institution to be open to change.

1   John de Manincor and Christian Duell, *Burst Open-About* (2014), www.burstopen.org (accessed May 13, 2015).

2   Jane Broadbent, Michael Dietrich and Jennifer Roberts, eds., *The End of the Professions? The Restructuring of Professional Work* (London: Routledge, 1997), 2.

3   Naomi Stead, "Losing my illusions about open-source criticism," *Volume* 36 (2013): 119.

4   Open Source, Open Source Design (OSD) and Open Source Architecture (OSArc) share common histories and traits. For the purposes of this paper these terms should be considered interchangeable.

5   Carlo Ratti et al, "Open Source Architecture (OSArc)," *Domus* 948 (2011): iii.

6   Pieter Jan Stappers & Co., "Creation and Co: User Participation in Design," in *Open Design Now,* ed. Bas Van Abel *(*Amsterdam: BIS, 2011), 142.

7   Broadbent et al, *The End of the Professions?, 2.*

8   See Geoffrey Millerson, "Dilemmas of Professionalism (1964)," in Terrance Johnson, *Professions and Power* (London: Macmillan, 1972) and Alexander Carr-Saunders and Paul Wilson, *The Professions* (London: Frank Cass, 1956).

9   Clare O'Farrell, *Foucault: The Legacy* (Brisbane: Queensland University of Technology Press, 1997) via www.michel-foucault.com/index.html (accessed May 10, 2015).

10 http://en.wikipedia.org/wiki/HTML (accessed February 13, 2015).

11 The Buggles, "Video Killed The Radio Star" (Island Records, 1980), www.youtube.com/watch?v=W8r-tXRLazs (accessed February 7, 2015).

12 Open Design, www.opendesign.org (accessed February 7, 2015).

13 It is ironic that the term 'blueprints' remains a common term in the software industry and throughout discourse on Open Source yet rarely used as a term in the architectural profession.

14 Ratti et al., "Open Source Architecture (OSArc)," iii.

15 Copyright was not introduced in Britain until 1710 with the Statute of Anne.

16 That is to say make the raw design data freely available.

17 Alastair Parvin, "Architecture (and the other 99%): Open-Source Architecture and Design Commons," *Architectural Design* 83, no. 6 (2011): 93.

18 Fashion Architecture Taste (FAT), *Villa Rotunda Redux* (2012), unpaginated. Downloaded from www.fashionarchitecturetaste.com/2012/08/villa_rotunda_redux.html (accessed February 12, 2015).

19 Christopher Alexander, *A Pattern Language* (New York: Oxford University Press, 1977), ix.

20 It is acknowledged that the institutionally trained architect postdates Vitruvius.

21 Carolyn Goldstein, *Do It Yourself: Home Improvement in 20th-Century America* (Washington and New York: National Building Museum, Washington and Princeton Architectural Press, 1998), as cited in Catherine Smith, "Productive Matters: The DIY Architecture Manuals of Ant Farm and Paolo Soleri" (PhD dissertation, Faculty of Architecture, Design and Planning, University of Sydney, 2012).

22 Sears Archives, www.searsarchives.com/homes/index.htm (accessed February 13, 2015).

23 Andrew Kirk, *Counterculture Green: The Whole Earth Catalog and American Environmentalism* (Lawrence, Kansas: University of Kansas Press, 2007) in Smith, "Productive Matters," 23.

24 Gabrielle Kennedy, "Joris Larrman's Experiments with Open Source Design" in *Open Design Now,* 123.

25 Stewart Brand, *The Last Whole Earth Catalogue: Access to Tools* (Harmondsworth: Portola Institute, Penguin Books, 1971), 3.

26 Brand, *The Last Whole Earth Catalogue, 3.*

27 Simon Sandler, "An Architecture of the Whole," *Journal of Architectural Education* 61, no. 4 (2008): 124.

28 Sandler, "An Architecture of the Whole," 108.

29 See Naomi Stead's humorous discussion on purchasing a vacuum cleaner in Stead, "Losing my illusions about open-source criticism," 123.

30 opensourceecology.org/gvcs/ (accessed February 13, 2015).

31 Ant Farm, www.spatialagency.net/database/ant.farm (accessed February 13, 2015).

32 Down details at opensourceecology.dozuki.com/c/LifeTrac (accessed February 13, 2015).

33   Joseph Grima lecture, 'Open-Source Architecture', www.youtube.com/watch?v=UgiyZd0YwXM (accessed February 12, 2015).

34 www.spatialagency.net/database/drop.city (accessed February 13, 2015).

35 Sandler, "An Architecture of the Whole," 114.

36 Beste Sabır and Elvia Wilk, "Global Tools: A Radical Italian Pedagogy Group from the 1970s gets

Brought Back to Life," www.uncubemagazine.com/blog/12651903 (accessed May 8, 2015).

37   Alice Rawsthorn, "Enzo Mari: A rebel with an Obsession for Form," www.nytimes.com/2008/11/03/
     style/03iht-design3.1.17414904.html?_r=0 (accessed February 12, 2015).

38   Enzo Mari, *Proposta per Un'autoprogettazione [Proposal for a Self Project]* (Bologna: Duchamp Center,
     1974).

39   Grima, "Open-Source Architecture".

40   Alan Boyd and Lucy Acheson, "Enzo Mari: Me and the Farmer*," www.smow.com/blog/2011/09/enzo-
     mari-me-and-the-farmer (accessed February 12, 2015).

41   Greg Satell, "The New Industrial Revolution*," www.digitaltonto.com/2012/the-new-industrial-revolution
     (accessed February 13, 2015). The later should not be confused with the book by Jeremy Rifkin, *The
     Third Industrial Revolution: How Lateral Power is Transforming Energy, the Economy, and the World (*New
     York: Palgrave Macmillan Trade, 2000).

42   See "A Third Industrial Revolution," *The Economist,* www.economist.com/node/21553017 (accessed
     February 12, 2015).

43   Roberto Naboni and Ingrid Paoletti, *Advanced Customization in Architectural Design and Construction*
     (Milan: Springer, 2015), 7.

44   See "Who/What qualifies as a Fab Lab?*," www.fabfoundation.org/fab-labs/fab-lab-criteria (accessed
     February 12, 2015).

45   See Matthew Rimmer in "The Two Treaties: Obama, Trade, and the State of the Union," in *The
     Conversation*, http://theconversation.com/the-two-treaties-obama-trade-and-the-state-of-the-
     union-12197 (accessed February 13, 2015).

46   Broadbent et al., *The End of the Professions?, 2.*

47   Millerson, "Dilemmas of Professionalism".

48   Alastair Parvin, "Architecture for the People by the People," Ted Talk (2013), www.ted.com/talks/alastair_
     parvin_architecture_for_the_people_by_the_people?language=en#t-99387 (accessed February 12,
     2015).

49   By "print" Parvin refers to CnC routing, not 3D printing.

50   Parvin, "Architecture (and the other 99%)," 90. Note the term "print" here refers to CnC routing of
     plywood sheets.

51   https://creativecommons.org/licenses/by-sa/4.0 (accessed February 12, 2015).

52   WikiHouse has 384,000 results on Google.

53   Parvin, "Architecture (and the other 99%)," 94.

54   The survey states that an Internet user is a person with access to the worldwide network. See http://
     data.worldbank.org/indicator/IT.NET.USER.P2.

55   "The Limits of Leapfrogging," *The Economist,* www.economist.com/node/10650775 (accessed February
     18, 2015).

56   Theodora Vardouli and Leah Buechley, "Open Source Architecture: An Exploration of Source Code and
     Access in Architectural Design," *Leonardo* 47, no. 1 (2014): 51-55.

57   Vardouli and Buechley, "Open Source Architecture," 53.

58   $100K Garage are places "for people who have designs (or just ideas for things they want to make) to
     connect with digital fabricators who can help make these ideas become real." See 100kgarages.com
     (accessed May 10, 2015).

59   www.burstopen.org/author/edrie-ortega (accessed May 12, 2015).

60   www.burstopen.org/author/edrie-ortega (accessed May 12, 2015).

61   The studio was led by the author.

62   Joseph Grima in Stead, "Losing my illusions about open-source criticism," 36.

63   Vardouli and Buechley, "Open Source Architecture," 53.

64   www.australiandesignreview.com/architecture/51668-chinese-firm-builds-tallest-3d-printed-building
     (accessed May 15, 2015).

65   Stappers & Co., "Creation and Co", 144.

66   Vardouli and Buechley, "Open Source Architecture," 54.

67   Broadbent et al., *The End of the Professions?, 2.*

68   Stead, "Losing my illusions about open-source criticism," 123.

69   Vardouli and Buechley, "Open Source Architecture," 55.