Real Time / Implication for Production Spaces

Nina Rappaport

INTRODUCTION

Systems of feedback loops and cybernetic methods as expounded by Norbert Weiner in the 1940s have influenced for decades the production and consumption networks and supply and demand chains in computer-integrated manufacturing, ultimately affecting the spaces of production (Weiner 1948). These mechanisms contribute to the increased efficiency of production, expanding the ability of both manufacturers and production engineers to create a workplace with smoother supply-chain management, as well as economies of scale and scope that are contingent on increased capitalism in a networked, globalized world. Since the introduction of assembly lines for mass production in the early twentieth century, the flexibility of economic services and accumulation, as David Harvey identifies, has increased the need for flexibility in spaces of production as well (Harvey 1990). Flexible accumulation in transient economic times such as today must follow when the new globalized economy is constantly in flux and automation and control are essential. Mobility and flexibility are both physical and philosophical imperatives, aided by new small-scaled controls such as handheld wireless devices, which also contribute to a rising culture of nomadism. The shrinking scale of technologies and facilities has provided the mobile worker with numerous opportunities within complexly networked systems, forming a new paradigm for urban production spaces of the future. Both centralized production management and financial power that agglomerated in the 1980s in key cities as described by Saskia Sassen (Saskia Sassen, 1991)3 are now transforming. The potentials for a decentralized work force and for places of production that will invigorate not only a new economic web but also local places, where objects can be made in clustered urban networks, are increasing.

MIDDLEWARE

1 MASS PRODUCTION

In the mid-nineteenth century, Colt, in Hartford, and Whitney, in New Haven, developed mechanized production for assembling uniform parts for rifles with stationary machine tools. These techniques were followed to assemble interchangeable parts for the mechanization of clocks, sewing machines, and bicycle production, among other products, allowing components to be changed out easily and replaced for repair or design adjustment, without reconfiguring the entire product (Hounshell 1984). This became known as the American System of Manufactures and was adopted worldwide. In this method, while workers assembled each product individually at stationary tables, the elements themselves were mass-produced (fig. 1. printing plant photograph by Ezra Stoller). With electricity supplied from

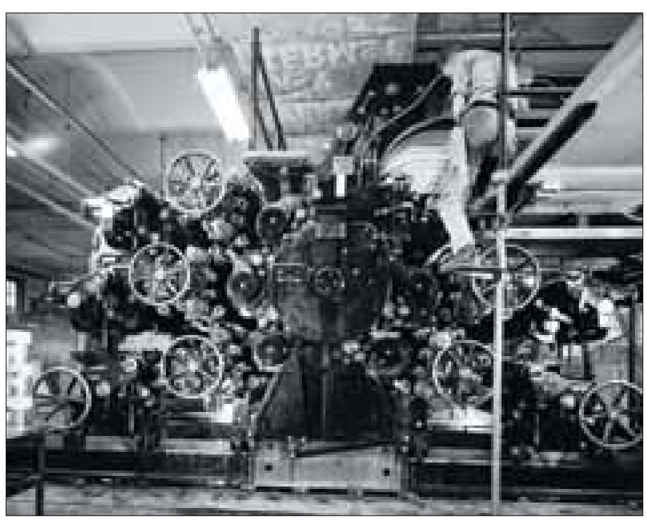

Figure 1 Printing Plant, Clarksville, TN, 1949, photograph by Ezra Stoller, courtesy Esto

a local source, such as water, the integrated building was a machine, and the factory floor became a jungle of belts, wheels, and bands (Biggs 1996). The floor layouts were rigid and inflexible. The machines defined the workplaces, such that workers often did not move their full bodies; thus, their repetitive hand and arm motions led to fatigue and, eventually, injury. In this system of manufacturing, humans served literally as the motors (Rabinbach, 1994). Floor engineers and supervisors directly controlled production in using Taylor's method of Scientific Management, which he developed in 1912. Henry Ford used this method, in combination with Frank and Lillian Gilbreth's motion studies, which were developed to enhance production speed and efficiency, on his assembly lines.

A corporation's goal of product choice—driven both by manufacturer inventiveness and consumer desire for ever-new commodities—came solidly to the forefront in the early twentieth century. However, choice remained limited at the time: the Ford Model-T automobile was black—and only black—and available in one design. In the 1913 Ford Highland Park Illinois factory, each element was produced separately and assembled step by step in a vertical chain of production, with fixed tooling at fixed locations. The Ford factory operation was multi-level, with the car parts delivered to the top floors (fig. 2: Ford Motor Company).

Figure 2 Ford Motor Company, Highland Park, IL, Albert Kahn Architect, 1913

As the automobile was assembled, gravity helped it down each production level to the ground floor for completion. Gradually, production methods evolved, allowing for the simultaneous assembly of different designs so that two or three types of cars could be made on one production line in just a few days. Any change to the car design would require a retooled production line, stopping production. By 2003, computer mechanization had increased the possibilities for mass customization to such a degree that the Lansing Michigan GM plant was able to produce one car in just less than seventeen hours (Weber 2002). The plant was also touted as being able to change out the type of car made on that production line, as needed, with each new inventive improvement. While GM dreamed of an exponential, nearly limitless increase in production capability, it never used the potential flexibility, and we are now seeing the ramifications of that product design and innovation stagnation.

2 JUST IN TIME

Automated production made a huge leap when the computer harnessed new systems to meet the urgent demands of the military industrial complex in World War II. Additionally, manufacturing methods were enhanced with concepts developed by the Toyota Motor Company team called, Just-In-Time production, which used the Kaizen system of teamwork to encourage social interaction, employee responsibility, and creativity in the production line. Toyota also emphasized not having waste or overstocked goods in their warehouses. Although Toyota perfected the Kaizen method, W. Edwards Deming, an American statistician who had studied with Walter Shewhart, the inventor of Total Quality Management, developed the philosophy and system. Deming, who had assisted manufacturers in the war, taught Japanese scientists quality-control methods in the 1950s. Toyota embraced his concepts in developing electronic overhead digital signboards, called Andon Boards, which are used in the factory to track the production process and gauge the production status (May 2007). This feedback loop signals differences between such manufacturing concerns as scheduled production and actual timing, missing items, downtime on a production process, or the timing impact of a robot.

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Using this information, employees can self-regulate, relieving production bottlenecks to maintain continuous assembly. While the signaling boards might produce anxiety and pressure for the workers at first, they also relieve those effects (fig. 3. Andon board in factory). As workers look to the board, they see problem areas before the machines malfunction or before they miss parts along the line, and workers act more effectively as a team through a collaborative process. In the design of factories, the development of common entrances for workers and managers and shared break areas, and the placement of R&D near production teams and workstations adjacent to the production floor, further enhanced teamwork and inspired interaction between white and blue-collar workers.

Figure 3 Andon board in factory

When factory automation and distribution networks replaced the worker, the touch of a button controlled production rather than skilled workers completing multiple tasks. Cultural critics such as Lewis Mumford praised the new technology but derided its lack of humanism (Mumford 1964). By the 1970s, older equipment was upgraded in a piecemeal way, with the attachment of computer controls and CNC machines, until the mechanizations subsumed them entirely and shop equipment was fully replaced by embedded digital controls. In many factories, workers sat fixed at one station, operating machines via computer programs and wired systems, bored from the repetitive activity and, thus, less productive because they didn't have a connection to what they were making (fig. 4: CBS factory Long Island City).

Figure 4 CBS/Columbia Records factory, Long Island City, 1953, photograph by Ezra Stoller, courtesy Esto

MIDDLEWARE

3 CONSUMER LOGISTICS

The logistics and goods distribution for globalized manufacturing became a sub-specialization in the 1960s as well. Since the ultimate goal in an increasingly globalized economy was to reach the consumer, integrating the feedback loop between supply and demand into a combined factory/warehouse/retail outlet was essential. Spatially, this meant that central places of control were networked into a broader decentralized economy, where physical distance no longer mattered and objects moved fluidly.

Figure 5
Toyota City, Japan

Companies from Benetton apparel to Zara, Nike, and BMW embraced the new ease at mass customization and consumer feedback, subcontracting production to an outsourced network of nearby and more distant manufacturers to reduce their operating costs with cheaper labor and less overhead costs, taking advantage of a locale's labor specialization. Toyota outsourced its manufacturing to local companies, which eventually developed into a complete networked city for Toyota manufacturing known as Toyota City (fig. 5: Toyota City).

The consumer gained control as a "prosumer" (Toffler 1980) in Benetton's 6000 franchise stores, which have an Electronic Data Interchange feedback mechanism that notifies the warehouse managers to restock shelves when sales of various items increase. Information about the product, embedded in bar codes, is transmitted via computer to the factory, where they increase the production of the most popular items. Production remains flexible, as sweaters of one style can be made all in white and then dyed according to demand. Hidden fiber-optic cable networks guide the manufacturing of 7,500 items a day. Spatially, these production methods influenced architect Tobias Scarpa. For his 1995 factory design in Treviso, he placed a central roadway spine between two production spaces to increase circulation flow and to provide more places for truck logistics, such as moving goods out. He also constructed a 170 x 80 meter automated distribution warehouse, thus, emphasizing distribution and marketing over making things.

To increase product tracking and market placement, Benetton and others such as Wal-Mart, Levi-Strauss, and Zara are switching from the use of bar codes to "smart shelf" technology. The Auto-ID tracking system, also used for locating items in shipping containers, palettes, and warehouses, has Radio Frequency Identification Tags, developed at MIT's Auto ID Center, that track inventory, location, and manufacturing needs in real time. This allows retailers to precisely record information so that they do not have to physically monitor store shelves, and the data is transferred automatically to the factory managers. A virtual umbilical cord links production and sales, factories and stores. Zara, which also focuses on flexibility and instantaneous development of new products, also has an in-house design team charged with the task of producing new styles monthly. This encourages customers to return and shop often for the latest goods. The digital communication between the design and the production branches of the company are monitored in a fluid distribution system, partially guided by a chain of command in real time that begins with the consumer in a controlled super organism (Kelly 1994).

4 WIRELESS SPATIAL MANAGEMENT

Such interconnectedness, both virtual and physical, coalesces in the reinvented twenty-first century factory. Here, automation furthers lean manufacturing efficiency and just-in-time production at every scale—from worker to worker, worker to robot, product to manufacturer, worker to the world—through the advent of smart handheld machines that are run as wireless installations, impacting worker activity and the organization of production spaces. (Zdnet.co.uk 2003). In the digitally automated factory, the spaces housing the technologies have been increasingly foregrounded over those housing employees. In clean rooms, for example, workers in their "bunny suits" fit in between the spaces for the processing of computer chips. Industrial engineers organize these spaces without architects, and with little focus on the worker who is the intelligent operator of the machine. More recently, to ease worker alienation, organizational management gurus have devised spatial systems to guide factory planning that diverge from the linearity of the Fordist plant where goods were processed in a singular line. Instead, raw materials can enter the production process at various points with the use of interchangeable modules for expansion and contraction. Companies such as BMW, which is now expanding their plants in Spartensburg, North Carolina, and Leipzig, Germany, use this system. Further experiments in factory layouts include combined R&D areas, "solar system" layouts, "main street" spines for increased personnel interaction, the "fractal," housing the management near the workers, centralizing break areas, developing communal entries for both workers and management, and an alphabet-soup-shaped layout where workers are being called "partners" and "team players" rather than "worker."

New factory designs have had to adapt to the shrinking scales of tabletop robotics and handheld computers, forming an operational and spatial shift in production spaces towards dynamic networked and interactive flexible spaces. Since the computer often directs the workflow, it is logical that the factory would adopt the network organization of the internal workings of the computer itself. This is similar to Paul Baran's analysis for the Rand Corporation (Baran 1964), where, rather than emphasizing a hierarchical system, he recommended distributed networks that extend branches of communication that can overlap, retract, or spread out further (fig. 6. Models of Organization Rand Corporation, 1964).

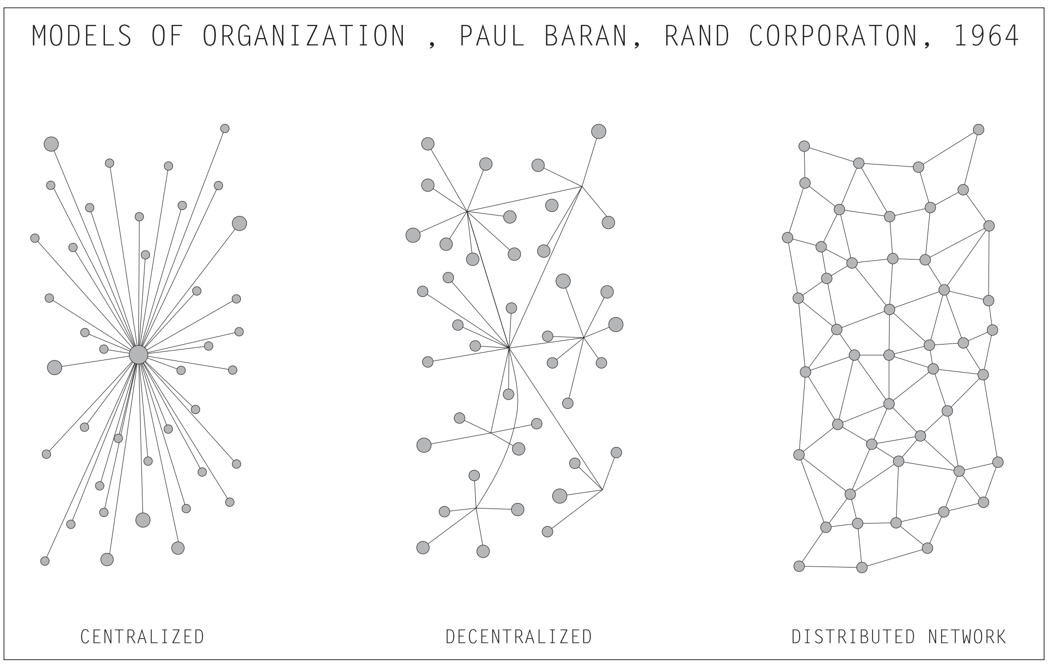


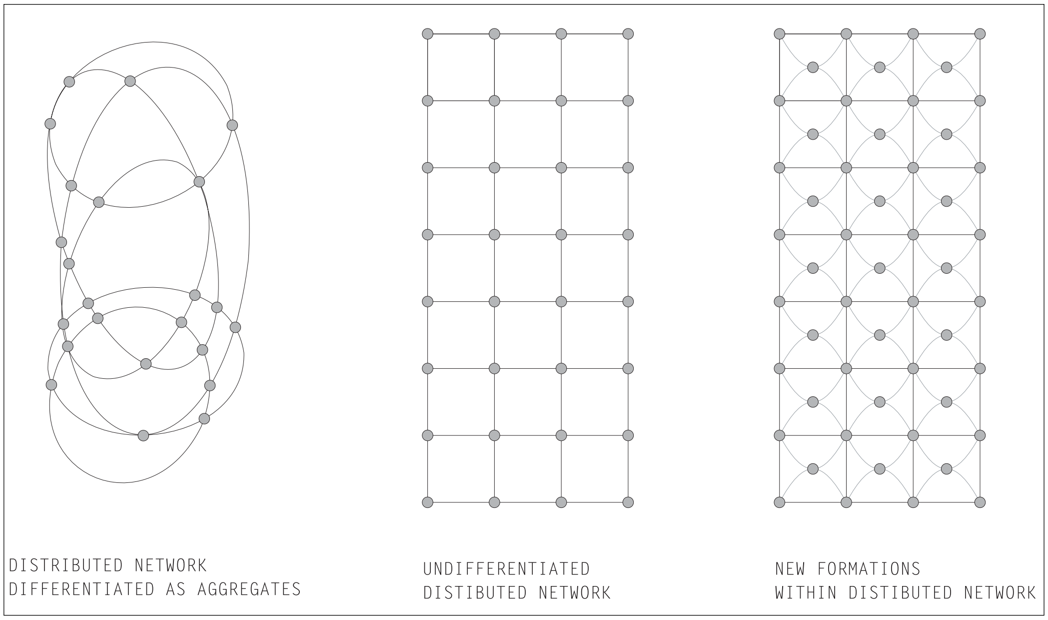
Figure 6 Models of Organization Rand Corporation, 1964

5 MOBILE DISTRIBUTED NETWORKS

With the use of remote controls for mobile workers in production plants that are controlled from a head office, but with numerous workers running the decentralized and distributed networks: This is seen not only as a physical manifestation of the worker-to-supervisor relationship, and team-to-team communication, but also as affecting the worker's increased mobility and training. The complexity of the networked distributed system guides the computer modeling of automation accordingly, which includes quality control, the worker's ability, and the consumer response. What workers give up in hands-on craft and machine tooling, they gain in managerial or supervisory experience (fig. 7. distributed networks).

The reorganization of production spaces because of handhelds also parallels the workflow of organizational network integration, defined by Luther P. Gerlach. Gerlach is an organization sociologist who classified three attributes of networks in social and nonprofit organizations as segmentation, polycentrism, or integration, "where there are real-time adjustments for continually changing circumstances across potentially expanding fields of operation" (Gerlach 1965).

Figure 7 Distributed networks, Rand Corporation, 1964



These real-time fluctuations are similar to manufacturing networks for mass customization and new manufacturing methods, as they constantly change with new desires.

6 HANDHELDS WITHIN THE FACTORY

With the shrinking of controls, high-powered handhelds, communication between departments, and to-and-from robots on a factory floor for scheduling, maintenance, and inventory: Workers can track repairs and work on machinery remotely, which can enhance the productivity of the mobile worker and increase flexibility of divisions of labor and their specific location on the factory floor. Numerous computer hardware and software companies such as Cisco, SAP, Accenture, and Oracle have all created systems that run programs for handheld PCs. Logistics companies such as UPS and FedEx now use handheld PCs to run their physical distribution networks, and transfer that knowledge as consultants for internal business management and production spaces (fig. 8. handheld PCs).

For example, SAP's programs for mobile production allow employees to view work instructions on their handhelds in the factory and, with bar code scanners, to check and control production processes through embedded chips, resulting in synchronous communication systems for real-time inventory, production control, and warehousing. Others, such as Intel, designed network processors with Rockwell Automation, as part of a line of high-performance tools that provide manufacturers with seamless information flow between factory floor and the R&D offices, wherever they may be outsourced. The food and beverage industry has taken advantage of the wireless PDAs for their quality control, palletization, gauging consistency and sizing of the food item, temperature control, and robotic arm movement in loading and packing food products.

When various components of a product, such as a car, need to be changed—just as in interchangeable parts manufacturing of the nineteenth century—computer-controlled robots can perform the job, directed by workers with handheld PCs. Robots displayed on the screen move components from storage areas, directed via a wireless system. The production process is programmed into the computer and tested in simulations until it is perfected. Once operational, any errors or bottlenecks are digitally reported in real time, and the process can be instantly adjusted. Rather than the large-scale Andon board that is visible to all, each worker can negotiate the issues on their individual small screen. Teamwork continues but at the level of virtual communications; there is less face-to-face time, but workers are able to move freely to achieve the production goals. Another system now under development, with assistance from the European Commission and a consortium of groups through the Fraunhofer Institute in Germany, is an Intelligent Networked Manufacturing System (IN-MANUS) that makes further use of wireless and smart controls, networking people, machines, and robots for smart production with sensors and cameras embedded in the equipment. In this process, computers do not get reprogrammed with each change in a design, but, rather, the new information input into the system fluidly adapts the Smart Connected Control Platforms. Mobile controls and headsets for workers also enhance communication, because the information on

Figure 8 Handheld PCs

the changes appears simultaneously on the handheld PCs and the workers are then able to discuss the changes. These devices allow factory managers to move freely and mistakes to be fixed with increased speed. Currently, Fiat factories in Italy are testing this (Fraunhofer, 2009). In the most extreme scenario, the factory can run automatically as does a power plant, or remotely by robotic control as the 1923, then futuristic, Karel Capek's play RUR (fig 9. digital robot Fraunhofer Institute).

The scene is like a puppeteer controlling the actions of the puppets, with a virtual string attached to each movable element, controlled from a central hub. This information flow allows instant decision making, which improves productivity, flexibility, and, ultimately, profitability. Corporations can have their front office and knowledge centers in major cities and take advantage of dispersed labor, throughout the city or in nearby areas, as in the case with Hong Kong and China.

7 AUTOMATED URBAN INDUSTRIES

Urbanistically, the automated mobile industry technologies can affect spatial configurations at the scale of the city, focusing on not only the globalization of industry between distant locations (Friedman 2008), but also a foreseeable potential for increased industrial urbanization that takes advantage of proximity and clustering across a city. The factories of the industrial revolution, which grew by accretion, might be revitalized in vertical urban settings, with a potential for smaller production, linked by virtual connections, and with more flexible investments and manufacturing. Imagine automated digital controls that formalize links between urban, cottage-type industries with tabletop robotic, computer-aided manufacturing and urban districts, making the mega-scale, horizontal suburban factory with the all-under-one-roof, obsolete. Small companies could print out their products from CNC controlled stereolithography and rapid prototyping at desktops. Rather than congealing into major corporations, they could splinter as networks of local manufacturers at a smaller scale. The automation of plants in rural areas of Norway proposed by industrialist O. Bjorke in 1979 to help with employment, serves as an example of cellular production in mini factories. Bjorke conceived of decentralizing automated plants similar to the Methodology for Unmanned Manufacturing, which was developed in 1972 in Japan (Merchant 1983). In the 1980s, the networks of companies in the Bologna region of Italy, Benetton's outsourced plants, or those of factory towns developed because their close proximity made it possible for them to share energy resources.

When industry in former Western city centers become automated, existing industrial buildings have the potential to be networked together to capitalize on the local production expertise. For example, the Garment District in New York City could be reborn, modeled on its former organization, just slightly more advanced than its automation age in virtually linked clusters. To expand upon this scenario: A designer in her office could complete a fashion concept and send the drawing digitally to the pattern maker. The pattern maker is linked to the sample fabricator, who transfers the files to the detail embroider. The detail embroider checks it, and then, finally, sends it to the main plant for production. Production is controlled via PDAs by the head office, which is communicating with the machine operators, who are also on their handhelds—all within five blocks of each other.

Local industries, flexible and versatile in what they make, could be formed to supply those adjacent communities that are networked from a centralized corporate office, decreasing production costs by eliminating distance shipping and storage, as some products would be made just in time for the local population. The idea of clustering enhances the new concepts in industrial symbiosis, where each element in the production is recycled into the next, and the "wasted" energy powers the town. Informal hidden cottage industries could become smaller and recognized as formal economies, as in Dharavi, Mumbai, or Queens, New York (Sassen 1991), where the seemingly informal economy is highly structured, but they could also be integrated into the urban fabric, eliminating the segregation of uses as determined by zoning the hybrid city. The scale of the multinational corporation could be reduced, showing a return to ideas of "small is beautiful" or a smallness within bigness (E.F. Schmaucher 1973) through mass customization, small batch work on flexible production systems, and finding the most productive rather than the cheapest laborers, who can be reeducated for each new manufacturing iteration.

The future smart factory, wherein mobile workers with PDAs are virtually connected to the production machines, moves beyond the modern assembly line and into the realm of organically integrated real-time processing, in a new networked spatial economy rather than an isolated heterotopia. This ubiquitous culture of making, thus, becomes part of the everyday urban experience.

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