ors, while left in great disarray
ears of abandonment, can serve
luable model for economic re-
pment. This is an approach that
renewable energy and green-
actices for future redevelop-
and creates jobs for residents
r aging commercial corridors.
h civic engagement and lea-
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e district.

s of the transformation of the beltline's
structure shot by Elke Eichmann
g the mobile workshop as part of
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The Mechanics of Invisibility:
On Habit and Routine as
Elements of Infrastructure

Paul N. Edwards

Infrastructure is rendered invisible
through familiarity. From transit
to the toilet, Paul N. Edwards shows
how the invisibility of infrastructure
also contributes -to the persistence
of injustice long after a change in
governance through the example of
post-Apartheid South Africa.

Infrastructures are often said to be
"invisible" or "transparent," in the
sense that they typically recede into
the background of everyday life.
Because mature infrastructures "just
work," they almost never enter our
consciousness. (When was the last
time you thought much about your
municipal sewage treatment plant, or
the sewers that connect you to it?)
When they fail—with consequences
ranging from minor inconvenience to
national catastrophe—maps, manuals,
and how-things-work sites sprout like
digital mushrooms on the Internet.
Once the crisis passes, we forget
them again. The lights come on, the
levees hold, the toilet flushes away
our waste, and cute animal videos
flow freely on the Internet. We go

back to living in and on infrastructures
we rarely notice.

When you read the preced-
ing paragraph, some of you—most
likely from prosperous parts of the
Global North—probably nodded
to yourselves: "Yes, it happens like
that." Others—most likely from the
Global South, or poor areas of the
North—thought, instead: "Not in my
world." For the majority of people, a
lot of infrastructure never becomes
transparent. Electricity goes on and
off randomly, or is only available at
specified hours. Water in the pipes (if
they exist) isn't reliably clean or free
of poisons. Absent a sewer system,
human waste can't be flushed away,
but only bagged, buried, or left to
dry. Internet access is too expensive
or completely unavailable, as well
as useless for most day-to-day con-
cerns. So the infrastructural transpar-
ency that concerns me here is a state
of privilege, one that remains nonexis-
tent or merely aspirational for billions
of people. Acknowledging this limited
perspective, it's still worth asking: Ex-
actly how does infrastructure become
transparent to users? What are the
mechanics of its invisibility?

Socio-technical Systems and
Individual Behavior

Most infrastructures can be character-
ized as complex, adaptive socio-tech-
nical systems, made up of many inter-
acting agents and components. Some
of these components are technologi-
cal: buildings, devices, software, and
other artifacts. Others may be social:

organizations, standards, laws, budgets, or political arrangements. Finally, some components are the individuals who contribute to the infrastructure's development and maintenance, or simply make use of it in their daily lives.

Over time and in differing circumstances, relationships among these elements often shift. One typical trajectory reduces the role of individual action (choices, skills, behavior) by replacing it with social mechanisms such as organizations, laws, and standards, and/or technological elements such as sensors and software. Yet it is equally possible, and sometimes desirable, to move in the other direction, replacing social and/or technological mechanisms with individual choice and action.[1]

Consider just one aspect of the automobile-roadway-fuel infrastructure: the speed limit. What socio-technical configurations create and support this limit? Normally, speed limits are set by law, in a process that involves legislatures, traffic engineers, and standards, but there are other aspects as well. The car's top speed is of course restricted by technical characteristics of its drivetrain, but since top speed is typically much higher than the legal speed limit, it's not really a constraint. Airbags and other safety technology can raise the threshold of socially or politically reasonable speeds. The technical characteristics of roadways also play a role. A deeply pitted, wet, muddy dirt road can slow drivers to a crawl, while the radius and banking of a highway curve sets a higher but equally absolute limit. Liability law governing traffic accidents in turn influences the cost of automobile insurance. The latter often rises dramatically if drivers receive multiple speeding tickets, with significant effects on subsequent driver behavior. The speed limit may be enforced by traffic police (human individuals) using radar guns and police cars (technology), backed by the authority of the legal system (social)—but in some jurisdictions, police officers have been partially or entirely replaced by automatic cameras and sophisticated software that photograph speeding cars, read their license numbers, and send out notices of violation, all with virtually no human or organizational participation.

In this example, the effects of different socio-technical configurations on driver behavior are striking. With enforcement by police officers, actual average driving speeds are typically 10 to 30 percent above legal limits, but in countries where automatic traffic cameras are widely deployed, such as France and South Africa, most drivers have adapted to keeping within the legal limit. A traffic-calming technique successfully used in the Netherlands involves removing all traffic controls from intersections, under the logic that lacking stop signs, yield signs, or traffic lights, drivers will pay greater attention to the immediate situation.[2] In the United Kingdom, speed bumps are known as "sleeping policemen," a name that clearly captures how they replace human enforcers with lumps of asphalt. The fact that human drivers rarely follow traffic laws to the letter has recently been underscored by accidents involving Google self-driving cars, which *do* follow laws to the letter—behavior unexpected by human drivers.[3]

Hiding in Plain Sight

One major mechanism of infrastructural transparency is obvious: we deliberately hide it. Wallboard conceals electrical wiring, plumbing, and gas lines. Cellular telephone transceivers peek out from the leaves of fake palm trees. In office buildings, routers, Internet servers, and telephone switches are relegated to closets, while Ethernet cabling snakes unobtrusively through drop ceilings. A lot of infrastructure is literally buried: natural gas lines, sewer systems, subway trains and stations, underground parking garages, stormwater drainage systems, and cables for television, telephone, and electric power.

A second way that infrastructures become invisible is through the perceptual mechanism of *habituation*. Human attention naturally focuses on what changes, rather than what remains constant, in any situation. Whether natural or human-made, elements of the environment that remain stable tend to disappear from our awareness. You notice the refrigerator's hum when it starts up, but after a few seconds it fades entirely from your consciousness—until it stops and you briefly notice it again.

Infrastructure also becomes transparent in another, less obvious way: it becomes embedded in the *habits and skills* of individuals. In a process I sometimes facetiously call "infrastructuration" (punning on Giddens's notion of "structuration"), infrastructure both shapes and is recreated by the continual performances or rehearsals of agents.[4] In addition to their skill in piloting their own cars and reacting appropriately to traffic signals and signs, drivers' reactions become finely attuned to minute signals from other vehicles that express the driver's state of mind: hesitation, drunken or distracted weaving, timidity, aggressiveness. Experienced motorists can drive safely while conducting complex conversations or listening to music, traveling for long periods with little or no conscious awareness of what they are doing. These habits and skills, acquired through frequent and ongoing practice, play vital roles in the smooth functioning of virtually all infrastructures.[5] At the same time, they shape the infrastructure itself, governing, for example, what counts as a safe speed, and other norms of driving.

Encounters with unfamiliar versions of infrastructure are part of what makes foreign travel both so interesting and so exhausting. Deeply entrenched habits must be deliberately, and with effort, suppressed in favor of (first) slow, cautious, conscious decision-making and (later, as they become ingrained) new habits.[6] Take driving on the "other" side of the road (whichever that may be for you). I lived in South Africa in 2003 and 2004, driving on the left-hand side (the opposite of my native American pattern). By the time I left, it had become so

habitual that when I watched an American film, my right foot would press involuntarily on an imaginary brake when somebody sped off in the right-hand lane. Everybody who's made this transition knows that the most dangerous moments lie not in the new situation, whose strangeness makes you nervous and alert. Instead, it's returning to your old situation, where you relax too quickly, expecting your old reflexes to return.

The social analogues of individual habits and skills are *social norms* and *organizational routines*.[7] These, too, are ways of black-boxing action patterns that may once have been deliberately chosen or designed. Norms and routines reduce the burden of decision-making and limit uncertainty in interactions by providing ready-made scripts. In the case of infrastructure, they do more than this; they become, in a sense, *components* of infrastructure, elements of its function on which users, maintainers, and builders can all tacitly rely. An intriguing example of this is how the habit of left- or right-lane driving carries over into other contexts, becoming a social norm in informal rights-of-way as well. If you're descending a staircase and meet someone coming up, which way do you move? In the United States it's to the right, but in South Africa, the United Kingdom, or Australia, it's to the left. You get in your lane, as it were. The same goes for sidewalks, unmarked parking lots, queues, and virtually any other public space. This quasi-automatic behavior is a manifestation of an infrastructural standard that exists as law on the road, but equally as social norm and individual habit in other rights-of-way.

Another simple example is the standard placement of light switches. In American buildings, these are usually at approximately the elbow height of an average man. An architect friend of mine designed several of his own houses with light switches placed, instead, about sixteen inches lower. When I asked him why, he replied: "Because that's where your hand is." Fair enough—but because most buildings use the elbow-height standard, when I spent a few weeks in two of his houses, I found myself constantly fumbling for the switches in the wrong place. The standard height, by contrast, permits the habit of flicking the switch to transfer among most buildings—functioning effectively as a component of the infrastructure's operation and a mechanism of its transparency.

Apartheid as Infrastructure

South Africa, where I lived with my family for thirteen months from, provides a striking illustration of how the mechanics of invisibility aid in the persistence of social norms, laws, and standards. During the apartheid era (1948–1994), South Africa's central government was controlled by a white minority determined to subordinate and control the people of color on whose criminally inexpensive labor it mainly relied. Supported by the vast wealth of its white-owned mining industry, that government grew powerful in large part by building new infrastructures. Apartheid ideology promoted "separate development" paths for the various races and ethnic groups, so major infrastructures were built or improved chiefly to benefit the white population. In white-run cities and towns, government departments and government-owned "parastatal" corporations constructed superhighways, railroad lines, water supply systems, electric power grids, a telephone system, television networks, and all the other apparatuses of developed societies. These projects helped apartheid leaders to construct an image of South Africa as part of "the West," holding the line against African communist insurgencies as a key Cold War partner of the United States and the United Kingdom.[8] Meanwhile, black townships and rural areas, especially the so-called homelands, fell far behind—not only because the government invested far less money in those areas, but also because it chose much lower quality standards and focused on different things: housing, schools, and health services, rather than transportation, electrification, and communication.

"Separate development" meant different yet intricately interconnected and overlapping infrastructures for blacks and whites. As in the segregated American South, laws required separate public facilities for blacks and whites, including bathrooms, waiting areas, railway cars, and buses. In other words, the architectural principles of virtually all South African infrastructure were technopolitical:[9] just as in the segregated American South, many infrastructures were deliberately designed to enforce, perpetuate, and strengthen the separation of racial groups. Yet these infrastructures also had to facilitate the massive daily movement of black labor into (and out of) white spaces.

The inherent contradiction between these two aims often forced secondary elaborations of infrastructure. In the 1960s, blacks living close to Johannesburg were forcibly resettled in the South Western Townships (known today as Soweto), about fifteen kilometers from the city center. Public buses and a railway line provided commuter transport to inner-city workplaces. (In the late 1960s, with the advent of "bullet trains" in Japan, apartheid planners fantasized about moving black workers to "homelands" hundreds of kilometers from the city, linked to white urban areas by high-speed commuter rail. Planning went quite far before the South African railway services nixed the idea on the basis of cost and practicality.) The inadequate speed and capacity of "their" transport system forced Soweto-based workers to spend up to five or six hours commuting each day. Walking the fifteen kilometers (over nine miles) to work was often the fastest way to get there. Meanwhile, whites-only buses and train cars often rode empty.

Demolishing apartheid's politico-legal context was easy and fast compared with eliminating these infrastructural forms of segregation. To this day, city neighborhoods and townships remain strongly identified with partic-

ular racial groups. Though a few white people have moved into areas like Soweto, for the most part whites regard black areas as too dangerous to enter. The irony, of course, is that millions of black people enter white areas on a daily basis—just as they did under apartheid—to service their homes and gardens, care for their children, and staff their businesses.

Fig. 1: Rubbish piles up next to chemical toilets in the township of Dunoon in Cape Town during April 2009 as a row over who will get jobs in a new Cape Town waste removal tender remains unresolved.

Public Transportation

South Africa's public transport systems, too, remain racially coded. When the influx control laws preventing blacks from living in white areas were abolished in 1985, poor black people poured into the major cities. Existing public transport couldn't handle the load. Bowing to pressure, the government deregulated taxi services in 1987, and hundreds of black operators began acquiring fifteen-seat minibus-

es. The "kombi taxi" or minibus taxi industry rapidly mushroomed into the country's single largest black-owned business sector, with revenues of R39.8 billion (about $3.7 billion) on an estimated 250,000 vehicles by 2014. It plays a huge role in the lives of urban poor people, not only by providing transport but through knock-on economic opportunities, such as vehicle maintenance services and the street markets that spring up around taxi ranks (pickup points). The minibus taxi system operates in parallel with much more expensive radio taxis (cars) of the type more familiar to Americans or Europeans; most of the faces emerging from these vehicles are white.

The kombi taxis are typically Toyota vans with three or four bench seats. They are designed for a maximum of fifteen passengers, but it is not uncommon to see twenty or more people crammed into a single vehicle. These vehicles account for some 65 percent of all passenger travel in South Africa—yet it is rare to see a white face inside one. The system extends to most of the country, not only within cities but even on long-haul intercity routes such as Johannesburg to Cape Town (about 1,400 km). In rural areas, there is a similar system of "bakkie taxis" (pickup trucks) for travel on dirt roads too rough for the minibus suspensions.

Driving in Johannesburg one morning with my radio tuned to a popular talk show, I listened in disbelief as an outraged white caller railed against South Africa's supposed lack of good public transport. The well-meaning

caller expressed, unknowingly, the habitual racial division surrounding transportation. It is true that the minibus taxis are privately owned, and they do have limits; few minibus taxis, for example, operate after around 7:00 p.m. Furthermore, they can be dangerous, and not only because of overloading and risky driving. Territorial "taxi wars" over access to passenger loading zones extend to gunfights and murders; while we were there, taxi drivers fought half a dozen pitched battles in various parts of Durban, sometimes in the midst of crowded commute-hour taxi ranks. To stem the violence, the government has engaged in efforts to regain regulatory control[10], as well as to "recapitalize" the aging and increasingly dangerous taxi fleet. Though initiated in 1999, these efforts still have not fully succeeded in their goal of bringing the minibus taxi system into the formal economy as a mainline public transport service.[11]

Still, they operate more cheaply and efficiently than many American or European public transit systems. The minibuses nearly always travel filled to capacity (or beyond). In 2004, the city of Johannesburg, its roadways choked by rush-hour traffic, began debating construction of new subway and rail lines. Yet if all the commuters in their private cars would hop into minibus taxis instead, Joburg wouldn't need them. Like infrastructure planners everywhere, those in South Africa thus find that their greatest challenges involve unseating entrenched habits and norms.

The Apartheid Toilet

The physical architecture of apartheid extended into private spaces as well as public infrastructure. Separate, outdoor bathrooms for nonwhite domestic workers were a typical feature of housing built for well-to-do whites throughout the period. When we lived in Durban in 2003–4, our house had one of these, in a filthy spot behind the garage, next to the garbage cans.

Fig. 2: The City of Cape Town's installation of toilets without enclosures in the area of Makhaza, Khayelitsha, as part of service delivery, stirred violent protests in May 2010 over issues of dignity following the African National Congress Youth League's complaints to the South African Human Rights Commission. The City claimed residents agreed more toilets could be provided with the available budget if they took on the responsibility of completing their own structures around the toilets.

It was a flush toilet without a seat, with a shower directly in front of it, so that you would be staring into the toilet bowl while showering. It had no

roof or any other enclosure, though some minimal privacy was provided by its position between the garage and the wall of the compound. When I first discovered this a few weeks after arriving, I thought it was abandoned. We were astonished to learn that our housekeeper Henrietta had been using it throughout the sixteen years she had worked in that building under various owners. Henrietta was equally shocked when we asked her to please use the bathroom inside. Old habits die hard; it took her a few weeks to take us at our word.

Fig. 3: An informal settlement resident uses the water tap outside toilets which are locked by certain residents. Calls for the ward councillor to resolve the situation have been ignored.

We soon learned that this expectation was still widely accepted. At an expensive B&B in trendy Melville, near Johannesburg, the white owner—a well-known journalist, now deceased—constantly and ostentatiously dropped what South Africans would call her "struggle credentials," such as a prom-inently placed picture of herself with Nelson Mandela. She herself used the indoor toilet near the sitting room. Yet her black staff were required to use the apartheid-era outdoor toilet. She gruffly ordered our black nanny—for whom we had rented a room, at full price, for a week—to use that toilet as well, though it was wintertime and quite cold. Separate facilities like these cannot enforce racial segregation by themselves, but *combined with deeply ingrained habits and norms,* they helped it to persist.

Toilet Wars

In 2009, Cape Town erected modern porcelain flush toilets in Makhaza, an informal settlement in the larger Khayelitsha suburb that houses some 400,000 mostly black South Africans (primarily of the Xhosa ethnicity). Prior to that, residents of Makhaza had employed the so-called flying toilet or bucket system: defecating or urinating into plastic bags or buckets, then hurling the waste into a nearby wetland. The flush toilets were a huge improvement, except for one thing: some fifty of them remained completely unenclosed, sitting on concrete pads right out in the open.

The backstory of this bizarre situation is complicated. In Makhaza, the Cape Town government had installed one toilet per family, an upgrade from the national standard of one toilet for every five families in informal settlements. In return, the council expected residents to build their own enclosures for these toilets, in a kind of cost-shar-ing arrangement. Most agreed, and residents did in fact build enclosures for 1,265 of the 1,316 toilets installed. However, some citizens of Makhaza claimed they could not afford to pay for the enclosures. A long, complex, mostly local political battle ensued, widely known as the "Cape Town toilet wars." Its details need not concern us here; the upshot was that for several years, Makhaza had about fifty modern flush toilets without enclosures. To maintain some shred of dignity, residents covered themselves with blankets while sitting on the exposed toilets.

Here, my point is simply to emphasize how much infrastructure incorporates and depends on habits and norms. As Steve Robins has pointed out[12], published photos of the "anti-dignity toilets" in Makhaza struck a nerve, outraging many residents—*despite the fact that for many years previously, open defecation and urination had been the habit and norm in exactly the same area.* The stark imagery of the exposed white porcelain toilet beside a residential street, in a crowded neighborhood with people walking by, had an almost pornographic character. Literally stripped of its normal enclosure, the naked toilet effectively revealed the norm of open defecation, forcing residents to do it even more publicly than before. This transformed the norm from invisible necessity to visible obscenity, insulting the dignity of people who understood that flush toilets and sewers are not merely waste-disposal technology, but part of a socio-technical package *that includes more stringent norms of privacy.*

In the South African context, the naked toilet stood as a symbol of ongoing inequality and incomplete infrastructure: graffiti posted nearby read: "Give us houses, not toilets." Robins and others interpret this to mean that residents wanted houses with their own indoor toilets, rather than out-houses, even ones with flush toilets.

Fig. 4: Children from the Sweet Home informal settlement drag a portable toilet onto Lansdowne Road before setting fire to it in protest against their ward councillor who they say has done nothing to improve their living conditions.

It may also have conjured up, for some, images of the outdoor apartheid toilets in white-owned houses, as described above (though in many cases, even those offered more privacy than the ones in Makhaza).

Conclusion

The infrastructures built under apartheid persist, in part, because people keep on doing what they have always done. Of course, this is not particular to South Africa; it's everywhere. Hav-

ing lived for long periods of time in foreign countries with customs very different from what I am used to, I've seen new habits entrench themselves in my own life. Watching this process closely has helped me understand (among other things) why and how racial segregation can persist *de facto* when it is no longer *de jure*.

We conceal infrastructure physically when we can, but it becomes invisible in other ways as well. One of those is through the acquisition of habits, skills, and social norms. These should be seen as vital components of infrastructure—they help explain how infrastructures work and why they endure. And habits, as we all know, die hard.

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Transformative Capacity of Resilience: Learning from Rebuild by Design

Henk Ovink

In 2012, Rebuild by Design was inaugurated as a new kind of design competition, aiming to combine public-private collaboration whilst setting a new standard for resilient development. Its developer, Henk Ovink, explains the approach behind the initiative, part of President Obama's Hurricane Sandy Rebuilding Task Force, and identifies six key lessons that can be learnt from the project.

Contemporary Context

The annual Global Risks Perception Survey released by the World Economic Forum (WEF) repeatedly proves the increase in frequency and impact of environmental risks such as climate change, water crises, biodiversity loss, ecosystem collapse, extreme weather events, and natural and man-made catastrophes. At the same time, these risks demonstrate a clear and strong interdependency on the regional and metropolitan scale. While this larger scale may multiply these risks' complexity and impact, this is also the scale at which we humans can best adapt to and mitigate these risks. This is the scale at which we can—and must—act.

The 2015 WEF report, presented in Davos in January 2016, put the impact of water crises as the number-one global risk facing humanity over the next decade. Water is global connector: Two billion people will be devastated by 2050[1]—four billion in 2080[2]—if we continue with our current practice of water mismanagement on all scales, over-extraction and pollution. Of all the disasters that occur worldwide, 90 percent are water related.[3] Added to this is the fact that 50 percent of the earth's aquifers—nature's own groundwater storage capacity—are now beyond the tipping point, meaning that a natural recovery has become impossible. Global urbanization may provide us with growth, prosperity, emancipation, and development opportunities, but climate change, rising sea levels, and the increasing impact these risks carry puts huge pressure on our cities, societies, and citizens. If we don't act, the economic, social, and environmental system this all hinges upon will collapse, leaving us as victims of our own failure to seize a last window of opportunity.

Water is at the heart of this uncertain future. It is through water that we feel the impact of climate change most forcefully.[4] Water is essential for our economy and our social and cultural well-being. Water quality defines our economic prosperity and, in turn, water provision determines the level of vulnerability for our societies: it is key for agriculture, food, and energy