URBAN INFRASTRUCTURE AND MORPHOSIS

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Summary

Humans, through infrastructure, now move more material around than nature, geological and atmospheric forces combined. Infrastructure is the connective tissue for resource exchange in the human material world, and thus central to its productive/consumptive processes. Most modern infrastructure are permanent transport systems dedicated singularly to the distribution of one medium, whether it is natural resources, waste, cars, or people. In contrast to the closed-loop organization of nature, infrastructure as an industrial system of energy distribution is open-looped. Open-loop systems are typified by dissipative linear flows requiring energy intensive inputs that result in non-useful outputs like pollution and waste. Since open-loop production has precipitated an alarming rate of natural resource liquidation, a new criterion of productivity reflecting better conservation practices is advocated in the interests of a more sustainable public realm.

The new conservation criteria for infrastructure addresses: 1) advanced resource productivity, 2) creation of closed energy loops and 3) stewardship of existing resources. This is achieved through recombinant design, an integrated design strategy for constructing cross-disciplinary spatial formations of urban, biological, and social systems not present in their respective parent organizations. Recombinant design seeks an ecological capacity in infrastructure to create intelligent systems with a high degree of interconnectedness and positive feedback. As part of its work, resource exchange in

infrastructure will provide collateral services like natural resource regeneration, conservation, and outputs in the form of nutrients rather than waste. New protocols of organization in street design, water management, and urban ecology reconfigure physical environments according to the new conservation criteria for radical resource productivity. Besides their contributions to the energy economy, social health, and regenerated biological productivity, recombinant infrastructures provide the foundations for an enriched sense of place. Not surprisingly, a new poetics emerges reflecting novel collaborations between machine and garden.

1. Introduction

Humans now move more material around than nature, geological and atmospheric forces combined. Due to the earth's strained ability to absorb such environmental stress, some critics would cite this threshold as another indicator of unsustainable human practices. With that aside, the reality warrants a closer examination into the distribution systems directing our resources and the value-laden determinants influencing their flows. Since all life depends on the capacity to exchange material and energy with its environment, the coordination of movement is a socially constructed activity beyond that of mere utility. Infrastructure is the connective tissue for resource exchange in the human material world, and thus central to the productive/consumptive processes enmeshed in our cultural lives. Contrary to classic Marxist thought—which assumes culture to be a byproduct of economic organization—cultural inclinations play a determining role in the movement of resources. Cultural influences on the economic realities of movement are particularly apparent in issues regarding the environment, notions of equitable access to resources, styles of problem solving, and concepts of spatial organization. Despite its cultural significance, we are inclined to hide infrastructure from our composed landscapes and public realms. Yet, the connective logic of roads, public transport networks, communications systems, utilities, sanitary systems, and resource extraction networks undergird our civic life and visibly express our values about the world around us. Considering the metabolic role of these infrastructural systems in resource exchange, how might their designs advance progressive cultural logics as important indicators of social productivity in addition to that of economic value?

Most infrastructures are permanent transport systems dedicated singularly to the distribution of one medium, whether it is natural resources, waste, cars, or people. Since infrastructure is often considered aside from the aesthetic norms of sound town making principles, its role in shaping the cultural dimension of civic life is easily underestimated. But as the most synthetic instrument of town planning, infrastructure could be easily harnessed to deliver value-added urban services beyond resource extraction and distribution. More intelligent networks would provide collateral services like natural resource regeneration, conservation, and output generation in the form of nutrients rather than as waste. Seeking greater organizational integration, we could ask how the connective logic of infrastructure might recombine with other landscapes to enrich a sense of place? Indeed, how might public and ecological realms be enhanced through infrastructure's productivity? The following is an exploration into recombinatory strategies for infrastructure design and the necessary shifts in design thinking to achieve greater environmental sustainability in resource exchange.

2. Material Flows

Nature's modes of transport are ecologically constructed systems with self-regulating capacities for aligning outputs, or wastes, from one organic system as nutrients for another. As ecosystems mature into multiple feedback loops, their nutrient chains undergo a process of shortening and branching to produce rhizomatous systems of significant biological wealth with minimal energy use. Their dendritic path structures favor responsiveness over stability, readily adaptable to disruptive internal and external fluctuations. These closed-loop systems are continually self-corrective, recycling and switching energy among alternative paths with a consequent multiplier effect. Matter fulfills a life-affirming, regenerative role in every phase of its circulation, serving symbiotic functions in composition, decomposition and morphosis. Here, ecological thinking demonstrates that everything is connected to everything else. In contrast, open-loop systems are typified by dissipative linear flows requiring energy intensive inputs that result in non-useful outputs like pollution and waste. Industrial production systems are classic open-loop organizations, making man the only species whose outputs are not usable as nourishment for another species. As closed-loops, ecosystems are paradigms of sustainable resource management since their "climax" systems are the most efficient users of energy and the concept of waste is nonexistent.

Infrastructure exhibits a range of systemic characteristics from the rare ecosystem-like, closed-looped networks to the more common industrial open-looped organizations. Unlike multiple feedback in biological systems, the latter's dynamics are path dependent, conditioned by technical notions of productivity, performance, design, and the natural. In contemporary industrial cultures, open-looped energy systems characteristically suffer from inefficient metabolisms requiring high quality resource investments—usually nonrenewable—with resultant low-grade material outputs of limited functional life spans. This is particularly evident in the diminishing returns intrinsic to productive processes in industrial economies. Based on nonrenewable fossil fuel energy, production often requires 100 to 100 000 times the energy for extraction and processing than available energy returns in the final product. This hidden history of energy expenditures on extraction and processing—a product's or service's embodied energy—represents a cost rarely proportional to functional returns and is further outweighed by post-functional liabilities from pollution, residual toxicity, and long hazardous half-lives. In Germany, this hidden history is known as "ecological rucksack" calling attention to the environmental stresses stemming from the movement of material and not just that caused by toxic emission.

Open-loop production systems have precipitated an alarming rate of natural resource liquidation. In the past three decades alone, one third of the planet's natural resources—its nonrenewable wealth—has been consumed. It takes 98 tons of various resources, for instance, to produce one ton of paper. Each Sunday edition of the *New York Times* consumes 75 000 trees, or 100 acres of pulp trees. The production of a semiconductor chip generates over 100 000 times its weight in waste, a laptop computer approximately 4 000 times its weight in waste. Meanwhile, cultivation of cotton—mostly in the desert—uses one quarter of all agrochemicals, and one pound of production requires several tons of water. Accordingly, the American economy requires more than one million pounds per American per year of material production and movement, equal to the consumption rate of 531 Ethiopians. At the other end of the equation, total annual industrial wastes exceeds 50 trillion pounds a year; if wastewater is included, the total annual flow of waste is 250 trillion pounds. In terms of ecological footprints, if other nations were to adopt American standards of living, two more earths would be needed, three more if population should double (projected to do so in the near future), and twelve earths if global standards of living doubled over the next four decades. Obviously, such inequities in access to resources will not be sustained without greater social conflict, inevitable with this degree of uneven social development.

Performance measures that gauge ecological capacity—that is, degree of decentralization, multiple and positive feedback, resource productivity, diversity, and resilience—are more honest descriptions of industrial impacts than measures focused on the fixed optimization of individual elements. Industry for example, privileges measure of productivity like the Gross National Product (GNP), a measure of absolute financial activity regardless of the consequent net gains or losses to social health. Disasters like the Exxon Valdez oil spill, the surge of cancer rates from environmental toxins, and the exponential growth of hazardous waste landfills—what noted urban critic Jane Jacobs calls “transactions of decline”—are counted by the GNP as productive market forces. Despite the loss of positive feedback, all boosted annual GNPs as they were considered to have enhanced national prosperity. Monetized measures of productivity neglect a more robust assessment of wealth like replacement value of natural resources and decline in overall social health. Indeed, the Fordham University index of social health, which tracks problems like poverty, crime, unemployment, the gap between rich and poor, infant mortality, and public health, has steadily declined over the last 25 years from its best 1973 value, while the economy registered record growth. Until measures of progress begin to recognize that economic activity ultimately depends upon healthy ecosystems, reversals in declining social health and lifestyle inequities will languish.

3. Mobilization versus Civilization: The Stresses of Movement

As mobilization replaces the civilization of resources, infrastructure institutionalizes the path-dependent liabilities of open-loop design. The automobile industry is a classic example of design protocols established to maximize efficiency of inputs with lesser regard for the effects of its outputs on health, space, and the landscape. While only eight percent of the world’s population owns a car, 50 per cent of all Americans now own more than one car, and one fifth of the United State’s Gross Domestic Product is dependent on the auto industry. America leads the world in road building with over four million miles of road. Its federal interstate system alone occupies an area the size of the state of Delaware. Auto-oriented cities like Los Angeles have paved over 40 per cent of their landmass in accommodation of the automobile, more than 250 tons of concrete per inhabitant by 1970. Most Western nations' superhighway systems are such impressive structures of mobilization that patterns of residential development, in response, have become dispersed. Extensive energy and time inputs are necessary just to maintain ordinary human connections prompting many to question the car’s alleged benefits in terms of its costs. The American family spends an average of 20 per cent of its annual income on transportation, more than twice that of other Western nations who favor public transit systems. Each one-ton car generates 66 tons of waste throughout its manufacturing, use, and disposal. Health costs from these wastes are comprehensive, contributing to cancer, emphysema, and other terminal effects on plant and animal ecosystems. In Southern California alone, the Environmental Defense Fund sets $3.7 billion as the cost of declining health linked to smog and particulate pollution. Even if automobile infrastructure were retooled to be “greener”, or more environmentally friendly, it continues a path-dependent logic, as it lacks intermodality with other resource and human networks.

Two factors conspire to maintain path dependent thinking in modern superhighway infrastructure. First, the ultimate desire for unhindered mobility resulted in universal design protocols, unsympathetic to the nuances of place in infrastructure design. Second, the centralized design of superhighways required massive capital costs, crowding out adequate resources for public transportation options. The American interstate highway system, for instance, was built exclusively around the protocols of speed, prohibiting diversity in human purposes from pedestrians, cyclists, stopping, gathering or stopping for that matter, and adjacent architectural development. Regardless of local circumstances, each mile was designed under universal engineering standards governing right-of-ways, dimensions, and geometry, limiting exchange with other transportation modalities. The singular concern for fast and far-reaching mobility encouraged a language of reductive abstraction that neutralized the role of planning in giving unique form to local places. Trees in standard transportation manuals for instance, are referred to as Fixed and Hazardous Objects (FHOs), negating not only an aesthetic sense for the ecological context, but also the biological capacity of trees to mitigate toxic exhausts. The cloverleaf, as the interstate’s only allowed mechanism of exchange, reproduces the same consumer franchise environment at exchange points with other roads. Contrary to the desire for intensification of exchange in closed-loop systems, the interstate highway as a path-dependent logic operates like a smooth monoculture, excluding recombination with other networks.

Unlike the celebrated regional parkways of early national road building efforts, the interstate highway is unresponsive to local landscapes and urban contexts through which it passes. Often, irreparable disruptions to local ecologies and social communities are created. Lawsuits are now occurring over infrastructure siting, particularly over highways that have contaminated minority neighborhoods, constituting civil rights violations. European town planning initially resisted the totalizing force of the American example through effective land use planning that tempered the influence of the highway and its culture of mobility. But even there, planners as early as the nineteenth century Spanish engineer Ildefonso Cerda observed that the shape of society’s transportation systems—their dominant forms of locomotion—will dictate the shape of the city. Modern planning proved this particularly true when it came to regard urbanism as a transportation problem, and less a humanistic discipline. Speed eventually marginalized traditional public space as the locus of civic action. As Holtz Kay observed in her study on the automobile and social behavior, “incivility stems from the lack of public space”.

The second factor contributing to the highway’s hegemony is the lack of other transportation options. Again, in the American example, public transportation is patronized by a small percentage of the population even though 53 per cent of the population lives within two miles of public transportation. Mass transit patrons are predominantly those that fall below middle class economic status; yet these users of buses, trains, and subways end up subsidizing the suburban automobile commuter. While the suburban commuter pays only 25 per cent of the costs to travel the highway, the inner city resident, through ticket purchases, pays 80 per cent of the costs to operate mass transit. Indeed, once investments for highways, parking, pollution cleanup, and emergency medical treatment are factored, the actual costs to operate an automobile runs as high as $9 per gallon of gasoline, a far cry from the average $1.40 Americans now pay. Of course these costs are socialized through government subsidies rendering taxpayers—whether or not they drove a car—responsible for the hidden costs of sprawling infrastructure serving those at the urban fringe. This American bias against public transit has been demonstrated in its national budgets. Since the Interstate Highway Act over 40 years ago, only one percent of transit funding went to rail with the majority going to construction and maintenance of highways. Common nomenclature betrays this prejudice as we “invest” in highways and airports, and “subsidize” trains and buses.

The interstate system is the ultimate example of an organization type that historian, Manuel de Landa, calls a hierarchy. De Landa contrasts hierarchical structures with meshworks as systems of energy distribution. Meshworks are aggregate organizations resulting from the accumulation of individual efforts operating within a free market environment. The Internet as a worldwide information superhighway operates as a meshwork intensifying commercial and political connectivity without the governance of a centralized authority. In contrast to the heterogeneous profile of meshworks, hierarchies operate from a command-and-control logic characterized by centralized planning, bureaucratic administration, and the absence of free market mechanisms. In an otherwise apt description of open-loop systems, de Landa commenting on hierarchies notes: “Bureaucracies have always arisen to effect a planned extraction of energy surpluses (taxes, tribute, rents, forced labor), and they expand in proportion to their ability to control and process those energy forms”. Clearly, subsidized automobile and highway infrastructure work outside of free market principles using command-and-control regulation to curb competing transportation interests and to socialize private costs. However, the organizational consequences of command-and-control run much deeper. The decentralizing tendency of the modern highway has produced exurban sprawl, homogeneous in its land use planning, strategies of property ownership, architecture, and character of regional landscapes. Homogeneity has become a function of mobility encouraging greater movement for some, but less access for others. Yet this unprecedented mobility of the population has taxed the very highway infrastructure built to facilitate faster and farther movement. More highways have induced more congestion prompting the predictable response of command-and-control administration to increase highway capacity. Ironically, studies show congestion to be a function of increased capacity and when roads were removed, 20-60 per cent of driving trips disappeared, failing to reappear elsewhere. Furthermore, accelerated population shifts have led to uneven utilization patterns leaving older highway sections in unplanned obsolescence while newer segments experience exponential growth in congestion. Hierarchies’ tendencies towards fixed relations and linear analysis lack the resilience to negotiate dynamic contexts, especially those with nonlinear behavior.

The necessity for hierarchical infrastructure like the modern highway is not in question, but rather the totalizing monoculture wrought by the highway. Few transportation options beyond the car exist. Suburban land settlement patterns lack the compactness of urban neighborhoods requiring considerable expenditures in personal income and energy just to move around. The abstract logic of superhighway culture has infected local realms diminishing the influence of traditional urbanism and the role of municipal planning in creating place. This is not surprising given that the history of modernity is one of command-and-control hierarchies' ascendancy over meshworks. Consider the great planned extractions of energy surpluses in modern history from the 15th century Western colonial powers' state-organized extractions of natural resources and forced labor from Africa and the Americas; the 19th century discovery of fossil fuel by industrial economies to extract 300 million years of nonrenewable energy stores; and the 20th century emergence of the vertically integrated multinational business monopoly. All use command elements in anti-market decision making to secure a monopolization of resources at a global scale. In yet another transformation of historic significance, automobile infrastructure since the post-World War II era functioned as a command force depleting urban meshworks of their interdependent, self-sustaining dynamics. The highway-induced suburban monoculture replaced the synthetic territory of urban meshworks, and, among other things, their patchwork of political coalitions, interlocking specializations in economic activity, mixed-use neighborhoods, and synergistic concentrations of human capital.

In its most extreme hierarchical form, capital intensive investments in infrastructure are submitted to the same accelerated cycles of planned obsolescence as consumer goods—the classic open-loop strategy of advertising—creating an archaeology of infrastructures with short half-lives. New roads or airports for instance, deliberately render adjacent predecessors and their attendant commercial facilities obsolete, establishing leapfrog patterns of economic development. Dutch architect Rem Koolhaas underscores the process of planned isolation infrastructure facilitates in the competition among hierarchical spatial developments—enclaves characterized by a high degree of internal organization surrounded by an external no man's land.

Infrastructures, which were mutually reinforcing and totalizing, are becoming more and more competitive and local; they no longer pretend to create functioning wholes but now spin off functional entities. Instead of network and organism, the new infrastructure creates enclave and impasse: no longer *grand recit* but the parasitic swerve. (The City of Bankok has approved plans for three competing airborne metro systems to get from A to B—may the strongest one win.) Infrastructure is no longer a more or less delayed response to a more or less urgent need but a strategic weapon, a prediction: Harbor *X* is not enlarged to serve a hinterland of frantic consumers but to kill/reduce the chances that harbor *Y* will survive the 21st century. On a single island, southern metropolis *Z*, still in its infancy, is "given" a new subway system to make established metropolis *W* in the north look clumsy, congested, and ancient. Life in *V* is smoothed to make life in *U* eventually unbearable. (Koolhaas and Mau: 1264)

While the self-sufficient enclave in its planned isolation has its beginnings in the lifeworld of the meshwork, the evolution from meshwork to hierarchical structure is not inevitable. Fermenting concern over escalating environmental degradation and declining social health holds the prospect for reversing the inclination towards command-and-control organization. Ecological thinking now permeates public policy and mainstream institutional thinking, potentially instigating another round of historic transformations, this time, favoring the entrepreneurial vitality in meshworks. As institutions and markets become more "biological" than before, industrial organizations will find themselves increasingly tailored to the functioning of ecologies and their dynamics of exchange. Escalating energy demand, compounded by the growing scarcity of nonrenewable resources along with extraction costs for what remains, has already affected an economic shift favoring the "green" economy. The most entrepreneurial markets of the future will be those that increase resource efficiency and find ways to close the energy loop as they uphold author Ernst von Weizsacker's "factor four principle: doubling wealth while halving resource use". Biological or natural capital then, will be a pivotal component in the economic shift from an emphasis on maximizing human productivity to increasing resource productivity. Indeed, the limiting factor to future economic development is the availability of natural capital for environmental life supporting services that cannot be replaced.

Open-loop toxicity and waste in hierarchical infrastructure are not a function of the materials being transported, but rather of infrastructure's end-of-the-line distribution practices. Their path-dependent logic concentrates output beyond the capacity of the local environment to absorb and recycle such outputs. Like the floating landfill waste barges of New York seeking sale of its contents to distant places, the standard solution to the problem of waste and pollution has been to simply move it around. Considering the metabolic role infrastructure plays in economic productivity, incentives exists to design intelligent meshworks that recombine socio-economic and biological networks to maximize exchange of inputs/outputs while eliminating waste. How might infrastructure become less a transport mechanism and more an ecology? The following case studies are explorations into how design culture might reshape its imaginary practices to construct synthetic environments with enhanced life supporting services and links to local ecosystems.

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