2 Networked Nation: Infrastructure Integration of the Netherlands

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"The word *landscape* literally refers to creating land and space. Without humans there would be no landscape. This is the essence of the Netherlands."[1] Thus the Dutch presentation of their country at the World Fair 2000 in Hanover, Germany. Several government documents further elaborate this image: this shaping of Dutch space, and also of the Dutch economy and society, particularly relies on human-built material infrastructure, or "networks."[2] The *Fifth National Policy Document on Spatial Planning 2000/2020,* published in 2001, and the *National Spatial Strategy* (in 2006) explicitly portray the Netherlands as an evolving "network society" and a "network economy."[3] Unlike modern network society theorists focusing exclusively on information and communication technology, Dutch policymakers emphasize that this process is carried by the "entirety of roads, railways, waterways, pipelines and sewers, digital networks, seaports, airports and transfer points."[4] These networks are conceived of as a spatial layer mediating between the natural condition and social life, shaping "where people live, work, and spend their leisure time."[5] For one, "the activities of [Dutch] citizens and businesses occur in increasingly larger spaces, in both a physical and a virtual sense."[6] Successive governments of different political stripes have long agreed on this pivotal role of networks in Dutch space and society and the need to sustain and expand them, despite recurrent disagreements about the role of the central government in this undertaking.

A survey of the current infrastructure landscape confirms this political assessment of the Netherlands as a country built on networks (see map on page 46). A variety of infrastructures for transport, communication, and energy supply, several of which rank among the densest in the world, create several features that make the country remarkable when viewed from an international perspective. These include a nearly complete cultivation of its territory (just a tiny percentage of its territory still counts as "natural"); remarkably high levels of population density, urbanization, intensive agriculture, and large-scale industries; a key position in European and global trade flows; and associated problems such as pollution, congestion, and vulnerability to technical failure.

The Netherlands is a networked society par excellence, with many different networks in a fairly small area, so that these networks are constantly intersecting. As part of the work on the A12 national highway, shown under construction in 1981, this aquaduct was built to carry the small Gouwe River over the automobile tunnel.

This Dutch infrastructure landscape, cherished by politicians and taken for granted by many Dutch citizens today, has a long and complex history. Some infrastructures are rooted in the Middle Ages and the early modern period. In the nineteenth and twentieth centuries infrastructures multiplied and proliferated, producing a veritable "networked nation."[7]

Often such infrastructure developments were pushed by politicians, industrialists, and engineers in search of ways to shape the Dutch polity, economy, or society. In other cases, infrastructure change was a byproduct of uncoordinated efforts targeting at different objectives. Either way, material infrastructures have become carriers of what the historical geographers Hans Knippenberg and Ben de Pater have labeled "the unification of the Netherlands": a social-spatial integration of its regions and communities, which accelerated in the nineteenth century and was by and large accomplished in the twentieth.[8]

This chapter aims to bring into focus the historical shaping of the Netherlands as a networked nation. It aims to interpret and synthesize the individual histories of a wide range of infrastructures and infrastructure-related societal changes into one coherent narrative. This effort is informed by, and is designed as a contribution to, the international literature on large technical systems, the main literature on infrastructure in historical and sociological technology studies.[9] Associated research aims include replacing a traditional history-of-technology focus on artifacts (automobiles, locomotives, telephones, dynamos) with a focus on spatially extended transport, communication, or energy supply *systems,* of which such artifacts are integrated parts; acknowledging and examining the intimate intertwining of system development and major societal changes; and analyzing system development by following key individuals and organizations that negotiated the shaping and uses of these systems. This literature has hitherto predominantly centered on the development of individual infrastructures.[10] This chapter, by contrast, aims to address the shaping of the Dutch infrastructure landscape in its entirety. Since the aim is to bring into view this infrastructure landscape without a priori limitations following from ownership (public or private), form (hierarchical versus weblike), or management structure (centralized or distributed), the terms "infrastructure," "network," and "system" are used interchangeably in their broad meaning of materially integrated, geographically extended structures.[11]

Infrastructure development is here intentionally interpreted in the historical context of nation-state building. This does not mean that the nation-state is taken for granted as the implicit, unproblematic, almost naturalized container for historic inquiry—which much infrastructure history unfortunately does.[12] Instead this chapter is an inquiry into how a networked nation emerged as an important historical category. It situates this development—if only briefly—against simultaneous and intertwining processes of international and local infrastructure building, and spotlights the limits and contested nature of national infrastructure integration.[13] To bring out contrast alongside connectedness, it repeatedly places the Dutch networked nation developments in comparative international perspective.

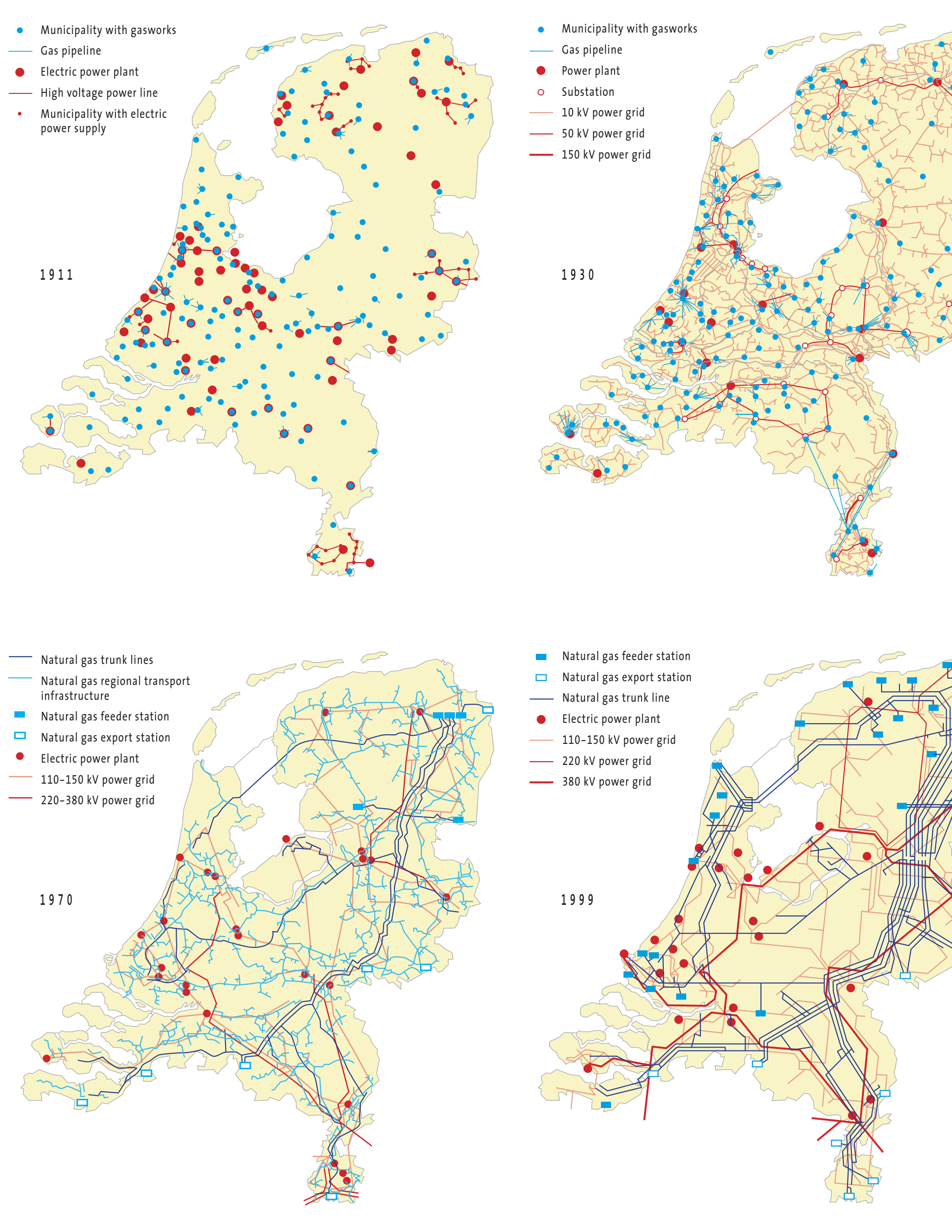
The Contested Integration of the Dutch Geography

Although this chapter focuses on nineteenth and particularly twentieth-century developments, interactions among infrastructures, landscape development, and societal change on what is currently Dutch territory have a much longer history. During the Middle Ages, settlers massively colonized and cultivated the extensive peat bogs in the coastal zones that covered perhaps half of the present country—the so-called Low Netherlands. They turned swamps into fertile agricultural lands by means of dense networks of drainage canals and dikes. Most of these still exist today unchanged.[14] By the late sixteenth and seventeenth centuries, the Low Netherlands had become the political and economic center of the Dutch Republic and the locus of a striking degree of urbanization and economic growth. As Jan de Vries, Ad van der Woude, and others have documented, the world's "first modern economy" was shaped along waterways that facilitated interurban transport systems as well as drainage: notable innovations include scheduled services along a dense inland navigation network for sail-powered freight ships, and horse-pulled passenger, parcel, and mail barges using dedicated canal systems. These boosted the republic's internationally competitive position by linking an exceptionally large hinterland to international trade flows at several large harbors. Peat provided power to the republic's industries, distributed via an extensive peat-shipping network.[15]

The political centralization and unification of the Netherlands during the French occupation (1795–1814) marked a decisive break in the country's history. A centralized, hierarchical state replaced the decentralized republic,

For the most part, Dutch natural gas and electricity facilities evolved from local and regional systems to a nationally integrated system. This process occurred through expansion and scale increase. The gas and electricity systems developed a layered structure consisting of a main network and extensive secondary and tertiary networks of local connections.

MAP 2-1: DEVELOPMENT OF NATURAL GAS AND ELECTRICITY NETWORKS



which had been characterized by urban and provincial autonomy; national citizenship replaced urban citizenship, and a national budget and debts replaced provincial ones. However, the country's new political unity did not automatically imply the economic or cultural integration of its people. Infrastructure integration would serve as a "material precondition" for such processes, but by 1800 it hard barely begun.[16] Many infrastructures that today seem an almost natural part of the Dutch landscape were still absent. Moreover, the infrastructures built in the era of the old republic were chiefly integrated on a intraprovincial and international level; interprovincial networks were poorly developed. Inland navigation networks—still the most important connecting infrastructure at this point in time—were found nearly exclusively in the Low Netherlands. Large parts of the country's more elevated eastern and southern areas, the High Netherlands, were hardly accessible, inhabited, or cultivated; its communities lived in relative isolation, its landscape covered with heaths and marshes. This led a prominent historian to characterize the Netherlands around 1800 as "empty lands."[17]

Not until the nineteenth and especially the twentieth century would infrastructure developments open up the country's inland regions. Wet infrastructures were expanded and interconnected on a national level, and also a variety of entirely new, nationally integrated networks was built. Eventually each and every part of the Dutch territory, dry- or wetland, became linked up in a nationally integrated and internationally connected geography. Households, factories, and farms were bound together by a host of infrastructures for energy supply, transport, and telecommunications. Even areas generally thought of as "nature" were integrated into this human-made space: like those of the Low Netherlands, the extensive marshes and heaths of the High Netherlands were transformed into cultivated woods, fields, and meadowland.[18] The flows of major Dutch rivers were equalized or canalized, and the territorial waters were divided into areas for shipping, fisheries, recreation, and the exploitation of sand, shell, oil and natural gas.[19] The Dutch sky was penetrated by air corridors and electromagnetic waves for radio, television, and data traffic. On the ground, the fragmented plots of "real nature" that remained were increasingly manipulated, engineered, and physically integrated by newly constructed "green corridors" into a so-called National Ecological Network, thus completing the human-built networked nation.[20]

The history of the infrastructure unification of the Netherlands is not merely a story of the unstoppable expansion of infrastructures in the service of nation building, however. The *Fifth National Policy Document on Spatial Planning 2000/2020* was subtitled *Making Space, Sharing Space*, implying that artificially created Dutch space is shared by many social groups that often have contradictory interests. These produce an ongoing dynamic of competing options and negotiated decisions in an ever-changing political, economic, and technical context, both in the past and present. Consider, for instance, the Dutch railroad network. In the last decades of the nineteenth century it became the national transport infrastructure par excellence, and its future development path was defined accordingly. In the 1920s and 1930s, however, automobility became a major competitor, requiring its own infrastructure. In a period of fierce competition, about half of the rail network was torn up, including most local lines and all inter-urban tram lines, and was replaced by roads.[21] Today, in the context of road congestion and environmental concerns, inter-urban light-rail networks seem to be making a comeback, as is the development of Trans-European Rail Networks. Such developments involved struggles between competing interests, the outcomes of which could not be anticipated. This chapter explores such struggles, examining a variety of actors involved in choices between alternative development path. It reminds the reader that the country's infrastructure integration was neither a strictly linear process nor an inevitable one.

I first map the development of the major infrastructure systems in the Netherlands. The following sections examine in detail a variety of social groups, negotiations, and struggles that shaped infrastructures and some of its uses. The chapter concludes with a historical characterization of the major regimes of infrastructure change.

Building the Networked Nation

Energy Infrastructure

To give the reader a sense of the vast changes in the infrastructure landscape in the twentieth century, I start this mapping exercise with energy infrastructures. In the course of the twentieth century nearly all buildings in the Netherlands were hooked up to two new energy infrastructures—electricity and gas supply—which were planned as nationally integrated networks.[22] These networks radically altered the Dutch energy geography: simply by pushing a button or turning a knob, everyone gained instant access to light and heat, regardless of social class or location. Other energy infrastructures, such as compressed air systems or district centralized heating, hardly made inroads in the Netherlands. This is clearly a matter of choice, not of naturally unfolding technological logic: in Denmark, for instance, more than half of the heating for homes and buildings is supplied by warm water or steam networks.[23]

The maps in map 2.1 outline the major transformations of the Dutch energy geography for selected years in the twentieth century. On the eve of World War I public electricity supply (here meaning supply *to* the public, not necessary public ownership), which had first been introduced only a few decades earlier, mainly consisted of a number of local systems in more densely populated areas. Some eighty power stations supplied electricity to consumers in their immediate surroundings via a local low-voltage cable network. Electricity supply delivered over longer distances by means of high-voltage transmission (higher transport voltages decrease relative transmission costs and thus increase the economically feasible supply range) had only made a modest beginning. The electrical map of the Netherlands showed mainly "blank" spots: over 900 of the 1,121 Dutch municipalities lacked public electricity supply. The much older system of gas supply had a local character as well. Since the first half of the nineteenth century, private and municipal companies had set up about 200 local systems that consisted of gasworks and pipe systems transporting so-called "city gas" to mainly local users. Some 330 municipalities were connected to such networks.[24]

Two decades later, the electricity map of the Netherlands had changed radically. By 1930 the electric power landscape was dominated by electricity supply systems that used high-voltage transmission—typically 10 kilovolts (kV) and sometimes 50 kV—to supply areas as extensive as entire provinces. Although these systems remained largely unconnected,[25] provincial electricity companies and a few municipal and private ones as key players had now electrified the country: 94 percent of all Dutch municipalities had access to an electricity supply network. There was almost one connection for every five residents.[26] By contrast, gas supply had hardly changed, even though the principle of long-distance supply had been introduced: the coke factories of Royal DSM (Dutch State Mines) and Royal Hoogovens (a leading steel producer in Europe) produced gas as a byproduct, which they supplied as "distance gas" to municipalities.

The energy map of 1970 shows that by that time, both electricity and gas infrastructures had been integrated nationally. The first electric interconnection of two provincial power plants dates from 1931, but especially during and right after World War II previously isolated provincial systems were interconnected. The first national power grid, coordinated by Cooperating Electricity Production Companies (Samenwerkende Electriciteitsproductiebedrijven, or SEP), established in 1949, and operating at 150 or 110 kV, was completed in 1953. During the late 1960s a second national grid with a still higher transport capacity of 380/220 kV was developed.[27] A similar development occurred in gas distribution. Soon after World War II the construction of a national gas transport network, powered by cokes factories and several large regional gas works, was being discussed.[28] By the mid-1950s three long-distance gas networks in the northern Netherlands were interconnected, but they remained isolated from two southern networks, run by Royal DSM and the new State Gas Company (Staatsgasbedrijf). The discovery of huge natural gas reserves in Slochteren near Groningen in the northern Netherlands in 1959, then considered the second largest gas field in the world and still the largest in Europe, triggered the establishment of a new national high-pressure transport grid to distribute Slochteren gas throughout the country, managed by the Nederlandse Gasunie. Local gas works gradually discontinued local production.[29]

Several patterns characterize the spatial development process of these two infrastructures. First, both experienced an evolution from local systems to "long-distance" systems to national and international systems. Infrastructure integration thus partly took place through expansion and scale increases.

Second, an important nuance to this expansion logic is the observation that national integration and international connection were mutually constitutive processes. The first attempt to connect Dutch electric power grids to foreign grids preceded national integration: during the German occupation (1940–1945) the occupying forces aimed to use Dutch power plants to help run the German war economy. Several delays meant that a large interconnection from The Hague in the west to the Southeastern mining district and its connection with German and Belgian grids was completed only after the war. Since then, the Dutch have completed a national grid while at the same time remaining on the forefront of European electrical integration as they have been with economic and political integration. The second national grid was originally, in the late 1950s, conceived of as part of a Western European grid; later, national concerns for security of supply took precedence. Still, today the Netherlands is one of the best-integrated countries in the European Union, with an import-export capacity of more than 20 percent of its national production capacity.[30] The gas grid was linked up with foreign systems in an even more ambitious way. The construction of a national grid went hand in hand with international connection, for the plan was to export about half the production of the newly discovered Slochteren gas field. In the 1970s exports began to Germany, Belgium, Luxemburg, France, Switzerland, and Italy, and the Netherlands rapidly emerged as a leading gas exporter.[31]

Third, network development was marked by an increasing degree of local branching. The density of the electricity and gas networks continued to increase during the expansion process; eventually almost every building in the Netherlands was connected. Because energy generation took place in a limited number of power plants or natural gas wells, the transmission networks connecting the sites of production and consumption were both extensive and dense. By the early 1990s the Netherlands counted 150,000 kilometers of gas lines, which is one and a half times the total length of all paved roads and is the highest gas-line density in Europe.[32] By 1992, electricity supply required no less than 230,000 kilometers of cable.[33] Both networks are multilayered and consist of "primary," "secondary," and "tertiary" networks, a terminology adopted in the 1930s to indicate the layered organization of infrastructure.[34]

Finally, the case of electricity serves as a reminder that nationally integrated infrastructures do not automatically produce national energy flows. For a number of decades the national electric power grid was used on a limited scale. Provincial power companies primarily planned and operated their systems to balance supply and demand in their own supply areas, using the grid chiefly for backup and additional power supply. By and large, electricity circulation continued to operate on a provincial scale. This changed with the introduction of national economic optimization (*landelijke economische optimalisatie*) in 1982, after which point all Dutch power plants should be deployed as part of a single system. Similarly, the Western European grid was initially used on a limited scale, such as for importing night-rate electricity and backup. In the 1960s Dutch electricity imports came to a near standstill. Only during the neoliberal era, when provincial power monopolies were deliberately broken up, did such exchanges become permanently integrated, involving, for instance, large-scale imports of French and Belgian nuclear power.[35]

Transport Infrastructure

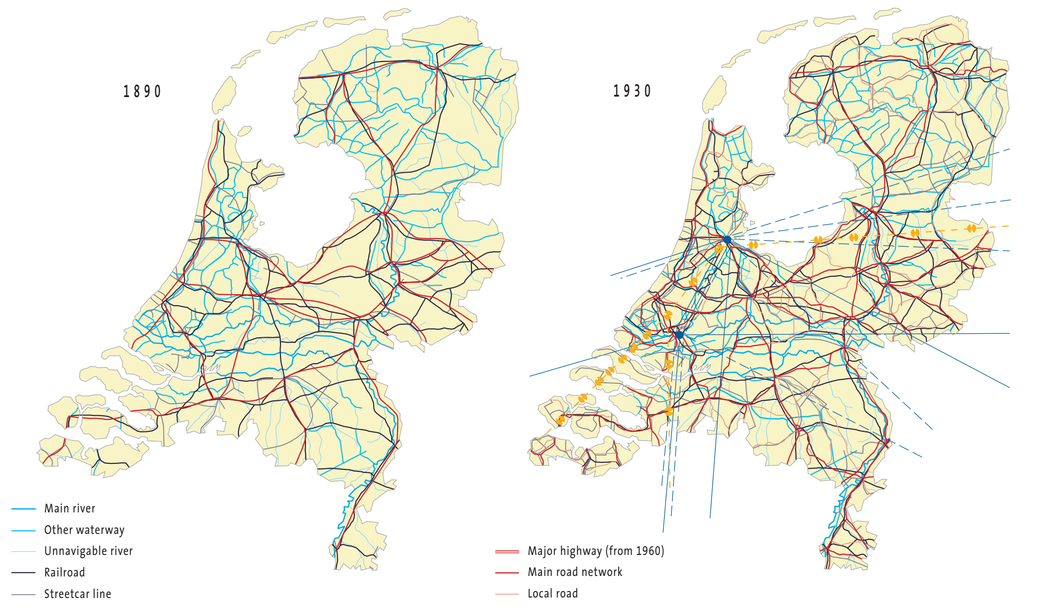
The geography of Dutch transport also changed drastically in the nineteenth and twentieth centuries.[36] Dutch transportation infrastructures have a long history. Much of the northern and western Netherlands were blessed with natural waterways; the digging of interconnecting canals started in the medieval period and was followed by improvements to natural waterways and digging new canal networks for horse-pulled barges during the era of the Dutch Republic (1581–1795). By that time Dutch harbors were linked internationally through maritime shipping: trade with the Baltic region was gradually expanded to include Atlantic ports, the Mediterranean and, finally, Africa, Asia, Australia, and the Americas. Amsterdam became a global marketplace. An unpaved road system existed, including a few long-distance highways, in addition to the water infrastructure.

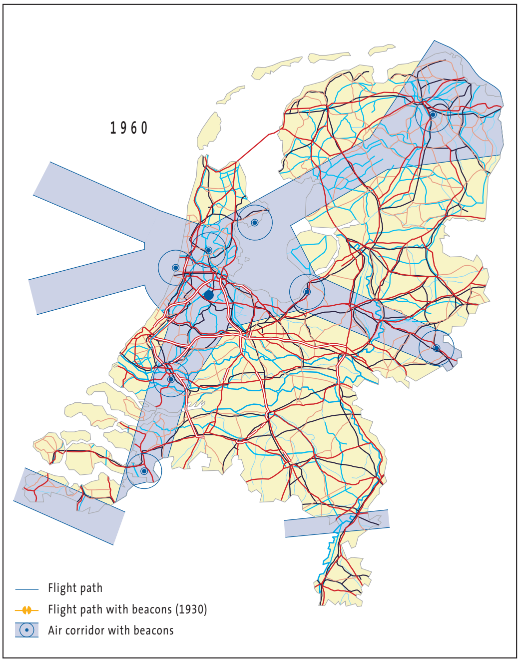
The country's large rivers presented major obstacles for networks of roads and railroads. Bridges serve as important elements in the national integration of these transportation infrastructures. The capacity of the network of bridges is regularly expanded. In 1976 the first bridge component of the old bridge across the Hollands Diep in Moerdijk was replaced by a new bridge section that was more than twice as wide as the old bridge.

By approximately 1800, transport infrastructures were better integrated at regional and international levels than at the national level. There were several obstacles to national integration. Inland navigation was complicated by wind, waves, currents, ice, shallows, sandbanks, narrow sluices, and bridges, while ditches and puddles made it hard to use unpaved roads.[37] In addition, few roads accessed the southern and eastern regions of the Netherlands. These circumstances translated into longer travel times: depending on weather conditions, freight shipped from the western Netherlands to the eastern town of Zwolle could take anywhere from two to fourteen days.[38]

By the late nineteenth century this situation had changed drastically (see map 2.2). The national government and some private companies had dug several new waterways and "improved" major rivers for navigation by standardizing their width and depth and eliminating curves. Such ways initially served the major trade routes between the North Sea, the main ports of

MAP 2-2: DEVELOPMENT OF TRANSPORTATION NETWORKS





On the eve of the twentieth century, railroads and waterways constituted the country's main transportation infrastructures. The development of the Dutch transportation landscape in the twentieth century can largely be seen as a process of expansion, scale increase, and concentration of existing and new transport infrastructures. Conversely, after World War II there was a decrease in the density of specific kinds of infrastructure, such as tramways and railroads, as tracks were taken up in several cities and regions.

Amsterdam and Rotterdam, and the German hinterland. In the last decades of the nineteenth century, however, a nationally integrated waterway network was established.[39] The road system, too, had been greatly expanded. King William I (on the throne from 1815 to 1840) had continued Napoleon's policy of building imperial roads on Dutch occupied territory, and a network of paved "national" roads was in place by 1850. In the century's second half, the network rapidly became more dense as provinces and municipalities paved smaller roads.[40] Finally, an entirely new transport modality was added to the transport landscape. In the first half of the nineteenth century, private companies built railroads between selected western cities with an eye to lucrative passenger transport, while the national government, as it had with waterways, financed rail connections between the ports of Amsterdam and Rotterdam and with Germany. The state subsequently pushed the development of a nationally integrated railroad network, which was in place by around 1880.

By the 1930s, all these networks were significantly more elaborated. After 1880 many "secondary" local railroads and interurban tramways, slower and built to lower construction standards, were established, as well as "tertiary" urban tramway systems. The total length of rail track peaked at some 6,500 kilometers. The total length of navigable waterways peaked in the late 1940s at 7,000 kilometers, categorized according to the size of the ships they could accommodate. For example, 1,300 kilometers of waterways were navigable for ships of over 1,500 tons (large Rhine barges) and 2,500 kilometers for ships with a cargo capacity of less than 150 tons (clipper, tjalk [canal boat or barge], motor ship, or flatboat). The principal international waterway was the Rhine, Europe's main water transport route, and to a lesser degree the Meuse River and several canals.[41] Ultimately the density of the paved-road network outstripped that of all other transport modes: already by 1920 at 20,000 kilometers it was the country's densest transport net.[42] Finally, aviation got off the ground in this period, starting with international connections. In 1920 the newly established Royal Dutch Airlines (KLM) started service to London, Hamburg, and Copenhagen.

In the second half of the twentieth century, the prewar picture of multiple transport networks of approximately equal density was replaced by a situation in which the road traffic network clearly prevailed.[43] Many local railroads, all inter-urban tramlines, most urban tram lines, and many smaller canals were turned into roads and highways. Road construction continued, resulting in a network that today has a total length of some 115,000 kilometers, producing a density surpassed only by those of Belgium and Japan.[44] At the same time a completely new network of freeways was built. The notion of automobile-only roads dates back to the 1920s, but only in the 1960s did their construction gain momentum; by 1990 the highway network would comprise over 2,000 kilometers. It was linked into the European E-road network, launched by the Economic Commission for Europe of the United Nations (1947) and subsequently developed by Europe's transportation ministers.[45] It is notable that during the twentieth century a national network of bicycle paths was created whose total length is comparable to the that of the motorway system's.[46] Finally, air traffic grew considerably and air corridors were defined in greater detail. In the 1970s, for instance, air lanes were commonly found at altitudes of 900 to 5,800 meters and had a width of ten nautical miles.[47]

This brief survey allows several interpretations. First, the development of transport infrastructures, like energy infrastructures, can be represented in terms of processes of scale increase as well as enlarged density. Strikingly, nationally integrated, layered road and rail networks emerged via an expansion process with national and international dimensions, followed by a process of growing density and infilling. Air transport, however, followed a different development path. The first airlines were international in scope. Interwar visionaries anticipated a subsequent branching process, in which airplanes would ultimately succeed cars as leading means of transportation.[48] This did not happen, but postwar government policies of stimulating inland air traffic between secondary airports only had some branching effects. Still air traffic remains overwhelmingly internationally oriented.

Second, in the case of railroads and waterways a period of steadily increasing density was followed by a process of "thinning," whereby secondary and tertiary lines were discontinued.[49] In the course of the twentieth century the total length of the Dutch network of railroad tracks was halved, though the system has recently begun to expand again. As briefly noted, road congestion and environmental concerns prompted new projects for interurban tramways, inspired by well-publicized German successes in Karlsruhe (1993) and Kassel (1996). Also, two entirely new primary rail lines are being developed, which compare to the freeway concept for roads. In 1997 construction was begun on the Betuwe railroad line, the so-called Betuweroute, a 160-kilometer "freight freeway" from the port of Rotterdam to the German border. It is accessible only to freight trains and is built for double-stacked container transport (two containers vertically stacked), and avoids city centers. This line provoked widespread protest but became operational in 2007. In addition, a high-speed line is planned to connect Amsterdam and Rotterdam to Brussels, Paris, and London, currently scheduled for commercial operation in 2009. These lines were planned as part of the Trans-European

Rail Network, meaning that they received limited EU funding and were built in accordance with anticipated EU traction and safety standards.

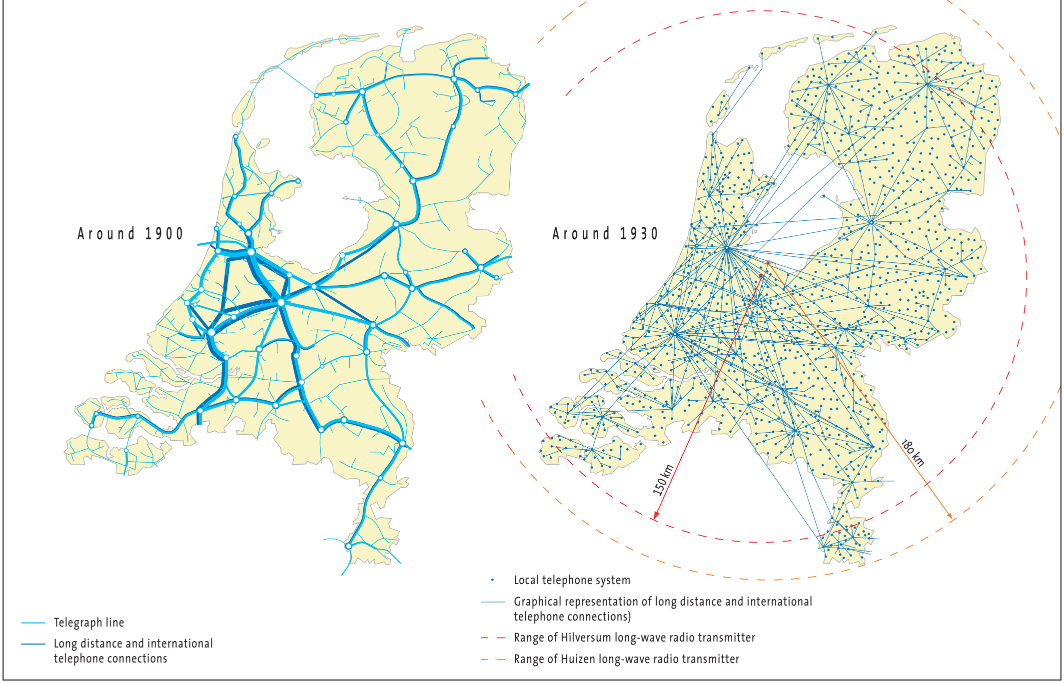
Third, in the wake of network expansion, individual mobility has increased to the degree that transport historians speak of a "mobility explosion."[50] Dutch passenger transport increased from 1 billion passenger-kilometers in 1900 to 17 billion at the eve of World War II to 190 billion in 2000. Still, as in the case of electricity supply, the national integration of transport networks did not necessarily imply national transportation flows. In the second half of the century, the average daily trip distance remained stable at some 50 kilometers. It seems that use of the new transport networks is increasing, but for local and regional rather than national travel. By contrast, freight flows have steadily mirrored network expansion, opening up formerly remote or isolated regions and stimulating their integration into the (inter)national economy.[51]

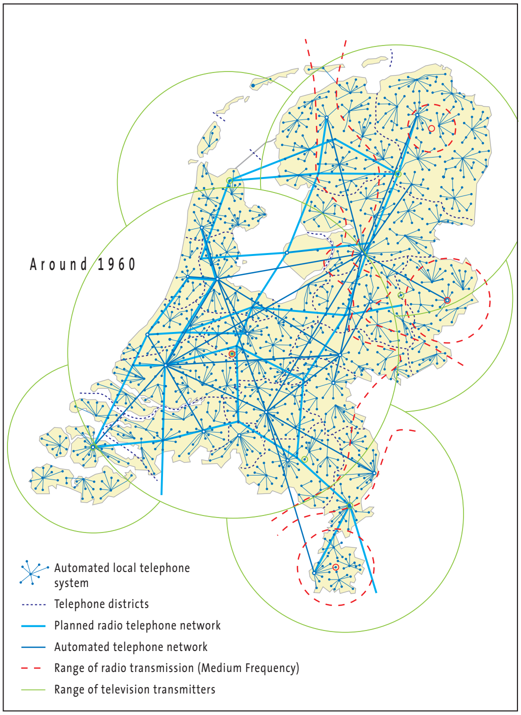
Communication Infrastructure

The Netherlands also became "covered with visible and invisible modes of communication."[52] Communication services had traditionally relied on transport infrastructure in the form of messengers and mail.

Yet, like the energy supply, communication gained infrastructure of its own in the nineteenth and twentieth centuries. The first newcomer was an electric telegraphy network (see map 2.3).[53] Prior to that, systems for optical telegraphy had been used in warfare, but these had had a temporary character. For example, during the Belgian Revolt of 1830 a chain of eleven optical telegraphs located in church steeples made it possible to send a message from the seat of government in The Hague in the west to 's-Hertogenbosch in the south in a matter of minutes, provided the weather was favorable. Electric telegraphy made transmission of letters even faster and more independent of weather conditions and daylight. Its pattern of development is similar to that of railroads: private initiative tried to cash in on several lucrative short routes, but the national government decided to set up a nationwide system. By 1855 major Dutch towns were connected and also linked to the networks of Belgium, Prussia, and Hanover. This was followed by a phase of increasing density. By 1900 over 600 telegraphy offices were interconnected through some 20,000 kilometers of telegraph wire. After the turn of the century a new international "primary grid" was added in the form of radiotelegraphic connections with ships and with other countries.[54] Where the telegraphy network had become nationally integrated and transnationally connected, the telephony network still had a local character. In 1895 there were just thirty-two local phone networks in the Netherlands and just eighteen of these were connected in a long-distance network.[55]

MAP 2-3: DEVELOPMENT OF COMMUNICATION NETWORKS





Pace of development of the Dutch communication infrastructure in the twentieth century. Communication infrastructures develop as networks almost by definition. The twentieth century saw an enormous increase in the density of communication infrastructures, and the number of means of communication also grew markedly.

By 1930 the telecommunications landscape had become much more crowded. First, the telephony system had been nationally integrated after the national government took over responsibility for long-distance connections and most local networks. About 1,500 local telephone networks were connected, via twenty district exchanges, into a national system. In 1937 five district switching stations were interconnected into a new national primary network. Many international connections were available via telephone lines; radiotelephony had been in operation since the late 1920s, and this huge network was now used for telegraphy as well.[56] In addition, a completely new system was added to the communications landscape: radio amateurs and manufacturers of radio appliances developed radiotelephony into broadcasting networks and transmitted the first programs, from The Hague in 1919 and from Hilversum in 1923. In 1925, using two radio towers donated by the large electro-technical manufacturer Philips, Hilversum attained a national range and became the basis for a national broadcasting system. A second national radio station in Huizen doubled the available broadcast time. By 1940, 65 percent of Dutch households owned a radio and were able to listen to national programming, either through their own radio set or via a local radio distribution system connecting a local receiver via a local wire network to loudspeakers in individual homes.[57]

By 1970 the telephone network had grown even denser. Between 1950 and 1980 the number of fixed connections increased from five to thirty-four per hundred inhabitants, practically connecting every Dutch household. In addition, a modest start had been made with mobile telephony. From 1949, the Dutch PTT (Post Telegraphy Telephony) set up its first mobile telephony system consisting of dozens of base stations that fixed phones could use to call a car or boat with radiotelephone. By the 1970s this network had 2,000 subscribers. Also, separate telegraph lines were put in for the successful telex system, originally set up in the 1930s using the telephone network but now in desperate need of additional capacity.[58] The ether had become busier as well, as a new system for "television" was introduced. Test broadcasts had been made by Philips starting in 1948, with a range of 40 to 50 kilometers around its home city of Eindhoven. In 1951 the Nederlandse Televisie Stichting (Dutch Television Foundation) began national television broadcasts from the radio broadcasting station in Lopik. A system of auxiliary transmitters guaranteed near national coverage by 1958. The rapid diffusion of TV sets (75 percent of all Dutch households owned a TV set by 1970) tied the Dutch population into a very influential new network. As earlier with radio, programs were received either via one's own TV set or via antenna stations with local cable infrastructure.

By 2000 it was clear that the rapid expansion of mobile phone networks had increased density of the telephony infrastructure still further. After the adoption of the European GSM-standard in 1994, a number of private companies in the Netherlands set up national networks consisting of base stations interconnected by underground cable networks. At the start of the twenty-first century, the Netherlands, with a population of 15 million, was home to 11 million cell phones. The fixed and mobile telephone networks also supported data transfer by acting as connecting links between computers or computer networks. Finally, many new radio and television stations became available, including local stations transmitted via local cable networks and international stations that could be received via satellite. At the end of the twentieth century, the telecom landscape consisted of a "colorful palette of services, infrastructures and actors."[59] Fiber optic networks, first announced in the mid-1980s, now carry different services between main nodes. However, on the so-called "last mile" to individual homes, copper (originally for telephony) and coaxial (originally for television) cables still dominate, increasingly carrying telephone, television, and data transport signals.

The physical integration of communications infrastructures can also be described in patterns of expansion and density. Two qualifications are relevant regarding these networks' flows. First, information can be transported on various types of infrastructure. Telegraphy pulses can be transmitted via the telephone lines; the telex service, set up in 1932, initially relied on the telephone network, until the success of this service justified putting in a separate system of telex lines. Also, some radio distribution exchanges distributed radio programs locally with the help of telephone networks. Thus, even before the era of digitalization, there was exchangeability between different communication networks.

Second, in Dutch broadcasting a distinction was made between physical infrastructure and the circulation of information. Various religious and political groups set up their own broadcasting organizations to cater to specific segments of the national population, but they used the same physical network. Households received programs specifically aimed at Catholics, Protestants, workers, or apolitical entertainment. Thus, broadcasting was nationally integrated yet socially fragmented—although it must be emphasized that individual households obviously could not be restricted to looking only at the programs that were intended for their specific social group.[60]

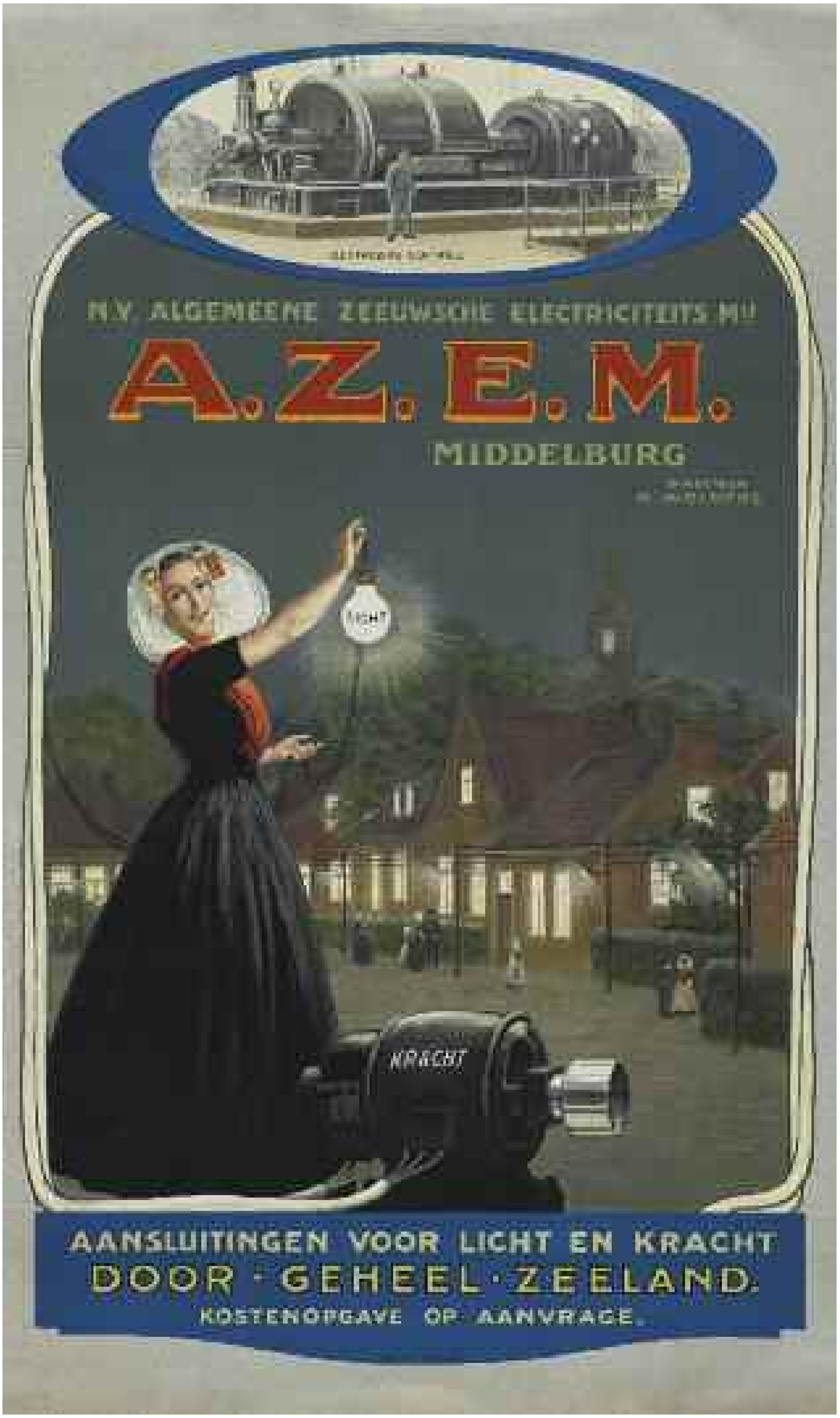
Nature as Infrastructure

The huge proliferation of infrastructure on, above, and under the ground has transformed the Netherlands into an artificial, human-made spatial configuration.[61] By opening up previously peripheral areas, transport systems promoted its nationwide integration. Telecom systems seemed to shrink time and space even further by facilitating simultaneous communication between connected points. Energy infrastructures had a similar effect. Where people used to be dependent on a local wind or water mill, a steam engine, peat or petroleum, now energy networks made light and power instantly available everywhere.

Remarkably, during this process areas that are commonly considered "natural" and antithetical to human-made space were infrastructurally integrated as well. The first examples are the creation and cultivation of the peat bogs in the coastal Low Netherlands since the medieval period and the opening to cultivation of the pristine wastes in the High Netherlands in the nineteenth and twentieth centuries. I also mentioned the manipulation of wet nature above. Natural watercourses were "improved" (deepened, standardized, canalized) and artificial ones were added. Starting in the Middle Ages this was undertaken at a local and regional level, and from the late eighteenth century this effort was extended to the country's major rivers. The first achievement with national ramifications involved the stable distribution of Rhine River water to its downstream branches the Waal, Lower Rhine, and IJssel rivers in a proportion of 6:2:1. This was followed in the nineteenth century by dredging of river beds and the construction of three new artificial river mouths, including the New Waterway (1863–1872) that became crucial to the competitive position of the Rotterdam harbor. The capstone of Dutch wet network building was the ambitious construction of a national system for manipulating water flows (1940–1971). A system of dams, weirs, and sluices distributed the incoming water of the Rhine and the Meuse rivers into the country's various smaller rivers, canals, and reservoirs. This system will be further discussed later; here it suffices to say that the natural wet ecosystem was transformed into a human-controlled infrastructure.[62]

In the second half of the twentieth century, the North Sea, too, was brought under human management. Waterways were dredged to keep open the ports of Rotterdam and Amsterdam, and a network of shipping routes was defined and marked with buoys and light markers. In the mid-1970s oil and natural gas exploitation started; by 1997 there were 121 permanent natural gas and oil platforms, connected to the mainland by 1,880 kilometers of pipelines. In addition, specific zones were reserved for mining seashell deposits and sand; sand was deposited where needed for coastal protection.[63]

The Netherlands' wet network cannot clearly be classified as belonging to one of the previously mapped types of infrastructures. It is essentially multifunctional: a single physical infrastructure is used for water discharge, water


N.V. ALGEMEENE ZEEUWSCHE ELECTRICITEITS M[IJ]
A.Z.E.M.
MIDDELBURG
LICHT
KRACHT
AANSLUITINGEN VOOR LICHT EN KRACHT
DOOR · GEHEEL · ZEELAND.
KOSTENOPGAVE OP AANVRAGE.

supply, inland navigation, national defense, and fishing.[64] Still, the layered structure that characterizes other infrastructures can be seen here as well. The layered waterway network has already been mentioned, and the water discharge system is also layered. The major rivers and estuaries were connected to many local or regional subsystems were for water discharge and drainage, such as urban sewer systems put in since the nineteenth century, and the waste water systems of industry. These large rivers also were main arteries in the system for freshwater supply; many subsystems were hooked up to them, such as urban water services, agricultural irrigation systems, and water-intensive industries.[65]

By 1970, over a millennium of reclamation, cultivation, and networking had left only fragmented pieces of "untrodden nature," which together made up about 6 percent of the Dutch territory (in addition to human-made forests, which account for 8 percent).[66] Currently, these fragmented plots find their place in the Dutch networked nation as they are being interconnected and transformed into a green infrastructure. This development dates back to the 1970s. Up to then, Dutch nature conservation had developed a rich tradition predicated on extensive human interference: nature management techniques included fishing and hunting, grazing by sheep, tree cultivation, mowing and peat cutting, even maintaining water mills—in short, preserving preindustrial landscapes. Yet the 1970s witnessed a paradigm shift in nature management. This new paradigm was about creating new "real nature," defined by ecological standards as nature "as it would have looked without human interference."[67] This idea was inspired by the new disciplines of systems ecology and ecological engineering, developed by Eugene and Howard Ogdum in the United States. The Ogdums looked at nature in terms of ecosystems that run on solar energy, which after being fixed in green plants flows throughout the entire system via the various food chains, resulting, through several feedback mechanisms, in a natural balance. Nature conservationists should create the proper initial conditions, after which nature itself should evolve naturally, that is, without human interference.

This poster of the AZEM (N.V. Algemeene Zeeuwsche Electriciteits-Maatschappij, or General Zeeland Power Company), the provincial electricity company of Zeeland, informed the people that they could enjoy the advantaged of electricity everywhere in Zeeland. In the Netherlands, provincial electricity companies have been the main builders of the electricity system. For rural provinces such as Zeeland, North Brabant, and Groningen, the principal motivation for building an electricity network was not profit but land use: delivery of electricity to residents in all corners of the province was seen a way to prevent massive urbanization of rural parts of the country.

In this new style of "nature building," the size of natural areas was considered crucial to the abilities of species to survive on their own in "the wild." Creating larger nature development areas was thus the top priority. There were two ways to achieve this. First, existing nature zones could be expanded and improved. The Oostvaardersplassen—a sixty-square-kilometer (big by Dutch standards!) wetland on the large reclaimed South Flevoland polder northeast of Amsterdam—served as a major showpiece. Previous planned as an industrial zone, it was claimed for nature development, and the existing nature was "improved" to recreate the type of landscape that biologists thought typical to the prehistoric Netherlands—a mosaic of open and wooded patches home to a rich variety of species. To keep the landscape open biologists introduced large herbivores such as the Heck oxen (the result of retrobreeding aurochs from existing species in the 1920s in Germany), konics (European wild horses), and red deer.

A second method to increase the size of natural territory was to link up fragmented nature areas, including human-made forests, by means of so-called ecological corridors. The first initiative was the so-called Ooievaar Plan (1985), which aimed at setting aside lands in the Lower Rhine, Waal, and Meuse river regions for conservation. Two strategic junctions served as "generator sites" of biodiversity. From there, plant and animal species could migrate to other stretches along the rivers via smaller nodes, called stepping stones. Another example of such nature networking on a subnational scale is the defragmentation of the wooded Veluwe region by means of "gray-green crossings" such as badger tunnels and so-called ecoducts, viaducts for animal migration, to facilitate animals' access to a larger territory.

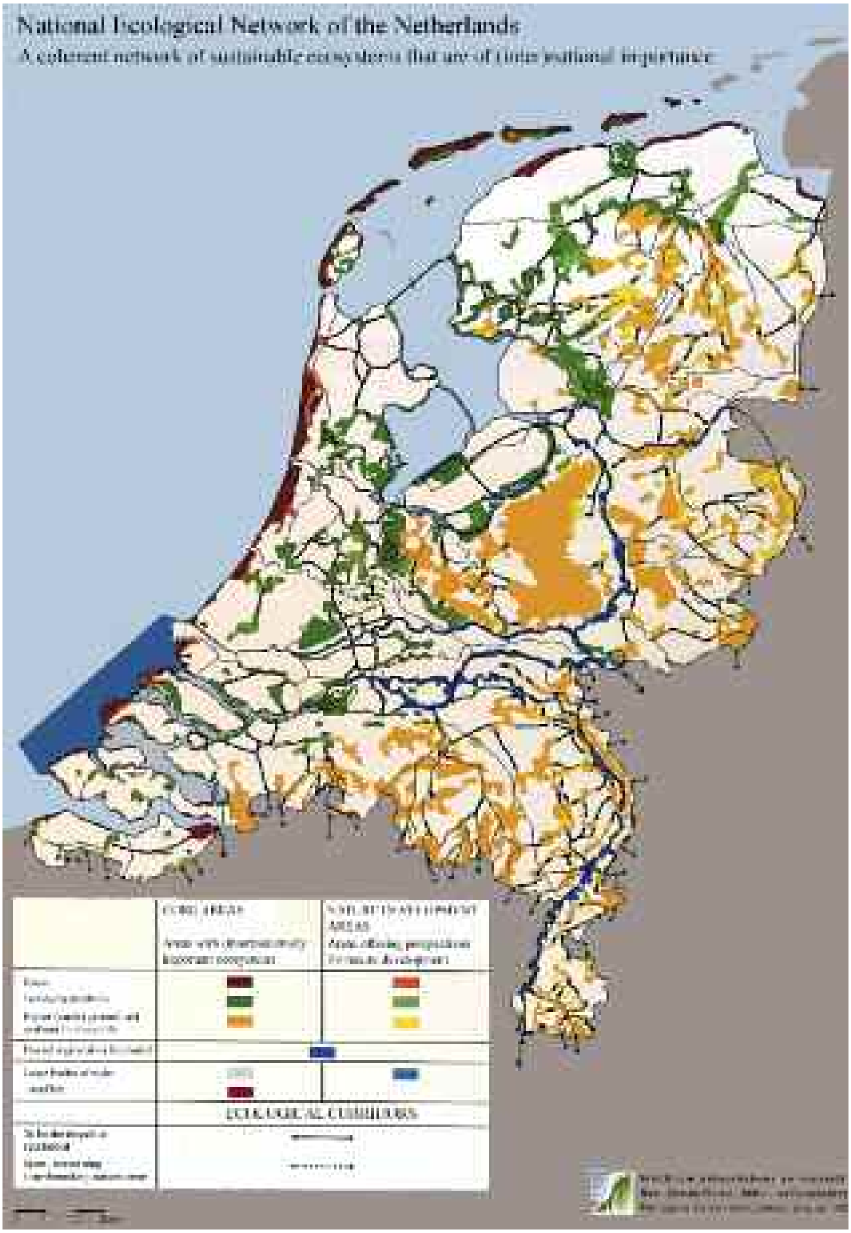
Ecological system building became a matter of national policy in the Nature Policy Plan (Natuurbeleidsplan) of 1990.[68] The plan proposed to establish a physical infrastructure for the circulation of plants and animals on a national scale. This so-called National Ecological Network should comprise core areas and nature development areas connected by ecological corridors, which are green or wet "robust corridors" facilitating the migration of species from one area to another (see map on page 70). One example of such a corridor is the wet corridor connecting northeastern wet zones to the southwestern Zeeland delta. Another example is the dry connection between the Oostvaardersplassen and Veluwe, which should facilitate the migration of red deer between these zones. Less profoundly, ecological corridors may take the form of, say, twenty-five-meter-broad strips of wild nature cutting through agricultural fields. The ecological backbone of the Netherlands is scheduled for completion in 2018 and it should be connected to a Pan-European ecological network, presented by the Council of Europe and originally endorsed by forty-nine countries, in 1995, with the Dutch example as a model.[69] Progress on these networks is slow and complicated, though, an issue to which I shall return. What is important here is that the Dutch seek to integrate even their country's last remaining areas into a single comprehensive, human-made and -controlled network geography. The National Ecological Network will complete the Dutch networked nation.

The Netherlands as Problematic Achievement

In the twentieth century, one historian recently wrote, the Netherlands has been "a colossal work in progress" in terms of its urban space, agricultural land, infrastructure, and nature.[70] Its geography became covered with networks of steel, stone, wiring, pipes, electro-magnetic waves, water, and air corridors—and a beginning was made on establishing green corridors. Often these national infrastructures were further developed and refined at provincial or local levels and connected to networks in other countries.

This achievement is striking, but not necessarily hailed by all. Some praise the ultimate victory of human might over the cruel order of nature. Thanks to its human-made landscape, a densely populated country such as the Netherlands can still remain habitable, livable, and rich. This was the message conveyed by the Dutch pavilion at the Hanover Fair 2002 and several governmental spatial planning documents. Others argue, however, that the extreme density of cars and the country's exploding energy use precisely and poignantly reveal the critical boundaries of a technological society for public health and the environment.[71] They point to a new kind of "emptiness" that has surfaced in a "full country."

As early as the 1930s the prominent Social Democrat Henri Polak described how major forces had deprived entire regions "of all that made them appealing, in ways that make them unrecognizable… crude banalities, stripped even of each memory of what once was." At mid-century, the author Nescio (the pen name of Jan Hendrik Frederik Grönloh) felt the reclaimed Wieringermeerpolder to be "barren throughout, a country of 'tractor devotees'"; only in villages in the southern part of the country did he still find a world without "steel and concrete" and without the familiar stores and commercial interests prevailing elsewhere."[72] In 1990 the novelist Willem van Toorn touched on these changes in the landscape and the loss of historical identity in his *Een leeg landschap* (*An Empty Landscape*).[73] Notably, supposedly benign ecological system building does not escape criticism as it potentially facilitates not only the migration of red dear and badgers, but also of ticks, foot-and-mouth disease, rabies, tuberculosis, and exogenous species that threaten indigenous species.



The growth of infrastructures has turned the Netherlands into an increasingly artificial country. The mounting pressure on the environment has also been integrated into the concept of networks. In 1990 the national government presented a first indication of the future basic ecological structure according to the Nature Policy Plan.

Infrastructures were not just contested a posteriori by outside observers, however. A critical analysis of the process of infrastructure change itself reveals multiple conflicts and choices that gave the Dutch networked nation its particular shape.

Social Latitude for Infrastructure Development

Several examples have already suggested that the re-creation of Dutch space and society by building infrastructures did not involve an automatic or unstoppable process, driven by an unambiguous logic of technological and societal progress. Instead, specific patterns of infrastructure development followed a host of choices involving a variety of social groups with divergent, if not opposing, objectives, in ever-changing political, economic, and technological contexts. Closer scrutiny of several cases of infrastructure change may convey a sense of the complex social dynamic that shaped the infrastructure integration of the Netherlands.

Analysis of the case of electricity supply and several other cases spotlights the various design choices made by "system builders," that is, private or public actors to whom infrastructure building was or became a core task.[74] Such choices were informed by specific goals, but these might change over time. Moreover, system builders often competed with each other on preferred modes of infrastructure development. In many cases it was not clear in advance which view, option, system builder, and system design would become dominant, in part because of continuous lobbying efforts by diverse players aimed at influencing system builder preferences and decision-making processes.

I also discuss the role of several sectoral or "institutional users" of infrastructures, such as the chemical industry, the food sector, and the Dutch military, as co-constructors of infrastructure and its uses. These actors contributed to the infrastructure integration of the Netherlands in at least two ways: they organized flows of people, things, energy, and information in existing infrastructure, and they did not refrain from building new infrastructure themselves if public infrastructure seemed insufficient.[75] They, too, were key players in the shaping of the networked nation.

Power games: A Second Look at Electricity Supply

The spatial scale increase of the electricity supply system in the Netherlands up to 1970 has often been described as a more or less linear process. Potential conflicts or alternative development trajectories remained hidden from view. Indeed, at first sight Dutch electrification appears to follow developments in leading countries such as the United States and Germany, confirming the standard historical narrative of electrification: electricity supply supposedly went from self-generation in individual factories to local public supply systems serving inner cities or villages, to systems covering entire urban or rural districts to national and ultimately international power pools.[76] This development seems quite universal and therefore subject to a quasi-autonomous technical-economic dynamic or, given the existence of exceptions, a 'soft-determinism.'[77] Several generations of Dutch historians of technology have followed a similar historiographical format, stressing or assuming the economic superiority of large-scale systems vis-à-vis their small-scale predecessors.[78] It was argued that "the introduction of larger and more efficient generation units and the beginnings of regional electricity supply" would have caused "many smaller power plants to close down"; "technological and economic developments eventually led to scale increase and the demise of a variety of systems."[79]

A number of studies, however, have called into question such quasi-linear development models, suggesting that they may result from a specific historiographical interest or bias. These studies instead advocate keeping an open eye for alternative development trajectories and not taking for granted technical or economic superiority of one of them in historical explanation, since the process might work the other way around: successful technological systems in time produce technological and economic advantages that they did not yet possess in their early development stages.[80] Indeed, an international comparison based on more recent literature on electrification history confirms that specific natural, social, and political circumstances inspired different electrification trajectories in various countries. This applies not only to development pace or spatial design, but also to the successive phases in the process of scale increase. In some countries scaling up met limited success. For example, after World War II Danish engineers deemed it nonsensical to deploy the standard ideology of scale increase and its associated technologies in Greenland. Its electrification took on the shape of many local and sometimes district systems that were not interconnected.[81] In other cases, supposedly outdated "development phases" remained important or even dominant. In Norway, electrically the most developed country in the world with a per capita electricity use twice that of the United States, decentralized systems remained dominant even after the national government set up a national system based on large-scale hydropower generation in the 1980s.[82] The argument also pertains to the first phase of industrial self-generation. Even in 1970, when large-scale thinking about electricity supply climaxed, industrial generation was responsible for no less than a third of the annual electricity production in advanced economies such as Germany and Belgium.[83]

International comparison also reveals how in various countries different actors managed to gain control of the building of electricity systems, with implications for national patterns of electrification. According to existing scholarship, in the United States small systems were brushed aside by a powerful alliance of expansive private electricity companies operating on a grow-and-build ideology; a strong electro-technical industry, which put all its cards on developing ever larger-scale equipment; and state governments, which granted monopolies to electric utilities in exchange for extending electrification of the entire state instead of merely its most densely populated—and lucrative—areas.[84] Systems for electricity supply developed into statewide systems and later interconnected individual state systems, but further nationwide integration was not deemed interesting. According to the U.S. Department of Energy, a U.S. national grid still does not exist, since the eastern, western, and Texas interconnected systems are poorly interlinked.[85] By contrast, in the early 1920s the French and British national governments set up state companies to enforce the construction of national power grids. These governments used their financial and legal power to build a national grid and then determined which power plants could be hooked up to it. A similar thing occurred in Sweden. As a result, these countries were quick to create national power pools.[86]

Denmark opted for a third alternative, and stands as the prime example of the temporally stable coexistence of large-scale and small-scale systems.[87] In the Danish electricity playing field, higher levels of government and multinational companies hardly gained a foothold. Instead, electricity supply was predominantly claimed and organized by municipal utilities and consumer-owned rural cooperative societies. Already in the 1920s, some of these collaborated in the construction of state-of-the-art large-scale power pools whose high-voltage networks soon covered large parts of the country. Until the 1960s, however, decentralized systems continued to thrive, even within the supply areas of these large-scale systems. Alongside the urban systems of most municipalities exist several hundred very small, consumer-owned local village systems. With sizes varying from a thousand down to a dozen connections, these proved technologically, economically, and socially feasible: time and again, decentralized expansion of production capacity was preferred to connecting to an external power grid. Although larger systems enjoyed economies of scale and a superior load factor, decentralized systems had advantages of their own: small direct-current systems might turn off their machinery at night and use batteries instead. They could also opt for power generated by wind, diesel, peat or steam, depending on fuel prices. Decentralized municipal systems often sold waste heat as district heating, allowing an energy efficiency and income that would not be possible when purchasing power from an external grid. Most important, decentralized systems did not require investment in costly power grids, the costs of which often made up well over half of the KWh price.[88]

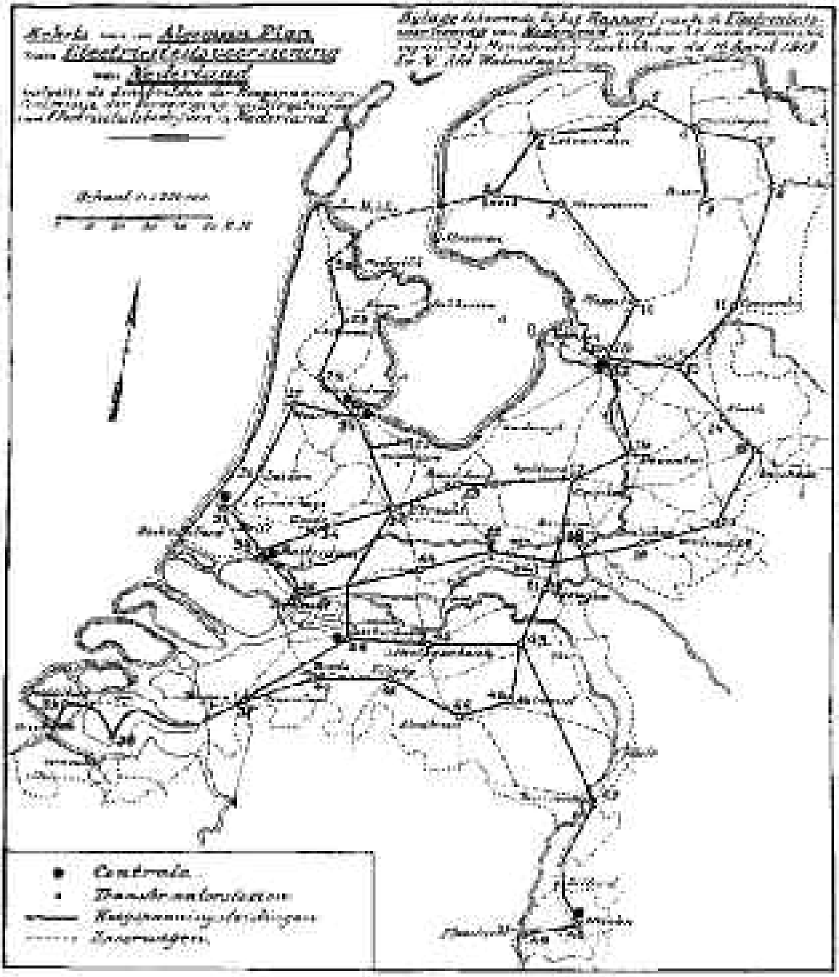
With these examples in mind, a reexamination of Dutch electrical history indicates that here, too, social and political dynamics produced the particular Dutch electrification trajectory. In retrospect the 1910s and 1920s were decisive in producing a playing field that proved remarkable stable until the 1980s. At the beginning of this period, a number of players tried to lay claim to the future electrification of the Netherlands, including existing private and municipal electric power companies and industrial power producers, as well as potential new entrants—the state and provincial governments and even international organizations, which discussed the option of supranationally financed and owned power systems around 1930, as they would again in the late 1940s.[89] Yet in the 1920s it became clear that provincial electricity companies had become the dominant system builders.[90] It was they who engineered the move from local to district systems in the Netherlands and had electrified the country by 1930. It was they who would organize, establish and control the national power grid after World War II.

These provincial utility companies were set up by provincial governments, which unlike municipalities had little history of entrepreneurship. For them, profit was not the top priority, as it had been for many municipal councils. The provincial government of North Brabant, one of first to take on the electricity supply issue, explicitly rejected the profit argument. Instead, its rationale for engagement in electrification was the political objective of countering the countryside's depopulation. From this angle, rural development by means of electrifying the *entire* province became a preeminent task of provincial government. The province of Groningen took the same step to raise overall prosperity in its countryside, thereby ignoring an alternative scheme that its advisory commission had presented as economically superior. In the early 1920s most other Dutch provinces copied the model by setting up electricity companies and electrifying the entire province, typically using 10 kV cable distribution networks.

The emergence of provincial power companies as dominant system builders encountered resistance from the other candidates for electrification, resulting in fierce political and legal struggles. For example, the national government repeatedly tried to interfere in electricity supply to bring about faster electrification. When the first provincial companies were established, it feared—in retrospect correctly—that provincial boundaries would function as "electric barriers."[91] After World War I, top-down national electrification—as in France, England, and Sweden—was almost achieved.

Criticizing provincial utilities for insufficient cooperation, the Lely Commission, established in 1919, proposed to establish a national power company to build and run a national power pool in the national economy's interest (see figure on page 76). The government-proposed legislation to achieve this was, however, rejected by Parliament. Following intensive lobbying by municipalities and their organizations, Parliament decided that the bill's weak financial underpinnings did not justify undermining the autonomy of lower governments and their power systems. Several subsequent attempts to pass national legislation were rejected or were withdrawn in the last moment, and the Dutch government never became an electricity system builder. Accordingly, the proposed national power pool did not materialize.

At the same time, the provincial governments were successful in discouraging municipal and private system builders from exploiting smaller-scale systems. This was rather a matter of exercising political authority than fair competition based on technological or economic performance. An important political instrument was a kind of provincial concession system. The province of North Brabant, for example, obliged potential newcomers to obtain a concession to establish and exploit a new electricity company in 1912. Municipal and private players did not plainly accept this move and accused the provincial government of trying to monopolize the power business and of violating municipal autonomy and freedom of enterprise. The provincial government plainly responded that its taking over tasks from a lower level of government was not in violation of the constitution.[92] The municipalities of Breda and 's-Hertogenbosch, which both wanted to set up their own electricity supply systems, then formed a coalition and gained further support of local industrialists, the chambers of commerce of both towns, the Association of Dutch Municipalities, and twenty other municipalities nationwide. Jointly they lobbied the national government to reject the provincial legislation involved. The provincial government mobilized support as well, including 158 rural municipalities. The Minister of Interior Affairs and the Senate were inclined to support the municipalities, but the responsible minister of public works wished to support the provincial practice. As a compromise the provincial concession system was allowed, but municipalities were given the possibility to request the Crown for release. When the 's-Hertogenbosch municipality tried to do so, however, its request was rejected. A new appeal gained the support of the Council of State, the highest body for appeals against the state—but then, unlike now, it had only an advisory status. In the end, the appeal was again rejected.[93]



Right after the First World War the government proposed to make the building of a national electricity supply system a state policy: a state power company would put in a nationwide grid. The proposal was specified in a report that also contained the map shown here. It shows the proposed electricity supply system with power stations, a high-tension network, electricity substations and railways. But the plan was voted down by Parliament. Provincial governments turned out to be main players in the country's electrification.

Private companies also failed to make a dent in the emerging power monopoly of the provinces. In North Brabant, for instance, the N.V. Peelcentrale was forbidden by the province to cross provincial roads. Uncertain about its future prospects when unable to expand, this power company underinvested in its system. Technological and economic inferiority became a self-fulfilling prophecy. It lost customers and eventually went bankrupt. Similar circumstances doomed small companies in other parts of the country.[94]

One further group of potential system builders, the industries that generated their own power, advocated the possibility of very cheap decentralized electricity production in factory plants. Many factories already had power generators or produced a surplus of steam, but electricity generation would only be profitable if there was a market for the electricity generated. In 1925 A. W. Hellemans, the spokesman for the power-generating industries, proposed a national electrification scheme powered by industrial companies, even if it would mean "decentralization of power production in accordance with the power sources of Dutch industry."[95] In Hellemans's view, a national power pool was in fact a huge waste of national capital. Government support was needed to break the provincial and local hegemony, but for the time being the main government policy was to support the provinces, which represented at least some form of scale increase.

These struggles had profound effects on the development trajectory of Dutch electrification. They facilitated the rapid move from local to provincial district systems in the interwar period. By the 1930s, provincial utilities had produced a geographical density of power networks as well as a degree of centralization of power production that were exceptional in international perspective, even when compared to Germany and the United States.[96] At the same time, however, the dominant position and preferences of the provincial utilities thwarted further scale increase to a national system. While interconnected power pools were being set up in England, France, Germany, the United States, Denmark, and Sweden, the Dutch electrification process lingered at the stage of isolated provincial systems. National government plans for a national grid had been warded off, and provincial utilities themselves did not agree on the necessity of a common power grid. Some argued the economic advantages of interconnecting Dutch power plants in one power pool, but most utilities had doubts. For example, the influential J. C. van Staveren, whose office at the Dutch Association of Electricity Company Managers (Vereniging van Directeuren van Elektriciteitsbedrijven in Nederland) did calculations on this issue, believed that further scale increase to a national system would not be profitable because electricity production had already been centralized. Other economic benefits of a national system, such as higher load factors or savings in backup machinery, did not outweigh the huge investment in a national grid.[97]

World War II and increasing government pressure, including implicit threats of nationalization, finally triggered a utility consensus about the desirability of a national grid. Still this involved a redefinition of the purpose of such a grid, from economic benefits to increased reliability. In the postwar context, the possibility of drawing power from the grid in case of breakdown justified "the economic drawbacks" of the scheme.[98] The provincial utilities now decided to collectively build a national grid, the design of which reflected the lead motive of reliability. Outside the Netherlands, many grids were initially built in a star-shaped form, so as to cover the country with a minimum investment in power lines. In the Netherlands, by contrast, the national grid took the form of two connected rings allowing each major transformer station to draw in power from two sides (see map 2.1). The uses of the national grid reflected its purpose as well; as noted, for decades power exchanges remained limited to emergency and other occasional deliveries. The grid was not used as a true power pool until the neoliberal era.[99]

Finally, the mutual dependency of infrastructure development and social dynamics reemerged in the closing decades of the twentieth century. Influenced by the 1972 Club of Rome report *Limits to Growth*, the energy crises, and rising electricity costs, and an emerging neoliberal ideology, the coalition between provincial power companies and the Dutch government ended. In its 1974 and 1979 energy white papers, the government argued for electricity conservation and for strengthening its control over the electricity sector through covenants and legislation. The purpose of the electricity acts of 1989 and 1998 was increased efficiency through market liberalization and increased competition, which should be achieved by splitting up power companies by enforcing a radical separation of electricity generation and distribution. The government also now supported decentralized industrial power generation. Industrial proponents of this effort, formerly "voices in the wilderness," now actively contributed to policy making. Decentralized systems were allowed to supply electricity to the public system, much against the electricity generation companies' wishes: between 1989 and 1994, the share of current produced in decentralized systems increased from 14 percent to 22 percent.[100]

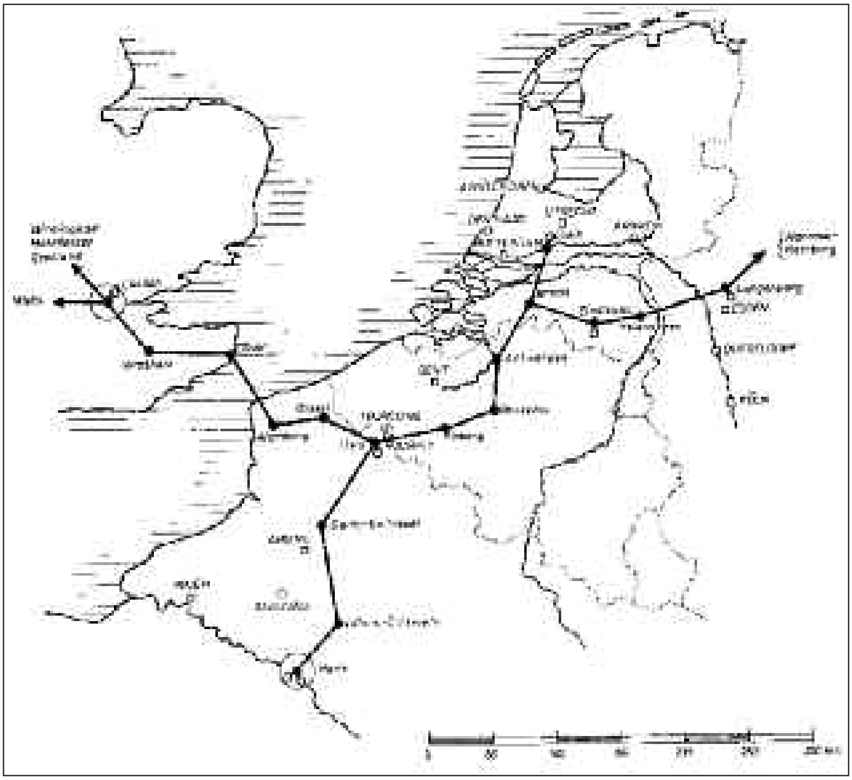
We see this change reflected in changing views of the infrastructure future. The notion of scale increase surfaced in Germany around World War I, in the context of the option to integrate remote hydropower and brown coal plants in the supply structure, and reached a high in the 1960s with the generation potential promised by nuclear plants and fusion reactors. But alongside this line of thinking a view of the future radically opposed to scale increase has emerged. It foresees an era of *micro-power:* by 2050 the electricity supply would be based on decentralized generation in millions of microturbines, solar cell installations, and fuel cells that function cleaner and more efficiently, cheaply, and reliably than large-scale systems.[101] Companies such as Siemens Westinghouse, Asea Brown Boveri, Shell, British Petroleum, and even Bayer and Akzo today invest in research into decentralized generation technologies with an eye to tapping future power markets. Whether this vision will become a reality is quite another matter; as in the first half of the twentieth century, the route to this outcome is highly contested.

Patterns and Choices in Infrastructure Development

The case of electricity supply networks illustrates several general features of infrastructure change. First, patterns of infrastructure development are not fixed in advance. The seemingly linear development trajectory of the Dutch electricity supply resulted not from an autonomous technical-economical logic, but from social and political dynamics and dominant system builder preferences and choices. The open character of infrastructure change is all the more visible when expected infrastructure developments do not materialize. In electricity supply, isolated power systems were carried far into an era where interconnected power pools were thought to represent the state of the art. Television presents a similar case on a European scale. Dutch television had a nationwide infrastructure from the start, and in the early 1950s a European system was envisioned. The European Broadcasting Union, founded by twenty-three national public broadcasters, set up Eurovision to develop an interconnected broadcasting system and prepare for the anticipated shift toward European programming.

Yet this initiative almost completely lost out to national programming—with the exception of an occasional coronation, soccer match, or song festival (see figure on page 80).[102] In aviation, the expected increase in density hardly materialized, despite Interwar visions that airplanes would soon be more important than automobiles.[103] Some trends were even reversed. In electricity supply, an era of expansion, scale increase, and closing down of smaller power stations was followed by a stagnation in the growth of power plant sizes and an upsurge in decentralized generation units. Railroads went from booming business to stagnation and ultimately declined by 50 percent in the period from 1930 to 1990. Later the railroads recovered some of their earlier dynamics.

Three aspects of the social dynamics affecting the infrastructure development trajectory deserve closer examination. First, frequently infrastructure development followed concerns and goals of the players involved, rather



The coronation festivities of Queen Elizabeth II in London in 1953 were an opportunity for the first practical experiments with international television broadcasts. To transmit images, an improvised network of television stations (the circles on the map) was linked to transmitters and receivers (black dots on the map); telephone lines were used for sound. In the 1950s a European network of television connections was put in. In the early years there was virtually no European programming. Television would continue to be nationally and regionally oriented for some years to come—except for soccer ("football") matches and the Eurovision Song Contest.

than technological developmental laws that circulated widely in international engineering journals. Second, if the players involved held opposing goals, such goals had to be prioritized in processes of negotiation and sometimes open conflict. Here, strategy and power games became important. Finally, the design process itself might be adapted so as to align and accommodate multiple concerns and goals.

As for the concerns and goals of system builders, in the case of electricity supply they displayed a considerable variety. The goals of private, municipal, and provincial utilities and industrial generators included profit making, countering the urbanization process, improving the reliability of the supply, and fending off government interference. Goals could also vary over time. For instance, the national government pursued national economic development in the 1910s, reduced dependency on foreign energy markets in the 1970s, and market liberalization and CO_2 reduction in the 1990s.

Transport and telecommunication infrastructure developments reflected a similarly large variety of goals. The national government, for example, engaged in massive canal and railroad construction in the first half of the nineteenth century for reasons of economic policy. Infrastructure was seen as a "miracle drug" to restore the lost economic structure of the Golden Age. And the government's efforts to link the country's large ports to the German hinterland proved successful: for some decades Amsterdam became again a major European marketplace, notably for colonial products such as sugar, coffee, and indigo.[104] In the final decades of the twentieth century, the government pursued a comparable strategy using infrastructure connections to boost the position of the so-called "mainports" of Amsterdam Schiphol Airport and the port of Rotterdam. Recently this concept was expanded with the definition of "greenports" and "brainports," economic centers of agricultural and knowledge production for export, which are internationally connected to transport and communication infrastructures.[105]

By contrast, the same government invested in nationally integrated highway, railroad, telegraph, and telephone systems in part to create a national Dutch space. In the early nineteenth century, the national system of paved roads was meant to demonstrate that the provinces were interconnected.[106] In 1895 a Dutch member of Parliament, M. Tydeman, was partly successful in convincing the national government why the state should back the expansion of telephony, arguing that it was "such a preeminent means for reducing and removing the drawbacks of remoteness because it does away with distances; because it brings all corners of our country in direct contact with the centers of traffic; because, in combination with local railroads and streetcar lines, it will encourage those who are diligent and well-to-do to go living in the countryside and it will facilitate the establishment of factories and businesses, also in faraway places."[107] During much of the twentieth century the improvement of major roads was legitimized by the needs of automobile traffic and people's desire for increased mobility. After 1970, the building of freeways was linked to the policy of opening up the country nationally and regionally.[108]

There was a host of relevant motives in the field of water management: protecting the water supply, protection against flood disasters, and the exploitation of pristine areas. Frequently individual waterworks served several goals simultaneously, as exemplified by the Zuiderzee Works (1922–1975), which aimed at the closure and partial reclamation of the large inland sea, the Zuiderzee. In 1932 this inner sea was separated from the North Sea by a thirty kilometers long dam, which would remain the pride of Dutch civil engineering for decades to come. This dam served multiple goals: coastal protection, land reclamation and cultivation, opening up the northern Netherlands by means of a highway atop the dam, creating a fresh water buffer against seeping saltwater, ensuring a freshwater supply to cities and agriculture, boosting engineering pride, and employment relief in the context of the Great Depression.[109] Finally, the 1990 plan for a National Ecological Network added supporting biodiversity to the national government's impressive list of goals. Ten years later, however, its ecological priorities had shifted again: breaking with a purely conservationist agenda, the wet and green corridors would serve not only the circulation of red deer and otters, but also the leisure of sporty urban residents enjoying canoeing or bicycle-riding. From then on nature was explicitly developed for people's pleasure as well.[110]

Power Struggles over System Building

Often, infrastructure development involved many potential system builders and regulatory bodies with different, and sometimes contradictory, goals. So it is important to establish whose concerns gained priority in decision making processes, why, and how these affected infrastructure development trajectories. Diverging goals often led to negotiations that could erupt in open, sometimes public, conflict.

As described above, national, provincial, and local governments; private electricity companies; and industrialists competed for the opportunity to electrify the Netherlands. The prioritization of goals was settled in a number of power struggles, the result of which could not be anticipated. A vote in Parliament prevented the establishment of a state company and the early implementation of a national power pool. Provinces blocked municipal and private system expansion across provincial roads. The Crown rejected several appeals and chose to let this happen. In short, the prolonged dominance of the provincial companies in electricity supply rested on legal power plays and struggles.

A similar struggle as to who was going to exploit the natural gas reserves took place largely behind closed doors. Key players in the negotiations included the national government; the state-owned steel works Royal Hoogovens (currently Corus IJmuiden); the chemical company Royal DSM, which owned large gas distribution networks; and the oil companies Royal Dutch/Shell and Esso, which cooperated in Nederlandse Aardolie

This photo, taken around 1970, shows the control room of Gasunie in Groningen, where the central distribution of Dutch natural gas was coordinated. The control panel shows the network of pipelines across the Netherlands.

Maatschapij (NAM, established 1947). Negotiations were quite arduous. Several political parties desired full nationalization to secure the national interests. Conversely, other parties realized that state involvement at home would not help the Royal Dutch/Shell when negotiating for concessions in OPEC countries. Ultimately a structure was negotiated in which the Dutch state participated heavily but quite invisibly in the Dutch gas system: the oil companies acted as gas producer, and would own half of the distribution company, Gasunie (established 1963). The state-owned Royal DSM owned the other half. A separate company was set up to distribute the revenues; the state share would increase with increasing gas sales. In the 1970s the state treasury received some 70 percent of the revenues.[111]

The field of broadcasting, by contrast, has been characterized by open and highly visible conflict as well as the use of political, public, technological, and police force, from its very beginnings to the early twenty-first century. Dutch radio broadcasting was born in illegal practices.[112] In 1916 radio amateurs organized in the Dutch Association for Radio Telegraphy (Nederlandsche Vereeniging voor Radiotelegrafie) to obtain legal access to the ether. A decade later another conflict followed. The first national broadcaster, the Hilversum Draadloze Omroep (later the General Radio Broadcasting Association, Algemene Vereniging Radio-Omroep, or AVRO), which wanted to broadcast entertainment with a broad secular appeal, was given less broadcast time after Catholic, Protestant, and labor broadcasters gained access to the ether. The AVRO gathered 400,000 signatures in an attempt to maintain its broadcast time, but the confessional government legally confirmed the compartmentalized organization along socio-political lines of broadcasting in 1930. This triggered one of the largest social protests of the interwar period: as many as 130,000 people traveled to the seat of government in The Hague to demonstrate. The government did not yield. For many decades, successive confessional cabinets used their political power to control Dutch radio programming and, later on, television, to ensure that it conformed to Christian norms and not "moral decay."[113]

In the postwar era, resistance to this control of the radio waves took on another form. The general public preferred entertainment to "high culture" and moral values, and massively tuned in to the so-called pirate stations. A Radio Control Service had been set up in 1927 to fight this decentralization of the broadcast system. In response, and inspired by the Danish *Radio Merkur*, some pirate stations started broadcasting from ships anchored in the North Sea. In 1960 Radio Veronica began broadcasting from a ship anchored just outside Dutch territorial waters. In a similar way, the Reclame Exploitatie Maatschappij (REM) started TV transmission from a former oil platform. By November 1964, 350,000 Dutch television sets had special REM antennas.[114] The Dutch government, citing the "war against onrushing popular culture," passed an anti-REM emergency act enabling the Royal Navy to stop this form of "illegal" broadcasting by force.[115] It also signed the Strasbourg Treaty of 1965, also known as "anti-piracy treaty," in which several European countries agreed to forbid broadcasting from international waters. The turmoil was complete when the Dutch cabinet was brought down by disagreement among coalition partners on allowing commercial broadcasting in the public system; the Strasbourg Treaty was not ratified until 1973. In the end, maritime pirate broadcasters did close down, but some were reborn as legal commercial broadcasters within the public broadcasting system.

The struggle between illegal and legal broadcasting continued, however. The Dutch government banned foreign commercial TV programming geared to the Dutch market by forbidding local cable companies from transmitting such programming. Not until the late 1980s did the European Union, the European Court, and the Dutch Council of State permit the legalization of commercial television outside the public system. In the next ten years, the market share of the Dutch "public stations" plunged from 88 percent to 35 percent.[116] In radio broadcasting, some sort of technological arms race occurred between detection networks and illegal transmitters using unmanned studios, mobile studios, and small relay stations tapping electricity from lampposts.[117] By the early 1980s a study by the Scientific Council for Government Policy estimated the number of Dutch ether pirates at between 3,000 and 4,000; the number of TV pirate stations had peaked at around sixty. The public had a generally positive view of radio piracy; some 40 percent regularly tuned in (some 17 percent to TV pirate stations).[118] One estimate from the beginning of the twenty-first century is that there are thousands of active pirates. In light of the government policy for redistribution of frequencies in an “ether auction” in 2003, these pirates were attacked with renewed urgency. “Operation ether-flash,” which involved a nationwide detection network, supposedly reduced the number of pirates by two-thirds, but it also produced an “operation counterflash”: ether pirates established their own Association for Free Radio (Vereniging Vrije Radio) to lobby for a change in government policy. Meanwhile, many pirates remain active, and the successor of the Radio Control Service still takes out pirates on a daily basis.[119]

If the national government acts as system builder, Parliament is an important arena of conflict and contestation, as when it rejected the Lely Commission plan for a national electric power pool. At times, such conflicts over infrastructure between different state bodies have served as negotiating sites for the structure of the Dutch political system itself. In the first half of the nineteenth century, King Willem I repeatedly and illegally allocated money for building canals, against the wishes of Parliament. His strategy, as one historian put it, stood midway between “fraud” and “creative bookkeeping.” The canals were dug, but at the cost of violating the constitution and, after it was disclosed, triggering furious reactions from both Parliament and the public. This breach of confidence was cited as a major reason for the Belgian secession (1830–1839) and changes of the Dutch constitution in 1840 .[120] Since then, ministers have cosigned royal decisions.

The 1838 decision to build an Amsterdam–Cologne railroad line (called the Dutch Iron Rhine) was no less controversial. Parliament rejected legislation whereby the state would build the line 46–2, but the King went ahead and carried out the plan by royal decree, which did not require parliamentary consent. A large government loan was made available. Later it turned out this money was partly used to cover up financial holes in the state budget, so as to hide them from parliamentary oversight.[121] In these incidents the organization and make-up of the Dutch state system was at stake; as a result, the political rules were changed and tightened, and the king was relieved of virtually all governing functions.

The functioning of Dutch parliamentary democracy was also at stake in one of the major infrastructure-related controversies of recent times, the decision process involving construction of the Betuwe freight-only railroad line.

This railway line connecting the Rotterdam harbor to Germany emerged on the political agenda in the late 1980s; it opened for business on June 16, 2007. By the mid-1990s it was meeting with widespread resistance from environmental and residential groups and local governments. The Betuweroute Commission, established by two ministries in 1994 to investigate the planning process of the line, mentioned a "a referendum-like atmosphere.... You either favor it or you don't."[122] Proponents actively tried to keep criticism under wraps, while opponents used methods both legal (such as filing over 130 actions against the state) and illegal (such as sit-ins and sabotage) to derail the plan.

As for the relationship between government and Parliament, several reports of the Netherlands Court of Audit criticized the quality of information that served as the basis of the decision-making process as well as the subsequent budget control. In 2003 Parliament acknowledged that it had completely lost control of the decisionmaking process and the budget. The same was true for the high-speed line, which was being built simultaneously. Parliament felt it had been misinformed and bypassed by the government in major decisions; indeed, its role was reduced to debating and facilitating the implementation phase, making at best minor changes. A parliamentary inquiry followed. The investigation commission identified several mechanisms that had kept Parliament on the sidelines in key decisions. Also, progress reports provided by the government contained too many details and obscured relevant cost management information. The commission proposed a number of changes, which were accepted by the government. In the wake of this critique, the government also postponed, and later canceled, the construction of the planned northbound "Zuiderzee" high-speed line.[123]

The case of the Betuweroute leads to a final observation on prioritizing goals in infrastructure development. System builders and government concerns were systematically influenced by various lobby groups. According to opponents of the Betuweroute, the project was placed on the political agenda by a powerful, politically well-connected Rotterdam harbor lobby. The lobbyists' clients were the sole beneficiaries of the new line, but they wanted the taxpayers to foot the bill for the investment. The group included major Rotterdam interests such as Europe's largest container transshipment company, Europe Combined Terminals (ECT); several large maritime shipping companies and the Municipal Port Authority Rotterdam (Gemeentelijk Havenbedrijf). These teamed up with the Dutch Railroads (Nederlandse Spoorwegen), the chambers of commerce in the eastern Betuwe region, the provinces of South Holland and Gelderland, and the transport organizations. A dedicated transport lobby, Holland International Distribution Council

(1987), was founded to influence politicians. By the mid-1990s a network analysis completed by opponents revealed an intimate relationship between this lobby and relevant national government bodies and commissions, including the transport minister: a mere ten persons performed forty-three functions in nine key organizations and government commissions involved in the Betuweroute project.[124] The report of the parliamentary investigation commission, drawing on interviews of several key players, reliably confirmed the role of informal lobbying by Rotterdam interests in placing these railway projects on the political agenda.[125]

Although such practices seemed outrageous to opponents, to proponents they seem a natural—even necessary—element in every major achievement. As one ECT director, Gerrit Wormmeester, told the parliamentary Commission of Inquiry, "You have probably never been an entrepreneur…. A country without infrastructure has no future…. Heading a company with significant interests in this matter, I do my very best to lobby." In fact, Transport Minister Nelie Kroes encouraged and subsidized the establishment of the Holland International Distribution Council, a lobbying organization, stating that "this makes it much easier to canalize the multiple transport interests and get them represented in Parliament and the ministries."[126] To her, effective lobbying served a political need. Moreover, in this case policy makers tried to align commercial interests and political forces with a vision of sustainable economic growth that should truly benefit the country; developed in the late 1980s, this vision aimed to combine attracting international trade flows to the Rotterdam harbor (as well as transshipment terminals planned at the Dutch-German border) with using clean railways, not polluting trucks, for transport to the hinterland. Lobbying, aligning political, commercial, and societal interests, stressing (but not critically examining) the financial benefits, and keeping Parliament at a distance were seen as important strategies in getting such large projects done.

Lobbying is hardly a new strategy of course. The history of infrastructure development is full of it. To mention just a few instances: When, during the French Occupation, the emperor Napoleon visited the city of 's-Hertogenbosch in 1810, the local elites seized the opportunity to argue for improving their trade position. They lobbied in particular for the construction of a canal to the south and main roads to Antwerp, Nijmegen, and Luik.[127] Around the turn of the twentieth century, municipalities did a great deal of lobbying to attract local railways or inter-urban tram lines, then perceived as major levers of economic development, to their towns or villages. And in the 1920s another lobby of user groups of car owners, including the touring associations the General Netherlands Bicyclists Association (Algemene Nederlandsche Wielrijders Bond, ANWB) and the Royal Automobile Club (Koninklijke Nederlandse Automobiel Club, KNAC), and oil companies managed to put speeding up road construction on the national government's agenda. Lobbying, then, seems a normal aspect of infrastructure development.

Aligning Interests in Infrastructure Design

Opposing interests in infrastructure development could be resolved in several ways. In the cases of electricity supply and broadcasting, various options were possible; after some struggle, one was ultimately chosen. In many other infrastructure decisionmaking processes specific options were either fully adopted or fully rejected. Ideas that were fully rejected include building a second national airport in the planned Markerwaardpolder (which local resistance prevented from ever being reclaimed), reclamation of the Wadden Sea in the 1970s, and construction of new nuclear plants in the 1980s. Especially when technologies were exposed to public controversy the resulting debate seemed to culminate in a standoff between advocates and opponents. Here, power struggles were a key mechanism influencing the infrastructure development trajectory.

Often, however, choices between alternatives were hardly straightforward because project aims and technological features might change in the course of the decisionmaking process. The introduction of wind turbines is a relevant example here. In the 1970s wind energy was mainly seen as a small-scale alternative to large-scale power generation. However, two decades later wind turbines were deployed in arrays of wind turbines as large-scale generation units in large-scale electricity supply; following the Danish example, the Netherlands is currently building it own wind power plant in the North Sea. It was not just a matter of a choice between large-scale and small-scale. Single wind turbines, too, could be connected to the existing system. This gave rise to a hybrid system, in which large-scale and small-scale generation units operated side by side.[128]

Moreover, it is possible to adapt aims and design criteria of infrastructures so as to accommodate the interests of many social groups. An exemplary case of aligning opposing interests by design—by "technical fix"—is the construction of the national freshwater distribution system in the 1940s, '50s and '60s.[129] As noted, by the early 1970s the national water-management system enabled the manipulation of water flows in the main Dutch water arteries. To understand how the system was planned it is necessary to understand Dutch river geography, and the Rhine delta in particular. Rhine water that enters the Netherlands from Germany can follow three possible routes to the sea: (1) southwest, via the Waal River to the Hollands Diep, which is also fed by Meuse River waters, to Haringvliet and the North Sea; (2) west via the Lower Rhine and Lek rivers to Rotterdam's artificial river mouth, the New Waterway; and (3) north, via the IJssel River to the dammed IJsselmeer, the large inland sea. From there, discharge sluices in the dam feed it into the Wadden Sea and the North Sea.

As noted, the IJsselmeer was separated from the sea in 1932; by 1936 its water was declared fresh. Soon an emerging struggle over use of the newly fresh water basin became visible. The large city of Amsterdam, using the lake as a sewage outlet, now also planned to take its drinking water from the lake. Meanwhile, the farmers farming the new polders surrounding the lake, which were former sea bottoms impregnated with salt, demanded huge freshwater intakes to flush out saltwater and irrigate fields. Eel fisheries also desired a large freshwater discharge in spring through dam sluices to attract elvers in the lake. In view of these multiple claims on a still limited supply of fresh water, in 1940 the director of Amsterdam's municipal water works concluded, "The future manager of the IJsselmeer will bear a heavy burden."[130]

The discussion reached a national level when navigation interests became involved. The navigability of the IJssel River feeding the IJsselmeer was a recurring problem during periods of drought. The river was of major economic importance for the northern and eastern regions of the country, and in 1940, before the German occupation, plans for its canalization were submitted to Parliament. Canalization would enable artificially increased and manageable water levels to benefit IJssel navigation. Moreover, an artificially increased IJssel water level would push more Rhine water westward into the Lower Rhine–Lek–New Waterway system to benefit greenhouse agriculture in the Westland, the area roughly between Rotterdam and The Hague, the home of Dutch intensive agriculture. Here, agriculture needed freshwater to setoff salt intrusion from the coast. Pushing Rhine water westwards, however, implies reduced northbound freshwater flows through the IJssel, which would endanger the freshwater supply of the northern agricultural regions, the Amsterdam municipal waterworks, and the eel fisheries. Navigation, drinking water, western and northern agriculture, and fishery interests were at loggerheads in an increasingly fierce debate on the national distribution of fresh water.

This dilemma did not, however, result in a power struggle in which some won and others lost. Instead, the national civil engineering agency, the Rijkswaterstaat, developed a plan that seemed to satisfy all interests. In a first innovative step, in late 1940, the agency's director-general, L. R. Wentholt, defined a new concept of a national water management plan and listed twenty criteria of national water circulation that had to be satisfied. Thinking in terms of solving a national problem, the Rijkswaterstaat's chief engineers proposed several measures. The IJssel canalization was replaced with a canalization of the Lower Rhine. Depending on need, a weir at the IJssel–Lower Rhine junction could divert Rhine water (all of it if necessary) to the north to ensure adequate water for shipping, drinking water, agriculture, and fishing interests. Canalization would also ensure navigability of the Lower Rhine itself. In addition, the freshwater needs of Westland agriculture were served from another source and by another set of works: closing off the estuaries of the southwestern delta, which had been studied by the agency since the 1930s in the context of flood control. The system was completed with the Haringvliet dam and sluices (1971), closing off the upper estuary in the delta, creating new freshwater basins fed by Meuse and Waal water, and diverting these to the Westland where they entered the sea through Rotterdam's New Waterway.

Such design solutions to deal with conflicting interests, often at considerable financial expense, sometimes led to the resolution of conflicts and successful infrastructure construction. In other cases, however, conflicts persisted. The Betuweroute is a case in point. Many attempts were made to accommodate conflicting interests by design change, both in the initial government plans and during their repeated treatment in Parliament. Much of the opposition came from NIMBY ("Not in my backyard") and environmentalist groups. In response to their concerns, the major part of the new railroad was located directly alongside existing freeways, thus minimizing the need to open new land to transport needs. The track is flanked by noise reduction walls. The stretches that cut through green areas were upgraded with five tunnels totaling fifteen kilometers in length, and 190 wildlife passages were built.

Despite such measures the controversy did not go away, and opponents still perceive the project as mainly a project of Rotterdam capitalists at the expense of Dutch society and nature. Moreover, vast cost overruns of 100 percent were increasingly mentioned as a main point of criticism. The 2004 parliamentary inquiry suggests that opponents rightly criticize the poor financial planning of the project, but fail to acknowledge that subsequent budget overruns were the price tag for design changes to accommodate NIMBY and environmental concerns, and thus were the result of a democratic design process. These measures accounted for approximately half of the total overruns; the other half stemmed mainly from inflation.[131]

Finally, the example of automobile traffic illustrates how major problems may persist despite rules and designs meant to address these problems, and despite broad societal acceptance of a technology. Opponents of car traffic have repeatedly referred to the "slaughter on Dutch roads" in the wake of the success of road transportation.[132] Automobiles became the dominant transportation mode as part of a complex embedding process. Automobile organizations and the car industry utilized the leeway granted to them for introducing their own solutions to safety issue, including safer car designs, infrastructure for the separation of traffic flows, driving tests, and far-reaching control of bicyclists' and pedestrians' use of public ways: streets gradually became off-limits for pedestrians and playing children.[133] Still, the annual number of traffic fatalities in the Netherlands continued to increase, to 3,000 annually by 1970—one of the major causes of unnatural death. This figure has since been reduced to under 1,000 deaths annually, plus 15,000 serious injuries and countless minor injuries. Although relative to population these figures are low in international perspective—in Europe only Malta has a better score—Dutch road traffic still accounts for a number of deaths and injured that would seem to be completely unacceptable for any other infrastructure. It still is the main cause of death after suicide for those fifteen to twenty-four years of age.[134]

Using and Co-constructing Infrastructure

System builders and lobby groups were not the only actors giving shape and meaning to the infrastructure integration of the Netherlands. Even after infrastructure was built, users often had considerable room to maneuver, regularly interpreting and using systems in ways unforeseen by system builders. Often users, not system builders, created flows through systems; road transport and telephony are familiar examples. Sometimes the role of users was not limited to mobilizing and using systems for their purposes; if infrastructures were deemed insufficient, users or their representatives might engage in the system building process on their own, either through lobbying or by taking construction into their own hands.[135] One example of a user organization interfering in the infrastructure design process is the Dutch bicyclists association, the ANWB. Representing both bicyclists and car users, in the 1920s the ANWB was a pivotal force in the lobby that put accelerated road construction on the national agenda and arranged for its financing, and it took matters into its own hands by purchasing a motor roller for building bike paths.[136] Another such example is housewives and their organizations who expanded electrical infrastructure in private homes. Before the era of electric sockets, each house got only one hookup for current. Housewives introduced adapters to hook up electric irons, the first widely used electric household appliance. Later, organizations such as the Dutch Women's Electricity Association (Nederlandse Vrouwen Elektriciteits Vereeniging), established 1932, and local women's advisory committees worked for the proper distribution of electricity and gas in homes.[137]

Most user studies are concerned with the use of cars, telephones, arc lights, electric or gas stoves, and electric streetcars by local actors, often individuals, in homes, factories, farms, and cities. By contrast, I shall here consider the role of what I call institutional users in the infrastructure integration of the Netherlands. The chemical industry, the military, and the food sector are examples of collective actors that mobilized, used, and possibly changed existing infrastructures to transform such social institutions as chemical production, food supply, and national defense.[138]

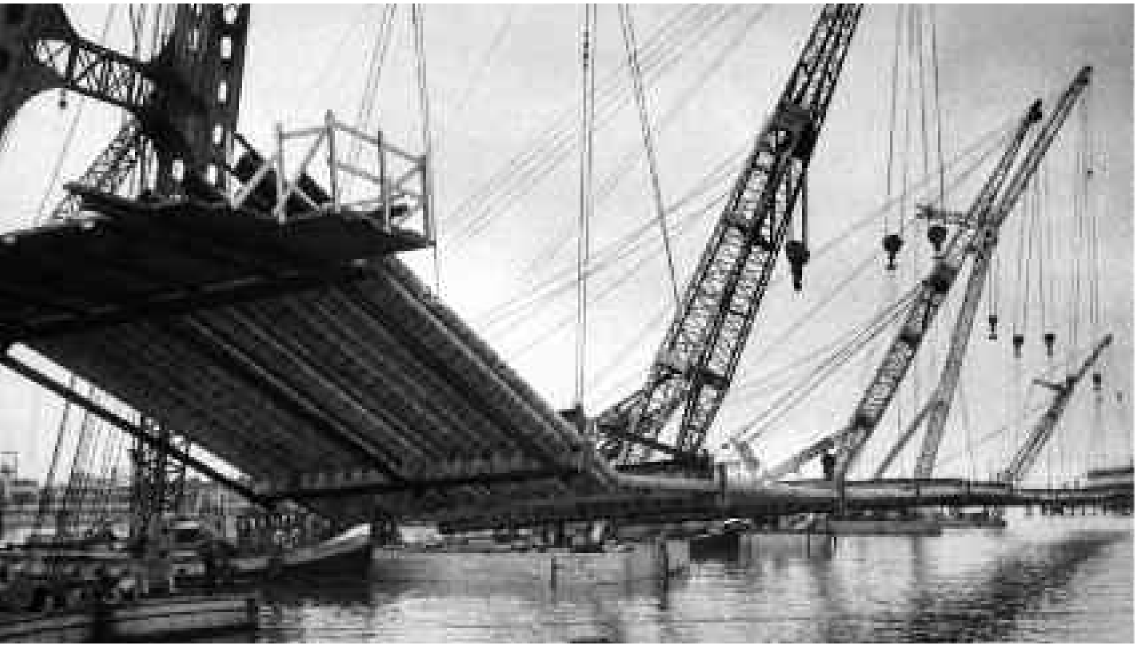
Pipelines and Petrochemistry

The use and construction of infrastructure by the chemical industry took place in the context of the development of "chemical complexes."[139]

The formation of complexes is known in chemical history from the sulfuric acid complex in England in the second half of the eighteenth century, and the synthetic dyestuffs complex in Germany in the second half of the nineteenth century. In such complexes, products and by-products from one factory were locally supplied as raw material for the next, creating complex local flows of chemicals.

In the Netherlands such intertwining of production processes first emerged around the nitrogen fixation plant of Royal DSM in the southeast in the 1930s, and around the Shell Chemicals oil refinery in the Rotterdam port area in the 1950s. In part thanks to the active port policy of the city of Rotterdam, many other international and domestic chemical companies built factories in the Rotterdam port area; by the 1970s it had become one of the world's largest chemical complexes, stretching from Europort in the Rotterdam harbor to Antwerp (Belgium), and well integrated in global, European, and Dutch flows of chemicals.

To set up this industry, chemical companies made great use of existing rail, road, and waterway infrastructure by means of specially built rail wagons, barges, or trucks for transporting chemicals.[140] They also built new networks, mainly local company railroads and extended pipeline networks. Pipelines are a fascinating case, for the construction and operation of which dedicated pipeline companies were created. Initially the Rotterdam port area served as a major oil port and refining location for the German hinterland. Crude oil and naphtha were transported to the German Ruhr region via, among others, the pipeline of the Rotterdam-Rhine Pipeline Society, set up jointly by Shell, Mobil, Gelsenberg, Texaco, and Chevron in 1960.[141] Later, with the development of diverse chemical flows in the rapidly growing Rot-



The petrochemical industry is set up as a network: oil terminals and plants are connected through railroads and pipelines. In the Botlek region this network regularly cuts across major waterways. In the mid-fifties, a depot in Vlaardingen was connected to the premises of Shell Pernis by means of a so-called “swing connection,” a five-hundred-meter-long bundle of pipes.

terdam harbor complex, a multitude of local pipelines were added to transport crude oil, naphtha, ethylene, chlorine, and oxygen. Eventually, over seventy factories and complexes in Europort, Rotterdam, and Antwerp were interconnected through pipelines and railroad connections. Ethylene and naphtha pipelines tied this huge complex to Royal DSM’s complexes in the southeast, a new complex near Delfzijl in the northeast, and factories and complexes in Belgium and Germany. By 1995 the Dutch chemical industry’s main pipeline network was 1,900 kilometers for petroleum and petroleum products and 1,400 kilometers for other chemical products; interconnected factories formed one giant chemical machine producing and circulating chemicals throughout Dutch territory and beyond.[142]

The production, transport, and use of chlorine is an instructive example of how chemical production structures can be shaped by means of pipelines and of the contested nature of this process. Chlorine is generally considered to be a key substance to the chemical industry, used as a catalyst or in the end product of 60 percent of all chemical processes. In the 1950s, Dutch chlorine production was completely dominated by the Royal Dutch Salt Company (Koninklijke Nederlandse Zoutindustrie, or KNZ; now Akzo Nobel) factory in Hengelo, near the Dutch-German border, whence trains transported it across the country to the largest chlorine user, Shell Chemicals, in the Rotterdam harbor complex.

In 1961 KNZ opened a separate chlorine factory in the Rotterdam port area, linked directly by pipelines to the Shell factories, though chlorine deliveries by train continued for the time being. In the early 1970s KNZ built a larger factory in the Rotterdam harbor complex for production of chlorine in the form of vinyl chloride. The new factory received as inputs hydrochloric acid and ethylene from Shell Chemicals and ethylene from Gulf Chemicals, and supplied its product to factories of Shell Chemicals and Herbicide-Chemicals Botlek.[143] Finally, KNZ–Akzo Nobel set up a chlorine factory in the northern harbor town of Delfzijl, where a smaller chemical complex was emerging around natural gas production. In this chlorine geography, local pipeline networks carried most of the chlorine flow; additional chlorine transports by rail between the Akzo factories in Rotterdam in the west, Hengelo in the east, and Delfzijl in the north balanced supply and demand. By 2000 over 90 percent of all Dutch chlorine was transported by pipeline, 8 percent by rail, and 2 percent by road. Incidentally, approximately half of the chlorine pipelines run across publicly owned property.[144]

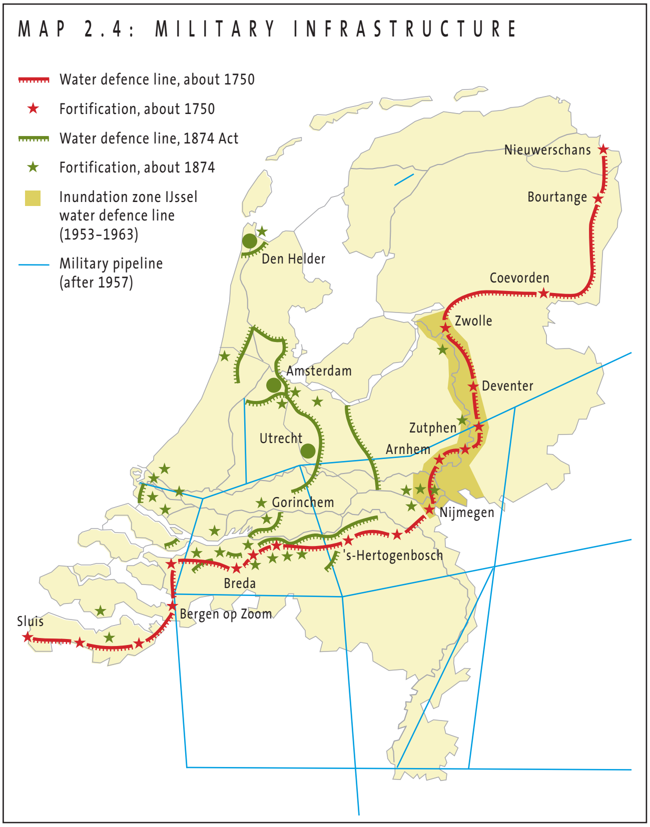
From the 1970s on, environmental groups increasingly targeted chlorine as an extremely dangerous substance that should be abolished. They launched protests such as demonstrations and blocking chlorine transports. The main targets of the public controversy were chlorine transports by rail, dubbed "chlorine trains" and "rolling bombs" by opponents. In response to an intensified Greenpeace International campaign called "Chlorine kills," Belgian and Dutch chlorine industry proponents set up a Belgium-based association of "chlorophiles" to counter "disinformation by environmental groups" on this highly useful chemical. Its first action was a counterdemonstration in front of Greenpeace's Brussels office in 1994. Actions in the Netherlands followed in 1995. Protests and lobbying by both sides initially resulted in Dutch legislation mandating higher safety standards for chlorine railway car designs, continuous monitoring of chlorine transports, lowering of maximum speeds, a ban on shunting, and a ban on transports during daytime.

After a near accident with a chlorine train in 2000, environmentalist groups allied with the small but active radical Socialist Party (not to be confused with the center-left Social Democrats) and developed a campaign to mobilize municipal councils and citizens in the fifty-five municipalities along the chlorine transport lines. Their message: "They come at night and roll slowly. Only a few people ever see them. Let alone know how dangerous they really are: the Akzo Nobel chlorine trains."[145] An accident in a city center, politicians and citizens were told, might cause 5,000 deaths and 18,000 injured. Some 2.5 million people lived in the danger zone. The campaign was successful and chlorine transport became a major issue on the national political agenda, which resulted in an arrangement that according to the responsible ministry is internationally unique. Parliament authorized the minister of environmental affairs to buy out Akzo's chlorine rail transports, which were to be replaced by pipeline distribution. A subsidy of 65 million euros subsidy persuaded Akzo to close its eastern Hengelo plant and expand the capacity of its Delfzijl and Rotterdam harbor plants by 2006. In that year structural chlorine transports by rail stopped, though incidental transports may still take place.[146] In early 2009 the government negotiated a similar buyout with Royal DSM to stop structural ammonia transport across the country.[147]

Military Infrastructure

Many other institutional users also constructed infrastructure. Starting in the 1890s, electro-technical manufacturer Philips built local transport, energy, and communication infrastructures to establish local production complexes. From the 1940s on, infrastructure considerations and active lobbying for infrastructure construction and routing were integral to its strategy to set up a nationally decentralized production system. The growth of globally dispersed production was mirrored by global transport networks and a globe-spanning private telex system for the company.[148] In the services sector, exchanges and stockbroker organizations set up mail, telephone, radio, and telex infrastructure along which the system for trade in stock and bonds was organized.[149]

Another intriguing example concerns national defense. In the early 1950s, the North Atlantic Treaty Organization (NATO) decided to build the Central European Pipeline System, a military European pipeline system for storage and transport of motor fuel.[150] It was a lesson from World War II, when the German general Erwin Rommel lost the battle for North Africa mainly because of inadequate supply lines. In 1957 the Pipeline Agency of the Ministry of Defense started building the Dutch section of this system. The Defense Oil Center foundation, a civilian organization led by officials from oil companies, was set up to manage and run it. In 1983, the Ministry of Defense took over this task as the Defense Pipeline Organization (DPO) under the Royal Air Force. By 1980 some 1,000 kilometers of pipelines con-



Military infrastructures developed early. From the time of the Dutch Republic until the 1960s, defense lines consisting of natural barriers, artificial water bodies, and fortifications played a prominent part in defending the Netherlands on the landside. A typical twentieth-century military infrastructure is the underground pipeline network for fuel supply set up in a NATO context in the 1950s.

nected strategically situated depots with refineries, tanker landing stages, and storage companies (see map 2.4).

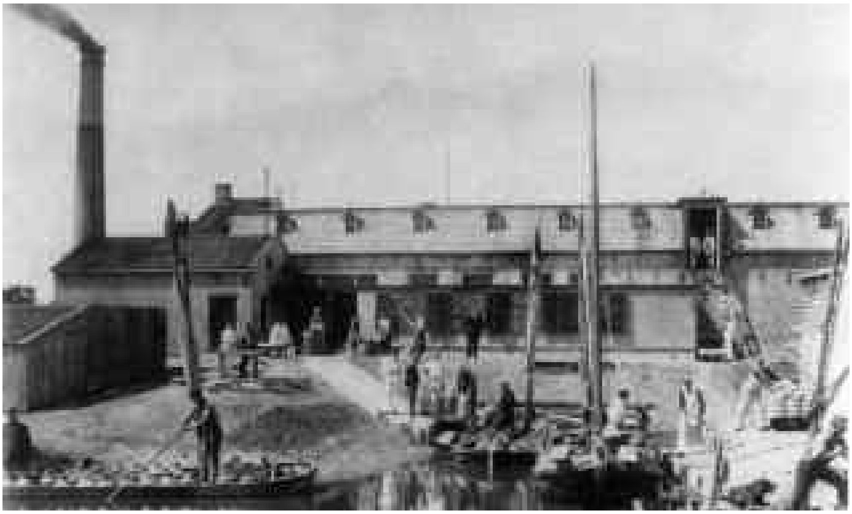
Another telling example of military infrastructure creation but one with a quite different function is the construction of water defense lines (see map 2.4).[151] Water defense lines were designed to be activated only in times of crisis: by means of complex systems of inundation sluices and culverts, zones of low-lying areas could be flooded with a shallow layer of water, shallow enough that enemy troops could not deploy boats, but deep enough to hide submerged drainage canals from view and thus complicate the advance of enemy armies.

Water defense lines became a pillar of traditional Dutch land defense. It had enjoyed near-mythical status since 1672, when an improvised defense line stopped a massive invading army 200,000 strong of the Sun King, Louis XIV. In the following decades, a new national defense scheme was designed and implemented: natural barriers such as marshes and sand drifts were interconnected by water defense lines to shield national borders. Breaks in these defense lines such as roads and dikes were enclosed in fortresses or sconces. When the Dutch, in 1874, decided on a policy of strict neutrality in European military affairs, the defense line system was revised: a much cheaper system protected only the western part of the country, which was considered the political and economic "center." By then, Dutch military prowess had considerably slackened; the idea was that the new defense lines would slow down enemy troops until foreign armies could come to the rescue.[152]

Historians disagree about the military significance of water defense lines; perhaps they mainly had a delaying and deterrent effect.[153] Still, Dutch territory has been successfully invaded only twice since the proclamation of Dutch independence. The first time was when the French crossed the frozen defense lines in the winter of 1794–1795. The second was the German Invasion in 1940, which relied on massive airpower, which seemed to make water defense lines thoroughly obsolete. Surprisingly, and largely unknown, the Cold War inspired the greatest water defense line project ever. By the end of the 1940s, NATO had identified the Rhine River as its defense line against potential Russian aggression. The Dutch government pleaded to extend this line to the IJssel River and IJsselmeer (see map 2.4), so as to include the cherished Western Netherlands safely in the allied defense zone. Initially they met with skepticism from NATO; Britain's Field Marshall Bernard Montgomery was reported to say that "Your IJssel River is no obstacle at all. I can jump over it."[154] So the Dutch devised a grand scheme. Floating dams stood by to block the Rhine, diverting all water into the IJssel River. Here, a system of inundation sluices could create a wet barrier 110 kilometers long and 5 kilometers wide. This defense line was operational from 1953 to 1963. During the Cuba Missile Crisis of 1962, alarm phase 1 was activated, and over 200,000 residents, ignorant of the system's very existence, were close to being evacuated.[155] The line became redundant when NATO shifted its defense line eastward to the Wesel River and later to the Elbe River.

Food Chains and the Unification of the Dutch Meal

Infrastructure building and use, then, intertwined with Dutch economic, environmental, and military history. Institutional and individual uses of infrastructure in the food domain, moreover, demonstrate an important ele-



In the old days, daily transport of milk cans was done by so-called milk shippers, sometimes literally on ships, as shown on the top photo, of a Frisian cooperative dairy plant. The second photo shows the milk truck of the Menken firm, near Hekendorp, around 1965. Effective organization of milk transport from farm to factory provided an essential link in the operations of dairy factories. Because of the limited transportation options and the need to ensure freshness of milk, dairy processing plants were initially numerous and well distributed, close to their sources of milk. In the 1960s new cooling and transport options became available, coinciding with a major scale increase and leading to a wave of mergers. The new system gave rise to larger factories with larger service areas. Milk transport now took place twice a week in purpose-built refrigerated milk trucks.

ment of sociocultural integration with implications for such intimate elements of life as diet and eating habits.[156]

By the mid-nineteenth century, Dutch food chains reflected the rather fragmented nature of Dutch transport infrastructure. Areas with access to the waterway network were firmly tied into a global economy and thus had wide access to foodstuffs. By contrast, comparatively isolated village communities in the southern and eastern parts of the country were dependent on local economies; food flows were predominantly local, in the form of self-sufficiency or local exchanges of products via bartering or local markets. These structural constraints were reflected in a rich variety of local eating patterns: the number, timing, and contents of meals differed from place to place.

As previously discussed, transport infrastructure was subsequently integrated on a national scale. In due time, Dutch food distribution expanded accordingly. This was not due to an inherent "homogenizing effect" of national infrastructure that some authors have assumed. Instead, our understanding of infrastructure and societal change suggests that this national integration of food distribution networks resulted from agency and choices of institutional users of infrastructure, in this case stakeholders in the food sector.

From the 1880s on, new players such as industrial firms and distribution companies inserted themselves into food chains. At the infrastructure level, new food factories were literally tied into food flows deploying trucks, riverboats, and railway cars. For instance, the transition of Dutch dairy production from farms to local factories, triggered by the successful takeover by Danish factory butter of the English market, mobilized road and water networks to collect raw milk from farms and, after processing, return the skimmed milk. It is telling that butter factory inventories listed milk barges or milk trucks next to buildings and crucial equipment such as centrifugal separators. Lists of employees included "milk collectors" alongside other types of staff.[157] Also the subsequent merging of local dairy works into a few large companies with much bigger markets has an important infrastructure component. Centralization of dairy production required long-distance refrigerated tank trucks for transport between farm and factory. To keep transport costs down, these trucks came with a second innovation: farms were to be equipped with deep-cooling tanks for local storage, so that daily milk collection could be replaced with weekly collection. Farmers did not always adapt smoothly to this new regime; the 1970s even witnessed a so-called "tank war" that climaxed in 1978 when farmers in Hoogeveen, refusing to abandon their milk jug system for the deep-cooling tank system, took the board members of their dairy company hostage. Such actions failed to turn the tide, however.[158]

Food distribution companies likewise used infrastructure to organize themselves. Imitating the British "satellite system," the leading Dutch retailer, Albert Heijn (which as Royal Ahold became a global player), set up a branch system in which local branches were stocked from a central warehouse in Zaandam. By 1920 the company had developed a network of over fifty branches. To create food flows between this warehouse and the branches, the company purchased its own fleet of trucks, serviced in its own garages by company mechanics. Later on, having parking available proved an essential precondition for the success of supermarkets, which as major nodes were linked up with households through the road system.[159]

Studies of these food companies show a dominant tendency toward organization on a national scale for reasons of competitive advantages, developing national markets for raw materials and food supply. These strategies were rewarded when export markets fell prey to several global crises and the protectionism that followed. In particular the Great Depression triggered a renewed focus on the home market of Dutch export-minded food industries. In the first decades after World War II, renewed protectionism further strengthened the national circulation of foodstuffs despite several attempts to construct a European food system.[160] By the 1960s, national-level food flows had become quite normal. Throughout the country, an elaborate and standardized assortment of food had become available in all provinces, in both city and countryside, and to all social classes.

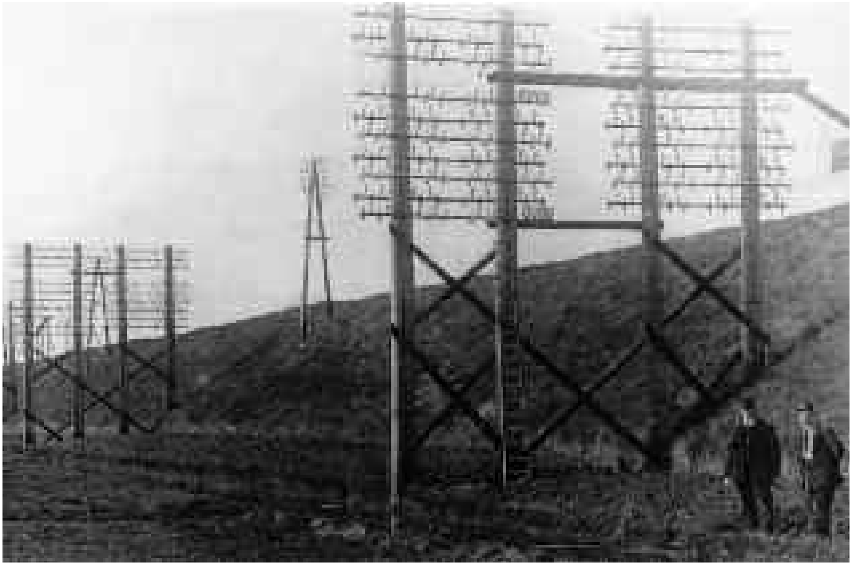
This development of food distribution networks coincided with a striking convergence of food and meal patterns by the 1960s, which Dutch food historians have dubbed the "unification of the Dutch meal": across the country and social class lines as well the Dutch ate regular meals three times a day, featuring a bread meal accompanied by milk or churned milk for breakfast and lunch, and a hot meal for dinner. The hot meal invariably consisted of soup, a main course of potatoes, vegetables, and a rather small piece of meat or fish, and a desert. Again, this event cannot be uncritically attributed to the homogenizing effects of either transport infrastructure or food chains. Nationally integrated transport networks and food chains were a necessary, but not sufficient preconditions for this convergence. Just as the emergence of predominantly nationally oriented food chains resulted from decisions made by food companies in a context of global protectionism, the unification of the Dutch meal followed choices of individual consumers—overwhelmingly represented by housewives doing the actual shopping —choosing foodstuffs from the available assortment in a remarkably homogeneous way. These choices were in turn shaped by decades of intense information campaigns explicitly aimed at Dutch housewives, involving home economics teachers, advertising campaigns, and so forth. Over the decades Dutch housewives were told quite consistently what and how to cook and eat in the service of national health and the home market of Dutch agriculture and food industries. Again the Great Depression was important, for the problems of Dutch food export industries triggered sectoral organizations as well as the national government to develop the domestic food market in terms of marketing, advertising and propaganda. After British example, the crisis office of the dairy industry (Crisis Zuivelbureau, established 1934) also managed to introduce schoolmilk in this period.[161] Such efforts had produced a remarkable convergence in consumer preferences by the 1960s. The nondeterministic character of this development was revealed decades later, when meal and food patterns again fragmented following new social and marketing dynamics. For instance, a new labor culture came with associated food habits such as "grazing": picking up snacks whenever possible throughout a busy day.

Periodization: Three Historical Regimes of System Building

So far our examination of the shaping of the Dutch networked nation has involved mapping its infrastructure integration; exploring the contested dynamics of this process, which did not follow an inevitable logic of development but instead resulted from the struggle between competing system builders' interests and priorities and the outcomes of conflicts and compromise; and examining the roles of institutional and individual users in shaping infrastructure as well as its societal implications. Now I shall combine these threads to attempt a historical periodization.

In a long-term perspective, we may identify three successive regimes for system building, each featuring a dominant social and regulatory structure that moderated the access of various groups to the system-building process, thus affecting specific choices and development tendencies in infrastructure change.[162] We can identify a fragmented system-building regime in the era of the Dutch Republic; a centralized system-building regime that marked the nineteenth and most of the twentieth century; and finally an "open" system-building regime that evolved in the era of participation and (neo)liberalization.

Most nationally integrated infrastructure was established during the centralized system-building regime. Its roots, however, go back to the times of the Dutch Republic (1581–1795). At that time the building of infrastructures was controlled by a number of parties who operated independently, generally on local and provincial levels and not on a national level. This is illustrated well by



The growing volume of long-distance telephone communications in the early years of the twentieth century required a large number of connection switches and lines. For instance, around 1925, the connection between Amsterdam and nearby Diemen required more than three hundred phone lines. Later, more conversations per "pair of cores" would become possible (120 around 1970) with the help of carrier wave telephony (alternating current in line); with beam connections the volume could increase even more (900 per beam in 1970).

the domain of water management.[163] From the Middle Ages, water-related interests pertaining to drainage, inland navigation, and fisheries had been assessed and coordinated by village councils of the newly established settler communities that cultivated the swamps and peat bogs. From the late medieval period, however, the institutional framework of wet system building became increasingly differentiated. First, from the 12th and 13th centuries drainage works were gradually taken over by specialized agencies, the provincial and, later, local water boards. These were dominated by large landowners, who gave priority to drainage, and regularly came into conflict with shipping or fisheries interests—for instance, concerning dams that blocked rivers or canals. The dams remained in place, and work-around solutions included carrying small boats over them.

Next, inland navigation became predominantly a concern of autonomous towns, which had become a key power factor in the late Middle Ages. Autonomous towns started to control (and levy tolls on) nearby waterways and from the sixteenth century on, some thirty towns in the western and northern Netherlands organized the regular barge service network for freight transport and the horse-pulled barge network for passenger and mail services. All connections were established as bilateral agreements between towns, which hired skippers and maintained the waterway infrastructure. The republic's wealthy merchants became a third group of system builders, increasingly setting up drainage projects as major investment projects, which yielded high returns in the form of land sales. The strong and autonomous provinces, who had created the republic as a loose confederation, constituted a fourth group, which, for example, worked to improve sections of larger rivers. The famous water defense line, the *Hollandse waterlinie,* was a provincial project. Finally, national entities such as the States-General (a kind of confederal government) had authority only to build the military system. National authorities created the eighteenth-century national belt of defensive water lines, natural barriers, and fortresses. Some defense projects, such as keeping the moors in the northeastern Dutch-German border artificially flooded, were regularly sabotaged by landowners wanting to cultivate the land. The decentralized and fragmented political structure of the Dutch Republic was thus reflected in a fragmented system-building regime, where different groups, with their own distinctive goals, built distinctive systems. Priorities were weighed and conflicts resolved on an ad hoc basis.

Toward a Centralized System-Building Regime

The French invasion and occupation (1795–1813) introduced a centralized state, and accordingly made the national government a more potent system builder. The new constitution of 1798 put the "condition of Dikes, Roads and Waters" under state jurisdiction. That same year a national agency for waterworks and management was established. After independence was regained, the Kingdom of the Netherlands retained this policy. The 1815 constitution formally placed centralized control of infrastructure works of "general importance" with the king. The national waterworks agency grew to a major system builder under its new name, the Rijkswaterstaat, the State Water Authority.[164]

The fragmented system-building regime gradually gave way to a centralized one, where national actors—the Crown, ministers, the Rijkswaterstaat, and others—assessed and prioritized various interests and made key investment and design choices. It was not immediately clear, however, in how centralized a fashion infrastructure building and management should be organized, and how the phrase "works of general importance" should be interpreted. In other words, which tasks were national government tasks, and which should be left to the private sector or lower bodies of government. Here a comparison is instructive. In his pathbreaking study of infrastructure regimes in Sweden, Arne Kaijser described the emergence of a Swedish "national regime" for infrastructure construction and governance in the nineteenth century. Railroads served as a paradigmatic case, which was subsequently copied to other infrastructure sectors: the state was responsible for main arteries and nodes (harbors, airfields), whereas other actors built and managed secondary lines and nodes.[165]

In the Netherlands, by contrast, a national model remained absent. Although national involvement clearly increased, its form was negotiated on a case-by-case basis. Some works were immediately labeled as state responsibilities, including the maintenance of major rivers and estuaries. A list of such works of general importance, or "state works," was drawn up in 1803.[166] Smaller works were handled by the municipalities or provincial or local water boards. For instance, the national government put in "state canals," but the old barge-canals were still owned and maintained by municipalities. The paving of "state roads" had been seen as a state task during the French occupation as well. This policy's main outline was simply taken over by King William I when he came to power. This task, too, was executed by the Rijkswaterstaat.

In the second half of the nineteenth century two new infrastructures were added to the list of state works: telegraphy and the railroads. Notably, this so-called liberal era in Dutch political history hardly meant a break in national infrastructure policy. Dutch liberal policy in this period is characterized less by the internationally known slogan *Laisser faire, laisser passer* than by "Mark our deeds" (*Wacht op onze daden*), the activist parole of the leading liberal politician, Johan Rudolf Thorbecke, who headed three liberal cabinets between the 1850s and the 1870s and is generally regarded as the founding father of Dutch parliamentary democracy.[167] His mantra also applies to infrastructure. Regardless of whether liberals or conservatives headed the government, infrastructure was conceived as a political instrument of progress. Of course, liberals preferred construction and operation by private companies as long as national interests would be secured. Still, Thorbecke's first liberal cabinet initiated major state-led river improvements and took the decision to establish a state telegraphy system. The first telegraph lines had been introduced by private companies, but, he stated, "the government will do whatever it can to engage the entire nation in the new means of communication."[168] The Telegraph Act (1852) was passed without significant opposition. A national telegraphy agency, the *Rijkstelegraaf*, was established, which took over all private systems to complete the national network by 1884. The state had become the sole telecommunications system builder.

In railroad construction the same concerns emerged, but negotiations and political processes produced a different outcome. In railways, too, the first lines were constructed by private enterprise. Prior to that, a state commission (1836) had argued that the state should take responsibility for railway lines of national interest, and the state indeed financed the Amsterdam-Cologne line, but in addition to the problems previously noted, it proved a financial disaster. In the end it was taken over and completed by a private company. By the mid-century, with this experience in mind, Dutch politicians studied the variety of alternative foreign models for rail development. In Belgium the state put in a railroad system. In Prussia the state was the main stockholder. In France the state was in charge of building main lines, and private companies constructed secondary lines. In England the construction of roads, canals, and railroads was entirely left up to the private sector. The Dutch liberals and conservatives could not reach consensus. A liberal–conservative cabinet settled on a plan to encourage private railroad construction (1860) through financing. Its predominantly conservative successor managed to get Parliament to adopt a Railway Act in 1860, which authorized the state to develop a national railroad system. A new liberal cabinet in 1863 decided that the exploitation of this network should exclusively be in private hands. Later acts (1873 and 1875) confirmed this distribution of tasks.[169] In the resulting institutional railway framework, private companies continued to build their own lines while the Dutch state built a national rail network to be operated by private railway companies.

In the first decades of the twentieth century, the state stepped up its involvement in infrastructure building. This was in part triggered by World War I, which created economic problems but also led to increased acceptance of state involvement in economic life. Increasing state involvement in infrastructure again took different forms.

Private participation in the railways was gradually phased out. During the war the largest private companies sought to counter economic distress by setting up a cooperation, the Dutch Railways (Nederlandse Spoorwegen, NS). After the war economic performance did not improve. Since railways were considered to be of national interest, but the weak financial condition of the state prevented a full takeover, the government opted to become the largest shareholder of the NS. In 1937 the state finally became the sole shareholder.[170]

In telephony, which also had been pioneered by private enterprise, the government nationalized long-distance services in 1897. From 1913 on it increasingly took over local private systems and, later on, municipal systems, in addition to building entirely new local systems.[171] By the late 1920s the state controlled the entire telephony network except for the large municipal networks of Amsterdam, Rotterdam, and The Hague, which successfully resisted a takeover. The state-owned network was managed by a state-owned company, Post & Telegraphy (P&T, 1913), in 1928 renamed Post, Telegraphy, and Telephony (PTT). In 1940 the remaining municipal systems were nationalized under the German occupation.

Regarding broadcasting infrastructure, the state gained a say when the PTT teamed up with private broadcasters to set up the company NOZEMA (Nederlandsche Omroep-Zendermaatschappij) to build and maintain the broadcasting infrastructure, a move that was orchestrated by the national government. Leading manufacturers of broadcasting equipment were kept out of the deal, despite their protests.

National players also emerged in civil aviation and electricity supply. Here, state influence was crucial but it took a more invisible form. In aviation, the Royal Dutch Airlines (Koninklijke Luchtvaart Maatschappij, KLM) established in 1919, counts internationally as one of the very few older airlines set up by private rather than state initiative. The national government supported the enterprise in the background, however, by covering a large part of the airline's operating losses; not until 1946 did the airline actually make a profit. After World War II the government took over 51 percent of KLM's capital stock.[172]

In electricity supply, immediately after World War I Parliament rejected government plans for a state-owned company that would establish a nationwide power grid. After several failed attempts, the central government managed to get an Electricity Act passed by Parliament on the eve of World War II. This legislation provided for the electricity companies to voluntarily develop a national network; if they did not do so, it gave the government the authority to force them to do so. The act was never formally enacted and served as a threat only, but after World War II, this threat certainly informed the electric utilities' decision to jointly establish a national grid, although—as we have seen—they did not actually use it fully until the 1980s.[173]

The regime of centralized system building peaked in the 1950s and 1960s. Interests were weighed—and investment and design decisions made—at the national level in state agencies such as the Rijkswaterstaat, state-owned companies (the PTT), private companies with more or less state participation (KLM, NS, NOZEMA, Gasunie), or nationally cooperating companies such as the electric utilities. Decision making had increasingly assumed a technocratic character—Rijkswaterstaat historians speak of a "technocratic-scientific period."[174] Rijkswaterstaat chief engineers internally developed their stance to the importance, necessity, priority and designs of specific works;

ministers and parliament had limited influence, being involved only at the later stage when major decisions had already been made. This applies to other centralized system builders as well. The decision processes were in the hands of national experts and often hidden from public view and democratic control, while in the background government was working to further scale increases.

Crisis

In his analysis of system building in the United States, the American historian Thomas P. Hughes argued that the late 1960s and 1970s were characterized by severe crisis. Not least as a result of the compromising of military systems in the Vietnam War and emerging counterculture values, large-scale technocratic system building was increasingly condemned by environmentalist and civil rights groups. As these gained public and political support, several system builders thought the days of large infrastructure projects were over. Out of this crisis, however, a new mode of system building emerged that was responsive to counterculture values. A new participative or "open" process gave interest groups access to the design process and became a key element of what Hughes termed "postmodern system building," comprising the various social and political complexities of the postindustrial world.[175]

In the Netherlands a similar crisis occurred. Here, too, centralized system building came under great pressure, causing serious delays in infrastructure development, large budget cuts for public works, and cancellation of some major projects. In the 1960s civil rights and environmental issues made their way onto the political agenda.[176] In contrast to the approaches of earlier political innovators, such as the mid-nineteenth-century liberals, the new social critique was directly aimed at infrastructure. Radical groups such as the Provo (from "provoke") movement declared war on the "asphalt terror." Mainstream organizations as the Dutch motorist and bicyclist association, the ANWB, also changed course. Its chairman stated in 1965: "Man discovers a large and gifted species of salamander, loves it, takes it in as a pet, raises it to be his equal, and soon the salamander ambitiously starts generating offspring. Its number increases along with its intelligence, and it threatens to start ruling mankind. Replace "salamander" with "automobile" and you get some idea on this era's problems."[177] The ANWB even left the car lobby. Meanwhile, protest groups rallied against concrete infrastructure projects on both the local and national level, gaining significant popular and political support.

This movement was further supported by new rules and procedures. Henceforth, plans for highway routes became subject to prior public scrutiny, the results of which were taken into account in the decisionmaking process. Also, environmental groups were invited to join in the planning process. In the context of openness, the center-left cabinet Den Uyl (1973–1977) legally enshrined the public's right to participation in system building. Projects of national significance were marked as "key planning decisions," which entailed the obligation to arrange hearings involving various councils and agencies, to follow public participation procedures, and to present the ultimate decision to Parliament. Soon, such projects had to be integrated into provincial and municipal zoning schemes, each having their own participation procedures.[178]

The effects of resistance, extensive participation procedures, and changed priorities are unmistakable. For example, the Rijkswaterstaat share of the state budget dropped from almost 8 percent in 1971 to 2.8 percent in 1981 and 1.6 percent in 1993.[179] In the 1970s and 1980s its construction activities did not come to a complete standstill, but the emphasis clearly shifted to maintaining and managing existing infrastructure rather than initiating new projects.[180] A number of approved projects were reconsidered. Plans for reclaiming the Wadden Sea and the large Markerwaard polder in the IJsselmeer, as well as for building a second national airport, gave rise to major protests and were cancelled.

Other system builders faced symptoms of crisis as well, but the implications for infrastructure development differed from one case to the next. Although the second national airport was canceled, the expansion of Amsterdam Schiphol Airport with a fifth runway remained on the table. This runway, under discussion since the late 1960s, met fierce resistance as well, and was not opened until 2003.[181] The electric power sector for the first time encountered real government interference in the wake of two energy crises and massive public protests against nuclear power. The Ministry of Economic Affairs initiated what it termed a "broad societal debate" on nuclear power from 1981 to 1983 to elicit the opinions of stakeholders and the public. The debate identified a clear majority against nuclear power. The national government overruled this majority, but after the highly profiled Chernobyl disaster in 1986, its plans for nuclear expansion were shelved.[182]

Occasionally, institutional users and their systems came under fire as well. The extension of the food distribution network, which previously had been supported by government, agriculture, industry, and households, was increasingly criticized for being unnatural and harmful because of the use of pesticides and additives and the general evils of large-scale production and capitalism. The call for "natural food" and a "life free of chemicals" was expressed in a fairly small counter movement favoring small-scale food flows or self-sufficiency and uncontaminated products.[183] Furthermore, Greenpeace and other environmentalist groups mounted campaigns against the chemical industry.

Remarkably, in this period some types of infrastructure expanded rapidly. Unaffected by the public debate, the size of the gas supply system doubled in the 1970s, as did the chemical industry's pipeline systems and, strikingly, the highway system: even though some newly planned highways were fiercely contested, thousands of kilometers of highways were in fact built, completing almost half of the 5,300-kilometer system announced in the mid-1960s.

The Contested Shaping of an "Open" System-Building Regime

As occurred in the United States, this crisis ultimately produced a new mode of system building that responded to the new demands. It remained centralized, but technocracy gave way to participation of a large number of new players. The national system builders lost their monopolies and the system-building process opened up, but the degree and form of access and openness remained highly contested—which is why we put "open" in quotation marks. Still, infrastructure construction itself received a major boost, particularly in the 1990s. Two processes played a major role in shaping the new regime: the (neo)liberalization of the economy, and learning to build systems within a context of public participation.

The neoliberal current began to reveal itself in the Netherlands in the 1980s.[184] The initial effort to reduce the national budget deficit evolved into the ideology that government should not engage in tasks that the market could perform as well, if not better. In complete contrast with the 1950s and '60s, government and corporate monopolies and cartels were now viewed as obstacles to lower prices and high-quality services, consumers' free choice, and client-centeredness, not guarantors of them. Now it was believed that government would serve the common interest best by ensuring open markets, not by acting as a system builder. The context within which these developments took place was that of the European Communities (later European Union), which was encouraging the development of European inner markets.

Again, the institutional framework was negotiated on a case-by-case basis. In theory, state-owned monopolies should be privatized and infrastructure building and management should be separated from services; different service providers, be it telephone, energy, or transport companies, should compete on the basis of equal access to the fixed infrastructure. In highway and waterworks construction, however, liberalizing had no effects on ownership;

In the 1960s, Gasunie put in a network of gas mains to distribute and sell natural gas throughout the country. This infrastructure was partly visible when it was installed, but soon completely disappeared from view forever.

here it merely entailed contracting with companies to design and construct works, which were still planned and financed by the responsible ministry and operated and maintained by the Rijkswaterstaat. Examples are the Amsterdam ring road, improvements of the Waal River, and the Maeslandt storm surge barrier in the New Waterway, which currently inspires storm surge barrier construction in post-Katrina New Orleans.[185]

In railroads, telecommunications, and electric power generation and distribution, privatization and the separation of infrastructure and services were implemented to varying degrees. In telecommunications, the state-owned PTT was gradually privatized after 1989. The state retained the final decisionmaking power during a transition period, but eventually all shares were sold. Negotiations on liberalization of the railway sector ultimately resulted in the state's becoming the direct owner of the infrastructure, while the NS operated rail service. The state remained its only shareholder, though. This was a case of marketization, not privatization: structural subsidies were withdrawn, and the company increasingly had to survive on market terms. Still, the NS gained a monopoly on operating service on the main network until 2015; on a few secondary lines service is operated by other companies. The electric utilities were forced to split production and transport functions. As with the railways, the state became the owner of the national power grid via the Dutch transmission system operator TenneT (established in 1999). For power generation, a series of mergers and purchases led to the existence of several competing suppliers.[186] These different outcomes reflect the fact that these processes were heavily contested and negotiated; indeed, they are still in flux.

A second pillar of the new regime of "open" system building is the participation of stakeholder groups. Three projects served as high-profile learning experiences in open system building: the extension of national motorway A27 from Breda-Vianen to Hilversum, the successful adaptation of the Oosterschelde Dam, and the Betuweroute railway.

The expansion of the A27 motorway from Breda to Hilversum, which was planned to cut through the Amelisweerd Woods, near Utrecht, initially seemed to be an exemplary case of open, ecotechnical system building.[187] In the early planning stages the wishes of both the National Forest Service and the agency for aesthetic design of national roads were incorporated in the design. When a local action group, Working Group Amelisweerd, in 1971 proposed to divert the road around the woods, the design was adapted accordingly. The ANWB even gave the working group and award in appreciation of its constructive contribution to road planning. In the course of the 1970s, however, resistance revived, allegedly because the Rijkswaterstaat did not keep its promise to spare as many trees as possible. New action groups emerged and tried to delay or block the project, taking advantages of the new participation regulations as well as using outright sabotage. Squatters built a village of tree huts in the contested woods; they were ultimately removed by antiriot police with support from the Dutch army. The motorway was finally completed in 1986. Despite its environmentally friendly design, both government and opponents looked back at the decision process with mixed feelings.[188]

The building of the Oosterschelde Dam, by contrast, became a showpiece of the new style of system building. The dam to close the Oosterschelde estuary was the largest project in the Delta Works, the ambitious scheme to close the southwestern delta area in Zeeland in the wake of the 1953 flood that had killed over 1.800. Whereas earlier works had been planned and executed relatively smoothly, this last project in the Delta Works was scheduled for the 1970s and ran into massive opposition. Environmentalists and biologists teamed up with representatives of the mussel and oyster industries, fishermen, and pleasure craft owners in a plea to keep the sea arm open, and prevent its turning into a freshwater basin behind a closed dam. The government was responsive to this pressure and set up an independent commission, which, tellingly, did not include a single Rijkswaterstaat representative. The commission proposed a semi-permeable storm surge barrier that would be closed only in case of a flooding threat. The government approved, and Rijkswaterstaat managed to design and build it. Completed in 1986, the barrier is an excellent example of integrating opposing concerns—flood protection and environmentalism—by design; the American Society of Civil Engineers counts the barrier as one of the seven wonders of the modern world. This marvelous achievement came with a price tag though; the cost was twice that of all earlier projects of the Delta Works combined.[189]

The contested decision-making process regarding the Betuweroute freight railway line, discussed earlier, involved experiments with new public participation procedures. These were in fact restricted; the system-building regime became less “open.” The background was the government’s fear of huge delays arising from extensive participation procedures. Even in the absence of serious opposition, national-level decisionmaking would take at least seven and a half years. But this decision would not be binding on provinces and municipalities, so negotiations and procedures would continue even after that. Following several studies, the government decided to experiment with new legislation to achieve “larger efficiency and time gains” in “large projects of national significance.” Decision-making on such projects, including public participation, was to take place exclusively on a national level. Henceforward, the results of this national-level procedure would be binding on provincial and municipal zoning planning, so environmentalists, NIMBY groups, and municipalities could not delay and frustrate such projects' local procedures. National decisions could only be appealed to the Council of State.[190] The Betuweroute decision-making process was the new legislation's first test case. It did help the project get through, despite massive opposition, but the new legislation itself provoked opposition. Such opposition was allegedly triggered by blunt NS spokespersons at local information meetings and negotiations, who referred to the new legislation in warning provinces, municipalities, and citizens that resistance was futile: the project could not be altered, except perhaps with the addition of some "camouflage by a few trees or sound screens," as one provincial delegate testified to the parliamentary Commission of Inquiry.[191]

In the wake of these learning experiences, infrastructure development in the Netherlands revived in the 1990s and early 2000s, but the regime of "open" system building" remains more open to some than to others. Policymakers embraced the concept of the "network society," and new players in the liberalized telecom market installed several nationwide mobile telephony networks within a few years. The Dutch sections of new European freight and passenger railroad networks are being completed, and a National Ecological Network is under way. However, there is still friction between national planners, system builders, and other constituencies. The mobile telephony providers were heavily fined in 2002 for making illegal cartel agreements. The telephony and internet provider KPN, the private successor of the PTT, was repeatedly charged with and fined for abusing its ownership of last-mile telephone connections to frustrate access on equal terms by new market entrants. State-funded projects such as the Betuweroute, high-speed train lines, and the expansion of Amsterdam Schiphol Airport have benefited from the legislation preventing local participation. By contrast, the National Ecological Network is not prioritized and has to take the slow and difficult route of implementation in local zoning schemes, where it runs into small-scale village corruption and resistance from farmers. Even in the Netherlands, judged by international standards to be an extremely advanced networked nation, infrastructure change is as contested as ever.

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Notes

1 Michiel Schwartz, "Holland schept ruimte," *Holland schept ruimte: Het Nederlandse paviljoen op de wereldtentoonstelling EXPO 2000 te Hannover* (Blaricum: V + K Publishing, 1999), 56.
2 Some of the conclusions of this chapter are also presented in Erik van der Vleuten and Geert Verbong, eds., "Networked Nation: Technology, Society and Nature in the Netherlands in the 20th Century," *History and Technology* 20 (special issue), no. 3 (2004).
3 English summaries of these policy documents have been published by Ministry of Housing, Spatial Planning, and the Environment, *Making Space, Sharing Space: Fifth National Policy Document of the Netherlands 2000/2020—Summary* (The Hague: 2001); and Ministry of Housing, Spatial Planning and the Environment et al., *National Spatial Strategy: Creating Space for Development—Summary* (The Hague: 2006).
4 Ministry of Housing, Spatial Planning, and the Environment, *Making Space*, *Sharing Space*, p. 11.
5 Ibid.
6 Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, *Ruimte maken, ruimte delen: Vijfde nota ruimtelijke ordening* (The Hague: 2001), part 1, chapter 1, 2 (author's translation).
7 Erik van der Vleuten, "In search of the Networked Nation: Transforming Technology, Society and Nature in the Netherlands in the 20th Century," *European Review of History* 10 (2003): 59–78.
8 Hans Knippenberg and Ben de Pater, *De eenwording van Nederland: Schaalvergroting en integratie sinds 1800,* 2nd ed. (Nijmegen: SUN 1990). Compare with Ben de Pater, ed., *Eenwording en verbrokkeling: Paradox van de regionale dynamiek* (Assen: Van Gorcum, 1995), which speaks of "incorporation" rather than "integration" to highlight the contested nature of this process.
9 For discussion and references see Erik van der Vleuten, "Understanding Network Societies: Two Decades of Large Technical Systems Studies," in Erik van der Vleuten and Arne Kaijser, eds., *Networking Europe: Transnational Infrastructures and the Shaping of Europe, 1850–2000* (Sagamore Beach, Mass.: Science History Publications, 2006), 279–314.
10 Thus complained Arne Kaijser, whose work is an inspiring exception. Arne Kaijser*, I fädrens spår:Den svenska infrastrukturens historiska utveckling och framtida utmaningar* (Stockholm: Carlssons, 1994); Arne Kaijser, "The Helping Hand: In Search of a Swedish institutional Regime for Infrastructure Systems," in Lena Andersson-Skog and Olle Kranz, eds., *Institutions in the Transport and Communications Industries: State and Private Actors in the Making of Institutional Patterns 1850–1990* (Canton, Mass.: Science History Publications, 1999), 223–244.
11 Narrow definition leads to controversy and sometimes to a priori exclusion of important aspects of the infrastructure landscape. For a discussion see Erik van der Vleuten and Arne Kaijser, "Prologue and Introduction," in Van der Vleuten and Kaijser, *Networking Europe*, 5–6.

12 Erik van der Vleuten and Arne Kaijser, "Networking Europe," *History and Technology* 21, no. 1 (2005): 21-48. Compare Erik van der Vleuten, "Toward a Transnational History of Technology: Meanings, Promises, Pitfalls," *Technology and Culture* 49, no. 4 (2008): 974-994.

13 For explicitly transnational infrastructure history see, for example, Van der Vleuten and Kaijser, *Networking Europe*; Johan Schot, ed., "Building Europe on Transnational Infrastructures," *Journal of Transport History* 28 (special issue), 2 (2007): 167-228; Alexander Badenoch and Andreas Fickers, eds., *Europe Materializing? Transnational Infrastructures and the Project of Europe* (Basingstoke: Palgrave Macmillan, in press). See also www.tie-project.nl.

14 G. P. van de Ven, ed., *Man-made Lowlands: History of Water Management and Land Reclamation in the Netherlands* (Utrecht: Matrijs, 1993); Erik van der Vleuten and Cornelis Disco, "Water Wizards: Reshaping Wet Nature and Society," *History and Technology* 20, no. 3 (2004): 291–309.

15 Clé Lesger, "Interregional Trade and the Port System in Holland, 1400–1700," *Economic and Social History in the Netherlands* 4 (1992): 186–218; Jan de Vries and Ad van der Woude, *The First Modern Economy: Success, Failure, and Perseverance of the Dutch Economy, 1500–1815* (Cambridge: Cambridge University Press, 1997).

16 Knippenberg and De Pater, *Eenwording van Nederland*, 13, 19, and 209.

17 Auke van der Woud, *Het lege land: De ruimtelijke orde van Nederland 1798–1848* (Amsterdam: Meulenhof, 1987).

18 Taken together these produced 5,000 square kilometers of additional cultivated land, one seventh of the surface area of the Low Netherlands and considerably more than the yields of large reclamation projects in the Low Netherlands during the same period. See Van de Ven, *Man-made Lowlands*, 224–225.

19 Ministry of Housing, Spatial Planning, and the Environment, *Making Space, Sharing Space*, chapter 6.

20 Van der Vleuten, "In Search of the Networked Nation." Compare Luuk Boelens, ed., *Nederland netwerkenland: Een inventarisatie van de nieuwe condities van planologie en stedebouw* (Rotterdam: Nai uitgevers, 2000).

21 J. W. Schot et al., "Concurrentie en afstemming: Water, rails, weg, en lucht," in Schot et al., *Techniek in Nederland*, vol. 5, 19–43.

22 The main reference work for Dutch energy history is Geert Verbong, ed., "Energie," in Schot et al., *Techniek in Nederland*, vol. 2, part 2.

23 In 2000 the Netherlands possessed thirty-nine district heating systems connecting 3,000 kilometers of pipeline and 220,000 consumers. This is less than the district heating system of the Danish capital, Copenhagen, alone. *Energie in Nederland 2000* (Arnhem: EnergieNed, 2000).

24 G. P. J. Verbong, "Grote technische systemen in de energievoorziening," in Schot et al., *Techniek in Nederland,* vol. 2, 115–123; A. N. Hesselmans and G. P. J. Verbong, "Schaalvergroting en kleinschaligheid: De elektriciteitsvoorziening tot 1914," in Schot et al., *Techniek in Nederland,* vol. 2, 124–139; *Eerste Nederlandse systematisch ingerichte encyclopaedie*, 1950, s.v. "Electriciteitsvoorziening"; Hans Schippers, "Statistiek van de gasvoorziening," unpublished manuscript, Eindhoven, table 3a. Copy in the author's collection.

25 "Unified systems" in the terminology of Thomas Hughes; see Hughes, *Networks of Power: Electrification of Western Society 1880–1930* (Baltimore: Johns Hopkins University Press, 1983).

26 A. N. Hesselmans et al., "Binnen provinciale grenzen: De elektriciteitsvoorziening tot 1940," in Schot et al., *Techniek in Nederland,* vol. 2, 157.

27 A. N. Hesselmans et al., "Electriciteitsvoorziening, overheid en industrie 1940–1970," in Schot et al., *Techniek in Nederland,* vol. 2, 222–232.

28 *Eerste Nederlandse systematisch ingerichte encyclopaedie,* 1950, s.v. "Nutsbedrijven."

29 A. Correljé and G. P. J. Verbong, "The Transition to Natural Gas," in B. Elzen, F. W. Geels, and K. Green, *System Innovation and the Transition to Sustainability: Theory, Evidence and Policy* (Cheltenham, U.K.: Edward Elgar, 2005), 114–135; J. L. Schippers and G. P. J. Verbong, "De revolutie van Slochteren," in Schot et al., *Techniek in Nederland,* vol. 2, 203–219; Hans Schippers, *De Nederlandse gasvoorziening in de twintigste eeuw tot 1975* (Eindhoven: Stichting Historie der Techniek, 1997).

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31 Schippers and Verbong, "Revolutie van Slochteren"; Informatie- en Documentatiecentrum voor de Geografie van Nederland, *Kortfattet oversigt over Nederlands geografi* (The Hague and Utrecht: 1974), 28.

32 P. J. M. Groot, *Goederenvervoer per pijpleiding* (Amsterdam: Economisch Instituut voor de Bouwnijverheid, 1991), 22.

33 *Elektriciteit in Nederland 1996* (Arnhem: Samenwerkende Elektriciteitsproductiebedrijven, 1997), 5.

34 W. E. Boerman, "Inleiding," in W. E. Boerman et al., eds., *Het verkeer in Nederland in de XXe eeuw: Tijdschrift van het Koninklijk Nederlands Aardrijkskundig Genootschap* 50 (1933): 333.

35 Verbong, "Dutch Power Connections"; Geert Verbong and Frank Geels, "The Ongoing Energy Transition: Lessons from a Socio-Technical, Multi-Level Analysis of the Dutch Electricity System (1960–2004)," *Energy Policy* 35 (2007): 1025-1037.

36 J. W. Schot, ed., "Transport," in Schot et al., *Techniek in Nederland,* vol. 5, part 1, 13–149.

37 De Vries and Van der Woude, *First Modern Economy*, 13ff.; Van de Woud, *Lege land*, 144–147; R. Filarski, *Kanalen van de koning-koopman: Goederenvervoer, binnenscheepvaart en kanalenbouw in Nederland en België in de eerste helft van de negentiende eeuw* (Amsterdam: Nederlandsch Economisch-Historisch Archief, 1995).

38 H. W. Lintsen, ed., *Twee eeuwen Rijkswaterstaat 1798–1998* (Zaltbommel: Europese Bibliotheek, 1998), 13; Knippenberg and De Pater, *Eenwording van Nederland*, 55–57. Compare Filarski and Mom, *Transportrevolutie*, vol. 1, chapter 1.

39 Not all authors agree on this characterization of the inland navigation network as "national." Compare Rainer Fremdling, "The Dutch Transportation System in the Nineteenth Century," *The Economist* 148 (2000): 521–537; see especially 526ff.

40 Ewout Frankema and Peter Groote, "De modernisering van het Nederlandse wegenet: Nieuwe perspectieven op de ontwikkeling voor 1940," *NEHA Jaarboek* 65 (2002): 305–328; J. R. Luurs, "De aanleg van verharde wegen in Drenthe, Groningen en Friesland, 1825–1925," *NEHA jaarboek* 59 (1996): 211–237.

41 F. L. Schlingemann, "Het verkeer te water," in Boerman et al., *Het verkeer in Nederland in de XXe eeuw*, 334–419; *Eerste Nederlandse systematisch ingerichte encyclopaedie,* 1950, vol. 7, s.v. "Verkeer en vervoer."

42 R. Loman, "De wegen voor gewoon verkeer en het gebruik daarvan," in Boerman et al., *Het verkeer in Nederland in de XXe eeuw*, 480–481 and 489–490.

43 J. W. Schot, "De mobiliteitsexplosie in de twintigste eeuw," in Schot et al., *Techniek in Nederland,* vol. 5, 13–17; Filarski and Mom, *Van transport naar mobiliteit*, vol. 2.

44 Kees Schuyt and Ed Taverne, *1950- Prosperity and Welfare* (Assen-Basingstoke: Van Gorcum-Palgrave/Macmillan, 2004) 157-158; Ministerie van Economische Zaken, *Toets op het concurrentievermogen, Juni 1985*, chapter 4, 4. The railway and waterway networks had been reduced to 2,760 kilometers and 5,000 km, respectively, by 1980.

45 Frank Schipper, *Driving Europe: Building Europe on Roads in the 20TH Century* (Amsterdam: Aksant, 2008).

46 By 1999, 1,920 kilometers. From the early twentieth century on, bike path associations

constructed bicycle paths in nature areas. Starting in the 1920s, separate bike paths often were created when national and provincial roads were upgraded. After 1950 the needs of automobile traffic consumed nearly all the construction efforts, but starting in the 1980s the bike path network was improved, partly by creating connections by means of deserted country roads. Today there is a national long-distance bike path network. (Thanks to Frank Veraart for this information.) See Frank Veraart and Adri Albert de la Bruheze, "Fietsen in de Nederlandse bergen: Achterblijvend fietsgebruik in het zuiden van Limburg in historisch perspectief," in *Studies over de sociaal-economische geschiedenis van Limburg* 46 (Maastricht, 2001), 133–157.

47 *Summa encyclopaedie,* 1976, s.v. "Luchtvaart."

48 Schot, "Concurrentie en afstemming," 30–31.

49 Knippenberg and De Pater, *Eenwording van Nederland*, 49.

50 J. W. Schot, "De mobiliteitsexplosie," in Filarski and Mom, *Van Transport naar mobiliteit*, vol. 2: Gijs Mom and Ruud Filarski, eds., *De Mobiliteitsexplosie 1895-2005*.

51 Schot, "Mobiliteitsexplosie," 13.

52 W. O. de Wit, "Het communicatielandschap in de twintigste eeuw: De materiele basis," in Schot et al., *Techniek in Nederland,* vol. 5, 161). The authoritative reference work on Dutch communication history is W. O. de Wit, ed., "Communicatie," in Schot et al., *Techniek in Nederland,* vol. 5, part 2, 152–282.

53 W. O. De Wit, "Telegrafie en telefonie," in H. W. Lintsen et al., eds., *Geschiedenis van de techniek in Nederland: De wording van een moderne samenleving 1800–1890,* 6 vols. (Zutphen: Walburg, 1992-1995), vol. 4, 273–297.

54 R. De Boer, "De telegraaf," in W. E. Boerman et al., eds., *Het verkeer in Nederland in de XXe eeuw: Tijdschrift van het Koninklijk Nederlands Aardrijkskundig Genootschap* 50 (1933): 633.

55 De Wit, "Communicatielandschap in de twintigste eeuw," 162.

56 Fuchs, "Verkeer en vervoer," 321; *Eerste Nederlandse systematisch ingerichte encyclopaedie,* 1950, s.v. "Telegrafie en telefonie."

57 De Wit, "Communicatielandschap in de twintigste eeuw," 174.

58 *Summa encyclopaedie,* 1978, s.v. "Telegrafie."

59 De Wit, "De ICT-revolutie," in Schot et al., *Techniek in Nederland,* vol. 5, 262.

60 De Wit, "Radio tussen verzuiling en individualisering," in Schot et al., *Techniek in Nederland,* vol. 5, 202–229; see especially 211ff.

61 Others speak of a human-made geography or space-time. See Alain Gras, *Les macro-systèmes techniques* (Paris: PUF, 1997); Thomas Hughes, "Historical Overview," Todd La Porte, ed., *Social Responses to Large Technical Systems: Control or Anticipation* (Dordrecht: Kluwer, 1991), 185–186.

62 Erik van der Vleuten and Cornelis Disco, "Water Wizards: Reshaping Wet Nature and Society," *History and Technology* 20, no. 3 (2004): 291–309; C. Disco, "De verdeling van zoet water over heel Nederland 1940–1970," in Schot et al., *Techniek in Nederland,* vol. 1, 110–121.

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71 M. Bierman, "Infra Nederland is bijna klaar," www.pz.nl/m.bierman/infra.htm (accessed March 29, 1999).
72 Quotes from Lintsen, *Twee eeuwen Rijkswaterstaat*, 14–15 (author's translation).
73 Schuyt and Taverne, *Prosperity and Welfare,* 123–124.
74 The system-builder concept is developed in Hughes, *Networks of Power*. For a discussion and modification, see Van der Vleuten, "Understanding Network Societies"; Erik van der Vleuten, Irene Anastasiadou, Frank Schipper, and Vincent Lagendijk, "Europe's System Builders: The Contested Shaping of Road, Rail, and Electricity Networks," *Contemporary European History*, 16, 3 (2007): 321-347.
75 For more on the notion of institutional users of systems see Van der Vleuten, "In Search of the Networked Nation," and Van der Vleuten, "Infrastructures and Societal Change."
76 Hughes speaks of "local," "unified," and "regional" systems. See Hughes, *Networks of Power*. For a critical discussion of this historiographical format see Erik van der Vleuten, "Electrifying Denmark: A Symmetrical History of Central and Decentral Electricity Supply Until 1970," Ph.D. diss., University of Aarhus, 1998.
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81 Birgitte Wistoft et al., *Elektricitetens aarhundrede: Dansk elforsynings historie*, vol. 2, *1940–1991* (Copenhagen: DEF, 1992), 153–157.
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93 Hesselmans and Verbong, *Electriciteitsvoorziening in Nederland*, 37–39 and 41–42.

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97 J. C. van Staveren, *Electriciteitsvoorziening van Nederland: Overgedrukt uit de Handelingen van het XXVIe Nederlandsch Natuur- en Geneeskundig Congres, gehouden op 30, 31 Maart en 1 April 1937 te Utrecht* (1937).

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99 Denmark is a good example. See Van der Vleuten, "Constructing Centralized Electricity Supply."

100 Buiter and Hesselmans, *Tegendruk*, 81ff.; Verbong, "Systemen in transitie," 262–264; Verbong and Geels, "The Ongoing Energy Transition."

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