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Innovation Junctions

Office Technologies in the Netherlands, 1880–1980

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One striking aspect of the twentieth century is the rise of a number of organizationally and geographically distinct spaces—cities, factories, households, hospitals, harbors, supermarkets, airports, offices, to name some of them—as important sites for technology development. As the century progressed, the number of different technologies in simultaneous use in these spaces increased. This collocation of technologies encouraged various actors to develop mechanisms and arrangements by which they could coordinate the interaction of these technologies. Typically these actors also developed mediating technologies that facilitated and stimulated the interaction of different technologies.

A number of scholars have reflected on the management activities required to deal with the complex interactions of collocated technologies. Joel Tarr and Gabriel Dupuy have shown how, at the end of the nineteenth century, as the growth of Western cities spawned serious logistical challenges concerning energy and water supplies, waste handling, transportation, and communications, municipal bureaucrats responded by beginning to coordinate and plan the layout of urban areas.[1] Lindy Biggs has pre-

1. Joel Tarr and Gabriel Dupuy, eds., *Technology and the Rise of the Networked City in Europe and America* (Philadelphia, 1988).

sented a picture of a new kind of industrial engineer starting to systematically plan the physical design of factories and develop assembly lines and conveyors to handle the flow of materials between machines and work stations in the factory.[2] In fact, the concepts of "urban technology" and "factory technology" gained currency by the increased collocation of technologies at specific sites. As the city and factory shaped technologies, so in turn did technologies shape the city and the factory.

In this article we analyze the collocation of technologies and the resultant patterns of development created in a specific site: the office. For this purpose we advance the concept of the "innovation junction," which we define as a space in which different sets of heterogeneous technologies are mobilized in support of social and economic activities and in which, as a result of their collocation, interactions and exchanges among these technologies occur. These interactions and exchanges lead to location-specific innovation patterns. The problems posed and opportunities offered by the collocation and interaction of different sets of technologies in bounded spaces create a need for coordination. This need is defined not only by users themselves (companies, managers, employees) but also by a new type of intermediate actor positioned between producers and users of technologies, working and reflecting on their interaction. Like the city and the factory, the office became the subject of intense analysis and intervention by these reflexive actors. Two forms of interaction among artifacts resulted as well: the combined use of two or more technologies and the extension of the functional characteristics of technologies, including the transfer of functional characteristics from one technology to another.

Innovation junctions are not exclusively twentieth-century phenomena; many factory and harbor technologies (to name only two possibilities) were applied concurrently in earlier eras. However, in the twentieth century innovation junctions became increasingly important to the development of technology and society. Their impact on twentieth-century society is comparable to that of large, geographically dispersed, infrastructural systems, such as electrical grids, communication networks, and transportation systems.[3] They led to the emergence of a new range of infrastructures, prod-

2. Lindy Biggs, "The Engineered Factory," *Technology and Culture* 36, suppl. (1995): S174–88; *The Rational Factory: Architecture, Technology and Work in America's Age of Mass Production* (Baltimore, 1996).

3. On large technical systems, see Renate Mayntz and Thomas P. Hughes, eds., *The Development of Large Technical Systems* (Frankfurt am Main and Boulder, Colo., 1988); Thomas P. Hughes, *American Genesis: A Century of Invention and Technological Enthusiasm* (New York, 1989); Todd R. La Porte, ed., *Social Responses to Large Technical Systems* (Dordrecht and Boston, 1991); Renate Mayntz, "Grosse technische Systeme und ihre gesellschaftstheoretische Bedeutung," *Kölner Zeitschrift für Sociologie und Socialpsychologie* 45 (1993): 97–108; Jane Summerton, ed., *Changing Large Technical Systems* (Boulder, Colo., 1994); M. Karlsson and L. Sturesson, eds., *The World's Largest Machine: Global Telecommunications and the Human Condition* (Stockholm, 1995); Arne Kaijser and Marika Hedin, eds., *Nordic Energy Systems: Historical Perspectives and Current Issues*

ucts, activities, services, and industries, and to new sets of user patterns and identities. However, innovation junctions differ in fundamental ways from the infrastructure-based systems that have been studied using the large technical systems perspective inspired by Thomas Hughes's classic *Networks of Power*.[4] Hughes's study offers a generalized model of the process of large system development, arguing that a number of characteristic phases in that development can be distinguished: invention, development and innovation, transfer, growth, and momentum. During each phase specific groups are foregrounded—engineers-entrepreneurs, manager-entrepreneurs, and finally financier-entrepreneurs—to produce solutions to the problems encountered in building the system. In addition, in Hughes's model system development proceeds through a number of mechanisms: attention to a favorable load factor and economic mix, identification of reverse salients, and the creation of momentum.

Although understanding the mechanisms of systems development may be important for understanding the development of innovation junctions, the Hughesian framework is not appropriate for analyzing them. The main reason for this is that the change dynamics of innovation junctions are not determined by the process of creating and sustaining geographically dispersed, material infrastructures. Instead, technology development at innovation junctions takes place by dealing with the challenge posed by the existence of different sets of technologies at one location. Whereas large technical systems derive their dynamics from geographical expansion, innovation junctions derive their dynamics from collocation in specific spaces.[5] Their local and spatial base also distinguishes innovation junctions from second-order large technical systems. The concept of second-order large technical systems has recently been introduced as a necessary complement to the first-order large technical systems analyzed by Hughes.[6] Second-order large technical systems such as, for instance, postal systems or organ transplant systems, are built on top of first-order large technical systems, combining and utilizing elements of them. In this sense, second-order large technical systems are similar to innovation junctions, which also incorporate different sets of technologies. However, in contrast to innovation junctions, second-order technical systems are highly dispersed. As a result, they do not foster a location-based interaction and exchange among sets of technologies. Also, although first and second-order large technical systems contain sites of technology development, these are loosely

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(Canton, Mass., 1995); Olivier Coutard, ed., *The Governance of Large Technical Systems* (New York, 1999).

4. Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880–1930* (Baltimore, 1988).

5. This, of course, does not mean that innovation junctions do not expand.

6. Ingo Braun and Bernward Joerges, "How to Reconcile Large Technical Systems: The Case of European Organ Transplantation," in Summerton, 25–51.

or tightly coupled through large-scale infrastructural networks. Thus, airports and harbors can be viewed as hierarchically connected sites within larger systems of transportation. Factories, households, and offices, in contrast, are far less systematically coupled, although they too are part of common sociotechnical networks.[7]

Ruth Schwartz Cowan has pointed to the importance of user location in explaining technological development. In her view, to understand technical change, and especially diffusion, one needs to identify the consumption-production networks (ranging from producers through intermediate actors to final consumers) and to view those networks in which new technologies are produced from the consumer's point of view.[8] Cowan defines the household as "the consumption junction, the place and the time at which the consumer makes choices between competing technologies."[9] The way we address junctions is inspired by her concept, especially her emphasis on users, but differs from it in a fundamental way. We will emphasize innovation patterns that result from the combined use of different technologies and the transfer of functional characteristics between technologies. Cowan's analysis is restricted to competing technologies and consumer choices, while our focus is on problems and opportunities raised by the collocation of a number of technologies.[10]

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7. Braun and Joerges refer to firms and households as the opposite ends of the continuum of large technical systems, with second-order systems positioned halfway between these two poles; Braun and Joerges, 44–45.

8. Ruth Schwartz Cowan, "The Consumption Junction: A Proposal for Research Strategies in the Sociology of Technology," in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, ed. Wiebe E. Bijker, Trevor Pinch, and Thomas P. Hughes (Cambridge, Mass., 1987), 261–80. See also Thomas J. Misa, *A Nation of Steel: The Making of Modern America, 1865-1925* (Baltimore, 1995); Misa argues convincingly that innovation in steel manufacturing can only be understood by focusing on changing user-producer relationships.

9. Cowan, 263.

10. The issue of the interaction of technologies has been addressed from different viewpoints. Economic historians such as Nathan Rosenberg have pointed to the importance of interdependencies or complementarities among different technologies in explaining economic growth; see "Technological Interdependence in the American Economy," *Technology and Culture* 20 (1979): 25–50. Space has become an important concept in economics, especially as it contributes to understanding why innovations (defined as successfully introduced new products) are often clustered. Such a clustering delivers competitive advantages through spillovers, learning effects, informal information sharing, and scale effects. See Peter Hall, *Cities in Civilization* (New York, 1998), 291–500. See also John Seely Brown and Paul Duguid, *The Social Life of Information* (Boston, 2000); using the example of Silicon Valley, they argue that space remains meaningful in the age of globalization and expanding information flows. Francesca Bray, in *Technology and Gender: Fabrics of Power in Late Imperial China* (Berkeley and Los Angeles, 1997), has stressed the importance of studying different sets of technologies simultaneously. To understand the construction of gender, the relations between people, and the lack of overt change in China, Bray analyzed various technolo-

The Office as Innovation Junction

Our focus here is the development of the office in the Netherlands between 1880 and 1980, roughly the period between the introduction of the typewriter and the introduction of the personal computer. Since the kind of interactions we were looking for took place on the leading edge of office technology development and were therefore first implemented in larger offices, we have left smaller offices out of our analysis. New research will have to establish whether the technology dynamics identified in this article also hold true for smaller offices, offices outside the Netherlands, and other kinds of innovation junctions.[11] Our focus is not so much on what actually went on in the office—at the shop-floor level, so to speak—as on the design of the processes of interaction. Accordingly, we have primarily studied the actors responsible for decisions concerning the procurement and application of office technology.[12] We will draw mainly on case material from a number of Dutch companies in the service sector and in trade and industry, and on sales literature from office machine producers and importers.

The office as a distinct domain started to emerge in the Netherlands in the second half of the nineteenth century. At about the same time, copying presses and hectographs were introduced to supplement the traditional pen and paper. Large offices appeared at the end of the nineteenth century and continued to grow during the first decades of the twentieth century. A host of new technologies surfaced, among them typewriters; accounting, bookkeeping, stencil, and addressing machines; and punched-card installations. In the 1920s and 1930s, offices with over a thousand employees and substantially mechanized administrative operations were not unusual.[13] Computers followed in the 1950s. These technologies were employed in the performance of a number of different activities, ranging from the production, copying, storage, and transmission of documents to bookkeeping and accounting to administrative data processing. Since all were used in the same location and for more or less interconnected tasks, they had to be geared to each other to an increasing extent and so became, in various ways, more and more interdependent.

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gies that provide overlapping contexts for the processes of social construction. We share Bray's desire to leave single-technology case studies behind and her focus on incorporating a spatial dimension in the history of technology, but we add an emphasis on analyzing the shaping role of collocation of various technologies, which cannot be found in her work.

11. This research is well underway as part of the Dutch national research project on the history of technology in the twentieth century.

12. This choice, of course, resembles Hughes's focus on system builders.

13. Onno de Wit and Jan van den Ende, "The Emergence of a New Regime: Business Management and Office Mechanization in the Dutch Financial Sector in the 1920s," *Business History* 42 (April 2000): 87–118.

The existing literature on the history of the office and the history of office technologies can be roughly divided into three main categories. One category describes and analyzes the development of office technology in the context of changing labor and gender relationships.[14] Another focuses on specific user locations at which specific technologies, such as punched-card machines or computers, were introduced and applied.[15] A third considers the design of office machines and technologies at the level of specific artifacts.[16] Generally speaking, this literature as a whole does not systematically analyze the processes of interaction inside the office either at the level of the dynamics of office technologies or at the level of the actors involved. One notable and inspiring exception is JoAnne Yates, whose *Control through Communication* offers on the one hand historical overviews of several early office technologies and on the other case histories of the ways in which internal communication processes were transformed at several major American companies.[17] However, in contrast to the approach taken in this article, Yates does not conceptualize these interaction processes inside the office, and limits her analysis to text production, copying, and filing.

14. See, for example, Alan Delgado, *The Enormous File: A Social History of the Office* (London, 1979); Margery W. Davies, *Woman's Place Is at the Typewriter: Office Work and Office Workers, 1870–1930* (Philadelphia, 1982); Joli Jensen, "Using the Typewriter: Secretaries, Reporters and Authors, 1880–1930," *Technology in Society* 10 (1988): 255–66; Sharon Hartman Strom, *Beyond the Typewriter: Gender, Class, and the Origins of Modern Office Work, 1900–1930* (Urbana, Ill., 1992); Angel Kowlek-Folland, *Engendering Business: Men and Women in the Corporate Office, 1870–1930* (Baltimore, 1994); Francisca de Haan, *Gender and the Politics of Office Work: The Netherlands, 1860–1940* (Amsterdam, 1998).

15. Arthur L. Norberg, "High-Technology Calculation in the Early 20th Century: Punched-Card Machinery in Business and Government," *Technology and Culture* 31 (October 1990): 753–79; Martin Campbell-Kelly, "Large-Scale Data Processing in the Prudential, 1850–1930," *Accounting, Business and Financial History* 1 (1992): 117–39; JoAnne Yates, "Co-evolution of Information-Processing Technology and Use: Interaction between the Life Insurance and Tabulating Industries," *Business History Review* 67 (spring 1993): 1–51; Martin Campbell-Kelly, "The Railway Clearing House and Victorian Data Processing," in *Information Acumen: The Understanding and Use of Knowledge in Modern Business*, ed. Lisa Bud-Frierman (London, 1994), 51–74; Martin Campbell-Kelly, "Data Processing and Technological Change: The Post Office Savings Bank, 1861–1930," *Technology and Culture* 39 (1998): 1–32.

16. Stan Augarten, *Bit by Bit: An Illustrated History of Computers* (New York, 1984); Adrian Forty, *Objects of Desire: Design and Society, 1750–1980* (London, 1986); Andreas Knie, "'Generierung' und 'Härtung' technischen Wissens: Die Entstehung der mechanischen Schreibmaschine," *Technikgeschichte* 58 (1991): 101–26; Rodney Dale and Rebecca Weaver, *Machines in the Office* (London, 1993); Ellen Lupton, *Mechanical Brides: Women and Machines from Home to Office* (New York, 1993); Charles W. Wootton and Carel M. Wolk, "The Evolution and Acceptance of the Loose-Leaf Accounting System, 1885–1935," *Technology and Culture* 41 (2000): 80–98.

17. JoAnne Yates, *Control through Communication: The Rise of System in American Management* (Baltimore, 1989).

This article discerns three phases in the history of the office, each characterized by specific patterns of interaction between office machines and producers, users, and intermediary actors. We will discuss each of these periods in turn before proceeding finally to an analysis of the patterns that resulted from those interactions and a discussion of how they differ from the dynamics of large technical systems.

New Office Machines, 1880–1914

Between 1880 and 1914, the development of new management practices, the rise of large firms, and the establishment of new government requirements spurred demand by owners and managers of companies for new methods of bookkeeping and cost accounting.[18] Several new technologies accompanied the new office methods, and among these the typewriter was of central importance. The American Remington Typewriter Company began selling typewriters in Europe, including the Netherlands, in the early 1880s, and the trading company Fred. Stieltjes and Company became Remington's Dutch sales representative in about 1883.[19] By shortly after the turn of the century, one major office equipment company, Blikman and Sartorius, was selling almost two hundred typewriters a year.[20]

Available data suggest that in the Netherlands as elsewhere the first users of the typewriter were predominantly top male managers.[21] However, the typewriter was very soon transferred to the domain of male or female secretaries, who combined typewriting with dictation, shorthand, and telephone work.[22] Because the typewriter speeded up the process of text production, managers gradually separated the conceptualization and writing of text.[23] Innovations that were introduced almost simultaneously with the typewriter, such as the dictating machine and various shorthand writing

18. Jan A. de Jonge, *De industrialisatie in Nederland tussen 1850 en 1914* (Nijmegen, 1976), 234–36; Jan Luiten van Zanden, ed., *The Economic Development of the Netherlands since 1870* (Cheltenham, 1996).

19. Circular letter of Fred. Stieltjes and Company and accompanying testimonials of Remington typewriter users, 18 April 1890, Gemeentearchief Amsterdam, bibliotheek, N.42.175.18, nos. 2 and 3.

20. Cornelia C. van de Graft, *Lotgevallen van een Amsterdams koopmanshuis 1749–1949* (Amsterdam, 1949), 208.

21. Jensen (n. 14 above); Strom (n. 14 above), 48–49, 62, 177; Francisca de Haan, *Sekse op kantoor: Over vrouwelijkheid, mannelijkheid en macht, Nederland 1860–1940* (Hilversum, 1992), 141–50.

22. Although the decision concerning the purchase of a typewriter undoubtedly was the office manager's, at some companies that already used one or more typewriters employees insisted upon the purchase of additional machines; B. P. A. Gales, *Werken aan zekerheid: Een terugblik over de schouder van AEGON op twee eeuwen verzkerings-geschiedenis* (The Hague, 1986), 178.

23. Yates, *Control through Communication* (n. 17 above), 39–45.

techniques, enabled this separation.[24] Typewriter agencies capitalized on this development by combining typewriter courses with courses in shorthand writing.[25]

Typewriting also came to be linked to the reproduction of texts and documents. Before the introduction of the typewriter, the production and copying of a text were two separate activities: after the text was written, it was copied with the help of a copying press or hectograph. With the invention of carbon paper suitable for typewriters, it became possible to combine writing with copying.[26] At the turn of the century, almost all Dutch typewriter ads promoted this possibility.[27] With carbon paper, up to twenty copies of a letter or invoice could be made.[28] Also, typewriting was compatible with a new copying technology introduced during the 1890s, stencil duplicating. Although cyclostyles or mimeographs, as stencil duplicators were called in the United States, at first were used to make copies of handwritten texts, after the introduction of the typewriter stencil paper was developed that was suitable for making typewritten stencils. A 1904 advertisement claimed that the combination of the mimeograph and the National typewriter could produce as many as two thousand readable copies.[29]

The increased mechanization of the office not only affected the production and reproduction of letters and documents, it also influenced their filing and storage. The introduction of typewriters and carbon paper provoked the introduction of alternatives to the bound ledger. Duplication of current account notes, for example, became unnecessary if a loose-leaf current account book was used in combination with the typewriter and carbon paper. Files or ledgers consisting of loose leaves also made it feasible to arrange documents thematically instead of in the traditional chronological scheme. In some instances, the relationship between typewriter and file systems was reversed: at a number of insurance companies and registry offices

24. On the invention of the dictaphone, see Edward J. Pershey, "Drawing as a Means to Inventing: Edison and the Invention of the Phonograph," in *Working at Invention: Thomas A. Edison and the Menlo Park Experience*, ed. William S. Pretzer (Dearborn, Mich., 1989), 100–115; Mark Clark, "Suppressing Innovation: Bell Telephone and Magnetic Recording," *Technology and Culture* 34 (1993): 521–37; David Morton, *Off the Record: The Technology and Culture of Sound Recording in America* (New Brunswick, N.J., 2000).

25. De Haan, *Sekse op kantoor*, 45, 139.

26. Yates, *Control through Communication*, 46–50.

27. Various advertisements, catalogues and price-lists of typewriter companies, Gemeentearchief Amsterdam, bibliotheek, N.41.151.28-36 and N.42.175.10-18.

28. Circular letter, Amsterdam Bar-Lock Company, circa 1905, Gemeentearchief Amsterdam, bibliotheek, N.41.151.29, no. 1. In practice, the number of readable copies that could be made was probably less than ten.

29. Circular letter, Lutkie & Smit, Amsterdam, August 1904, Gemeentearchief Amsterdam, bibliotheek, N.42.175.11, no. 5.

(local census bureaus), new card systems stimulated the introduction of typewriters.[30]

Thus, although new office technologies were not necessarily introduced simultaneously at individual companies, the presence of the typewriter made it much more likely that changes in duplicating methods and file systems would soon follow. The typewriter became the center of a new administrative organization in which the technologies employed in producing, reproducing, and storing documents were increasingly linked. Although these technologies were discrete in principal, several forms of interaction emerged during this period at local offices and out of local initiatives. Sales agents and importers of office technologies in turn picked up on these interactions, pointing to the efficiencies created by the combined use of new technologies to reinforce their sales efforts.

System Machines and Efficiency Experts, 1914–1955

In the 1910s, accountants, efficiency experts, business managers, senior public servants, management consultants, and psychologists hotly debated new ideas of systematic and scientific management emanating from the United States. They argued for rationalized and more efficient procedures and management in a wide range of municipal, national, and industrial companies and service sectors. Through the implementation of office technologies and the systematic analysis of information flows and work procedures, managers and outside consultants also sought to optimize the monitoring and control of administrative activities and financial operations.[31] In the 1920s, their individual activities became institutionalized as part of a broader efficiency movement. Members of this movement increasingly directed their attention to office management and administrative work procedures, as opposed to production. Several consulting firms and institutions were established that came to mediate between the producers and importers of office machines on the one hand and the users of these office machines on the other.

In 1922, the Dutch Mechanical Administrative Office Organization (Mechanisch-Administratieve Bedrijfs Organisatie, MABO) came into being, founded by a number of employees from the Amsterdam headquarters of the Rotterdamsche Bank who sought to commercially exploit the various reorganization and mechanization measures that they had been developing since 1917.[32] This was not the first Dutch organizational con-

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30. Gemeentearchief Utrecht, Secretariearchief VI 11318, overzicht jan. 1929 van bij gemeentelijke afdelingen en diensten in gebruik zijnde type- en kantoormachines; Gales (n. 22 above), 178–79.

31. De Wit and Van den Ende, "The Emergence of a New Regime" (n. 13 above).

32. For the history of the MABO, see Commissie Tak, *Rapport over de oorzaken van*

sultancy, but it was the first to concentrate exclusively on administration and office technology.[33] Partly in competition with the private MABO, beginning in about 1928 the Governmental Office Machine Center (Rijkskantoormachinecentrale, or KMC) started advising government departments on the purchase of office machines. One of the tasks given to the KMC was to assess the ways in which new office machines fitted into the existing office organization.[34]

Of the many organizations and institutions founded in the 1920s to promote efficiency in businesses and households, the Dutch Institute for Efficiency (Nederlands Instituut voor Efficiency, NIVE) was undoubtedly among the most important.[35] Founded in 1925, it established various "management research groups" that studied administrative methods and office machines, visited companies, and set up inquiries into the diffusion of office technologies. Beginning in 1927, the Research Group for Modern Office Technology (Studiekring voor Moderne Kantoortechniek, STUMOKA) also served as an important medium for transferring experience with office technology from one company to another. Members included a number of large banks, insurance companies, public utilities, and industrial companies. In 1930 STUMOKA officially became part of NIVE.[36]

The ad hoc implementation of office machinery during the years before World War I thus gave way to a much more systematic and professional approach. Whereas between 1880 and 1914 companies had simply experimented with new technologies, sometimes in cooperation with sales agents and importers, they now could turn for advice to management consulting firms and other intermediary organizations focused exclusively on rationalizing administrative activities and introducing office equipment. Office machinery was subsumed in a larger concern for efficiency, reorganization, and control.

The emergence of these intermediary organizations was closely related to technological developments. Most of the office machines that had been introduced during the previous phase now underwent a broad process of

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de ontwrichting en van de verergerde ontwrichting van den Postcheque- en Girodienst en de schuldigen daaraan (The Hague, 1924).

33. Peter Hellema and Joop Marsman, *De organisatie-adviseur: Opkomst en groei van een nieuw vak in Nederland 1920–1960* (Amsterdam, 1997).

34. Jan van Oorschot, "De ontwikkeling van de kantoormachines en de taak van de Rijkskantoormachinecentrale," *Informatie* 20 (1978): 718–24.

35. Peter Zwaal, *Een gemene zaak: Efficiency-ingenieurs, accountants en psychotechnici & en het Nederlandsch Instituut voor Efficiency als presentatieplatform van scientific management 1925–1940* (Rotterdam, 1991); Erik S. A. Bloemen, *Scientific management in Nederland 1900–1930* (Amsterdam, 1988), 165–81; Cita Hartveld, *Moderne zakelijkheid: Efficiency in wonen en werken in Nederland 1918–1940* (Amsterdam, 1994), 216–34.

36. A. M. J. Kruissink, *Een en ander over de "STUMOKA"* (Purmerend, 1931).

diffusion. Typewriters became common in the Dutch office, although certain types of offices, such as municipal registries, lagged behind. A 1926 handbook on office machines mentioned no fewer than twenty different brands of typewriters. Its author rightly remarked that companies without typewriters had become almost unthinkable.[37]

Beginning about 1914, as the typewriter and counting and adding devices became broadly diffused in the Netherlands, various multifunctional office machines appeared that could perform simultaneously a number of previously separate administrative activities. Examples of these "system machines," as they came to be called in the 1950s, include typewriting cash registers and typewriting counting machines as well as bookkeeping, punched-card, and addressing machines.[38] As the number and complexity of office machines increased, the demand for advice, instruction, and information also rose. This demand was still met in part by the importers and suppliers of office machines. In fact, during this period they institutionalized and professionalized their instructional activities.[39] But management consulting firms increasingly came to meet the demand for information on how office machinery and reorganization could be used to optimize administrative processes.

Addressing machines, introduced in the Netherlands just before World War I, undoubtedly became the most versatile system machines. Basically, these consisted of a punching device or typewriter that stamped addresses into metal or stencil sheets that were then linked together on a mimeograph machine. Companies that periodically had to send letters to large numbers of clients were the first purchasers, but beginning in the 1920s addressing machines came increasingly to be used for broader administrative purposes, such as producing lists of client data or printing names and addresses on invoices, bills, tickets, patients' identity discs, and notices. To make all this possible, addressing machines were fitted with mechanisms that supported list management and selection, printing, and tabulating. Because of their increased multifunctionality, it became easier to link addressing machines to other office machines, such as bookkeeping and punched-card machines. The practice at the Dutch central circulation bank, the Nederlandsche Bank, which was one of the first firms to purchase an addressing machine, offers an example. The printed lists produced by the bank's punched-card installation were cut into standard sizes in letter

37. R. G. ter Haak, *Kantoormachines en administratiesystemen: Een beschrijving van moderne hulpmiddelen ten dienste van de administratie* (Amsterdam, 1927), 278–304.

38. A. Meeuwis, *Hulpmiddelen der administratieve techniek* (The Hague, 1959), 3–4.

39. In 1919, the Dutch Association of Stationers (Nederlandsche Vereeniging van Kantoorboekhandelaren, NEVEKA) founded its own monthly magazine, and the Association of Importers and Producers of Office Machines (Vereeniging van Importeurs en Fabrikanten van Kantoormachines, VIFKA) regularly organized exhibitions on office efficiency from 1924 onward.

format. An Adressograph and a signature machine, the Graphotyp, then processed the lists into bills to be sent to the bank's clients.[40]

Increasing multifunctionality also allowed addressing machines to be developed into "organization systems," a term first used in the 1920s and 1930s by the Andrema Company, an early manufacturer. The term was intended to differentiate between machines used for ordinary addressing work and more complex models around which the entire administrative process could be organized.[41] In some companies addressing machines became the central building blocks of the administrative organization. In the 1930s, for instance, local Dutch health insurance companies used punched identity discs for patients' forms, doctors' and pharmacists' cards, and internal administration registers. This application of addressing machine technology was codeveloped by the insurance companies and the supplier of the Andrema addressing machine, H. A. Kramers & Zoon.[42] Similarly, in 1920 a number of health insurance companies went to Kramers & Zoon looking for an addressing machine that could print lists itself; the company began development, and the new machine was patented by Andrema in 1923.[43]

Punched-card devices also became important system machines. Herman Hollerith had developed these machines at the end of the nineteenth century in the United States for statistical applications, and they were first used on a wide scale in the 1890 United States census.[44] In Hollerith's system, clerks used keypunches to record data onto cards that were subsequently processed by sorting and tabulating machines. Punching, sorting, and tabulating machines could not operate independently, and in fact worked in close conjunction with each other. In addition to the Hollerith Company, which in the 1910s became part of the Computing-Tabulating-Recording Corporation (CTR), the Accounting Machine Company, established in 1911 by James Power, became an important manufacturer of punched-card machines. These two companies competed for the American and European markets, and both set up local Dutch agencies around 1920.[45]

Punched-card machines were introduced into the Netherlands in 1916, by the Dutch Central Statistical Office (CBS), which used the Hollerith

40. Jozef L. de Jager, *De bank van de gulden: Organisatie en personeel van De Nederlandsche Bank 1814–1989* (Amsterdam, 1989), 95, 121.

41. Joan I. W. Klaassen, "Adresseermachines: Ontwikkeling en gebruik van adresseermachines in de administratie" (graduation thesis, Technical University Eindhoven, 1994), 56–57.

42. Klaassen, 70–75.

43. Klaassen, 41.

44. On punched-card technology, see Martin Campbell-Kelly, "Punched-Card Machinery," in *Computing before Computers*, ed. William Aspray (Ames, Iowa, 1990), 122–55; Norberg (n. 15 above).

45. James Connolly, "History of Computing in Europe," unpublished report, IBM World Trade Corp., 1968, 19–21.

machines to calculate foreign trade statistics. The numbers were read off from the tabulating machine and copied manually onto Burroughs adding machines.[46] In the 1920s the number and types of companies that deployed punched-card machines had increased significantly.[47] Among this new group of users were insurance and industrial companies, municipal services, state-owned enterprises, and banks. All had extensive administrative operations, which justified the acquisition of the costly punched-card equipment. The Rotterdamsche Bank was one of the main Dutch pioneers in the application of punched-card technology, and came to serve as a model for other large companies, in particular for the Dutch Giro Service and the Dutch State Mines. Both companies reorganized administratively, with the help of the former bank employees who in 1922 had established the MABO, along the lines set up at the bank.[48]

At first the Rotterdamsche Bank's punched-card installation was used only in the bank's giro transfer system: for every transfer a punched card was made, and these cards were then sorted, tabulated, checked against the earlier totals, and finally used in the making up of transfer notes. By 1921 some three thousand transfers a day were being handled in this manner.[49] In the years that followed the number of Hollerith and Powers punched-card machines at the Rotterdamsche Bank's Amsterdam office increased significantly, as the machines were deployed for an increasing variety of administrative purposes.[50] This became evident during a 1926 exhibition on office organization and technology held in Amsterdam.[51] The exhibit catalog showed that calculating, bookkeeping, and punched-card machines had become central to the processing of all financial data, not just giro transactions. The bank was using punched-card machines to make up daily balance sheets for central management and to keep salary records, and the technology had been adopted in the bank's forwarding and postage department as well.[52]

The large-scale application of office machines at the Rotterdamsche Bank was accompanied by a systematic analysis of administrative processes

46. Jan van den Ende, *Knopen, kaarten en chips: De geschiedenis van de automatisering bij het Centraal Bureau voor de Statistiek* (Voorburg and Heerlen, 1991), 2–28.

47. Connolly, 20, E-3/7.

48. The transfer of ideas and punched-card technology from the Rotterdamsche Bank to other companies is dealt with in De Wit and Van den Ende, "The Emergence of a New Regime" (n. 13 above).

49. ABN AMRO, Historical Archive, Amsterdam, Archive Rotterdamsche Bank, no. 109, verslag vergadering Raad van Commissarissen, 16 November 1921.

50. From about 1920 onward, the bank used both Hollerith and Powers machinery. In 1925 and 1930 more Hollerith punched-card machinery was ordered; Archive Rotterdamsche Bank, no. 94, stukken betreffende The Tabulating Machine Company.

51. *De tentoonstelling op het gebied van de openbare en particuliere bedrijfsadministratie T.O.P.A. 1926*, 3 vols. (Purmerend, 1926–27).

52. Sam Roet, "Moderne expeditie- en portiadministratie," *Administratieve Arbeid* (1924), 84–92; H. Fedder, "Personeels-Administratie," *Administratieve Arbeid* (1927), 186–90.

aimed at optimizing them to suit information flows within the bank and identifying strategic points at which machines could be used to speed up work processes. Such analyses were common.[53] In the meantime, a number of innovations in the 1920s and 1930s allowed punched-card technology, which had until then been used primarily for statistical applications, to be adapted to bookkeeping and even more general administrative tasks. Improvements in methods of adding, subtracting, and multiplying helped to speed up statistical calculations and made it possible to perform more complex types of calculations. Tabulators were introduced that could print alphabetical characters in addition to numbers, an important innovation because it allowed names and addresses to be printed as well as numerical data, thus greatly enhancing the amount of information that could be provided in list form or in other sorts of documents.[54]

Both printing and alphabetical capability were innovations pioneered by the Powers' Accounting Machine Company. Powers produced an alphabetical tabulating machine as early as 1924, some seven or eight years before its rival CTR (which in 1924 changed its name to the International Business Machines Corporation) came up with a similar device.[55] The Powers alphabetical tabulator was introduced in the Netherlands in 1926.[56] It was quickly adopted by the Rotterdamsche Bank and by some of the other big Dutch banks for their securities administration. In 1932, the Twentsche Bank became the first European company to use an IBM alphabetical tabulator.[57]

Not all of the technical innovations in punched-card technology came from outside the Netherlands. At the Rotterdamsche Bank, Jan Stuivenberg, who had been involved in the design and application of punched-card machinery as early as 1920, played an important role in the successful adaptation of punched-card technology. Stuivenberg introduced several

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53. At the Dutch Central Statistical Bureau in 1937, for example, outside consultants analyzed the flow of forms and punched cards in the Trade Statistics Department, through different units using machinery that included sorting devices, punchers, punched-card sorters, tabulators, calculating machines, typewriters, archival devices. Van den Ende, *Knopen, kaarten en chips* (n. 46 above), 49–52.

54. Yates, "Co-evolution of Information-Processing Technology and Use" (n. 15 above); Campbell-Kelly, "Punched-Card Machinery" (n. 44 above), 142; *De tentoonstelling op het gebied van de openbare en particuliere bedrijfsadministratie*, 2:310–32; R. G. ter Haak, "Powers en haar nieuwe vindingen," *Administratieve Arbeid* (1931), 287–320, 345–66.

55. Ter Haak, "Powers en haar nieuwe vindingen"; M. C. Winterstein, "De alfabetische Hollerith-Tabelleermachine," *Administratieve Arbeid* (1932), 32–34. See also James W. Cortada, *Before the Computer: IBM, NCR, Burroughs, and Remington Rand and the Industry They Created, 1865–1956* (Princeton, N.J., 1993), 106–9.

56. *Catalogus "Efficiency" Tentoonstelling van moderne hulpmiddelen voor fabrieks- en kantooradministratie van 18 tot en met 27 maart 1926* (Amsterdam, 1926); *Administratieve Arbeid* (1926), 106–7.

57. C. W. Wintersteijn, *Banken, hare boekhouding en organisatie*, vol. 1 (Leiden, 1932), 50–53.

improvements to the bank's Hollerith and Powers machinery, including an automatic paper feeder for the Powers tabulator.[58]

Especially after the Second World War, producers and users of typewriters and system machines such as addressing machines and punched-card machines began to devote increasing attention to methods of exchanging information among them. Devices were developed that aimed at optimizing the transfer of data between typewriters and system machines. In all cases, punched cards and punched paper tapes served as interfaces. The Flexowriter, for instance, was an electric typewriter with an additional perforator that automatically transferred written text onto punched paper tapes. The tape could be used to operate the card punch of an addressing machine, or punched cards could be created from it using a tape-to-card converter. The process worked the other way around as well; several machines, including the Flexowriter, the Cardatype, and the Justowriter, could process punched tapes or cards into written text.[59]

The Flexowriter and Justowriter came onto the market in the beginning of the 1950s.[60] One of the companies that developed such devices in the Netherlands was the Philips Electronics Company. Stock movements were registered and billed by a small bookkeeping machine. Simultaneously, a card punch connected to the bookkeeping machine produced a punched card, which was subsequently processed by a tabulating machine. By connecting bookkeeping and punched card technology in this way, Philips eliminated several intermediate operations. In 1955 the connecting device was put into use (for Philips' stock administration).[61]

Research into integration devices continued at Philips during the second half of the 1950s as researchers studied methods of determining differences between written and punched data and of converting punched cards to punched paper tapes or vice versa. As more and more typewriters and bookkeeping machines produced punched paper tapes the question of which medium was most appropriate as an integration device, punched cards or punched tapes, also arose. Because tapes were suitable for data transmission and because the similarity between written and punched data could more easily be checked in tapes, Philips settled on them.[62]

58. Connolly (n. 45 above), 20.

59. Meeuwis (n. 38 above), 198–218; Studiegroep Industrie Den Haag, *Administratieve techniek* (The Hague, 1954).

60. *Modern Kantoor*, July–August 1958, 121; VIFKA Archive, Woerden, files Efficiency Exhibitions 1959-1970, Efficiency Beurs 1960.

61. D. Pietersma, "Enkele kleine integratiehulpmiddelen in de administratie," in *Omschakeling naar automatie: Enkele bijdragen over de ontwikkeling naar automatische informatieverwerking*, ed. N. V. Philips (Eindhoven, 1960), 10.0–6.

62. A. Meeuwis, "Aanpak van automatie in de administratie," in Philips, 2.0–11. The telex service of the Dutch Post, Telegraph and Telephone Administration was using punched paper tape as a transmission medium by the early 1950s.

To summarize, after about 1914 the introduction and application of office machines grew more complex. The successful integration of system machines into an administrative organization called for much closer cooperation between suppliers and users, who also frequently called on consulting firms for advice about office technology. Sometimes these consulting firms were users who sought to transfer their own experience with office technology to other locations, emphasizing the interdependencies among efficiency, new management styles, and office machines. Devices with different functions, such as text production and data processing, came increasingly to be linked to each other: addressing machines were used in combination with typewriters or punched-card machines, punched-card machines in conjunction with calculating machines and printers. Both the addressing machine and the punched-card machine developed from rather simple technologies into complex data processing units, drawing together a number of administrative activities—counting, sorting, writing, listing, and the like—that had previously been separate. In addition to this functional integration, punched cards and tapes developed into media for transferring data between different office technologies. As a result, office technology increasingly came to mean a chain of stand-alone devices integrated by means of punched cards and punched tapes.

Integrated Data Processing, 1955–1980

From the mid-1950s on, the electronic computer gradually changed the Dutch office landscape. Although the computer was developed for scientific calculations, it did not take long for office equipment companies as well as office managers and efficiency consultants to recognize its potential as a data processing technology in the office. The 1953 introduction by IBM of the relatively small and cheap IBM 650 marked the definitive breakthrough of computers in the office; an IBM 650 installed in 1957 by the Dutch Land Cultivation Company (Nederlandse Heidemaatschappij) was the first computer in the Netherlands specifically used for office automation.[63] Although the company had never been in the forefront of office technology, its involvement in numerous postwar reconstruction projects led to a dramatic and increasingly problematic growth in administrative operations.[64]

63. By 1968 almost a thousand computers had been installed in the Netherlands. The Association of Importers and Producers of Office Machines estimated that eighty percent of these were used for administrative purposes: R. J. Romein, "Computers in Nederland," *Informatie* 11 (1969): 316; *Kantoor en Efficiency*, September 1968, 4011. The IBM 650 was called the Model T of computers; Rick Szostak, *Technological Innovation and the Great Depression* (Boulder, Colo., 1995), 198.

64. Speech, H. J. A. Hendrikx, 28 March 1957, and annual reports, 1947–57, Rijksarchief Gelderland, Arnhem, archief Heidemaatschappij, no. 538.

Technically, at the Heidemaatschappij and elsewhere, the computer was a novelty. The first generation of computers employed vacuum tubes, which had already been used in punched-card tabulating machines such as the IBM 604, which had appeared on the market in 1948.[65] The crucial difference between electromechanical punched-card machines and computers lay in the fact that computers had internal processing units and memories that could store not only data but also programs.[66] This made the computer much more programmable than punched-card machines. It also demanded different programming techniques.[67] Internal processors and random access memory gave computers the capacity to perform long series of operations in a single step. As a result, the computer integrated functions (sorting, collating, tabulating, and the like) for which punched-card installations needed different machines. Finally, computers were much faster than punched-card machines. Despite the fact that early computers were expensive, unreliable, and difficult to use, these new features were attractive enough for several actors to invest in domesticating this promising technology into an efficient office machine.[68] These actors embraced the computer as a symbol of the modern office and as a forceful instrument of the schematization and systematization of office work.[69]

A continuing intensive interaction among hardware suppliers, efficiency engineers, office managers, and employees accompanied the implementation of the computer in the office. Despite this pattern of interaction, users tended to become dependent upon the programming and systems knowledge of hardware suppliers. Since the programming of first generation computers was system dependent and programming techniques differed from those of punched-card installations, office managers and efficiency engineers could only partially rely on their earlier experiences. But managers and engineers were uncomfortable with the dominant position that their lack of knowledge gave hardware suppliers, and they responded by using existing intermediary organizations, such as NIVE and STUMOKA, to exchange knowledge and experience about office automation. In 1958 they established a new institution, the Study Center for Administrative Automation (Sticht-

65. Paul Ceruzzi, "Electronics Technology and Computer Science, 1940–1975: A Coevolution," *Annals of the History of Computing* 10 (1989): 261.

66. Paul Ceruzzi, "Crossing the Divide: Architectural Issues and the Emergence of the Stored Program Computer, 1935–1955," *IEEE Annals of the History of Computing* 19 (1997): 5–12.

67. Punched-card machines were programmed by wired switchboards that connected the reading devices of the machines with tabulating and print mechanisms, as opposed to putting abstract code into computer memory.

68. Paul N. Edwards, "Y2K: Millennial Reflections on Computers as Infrastructure," *History and Technology* 15 (1998): 7–29, at 13; Martin Campbell-Kelly and William Aspray, *Computer: A History of the Information Machine* (New York, 1996), 105–30.

69. Ellen van Oost, "Administratieve automatisering," in *Techniek in Nederland in de twintigste eeuw*, ed. Johan Schot et al., vol. 1 (Zutphen, 1998), 326–27.

ing Studiecentrum Administratieve Automatisering, SSAA). The SSAA, through various working and research groups, played a pivotal role in the development of office automation in the Netherlands until the mid-1970s. It became the central forum for managers, management consultants, economists, engineers, and mathematicians who were, in one way or another, involved with the growing field of information processing. As such, the SSAA became the cradle of a nascent group of computer professionals. It also quite successfully strengthened the position of user organizations with respect to hardware suppliers.[70]

Initially the computer constituted only a minor break as far as the interaction among office machines was concerned. Punched cards and punched tapes continued to serve as interfaces between computers and other devices. The Rotterdamsche Bank, for instance, introduced in the early 1960s a system to handle counter transactions by bookkeeping machines that produced a punched tape. During the night a tape-fed central computer processed all transactions.[71] In general, in this period punched cards and tapes only increased in significance, as they were the main input media for the first- and second-generation computers.[72] Significantly, when IBM introduced its third-generation 360/40 computer, which was suitable for both computing and data processing, the company called it a punched-card installation inside a computer.[73] In practice, punched-card departments were gradually transformed into central computing departments.[74] Often this transformation was accompanied by the integration of departments that had previously existed alongside each other.[75]

70. The SSAA was not a commercial consulting firm or a publicly financed nonprofit organization. During the first ten years its income came mainly from the contributions of associated companies that pioneered automation. From the end of the 1960s onward, it was gradually transformed into a training and examination institute that regulated and controlled the education of the new computer professionals. For the history of the SSAA, see Ellen van Oost, *Nieuwe functies, nieuwe verschillen: Genderprocessen in de constructie van de nieuwe automatiseringsfuncties 1955–1970* (Delft, 1994), 209–49.

71. Algemeen Nederlands Persbureau (General Dutch Press Association) telex news message, archive of the Rijkscentrale voor Mechnische Administratie, Apeldoorn, 21 June 1963.

72. The technical development of computers usually is characterized in generations. The first generation (1953–58) used vacuum tubes as central elements in the processing unit. The second generation (1958–64) used transistors. Transistorized computers were smaller and faster than those with vacuum tubes and did not need to be cooled. The third generation (1964–1972) incorporated the new integrated circuit (IC) technology. Not only were these machines (again) faster and smaller, but their internal programming was organized differently. They had a separate operating system, making such new functionalities as timesharing and multitasking possible.

73. *Kantoor en Efficiency*, September 1968, 4011.

74. Meeuwis, *Hulpmiddelen der administratieve techniek* (n. 38 above), 6.

75. S. Swaab, *Methodiek van de automatische administratie* (Alphen aan den Rijn, 1962), 174.

Although computers could process large sets of data faster than mechanical machines, the technology for producing the data input hardly changed. This led to an almost insatiable demand for typists, and it was difficult to staff the noisy punching rooms.[76] Several technologies were developed to automate data entry, not only by computer suppliers like IBM but also by technical departments in user organizations.[77] A relatively simple innovation was the so-called dual-purpose card, which contained both handwritten and machine-readable information. Probably the best-known dual-purpose cards in the Netherlands were remittance forms in the shape of a punched card; introduced by the Dutch Giro Service in 1961, when the service began to automate its account administration, these remained in use until the middle of the 1980s.[78] Dual-purpose cards could integrate the administrations of various actors—companies, banks, account holders, and clients.[79] An energy company, for instance, could send a punched card to a client, who would then manually fill in the missing information, keep one part of the card for their records, and then send the card to the Giro Service, where it would be automatically processed.[80]

In general, the tendency toward the integration of more tasks into a single machine that dated from before the computer era intensified between 1955 and 1980. Experts writing on office technology now explicitly began to call the new way of working "integrated data processing," thereby also retroactively labeling the tendency toward integration in the first half of the 1950s with this term.[81] Particularly in third-generation computers, which possessed timesharing and multitasking capabilities and could be controlled from terminals or consoles, interaction with other office machines, such as Flexowriters and Justowriters, became largely superfluous. The computer simply took over the tasks of devices such as addressing ma-

76. Van Oost, *Nieuwe functies, nieuwe verschillen* (n. 70 above), 175–97. In general, the 1950s and 1960s were a period of persistent labor shortage in the Netherlands; Van Zanden (n. 18 above).

77. In the mid-1960s the R&D department of the governmental Postal, Telegraph and Telephone Services developed the ALPINO system, a machine that could automatically read and punch numerical information, in an attempt to solve the data-entry problem at the Dutch Giro Service; Van Oost, *Nieuwe functies, nieuwe verschillen*, 195. Mark sensing was successfully used by the Dutch Central Statistical Office for the 1971 census: Van den Ende, *Knopen, kaarten en chips* (n. 46 above), 96.

78. Because of labor shortages, the Giro Service, where data processing was still predominantly done by hand until the end of the 1950s, twice had to stop accepting new accounts. After the second time, in 1961, management decided to initiate an automation project. Interestingly, the Giro Service then became one of the leaders in the field of office automation: Van Oost, *Nieuwe functies, nieuwe verschillen*, 95–133.

79. Meeuwis, *Hulpmiddelen der administratieve techniek*, 284.

80. The Giro Service called this "external integration": G. F. J. A. Groen, "De taaie ponskaart," in *Een halve eeuw Postcheque- en Girodienst*, ed. Hendrik Reinoud et al. (Utrecht, 1968), 236–42, at 239.

81. Meeuwis, *Hulpmiddelen der administratieve techniek* (n. 38 above).

chines. Remote control and data transfer over telephone lines replaced the traditional cards and tapes. Multipurpose databases could be used simultaneously for different purposes by different departments within the same organization. In the early 1970s hardware suppliers indeed developed several types of remote desktops (keyboard and monitor) to be used for administrative processes.[82] In the second half of the 1970s these remote workstations began to be equipped with processing units and connected to electronic typewriters or printers, thus creating the possibility of integrating data processing and text processing.[83] These so-called multiuser systems were similar in functionality to the personal computers that would conquer the office desktop in the 1980s.[84]

The computer continued the trajectory of punched-card machinery in the office but accelerated the pace of the extension of functional characteristics. This was particularly true of the third-generation computers that appeared in the 1960s, which had better systems for handling databases and possessed time-sharing capabilities. The computer assumed the functions of several other machines and office technologies, and data transfer between computers and other devices became far less important. This meant that some existing interfaces between different office technologies became superfluous—and were, in fact, incorporated in the design of the computer.

The Dynamics of the Innovation Junction

This article has attempted to analyze the workings of the office as an innovation junction at two different but connected levels: at the level of artifacts, and at the level of emerging and changing relations between producers and users of office technology. We argue that the office evolved through a set of specific interactions between artifacts and actors. The office that finally came about was partly an unintended consequence of this process, but also partly the deliberate aim of a number of reflexive actors pushing for the development of the modern office.

At the level of artifacts, the development and use of one type of office technology interacted with the development and use of other types. Two forms of interaction can be distinguished, both of which, in different periods and in different combinations, occurred in the office. First, two or more

82. Paul Atkinson, "Computer Memories: The History of Computer Form," *History and Technology* 15 (1998): 89–120.

83. Atkinson, 107.

84. The miniaturization that eventually led to minicomputers and personal computers stimulated a break in the centralized organization of data processing. Their rapid adoption in the 1980s resulted in a wide array of "incompatible, stand-alone machines and software." Managers attempting to regain (central) control were partly responsible for the rise of networked systems; Edwards (n. 68 above), 22.

technologies could be used in combination. Often this combined use was accompanied by innovation in one or more technologies or by the creation of interfaces between one or more technologies. Examples of combined use include the typewriter with carbon paper and dictaphone and the extension of the function of the typewriter through the interface of punched tape. Other examples are the Flexowriter and Justowriter; these had only a relatively short life before they were made superfluous by the second form of interaction, the functional integration of the digital computer. Second, the functional characteristics of technologies could be extended, or the characteristics of one technology transferred to another, leading to functional integration. Functional integration may refer to different technologies being used concurrently in one location, one of which takes over functions of human beings or of other technologies, as punched-card machines took over functions of bookkeeping and text-producing technologies. Functional integration may also refer to a new technology integrating the functions of different old ones, as the digital computer in a short period of time took over functions of various existing devices (punched-card machines, typewriters, bookkeeping machines, and desk calculators).

Generally speaking, the functional characteristics of an office machine and technology were at first clearly related to a specific functional domain inside the office: the production, reproduction, filing, or archiving of documents, as well as data processing, computing, or communication. Typewriters, for instance, were intimately linked to the production of letters and other documents, whereas punched-card machines primarily served data processing tasks. At first, interaction mainly took place between machines and technologies inside a specific domain, such as document production, reproduction, and filing. However, interaction increasingly crossed the borders of the various office activities.

The interaction process between different technologies was accompanied by historical changes in the relations among the actors involved. Four different actor groups can be distinguished: the producers of office machines and computer software, which in the Dutch case were almost without exception foreign companies; Dutch importers of office machines and office machine dealers, who often were represented in one and the same company; professional groups involved in the introduction and application of office technology, particularly efficiency engineers and, later on, computer professionals; and the users of office machines. It is important to note that the third group did not yet exist when the modern office started to emerge at the end of the nineteenth century. This group later became crucially important in creating a network of offices that are not hierarchically connected but which evolve interactively.

Based on the interaction processes and the various roles played by these actors, it is possible to distinguish three phases in the history of the Dutch office, each characterized by specific types of interaction between

office machines and actors. In the first phase, one of ad hoc integration, which lasted from about the 1880s until World War I, several new office machines were introduced that mechanized only one isolated administrative activity, such as writing or counting. One of these machines, the typewriter, was at the center of several other technologies applied to the production and reproduction of documents. In this period, three groups of actors were active in the office—producers, importers, and users—but none was dominant.

During the second period, the era of partial integration, lasting from about 1914 until about 1955, new kinds of more complex office machines were introduced. We discussed in particular addressing machines, which mechanized the process of sending large numbers of letters, and punched-card machines, which process large volumes of numerical (and, later, alphabetical) data by sorting and counting. These different types of system machines, as this new generation of office technologies was called in the 1950s, increasingly combined the mechanization of several administrative activities—for instance, data processing and printing. Moreover, punched cards and punched paper tapes served as interfaces between system machines and a wide range of stand-alone office machines. The introduction and use of these office technologies often resulted in dramatic changes in office organization. More than in the previous phase, office managers had to adapt administrative processes to the machines. Large-scale service industries created separate departments for processing punched cards. During this period consultants came to form a new and important professional group, which pushed unceasingly for integration. They advised on the organization of the office, including the introduction and implementation of new technology.

During the period from about 1955 until about 1980, a period of centralized integration, a transition took place to integrated data processing and electronic data processing. For some companies, the introduction of computers for administrative purposes, which in the Netherlands started in the mid-1950s, was a revolutionary break from the past. For others, computer technology replaced punched-card devices and some other office machines. Punched cards and tapes remained important in the early part of the computer age, and in fact became the main input media for computers. During this phase the position of users and intermediary professional consultants was threatened by hardware producers and their national representatives. However, users and their consultants were able to regain independence through the creation of new platforms for knowledge transfer, such as the Study Center for Administrative Automation.

Of course, further research is needed to determine whether this phase model is specific to the history of the Dutch office or can be generalized. It also remains to be seen whether and to what extent the model is appropriate to the study of other innovation junctions, such as factories and households.

Based on the history of the Dutch office, this article has tried to demonstrate that the dynamics of technological development in innovation junctions are different from those operating in large technical systems. Developments at innovation junctions do not follow a trajectory of invention, development and innovation, transfer, growth, and momentum. Rather, this case showed a process of ad hoc, partial, and centralized integration. Further, the change dynamics at innovation junctions are mainly dominated by interaction processes among users, various kinds of intermediate actors, and producers, including importers. It is not possible to identify system builders, although intermediate actors, such as efficiency engineers and management consultants, were important in identifying needs and opportunities for integration. Mechanisms such as load factors, economic mix, and reverse salients are not easily applied to the study of technical change at innovation junctions. Instead, a driving force must be located in the systematic effort to combine and connect various kinds of office machines. This effort has been provoked and reinforced by the continuing process of introduction of more machines at a bounded space, the collocation of various technologies, and the emergence of a new ideal of systemization and rationalization leading to the ideal of the rational office.