DIY Infrastructure and the Scope of Design Practice

Jonathan Lukens

Infrastructure both supports and constrains design action. In the first case, it is a system of imbricated technologies and artifacts that provides a substrate for new products and services. Designers creating new electrically powered projects—for example, a lamp—do not need to design a system of generating, distributing, or regulating electricity. They need only ensure that the products they design are compatible with the system that already exists.

In the second case—the converse of the first—designs are limited by existing infrastructure. Newly designed products and services have to interface with existing infrastructure and are therefore beholden to the legacy of design decisions that resulted in that infrastructure. Designers have to contend with the complex social, political, and economic results of past design decisions that are embodied in infrastructure.

As an example of the significance of infrastructure to the designer, consider again the design of a lamp. A designer shapes a lamp's formal properties in terms of overlapping criteria, such as function, aesthetics, and a consideration of the cost of its components, assembly, packaging, and shipping; a consideration of its interconnection with the electrical infrastructure may require very little thought, outside of specifying the appropriate components for the country in which the lamp will be used. The designer operates under the assumption that once the lamp is designed to interface correctly with the electrical system of a particular place, the electricity will be supplied. The degree to which the designer does not have to consider the electrical system speaks to the ubiquity and invisibility of infrastructure.

Nonetheless, the electrical infrastructure, itself an agglomeration of years of design decisions, is absolutely necessary for the lamp to function. Infrastructure limits the scope of design action. It separates what might be considered reasonable—designing a lamp—from something that might not be considered at all—redesigning the electrical grid.

By definition, infrastructure is an example of what Ivan Illich called a radical monopoly: a situation in which the ubiquity of a tool or service is so great that its use becomes compulsory,

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thus creating social control through design.[1] For example, the automobile possesses a radical monopoly in many cities like Los Angeles or Atlanta. As more design decisions are made to accommodate automobile traffic, the radical monopoly of the automobile increases.[2] Its widespread use might limit the ability to travel by other means.

Recently, however, some designers have begun to expose and challenge the radical monopoly of existing infrastructure. Through a series of DIY infrastructure projects, non-experts are building alternative infrastructural systems or modifying existing ones. These projects reveal the way that our lives are regulated by the design of technical systems. They question the contingent nature of modern life—the ability of infrastructure to withstand disruption—and erode the ontological separation between infrastructure and society. They reveal the relationship between design, infrastructure, and political authority.

In some ways, these projects reveal a change in the scope of design practice, with new actors designing systems and services that previously were within the domain of small groups of experts. Today's design decisions are influenced by long-established social and technological relationships—the aggregate result of many previous design decisions and their effects. DIY infrastructure projects detail the overlooked attributes of these decisions.

Writing on the sometimes stultifying perception of infrastructure as monolithic, Paul Edwards describes the "sense that infrastructures are beyond the control of individuals, small groups, or even perhaps of any form of social action, and that they exert power of their own."[3] This characterization highlights two of the more significant characteristics of DIY infrastructure design: First, they might represent a possible systemic change wrought by new technologies. In the case of DIY infrastructure, we might see that individuals and small groups do have the capacity to "exert power on their own," challenging the radical monopoly of infrastructure.[4] Second, even if DIY infrastructure projects prove quixotic and incapable of initiating such systemic change, they still can prove valuable because they reveal the degree to which design decisions are informed and restricted by the radical monopoly of infrastructure. Specifically, they highlight infrastructure's embodiment of political authority and the contingent nature of modern life.

This paper has three main sections. In the first, I discuss the radical monopoly of infrastructure, the properties of infrastructure, and the ways that infrastructure constitutes a sort of regulation through design. In the second, I present a challenge to the restrictions laid out in the first by discussing a DIY infrastructure project called Cloacina in detail. In the third, I conclude the paper by discussing the relevance of the challenges posed by Cloacina and DIY infrastructure projects in general to the work of designers and design researchers at large.

1 Ivan Illich, *Tools for Conviviality* (New York: Harper & Row, 1973), 52-54.

2 Ibid, 51.

3 Paul N. Edwards, "Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems," in T. J. Misa, P. Brey and A. Feenberg (eds.), *Modernity and Technology* (Cambridge, MA: MIT Press, 2003), 185-225. Edwards is the director of the University of Michigan's Science, Technology, and Society Program and has written extensively on the subject.

4 Ibid.

On Infrastructure

Infrastructure has several significant attributes. In the following sections, I discuss those properties, call attention to some non-mechanical factors which inform them, and explain infrastructure as an embodiment of political authority.

Properties of Infrastructure

A thorough discussion of DIY infrastructure demands a clear formulation of the properties of all infrastructures. To that end, I call on Susan Leigh Star's germinal article, "The Ethnography of Infrastructure."[5] In Table 1, I revisit the rubric she presents in the article, sometimes giving examples or commenting on the political nature of each of the characteristics discussed.[6]

5 Susan Leigh Star, "The Ethnography of Infrastructure," *American Behavioral Scientist* 43, no. 3 (1999): 377-91.

6 Ibid., 381.

Table 1 *Properties of Infrastructure with Examples*

Properties	**Examples**
Embedded Infrastructure is "sunk into and inside of other social structures,... arrangements, and technologies. People do not necessarily distinguish the several coordinated aspects of infrastructure."	Services such as television, internet access, and phone service, may be viewed as one amorphous utility, even though they may involve the coordination of distinct service providers, hardware and cabling systems, and software protocols.
Transparent It supports tasks invisibly and does not have to be reproduced or reassembled to facilitate action. It is already assembled and functioning. Infrastructures are the unseen substrates of informational and physical spaces.	Infrastructure is often only revealed when it ceases to function properly. The complexity of above- and below-ground telephone cabling, routing, and switching (not to mention the people who build and maintain these systems) may all go unnoticed until someone picks up the receiver and hears no dial tone.
Extended in reach or scope Infrastructure has reach or scope "beyond a single event or one-site practice."	Bathtubs, sinks, and toilets are thought of as separate devices, but they are really inputs and outputs to the larger plumbing system of a residence, and that residence is both an input and output of a larger system of water delivery and waste management.
Learned as part of membership "Strangers and outsiders encounter infrastructure as a target object to be learned about. New participants acquire a naturalized familiarity with its objects as they become members."	Toilet training is an almost universal experience with a human machine interface designed to both facilitate and obfuscate the infrastructure of waste disposal.
Interfacing Infrastructure achieves its transparency by interfacing with existing infrastructures and their inherent protocols and standards.	Examples include the design of packaging to comply with palletized and containerized shipping, and the standardization of the potato genome to facilitate the large-scale production of french fries.
Limited by the base upon which the infrastructure is installed	For example, computers depend on the existing electrical system.
Incremental repair Infrastructure is repaired "in increments—not all at once or globally."	If I find that I am unable to check my email, I need to determine whether the problem resides in my email client, my computer's wireless connection to my router, or my router's connection to my modem, with my email server and its attendant connections to the internet, or with any of the numerous exchanges and interconnects in-between.

The properties described by Star and detailed in Table 1 highlight the reach of infrastructure's radical monopoly. Note that these qualities extend the reach across the globe, making difficult the separation of infrastructure's importance from the practices and transactions it enables. According to Edwards, infrastructures "co-construct—the condition of modernity" and function as the "connective tissues […] and circulatory systems of modernity." Without systems such as transportation, electrical power, and waste disposal, we might find ourselves in an uncomfortable position—bearing a remarkable similarity to the people we deem "primitive."[7]

As such, infrastructure is a sort of wicked problem in a black box. As discussed by Rittel and Webber and by Buchanan, wicked problems are messy and indeterminate or, to use Star's phrase, extended in reach or scope.[8] As with other wicked problems, the boundaries of infrastructure are difficult to isolate, and the effects of a designer's interaction with it may have unanticipated consequences.

Non-Mechanical Factors

As an example of this indeterminacy, designers have to consider non-mechanical factors. The term infrastructure does not *just* refer to mechanical components, such as "'hard' technologies ('ducts, pipes and wires'), 'soft' technologies (computer software, networks, and the World Wide Web), and socio-technologies (bureaucracies, rules and procedures)."[9] It also includes "human operators and complex networks of relationships between the internal workings of the system and the outside environment in which it operates."[10] Edwards elaborates on this expansive understanding, adding to these criteria "socially communicated background knowledge, general acceptance and reliance, and near-ubiquitous accessibility."[11] All of these factors are especially appropriate because they are not limited to objects: They include human and nonhuman actors and their dialogue with those objects. This dialogue is in flux and might include adaption to these objects, including the possibility of their modification. For example, the designers of Cloacina, whose work is discussed at length in the next section, contend with the ways that the toilets they design interface with the cultural norms of human waste disposal as much as they contend with the physical construction of toilets and the logistics of moving waste.

Political Authority

The design of infrastructure embodies political authority in a few specific ways: as a signifier of the allocation of resources, as a platform for the generation of resources, and as a regulator of behavior. First, the design of infrastructure is political in its expression of societal values because it serves as a conspicuous signifier of the

7 Paul N. Edwards, "Infrastructure and Modernity," 188. We must acknowledge the regional bias of this text. In many ways, the worthiness of DIY infrastructure as an object of study is related to its contrast to the "established" infrastructural systems we rely on in the "developed" world. Of course, for many of the world's people, *all* infrastructure is DIY. As Edwards states, the "notion of infrastructure as an invisible, smooth-functioning background 'works' only in the developed world."

8 Horst W. J. Rittel and Melvin M. Webber, "Dilemmas in a General Theory of Planning," *Policy Sciences* 4 (1973): 155-69; R. Buchanan, "Wicked Problems in Design Thinking," *Design Issues* 8, no. 2 (1992): 5-21.

9 Matthew Jude Egan, "Anticipating Future Vulnerability: Defining Characteristics of Increasingly Critical Infrastructure-Like Systems," *Journal of Contingencies and Crisis Management* 15, no. 1 (2007): 4–17, 6.

10 Ibid.

11 Paul N. Edwards, "Infrastructure and Modernity," 188.

way that a society allocates resources. The design of the V. I. Lenin Order of Lenin Leningrad Metropoliten and the Dwight D. Eisenhower National System of Interstate and Defense Highways are distinct expressions of the cultures in which they are situated, embodying different ideas of universal access to transportation and different strategies for surviving a nuclear exchange.

Second, the design of infrastructure today affects the generation of wealth tomorrow. The allocation of today's resources—expressed through infrastructural design, as well as through infrastructure's maintenance or neglect—affects the development of future resources. Infrastructure might provide a substrate or platform for the generation of future resources. As such, the design decisions also raise the issue of equitable distribution of resources. Here, we can consider things such as the so-called "last mile problem" and the "digital divide." The former is a term for the cost of connecting individual residences to telecommunication infrastructure: Because rural residences may be significantly farther from central hubs than those in urban areas, connecting them might be more costly. This added cost might keep service providers from connecting them at all. The latter refers to the effect of socio-economic inequality on access to information and communication technologies.

Third, and in conjunction with the properties previously described, the design of infrastructure can also function as the regulator of behavior. This regulation can be deliberate, as in the case of "architectures of control"—a term referring to the regulation of behavior through the design of objects and systems, as opposed to regulation through laws, norms, or market forces.[12] For example, adding speed bumps to a busy street is an attempt to control behavior through the design of the street itself, while lowering the speed limit on that street or increasing its enforcement is an attempt to control behavior through law.

Of course, the radical monopoly of infrastructure means that regulation also arises as a consequence of its design. As Illich argued, radical monopoly "constitutes a special kind of social control because it is enforced by means of the imposed consumption of a standard product." To make a similar point, Edwards paraphrases Langdon Winner, arguing that "infrastructures act like laws. They create both opportunities and limits; they promote some interests at the expense of others. To live within the multiple, interlocking infrastructures of modern societies is to know one's place in gigantic systems that both enable and constrain us. The automobile/road infrastructure, for example, allows us to move around at great speed, but also defines where it is possible to go; only a few modern people travel far on foot to places where there are no roads."[13]

12 Lawrence Lessig, *Code,* 123.

13 Paul N. Edwards, "Infrastructure and Modernity," 191.

Infrastructure also limits future design possibilities through path dependence. Standards emerge after a user base exceeds a critical mass, and these standards create increasing pressure for designers to comply with them.[14] New designs are constrained by the expectation of being interoperable with existing designed systems, even if those systems were designed poorly or were designed to address problems about which we now have new information. For example, many products were designed as if the resources required to power them would also be cheap and plentiful, and as if their use would not alter the environment in which they operate. The properties of infrastructure discussed here detail the role of design as a regulatory force and its role in constructing infrastructure's radical monopoly. They also reveal some of the overlooked constraints that the radical monopoly of infrastructure places on designers—the way that age-old design decisions harden into expectations and protocols and limit new solutions.

In the next section, I discuss a group trying to challenge the radical monopoly of existing sanitation infrastructure through design. Their work provides specific examples from design practice that are of interest to any designer dealing with the interface of design and infrastructure or cultivating an awareness of design as regulatory force.

DIY Practice

Cloacina is one of several recent design projects I call DIY infrastructure. DIY involves the creative endeavors of non-experts in areas that are currently or were once considered the job of paid technical professionals, such as carpenters and electricians. DIY activities have increased as digital tools have become available that support them directly and as social computing technologies have become available that support the exchange of information about them.

According to design historian Paul Atkinson, DIY is "a more democratic design process of self-driven, self-directed amateur design and production activity carried out more closely to the end user of the goods created."[15] Of course, the distinction between professionals and DIY practitioners has not always been easy to make, but it has blurred even more since World War I. As Atkinson argues, "part of the sustained growth of DIY as a leisure activity from the 1960s onwards may be attributable, at least in part, to a gradual de-skilling of the processes involved, reducing much of Do It Yourself to a case of self-assembly and finishing."[16] If we examine what were considered DIY activities in the 1935 book, *The Practical Man's Book of Things to Make and Do,* we see "activities that lack of time alone is likely to prevent many people from undertaking today. Manufacturers and retail chains alike have worked to

14 Ibid., 207.

15 Paul Atkinson, "Do It Yourself: Democracy and Design," *Journal of Design History* 19, no. 1 (2006): 1.

16 Ibid., 5.

develop and promote easier methods of producing the results which once required so much dedicated input through new materials and kits of parts."[17]

The affordances of infrastructure have changed the necessity of DIY practice even as they have increased it. Participation in DIY practice is possible because of the leisure time made available by the infrastructures supporting modern life. People preserve blueberries for amusement and pleasure, while they once did so for survival. According to Atkinson, "the economics of global-scale mass production have put first-world consumers in the position where necessities such as cooked food, clothes, and furniture can often be purchased for less than it would cost to purchase the raw materials to produce them themselves—even if they did possess the relevant skills to do so. In these circumstances, it is no surprise that DIY today is often not seen to be a necessity of any kind, and can only make sense if it is seen instead as a leisure pursuit or lifestyle choice."[18] The radical monopoly of infrastructure changes the significance of DIY practice and makes it about leisure, not necessity.

With regard to DIY Infrastructure, note that DIY activities have long been enabled by new technologies, and in some cases DIY practitioners using these technologies have been viewed as a threat by entrenched professional interests. Examples predate the advent of personal computing and include mixed paint in cans and the invention of the paint roller in the 1950s, as well as articles on home electrical repair. Both of these developments were seen as threats to professionals and raised complaints from the British Electrical Development Associations and the U.K. Home Office about potential dangers they posed to the public.[19]

More recently, digital media, such as social computing and other collaboration technologies, have increased participation in DIY endeavors by providing newer and often more powerful digital tools and new ways to share information.[20] Kunznetov and Paulos argue that "an emerging body of tools allows enthusiasts to collaboratively critique, brainstorm, and troubleshoot their work, often in real-time. This accessibility and decentralization has enabled large communities to form around the transfer of DIY information, attracting individuals who are curious, passionate, and/or heavily involved in DIY work."[21]

These descriptions, however, do not go far enough in recalling the relationship between DIY, innovation, and tools. After all, without the results of earlier DIY practices by groups such as the Homebrew Computer Club, or the developers of the Apache http server, many of the tools Kunznetov and Paulos mention would not exist. DIY endeavors do not just benefit from technological change; they initiate it.

17 Ibid.

18 Ibid.

19 Ibid., 6.

20 Stacey Kuznetsov and Eric Paulos, "Rise of the Expert Amateur: DIY Projects, Communities, and Cultures," Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries Reykjavik, (Iceland: October 16-20, 2010), 1.

21 Ibid.

Cloacina: An Example of DIY Infrastructure

Cloacina is a series of projects described by its participants as "peer to peer waste processing"—projects that try to facilitate urban composting as a set of "self-organizing efficient services."[22] Taking their project's name from the patron goddess of the cloaca maxima, or main artery of Rome's sewers, Matthew Lippincott and Molly Danielsson—the project's participants—are trying to change what they view as wasteful practices resulting from the design of sanitation infrastructure.[23]

One of Cloacina's stated design goals is to address the waste of water and phosphorus that results from the design of the current sanitation infrastructure. Lippincott and Danielsson work toward a redesign of sanitation systems based on a different idea of which resources are abundant or scarce. Most importantly, these resources include water (they question the contamination of valuable and increasingly scarce water by using it to move waste) and fertilizer (especially phosphorous).

Danielsson and Lippincott describe their chief motivation as the reclamation of phosphorus from human excreta to replace mineable phosphorus, a resource that they feel is nearing depletion. Lippincott describes the condition: "The ability to identify mineable phosphorus is really well established. People have searched really hard, and it's pretty much all been identified. It's pretty much all being exploited, and it's going to disappear really, really, really fast. It's not like oil. They're not going to discover more of it under the Arctic and Antarctica or be able to boil it from tar sands; they're not going to be able to exploit different small parts of this resource. It's a known quantity, and it's going away. Within my lifetime, I could see a complete resource collapse of our agricultural system, and it's completely feasible to prevent that."[24] They argue that when compared to other problems with existing infrastructure, phosphorus reclamation's relationship to infrastructural redesign is unique. For example, Lippincott argues, "with our energy infrastructure, you could make the argument that we could discover fusion power, and with our road infrastructure, you could make the argument that we can discover a new power source or new form of synthetic fuel and it could continue to work. I'm skeptical of both of those things, but it's not completely outside possibility." However, in the case of phosphorus, he adds, "you're not going to find a new molecule to bind your cell walls together. Ain't happening."

Because work was already being done with the design of residential composting toilets, and because they felt that residential change was a prohibitively expensive project, Lippincott and Danielsson took another approach. They explain: "You're trying to convince someone to change a very private and difficult space at expense, competing against flush toilets." In seeking out a more accommodating design space, they thought, "Nobody likes port-a-

22 Molly Danielsson and Mathew Lippincott, "An Unsolicited Design Review of Composting Toilets & Composting Methods," www.cloacina.org/files/an-unsolicited-design-review-sm.pdf (accessed June 20, 2012).

23 Jon C. Schladweiler, "Cloacina: Goddess of the Sewers," www.sewerhistory.org/articles/wh_era/cloacina/cloacina.pdf (accessed June 20, 2012).

24 Molly Danielsson and Mathew Lippincott, interview with Jonathan Lukens, (Pioneer Courthouse Square, Portland, OR: October 17, 2011). All remaining quotations from Danielsson and Lippincott come from this interview unless otherwise noted.

Figure 1
Toilet stalls from Cloacina field test.

Figure 2
Toilet from Cloacina field test.

potties. The construction workers don't like using port-a-potties, concert-goers don't like using port-a-potties, and no one actually likes hauling the waste." To that end, they began designing portable composting toilets as an alternative to common portable toilets that treat waste with chemicals.

Cloacina's Design Goals

In October 2011, I witnessed the first large-scale test of Cloacina's portable composting toilet system (see Figures 1 and 2). Over three days, Danielsson, Lippincott, and their students and volunteers addressed construction and maintenance factors as they arose and collected observations on their designs from users and each other. During this period of observation, and through subsequent interviews, the Cloacina project's status as an attempt to challenge a radical monopoly through design became clear. This challenge is evident in the project's design goals. Danielsson and Lippincott envision a system based on voluntary labor. They believe that "sanitation as part of a technological package that is reproducible has to involve things that people will voluntarily do." They argue that our current infrastructure is based on non-voluntary or coercive tasks, and they would like to capture the same benefits without coercion. This approach echoes Ivan Illich's assessment that radical monopoly "exists where a major tool rules out natural competence. Radical monopoly imposes compulsory consumption and thereby restricts personal autonomy."[25]

In discussing Cloacina's design goals, Lippincott is fond of historical examples. He argues that explorers like Magellan travelled the world equipped with everything needed to repair and reproduce the technologies on which he and his crew depended. For example, their ships carried a blacksmith and carpenter, and Magellan's crew rebuilt their boats in Indonesia before returning home. He laments the fact that these sort of encapsulated tool sets

25 Ivan Illich, *Tools for Convivality* (1973), 53.

are gone, saying "when your equipment breaks in the middle of nowhere, you don't have any ability to remake it. You don't have any ability to sustain it." Compare this with Illich's characterization of radical monopoly: "The establishment of radical monopoly happens when people give up their native ability to do what they can do for themselves and for each other, in exchange for something 'better' that can be done for them only by a major tool. Radical monopoly reflects the industrial institutionalization of values. It substitutes the standard package for the personal response."[26]

So Cloacina's design goals challenge radical monopoly conceptually, and their design work is a challenge to the radical monopoly of sanitation infrastructure, but what can other designers and design researchers learn from these challenges? In the next section, I discuss these difficulties in challenging radical monopoly through design by drawing two points from Cloacina's design practice.

Radical Monopoly Challenged Through Design

Cloacina's work is an attempt to challenge radical monopoly by design; it thus suggests that large technical systems are not immutable and that history shows us that that very real change can happen in a short span of time.

When asked about redesigning infrastructure, Danielsson and Lippincott reply that "most cities in the world were all sewered up in the course of a very short period of time." So when people argue that the redesign of infrastructure is impossible, they need to recall that "the public at large was convinced to pay for the most expensive pieces of public infrastructure in the history of mankind—our water and sewer systems—and [recall] the fact that that happened in such a short period of time." They continue: "There is a significant historical precedent for a massive infrastructural shift in a short time scale: […] People in cities were almost universally using the toilet in buckets, and they were flushing their toilets within 15 years." So, why is it not possible that they could be using a different system 15 years from now?

In Illich's words, "the cost of radical monopoly is already borne by the public and will be broken only if the public realizes that it would be better off paying the costs of ending the monopoly than by continuing to pay for its maintenance."[27] Cloacina's designs are an attempt to articulate the costs of ending the radical monopoly of sanitation infrastructure. Their designs are an attempt to show how an alternative system would work and to offer a critique of—what they feel are—the myths of the existing system.

Valorization of Existing Monopolies

During my interview with Danielsson and Lippincott, they argued that a critical mass of established designs can become valorized, making historical design decisions more difficult to question. They

26 Ibid., 54.

27 Ibid., 56.

feel that their designs challenge the way that people imagine and perceive the function and benefits of the current sanitation infrastructure.

For example, they mention the "gross factor," according to which people are reluctant to use a composting toilet because they feel they will be exposed to excrement and germs, but add that most people do not evaluate the degree to which those things are present in their current situation. "Their toilet backs up and overflows into their bathroom about once a year, and, in a normal bathroom there's a toilet brush with microscopic amounts of feces dripping water onto the floor and a plunger right next to it doing the exact same thing."

They also feel that this unquestioning faith in the validity of past design decisions has lent itself to a sort of revisionist history. In other words, the phrase that "history is written by the winners" can be rephrased to recognize that "history is written by the designs with the largest user base." For example, Danielsson and Lippincott are resistant to the "idea that the flush toilet has a historical role in the prevention of human disease," claiming that "if you look at statistics on deaths in Paris—one of the first cities to completely sewer up—their sewers prevented deaths from cholera but increased deaths from typhoid. There was no related reduction in enteric diseases" until after the introduction of plumbed and chlorinated water. "Essentially," they add, "it's not about preventing excrement from entering the water; […] it's about poisoning the water so that the excrement can't kill you. That's really the only effective part of our modern sanitation system that's actually doing something to prevent diseases." In actuality, they argue, sewers were designed to prevent miasmas: pockets of alleged "bad air" that were blamed for diseases. According to Danielsson and Lippincott, the sanitation infrastructure we have today was designed in accordance with this now discredited theory of disease. "[T]he infrastructure precedes the modern understanding of disease. It does not arise from it [...] [t]he story is largely told from the opposite direction."

Much of the work of the designer challenging existing infrastructure involves design as a critique of this valorization. According to Lippincott, "The biggest problem in the field right now is that people can't imagine a different system, and they have no experience with anything different. If all we did was to help establish enough publicly accessible case studies so that this stuff was on people's radar, I would feel pretty happy with that."

Whether Cloacina will succeed or fail in redesigning sanitation infrastructure, or even in provoking discussion about the myriad issues affected by its design, remains to be seen. Nonetheless, the project is valuable in its capacity to bring the otherwise invisible force of infrastructure to light, and it reveals the influence of past designs on future designs. As designers become increasingly aware of the complexity of forces their designs influence and are subject to, projects that employ design to trace and challenge the often invisible constraints of those forces allow us to reassess the space of design action and its results.

DIY Infrastructure and the Scope of Design Practice

Understanding the relationship of their practice to infrastructure or other large entrenched systems can be difficult for designers. Projects such as Cloacina raise a host of significant issues for designers, but again, how DIY infrastructure projects might initiate broader systemic change remains to be seen. How might the work of today's designers influence the grey panoply of path dependence, obduracy, and monopoly? How can the objects and systems we design extend their reach into our daily lives? The first place to look for answers is in the literature that discusses the multi-level perspective (MLP) on transitions in socio-technical systems. This MLP explains change as the result of interaction between processes at three levels. Since the late 1990s, scholars such as Frank Geels and his contemporaries have developed the MLP by drawing on evolutionary economics and the sociology of technology. As they have refined the MLP, they have applied it to various cases, such as the transition from cesspools to sewer systems in the Netherlands, body disposal practices in the UK, and the Dutch electricity system.[28] After providing a brief overview of the MLP, I explain its significance to DIY infrastructure and examine what it means for design at large.

The MLP consists of three nested levels—the broadest of which is the socio-technical landscape. This level is the domain of "macro-economics, deep cultural patterns, [and] macro-political developments."[29] Changes at this level typically take place over the course of decades. The second, or meso-level, is called the socio-technical regime. This level includes entrenched technical artifacts and designed systems, as well as standards and protocols, cognitive routines, regulations, "sunk investments in machines," infrastructures, and path-dependence.[30] The third level is that of technological niches—the level at which "radical novelties emerge."[31] According to Geels and Johan Schot, "[t]hese novelties are initially unstable sociotechnical configurations with low performance… [N]iches act as 'incubation rooms,' protecting novelties against mainstream market selection."[32] These niches address a need raised by Victor Margolin in his 1998 article, "Design for a Sustainable World," in which he argued that design thinking needs to be decoupled from its role in shaping objects for the market so that design could help to achieve sustainability.[33]

28 Frank W. Geels and René Kemp, "Dynamics in Socio-Technical Systems: Typology of Change Processes and Contrasting Case Studies," *Technology in Society* 29, no. 4 (2007): 446; Adrian Monaghan, "Conceptual Niche Management of Grassroots Innovation for Sustainability: The Case of Body Disposal Practices in the UK," *Technological Forecasting & Social Change* 76, no. 8. (2009): 1026-43; Geert Verbong and Frank Geels, "The Ongoing Energy Transition: Lessons from a Socio-Technical, Multi-Level Analysis of the Dutch Electricity System (1960–2004)," *Energy Policy* 35 (2007): 1025–37.

29 Frank W. Geels and Johan Schot, "Typology of Sociotechnical Transition Pathways," *Research Policy* 36, No. 3. (2007): 400.

30 Ibid., 399-400.

31 Ibid., 400.

32 Ibid.

33 Victor Margolin, "Design for a Sustainable World," *Design Issues* 14, no. 2 (1998): 90.

DIY infrastructure projects occupy the technological niche level while also being conscious and critical of the constraints of the socio-technical regime. The Cloacina project involves the redesign of sanitation systems and components within a protected niche. For example, the decision to focus on portable toilets instead of permanent ones is an attempt to find a suitable space for iteration insulated from the socio-technical regime level. If Cloacina's prototypes were brought to market in their current state, they would face considerable resistance at the socio-technical regime level from regulators, established businesses, and established practices and preferences. The radical monopoly of infrastructure occupies the two upper levels of the MLP.

How do these "radical novelties" move upward from the protected design space of the technological niche so that they change things in the two upper levels of socio-technical regime and socio-technical landscape? How might the work of Cloacina, or of other DIY infrastructure designers leave the protected level of the technological niche and make any substantive change? Geels explains such transitions as occurring at the interface of the three levels of the MLP at times when the states of the individual levels align in particular ways. For example, innovations at the technological niche level might gain traction because of improvements on previous designs or support from external groups. At the same time, problems at the socio-technical landscape level destabilize the socio-technical regime, creating the opportunity for niche level designs to proliferate.[34] Thus, the ability of a novel design to break through into the upper levels of the MLP is contingent on both its improvements on existing designs in use at the socio-technical regime level and on problems at that level causing disruptions in the socio-technical landscape. Together, these factors provide the opportunity for the new designs to challenge the old.

While everyday resistance to infrastructure's radical monopoly may be as banal as bicycling or as invisible as infrastructure itself, Cloacina's challenge is noteworthy because it is pursued as a design project. Activists concerned with the same issues as Cloacina tend to focus their efforts on the socio-technical regime level, for example, in attempts to change building codes. Cloacina, in focusing on building a functioning system, operates at the technological niche level. This approach allows development and refinement of prototypes in a protected space until the problems they identify at the socio-technical regime and socio-technical landscape levels provide the opportunity for a technological transition.

Cloacina pits new designers against old designs, extending research and criticism into the environment of design decisions of the past. It brings infrastructure—the invisible—into the

34 Ibid.

foreground and exposes its significance to designers. Because infrastructure is as much a product of social arrangements as it is one of material components, Cloacina's work displays a flexibility that many product- and market-oriented design endeavors cannot. Supporting Margolin's assertion that "[w]hen design is not limited to material products, design can intervene within organizations and situations in a greater number of ways," Cloacina uses design to critique and reapply design's own regulatory force.[35]

The number of DIY infrastructure projects is increasing, including projects in logistics, telecommunications, and agriculture. Future scholarship of DIY infrastructure likely will investigate these individual projects. These investigations—and the projects themselves—will give us new ways of thinking about the reciprocal relationships between design, infrastructure, and regulation, and about design's place in technological transitions.

35 Victor Margolin, "Global Expansion or Global Equilibrium? Design and the World Situation," *Design Issues* 12, no. 2 (1996): 31.