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Urban Systems

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Interdependent Infrastructure: In the Eyes of a Designer

Given the world's current status of rapid progression and complexity, we are constantly finding ourselves at a threshold in which adaptation and re-evaluation are crucial to successful development. Among the most significant aspects of the aforementioned development is the implementation and utilization of advantageous infrastructure. As more and more infrastructural elements become information based (that is to say, more directly related to technology) these systems are increasingly evolving interdependent relationships in which each specific entity corresponds and influences another (either directly or indirectly). This paper will investigate the various genres, characteristics, and complexities of infrastructural design and how it's interdependencies are currently being quantified and analyzed as a means of better preparing and designing for future systems. In addition, it will also examine how professionals in design-related fields (i.e. architecture, urban design and urban planning) can contribute to the systematic development of specific infrastructure elements, especially when they directly influence the form and function of an urban environment.

The Idea of Infrastructure:

Infrastructure is oftentimes a word used in a rather blasé manner as a way of describing any number of ambiguous organized systems; however, the exact definition is something that has been concretely decided upon, and has even had slight alterations as time has progressed in order to completely depict it's exact denotation. The President's Commission on Critical Infrastructure Protection (PCCIP) initially defined infrastructure as "*a network of independent, mostly privately-owned, man-made systems and processes that function collaboratively and synergistically to produce and distribute a continuous flow of essential goods and services*."[1] Although this was later revised as "*the framework of interdependent networks and systems comprising identifiable industries, institutions (including people and procedures), and distribution capabilities that provide a reliable flow of products and services essential to the defense and economic security of the United States, the smooth functioning of governments at all levels, and society as a whole*" by the Critical Infrastructure Assurance Office (CIAO) after the fact.[2] While both above definitions are very similar and still seem to lack a sense of specificity, this paper will primarily focus on the slight, yet extremely significant addition of "*people and procedures*," as well as the 'critical infrastructures,' of which there are eight principal examples: transportation, water supply systems, electric power systems, telecommunications, natural gas/oil, banking and finance, government services, and emergency services.[3] These eight systems, along with the inclusion of social engagement (i.e. people and procedures), are among the most crucial factors that permit our nation (and any other) to properly function on a daily basis, given the almost infinite amount of varying factors/conditions.

Infrastructural Relations:

The most critical characteristic of infrastructure, though, is not necessarily the specific branch, but rather the interdependencies that exist within all of the branches simultaneously. These infrastructural entities, by nature, are virtually impossible to completely isolate given the fact that there are a myriad of external factors that are constantly overlapping and contributing to either the initial or eventual phase of operation (see Figure 1).[4] Consequently, due to this level of complexity, it is currently the most underutilized and misunderstood aspect of infrastructure. For example, in 2001 the derailing of a hazardous freight train in Baltimore caused an exponential ripple effect on related infrastructure that was completely unpredicted. Beyond the expected damages and delays from rail/automobile traffic and emergency services, additional consequences were seen as far down the line as affecting Mid-Atlantic States' steel production. This chain reaction occurred under the following pretenses: a fire was caused from the derailed train which then grew to rupture a water main which, consequently, broke through the tunnel surface, causing a flood. Then, due to the flooding, electricity was cut off from some 1,200 residences, in addition to telecommunications failure that interrupted data, web, phone, and email correspondence for 6 separate national companies.[5] While the cause and effects of this (and many other) examples can be expanded upon even further, the main concept behind each is that as demands for infrastructure increase, the reliance and therefore interdependencies increase exponentially. This is not to imply that infrastructure interdependencies are a negative issue, but rather to place emphasis on how reliant the world is on systems that often go unnoticed and/or taken for granted (or at least until a chaotic chance occurrence happens, which then displays the inevitable flaws and oversights of our existing multifarious infrastructure).

Research Methodologies:

Within the eight critical infrastructural systems there are four primary interdependency classifications that are a result how this "system of systems" is affected, and they are: physical, cyber, geographic, and logical.[6] Because each of these classifications require unique and deliberate actions and reactions, researchers have developed intelligent software that is able to calculate any number of circumstances and ultimately quantify the level of risk that results from the interdependencies after a specific event (i.e. September 11th or Hurricane Katrina).[7] The ultimate goal was to have created software that allowed for educated decisions in advanced designs of future infrastructural systems; however, creating an exact framework for something as complex as infrastructure analysis as a function of human behavior is hardly an exact science. Most models are unable to quantify all of the convoluted data, most notably the factor of emergent behavior (which is a crucial portion of interdependencies). Nevertheless, useful models and software (such as the CRUTIAL hierarchical modeling project)[8] have been created despite 5 primary challenges: "(1) data acquisition is difficult; (2) each individual infrastructure is complicated; (3) infrastructures are evolving; (4) governing regulations are changing; and (5) model construction is jointly performed by government agencies, academia, and private industries."[9]

A consideration that has never been fully investigated, though, is the potential that lies behind the minds of creative designers who are able to offer a complimentary way of thinking in terms of urban infrastructure design. The majority of research in the past has been based solely on computer aided software and calculable figures, whereas the importance of design intuition has been overlooked and undervalued. The lack of emphasis placed on designers, in addition to social engagement, is restricting improvements on the success of the complex interactions of interdependent infrastructure in urban environments. As a way of initiating this implementation of designers' intellect (with regards to research and execution), a closer assessment of each of the four classifications must be carried out using various scopes.

Physical Interdependency:

As the first classification, *physical interdependency* tends to be the most forthright categorization due to both its relevancy and frequency. To say that a particular interdependency is physical in nature, it implies a certain material correlation with the state of the infrastructure and its outputs (or material flow). This relationship can be defined as, "a commodity produced or modified by one infrastructure (an output) is required by another infrastructure for it to operate (an input)."[10] A unique attribute of this interdependency is its ability to function at a variety of scales and complexities. In both Rinaldi and Bagheri's illustrations of physical interdependency, a more involved situation is depicted. For example, the generators of an electrical infrastructure are physically reliant on water and sewage infrastructure given the fact that generators require water for cooling functions.[11] Conversely, an occurrence as simple and common as a tree falling onto a power line and therefore disrupting the electricity of surrounding homes/offices is also deemed a result of physical interdependency.

While this genre certainly tends to be the most apparent for engineers and researchers in terms of identifying, it is also the one most directly affected by designers (or at least potentially *could* be). With the influence of designers (in addition to engineers/researchers), a more diversely educated decision is able to be made by incorporating yet another key discipline in the creation of city form and function, something which urban designers, planners, and architects specialize in. The 'Parque Metropolitano de Manguinhos' project by Jorge Mario Jauregui's of *Atelier Metropolitano* is a prime example of how a designer's intuition is able to create a multidisciplinary piece of infrastructure while simultaneously enhancing the social environment and expediting the issues of physically interdependent systems. In the design, Jauregui elevates an existing rail line that is adjacent to a river and ten increasingly dense slums, and proposes a linear public park to occupy the newly created open space beneath it. When one takes careful note of the revised definition of infrastructure previously mentioned in this paper, he/she realizes the significance of the inclusion of people as a system of infrastructure. By Jauregui realizing the negative ripple effect caused by the rail line's disconnection of several infrastructures (people, transportation, and water supply), he was able to remedy the physical interdependency in a positive manner (or, metaphorically speaking, remove the fallen tree). By taking into consideration the unquantifiable value of public engagement, a previously-never-thought-of design was created that was able to simultaneously address the issues of physically interdependent infrastructure, while also introducing an additional successful interdependency between transportation, public space, finance, and water supply.

Geographical Interdependency:

Very similar to physical interdependency is *geographical,* or *geo-spatial, interdependency*. Where physical interdependency is heavily concerned with the material flow of outputs and inputs, a *geographically interdependent* relationship is created based solely on the key concept of **proximity,** specifically in terms of infrastructure components.[12] In this case, the state of a given infrastructure is not necessarily affected by the state of the other; rather the two are geographically interdependent merely due to their immediacy to one another. A simple example would be a telecommunications fiber-optic line that is strung together with an electrical line underneath a bridge.[13] Because each of the three systems involved is able to function independently of the other (i.e. the bridge traffic does not directly affect the flow of data or electricity) the shared interdependency lies exclusively in the systems geospatial proximity. This concept draws a parallel to the deconstructivist design work of Bernard Tschumi, which also ultimately influenced the contemporary design efforts of Rem Koolhaas. Tschumi's work is known for its investigations and implementations of abstract programming. His three classifications of *cross-programming*, *trans-programming*, and *dis-programming* hold extreme similarities to many of the notions of infrastructure interdependencies, most notably geographical interdependency. Tschumi's National Library of France (see Figure 2) is a project in which he employs his concept of *trans-programming*, which essentially is two different user programs both occupying the same space, yet having no jeopardizing affect on one another (in terms of programmatic function). While Tschumi designs the traditional functions of a library, he also includes a track that circumambulates the upper volumetric portions of the library as a metaphor for future scholarly athletes. Similarly, Rem Koolhaas' Kunsthal project (see Figure 3) is a realization of *dis-programming*, in which two traditionally separate programs occupy the same space, yet in order for one to function properly, the other is either severely altered or cancelled out (thus differentiating itself from trans-programming). The Kunsthal's primary entry and circulation path inhabits the same spatial conditions as the auditorium, resulting in an extremely unique and bold state of program. Consequently, as many modern engineers/researchers attempt to analyze and calculate the relationships of infrastructure through the utilization of data collection and software, contemporary architects/designers are similarly beginning to investigate the various relationships that exist between differing programmatic conditions via spatial design. In this way, designers and researchers are currently carrying out the *same task*, yet simply through different scopes. Following this train of thought, the correspondence of designers and infrastructure engineers is then simply being prolonged by a kind of nostalgia, or preconceived notion of what [now] seems to be non-existent differences.

Cyber + Logical Interdependency:

Both *cyber* and *logical interdependencies* are emerging classifications that tend to also correspond with the newly evolving paradigm that is a result of the amalgamation of architecture and urban design. All of these facets are a consequence of modern technology and societal conditions/behavior. *Cyber interdependency* is most directly related to the many technological advances of our current age, and is classified by the transference of information between two or more systems of infrastructure.[14] As more and more infrastructure systems begin to significantly utilize technology, the outcomes (which are both positive and negative) tend to occur tenfold. The inevitable characteristic of technology to exacerbate certain conditions is one that especially plays a role in infrastructure. Similarly, *logical interdependencies* are just as much unpredictable, if not even more so, primarily because human tendencies oftentimes are exaggerated and/or intensified. *Logical interdependency* relies greatly on the coordination of human behavior, which is influenced by social conditions and occurrences. For example, "the price of oil is strictly dependant upon the peace process in the Middle East. Therefore, major oil producers and consumers try to coordinate their decisions with the political developments in that region. It is visible that oil companies have no direct ***cooperation*** with the political side of the issue, but they are highly ***coordinated*** with their decisions."[15] Being that both of these classifications are currently rapidly evolving given the state of our world, both researchers and designers alike are attempting to gain a greater understanding of each as a means of remedying, and perhaps even preventing, particular circumstances.

Because attributes of adaptation and contemporaneousness are indicative of designers' roles in society, they become the most influential in terms of creating new infrastructure. Throughout history it has been their responsibility to employ the most advanced and innovative methods, materials, and intellect as a means of pushing the limits of what is possible. Additionally, the profession of design has an unprecedented relationship with people. There is a cyclical process in play that causes people (society) to influence design, as well as design to influence people, thus making it an endless affiliation. This process is directly correlated to the cyber and logical interdependencies in more ways that one. The Urban Think-Tank's *Metrocable* project in Caracas, Venezuela (see Figure 4) is a precedent that embodies the designer's influence on both cyber and logical infrastructure interdependencies. The firm was able to successfully create a completely new piece of infrastructure that was capable of democratically servicing the public by means of transportation, which in turn created a rare (but very practical) positive ripple effect throughout the surrounding area. This new method of infrastructure allows for the transference of information, economy, and ideas via the people that it transports; therefore fulfilling, and even going beyond, the exact definition of cyber interdependency. In terms of logical interdependency the *Metrocable,* rather than coordinating *economic* decisions with *political* development, coordinates *design* decisions based on *social* developments within the region. The lacking, insufficient existing infrastructure no longer allowed for successful interdependencies, and was therefore deemed unacceptable. Through the inclusion of design, not only was a new piece of infrastructure created, but also a more prosperous urban environment.

Conclusion:

All previous case studies help allude to the potential benefits that can be gained by intellectually and creatively designing infrastructural elements that are focused primarily on the progressive development of cities, rather than exclusively on economic and response-time figures. This notion that infrastructure can be utilized not only in a pragmatic sense, but also with a certain hedonistic ideal is one that has never been fully explored (primarily given the fact that up until this point most infrastructure design has come from researchers and engineers). With current issues of population growth (and therefore density), energy consumption, and access to resources a shift in economic values/principles has occurred, in addition to a certain uncharacteristic behavioral change. Given these newfound tendencies, the approach towards infrastructure design cannot remain stagnant, but rather it must progressively adapt and evolve along with its surroundings as way to enhance life and interaction through the opportunistic design of interdependencies. The aforementioned projects imply the advantageous benefits that are a result of such design, and serve as precedents for how future designers, engineers, and researchers can develop new investigative efforts that are as advanced and intuitive as our new society and the infrastructure that reflects it.

Figure 1: Infrastructure Interdependency Diagram

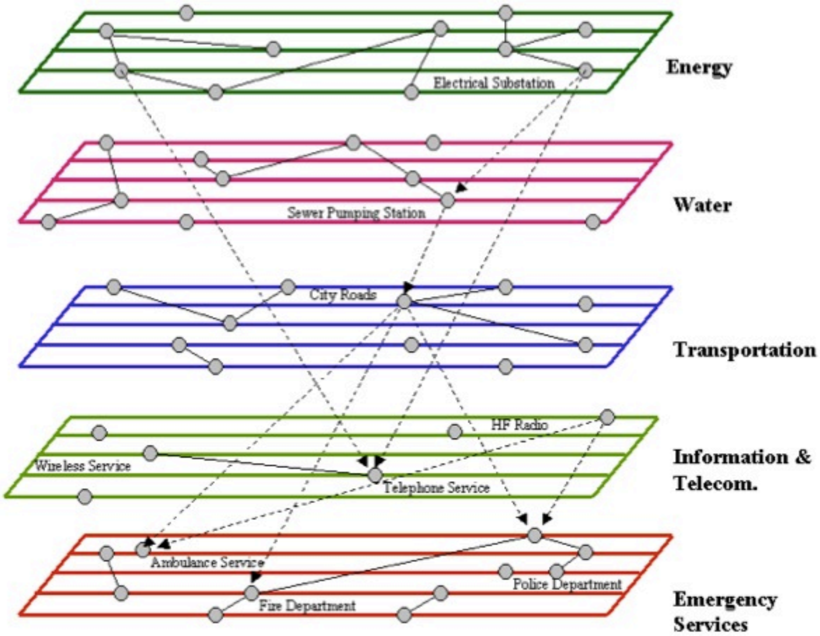

Figure 2: Bernard Tschumi's *National Library of France*

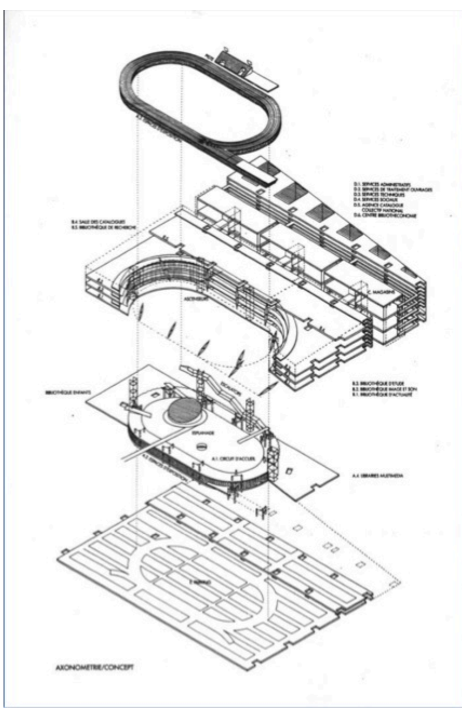

Figure 3: Rem Koolhaas' *Kunsthal*

Figure 4: Urban Think-Tank's *Metrocable*

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