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Geopolitical upheaval and embedded infrastructures: Securing energy and water services in a divided Berlin

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"These supply networks are like the internal organs of any living being. The life-supporting internal networks of an organism are protected, just like the underground infrastructure of a city. Any disturbance endangers the functioning of the whole. Substantial interference in these internal supply systems poses a threat to city life in general."

(Ernst Randzio, in a speech to the Reconstruction Committee of the Berlin City Council, 16 May 1946, cited in Geist/Kürvers 1989:243)

"The long-term success of any political division not based on popular wishes would necessarily rest upon the disruption of [the city's] integrated infrastructure."

(Merritt 1986:159, on the post-war division of Berlin's municipal services)

1. Introduction

On 24 June 1948 the Soviet military authorities in Berlin instructed the city's electricity utility Bewag, located in the Soviet sector, to cut off all power supplies to the three western sectors of the city. Deliveries of coal to power plants in the western part of the city were also to cease immediately. The following day the Soviet commandant dismissed Bewag's technical director, Wissell, for refusing to follow these orders and for holding a press conference to protest against the blockade of West Berlin. The western occupying powers retaliated by stopping the transport of coal from the Ruhr to the Soviet zone and cutting off all supplies of gas from West to East Berlin, since gas production required coal. The sudden truncation of flows of electricity and coal plunged West Berlin into a supply crisis far more severe than anything experienced during the wartime bombardment and invasion of the city. Draconian measures were introduced to curtail the consumption of electricity and gas for all but the most essential of tasks, with punishments for infringements ranging up to a 12-month prison sentence in the British sector. In the winter of 1948-9 West Berliners had on average only 2 hours of electricity during the day and 2 hours at night, resulting in their per capita consumption falling to a mere quarter of East Berlin levels. Without adequate electricity the sewage pumping stations in West Berlin were rendered temporarily inoperable, leaving the utility managers with no option but to empty sewage untreated into the city's watercourses, thereby creating a major public health hazard. Parallel to the physical division of the infrastructure networks the Berlin blockade heralded the organisational separation of the utility companies in the two halves of the city. Following months of political wrangling culminating in the occupation of the Bewag headquarters by police acting on Soviet orders and a walk-out by pro-western employees, the company was divided into a Bewag-West and a Bewag-East in December 1948. The city's gas utility (Gasag) and water utility followed suit on 26 March 1949 (on the above, Senat von Berlin 1964; Berliner Schicksal 1952; Merritt 1968; Merritt 1986).

The Berlin blockade and the proxy Cold War over Berlin's infrastructure systems pose an extreme and unusual, but also highly revealing, example of network failure, the vulnerability of cities and the relation between the two. The network failure at stake in post-war, divided Berlin was not the result of a natural disaster or a major technical fault, nor was it the outcome of human oversight or of operating technical systems beyond capacity. It was, firstly, the product of human deliberation. The disruption caused was not accidental but intentional (Merritt 1968:165). Secondly, the actions which led to and accompanied the division of the city's infrastructure systems were embedded in the geopolitics of post-war Europe. They were expressions of the Cold War in a city which had become the focal point of East-West tensions: an extreme case of "the contested politics of network development" (Graham/Marvin 2001:12). More than this, Berlin's infrastructure systems were deliberately used as instruments of the Cold War – both at the time of their division and during the 40 years of separation – to advance the interests of the occupying powers, city authorities and utility companies in the struggle to protect their respective political regimes. A third distinctive feature to this story of network failure relates to its duration. In contrast to most crisis situations, where a temporary interruption of service prompts those responsible to attempt to restore full functionality – or 'normalcy' – of the system as soon as possible, the division of Berlin's technical networks created a wholly new context for infrastructure management of uncertain duration. Division completely reordered the territorial scope, technical challenges, resource flows, organisational structures and institutional practices in both halves of the city, yet this was not immediately apparent and only developed over a period of several years. One of the most intractable problems facing infrastructure managers on both sides of the divide, therefore, was how far they should adapt their systems to conform to the new geopolitical realities and how far they should at the same time keep options open for a possible reunification of the city and its technical networks.

This paper is a study of the destabilisation of apparently highly durable technical systems precipitated by the Berlin blockade and the subsequent efforts of those responsible to restabilise the systems around new spatial, organisational, socio-political and technical parameter. It investigates the different experiences of division in the electricity, gas, water and wastewater sectors in the first instance in order to highlight the nature of the crisis situation and the coping strategies of the infrastructure managers. Beyond this, the second purpose is to use the analysis of an unusual case of infrastructural reorientation to raise our understanding of the durability and adaptability of embedded technical systems in the face of major upheaval. Here we follow Jane Summerton's exhortation:

> "By studying phases in which technical systems undergo radical change, we might expect to gain new insights into basic dynamics and properties of these systems" (Summerton 1994:2).

Three key dimensions of urban vulnerability and network failure provide the analytical focus to the paper. The first set of research questions relates to the coping strategies of infrastructure managers in crisis situations. What were the initial responses of those responsible to the physical, organisational and political division of Berlin's networks and what do these responses tell us about notions of security, stability and autonomy surrounding large technical systems? What longer-term coping strategies developed over time and how far were they directed at preserving the status quo and minimising dependence on the other side of the city? To what extent did infrastructure managers keep the reunification option open, taking the reversibility of their actions into consideration?

The second set of questions addresses the durability and adaptability of large technical systems under duress. What does the experience of division in post-war Berlin reveal about the stability of large technical systems? More specifically, which of the technical, physical, social and organisational components of the energy and water supply systems proved more resistant and which more amenable to change? Did division mark a turning point in the trajectories of the technical systems, provoking critical reflection of their "taken-for-grantedness", or did the dominant logic of what Stephen Graham and Simon Marvin term the "modern infrastructural ideal" (Graham/Marvin 2001:181-3) survive the forces of upheaval? Finally, to what extent were diverse pathways of infrastructure development pursued in the West and East of the city and how reversible did this diversity prove following reunification in 1990?

A third group of research questions draws attention to the complex relationship between a city and its infrastructure in periods of political conflict. How did infrastructure systems become enrolled in the geopolitics of Cold War Berlin and what role did they play? Did the resilience of parts of these systems prove a source of strength and stability for the two half-cities? If infrastructure networks traditionally serve as "integrators of urban spaces" (Graham/Marvin 2001:8) what effect did their division have on the territorial cohesion of Berlin as a whole and of each of its halves? To what extent did division reorder the "spaces of flows" of infrastructure management, reducing national and regional dependencies, dramatising cross-border transfers and creating new territories of supply and disposal services in West and East Berlin?

These questions are explored with the help of two conceptual approaches frequently used in analysing the dynamics of infrastructure systems of this kind: socio-technical understandings of large technical systems (LTS) and the concept of path dependency and trajectories. Within the body of literature on large technical systems (see esp. Hughes 1983, Hughes 1987, Summerton 1994, Coutard 1999) we are particularly interested in ways of understanding processes of stabilisation and destabilisation. In the evolution of large technical systems Hughes ascribes considerable importance to efforts by the "system builders" to stabilise their system against internal and external threats of whatever kind. The consolidation of a large technical system around specific, historically rooted technological styles, institutional structures and established practices makes it appear particularly resistant to change. In Summerton's words:

> "For most of us, technical systems conjure up images of stability and permanence. […] Pending system failure or other strong forces, reconfiguration appears unlikely to occur" (Summerton 1994:1).

The division of Berlin's large technical systems during and following the blockade posed a severe and prolonged challenge to the stability of the established systems for energy and water/wastewater. It represents a potential case where "political developments or contingencies […] (such as war or the threat of war) can […] radically alter the shape and direction of large technical systems" (Summerton 1994:14). From an LTS perspective this massive "reverse salient" (Hughes 1987:73ff.) raises two questions. Firstly, in what ways did political division alter the shape and direction of Berlin's large technical systems? The task here is to ascertain which components of the large technical systems changed as a result of division and which did not. Secondly, what does the experience of division reveal about the assumed stability and durability of large technical systems? Following the argument of Graham and Marvin that the appearance of durability of large technical systems can be deceptive, it is worth investigating whether the shock of division in Berlin caused the "black-boxed" systems to be opened up to greater critical scrutiny (Graham/Marvin 2001:183).

The related concept of path dependency is used here as a second tool for understanding the resilience and adaptability of Berlin's large technical systems. The concept was originally devised by economic historians to explain the causal relationship between sequences of events and technological (or institutional) evolution, with a view to explaining cases of technological "lock-in" and their (negative) effects on innovation. More recently, political scientists in particular have developed a broader, less normative and more contingent understanding of path dependency. They are interested in how past events can act as "carriers of history", embodied in specific social and material structures and procedures, influencing – though not determining – present developments and creating thereby an "out-of-phaseness" between causal mechanisms and their effects (Araujo/Harrison undated:3). The relationship between events and pathway is often described using the notion of trajectories and turning points, or "critical junctures" (Deeg 2001). Turning points are understood as events with the potential to redirect trajectories along new paths (Araujo/Harrison undated:4). This perspective on the development of technical systems directs attention in our paper on the extent to which the political division of Berlin marked a departure from an established path of socio-technical evolution and whether it heralded the emergence of two competing paths in East and West Berlin. Beyond this, it is useful to explore how far the established path of large technical systems in post-war Berlin proved a valuable asset in the process of reconstruction and reordering following political division. Rather than being a constraint to future development we ask whether the socio-technical embeddedness of the systems proved an important resource (cf. Bernhardt 2003) in maintaining essential municipal services at a time of great upheaval.

To provide answers to these questions this paper begins by describing the various manifestations of political division for each of Berlin's infrastructure systems (electricity, gas, water, wastewater), indicating how the dramatic events of the blockade affected flows of natural resources, people, information and money (Section 2). The following section explores the responses of the infrastructure managers in West and East Berlin to the division of their (socio-technical) networks, distinguishing between emergency measures and longer-term coping strategies (Section 3). As a prelude to analysing these responses the two conceptual approaches of LTS and path dependency are elaborated at this point (Section 4). On the basis of this conceptual framework the coping strategies of the infrastructure managers are interpreted in terms of the research questions set out above, focussing on issues of destabilisation/re-stabilisation, turning points and path divergence between West and East Berlin (Section 5). The validity of these observations on path dependency and divergence is then tested retrospectively, reflecting on the experiences of (re-)unifying the systems after 1990 (Section 6). Finally, conclusions are drawn on what the case study can tell us about the interdependence of a city and its infrastructure, the impact of crisis events on infrastructure management and the resilience and adaptability of large technical systems.

2. Dividing the city, dividing the networks

2.1 The political division of Berlin

The building of the Berlin Wall in August 1961 – dramatic though it was – marked only the culmination point of a process of political division between the Soviet and Allied sectors of the city since the late 1940s. The physical barriers erected in the sewers beneath the dividing line between East and West Berlin symbolised 'closure' not only of underground passageways of escape but also of any foreseeable chance of reuniting the city and its infrastructure networks. Whereas flows of people and vehicles beyond the 'overground' territory of West Berlin were halted abruptly by the Wall, the underground flows of electricity, gas, water and wastewater had been truncated or severely restricted much earlier, during or after the blockade of West Berlin in 1948/49 (Stoll 1995:240).

The story of the Berlin blockade does not need to be repeated here (see Merritt 1986:15ff). The initial objective of the Soviet military authorities had been to gain control of the whole of Berlin, cutting off western Berlin's supply routes in an effort to force the Allied powers to sacrifice the city. Following the success of the airlift, maintaining essential goods and services in the western sector for almost a year, Soviet strategy was reoriented towards enforcing the political division and isolation of West Berlin. By the end of 1948 Berlin had two city governments – for the East and the West. West Berlin became an "island outpost" (Merritt 1973:60) within the Soviet zone of occupation, isolated from its hinterland politically and economically, separated from the Allied zones in western Germany and deprived of its former functions as the capital of Germany. The following section examines how this process of political division manifested itself in the case of four municipal services: electricity, gas, water and wastewater.

2.2 Cutting the connections

Electricity

When the supply of electricity to West Berlin from the Soviet sector and zone was abruptly cut off in June 1948, in one of the first acts of the blockade, it plunged the half-city into an unprecedented crisis situation. Before the war electricity had been a far more important source of energy than in any other German city (Brocke/Brüss 1953:113), earning Berlin the recent title as "perhaps the most famous 'electropolis' of all" (Graham/Marvin 2001:46). The city's power supply had been heavily dependent on the national grid, with the Berlin utility Bewag importing some 40% of its electricity in 1932 (Merritt 1968:168). Most of Berlin's own generating capacity survived the war: of the 750 MW available in 1944, 391 MW were fully operational at the end of hostilities and a further 63 MW temporarily of action owing to destroyed power lines and coal shortages (Brocke/Brüss 1953:113; Berliner Schicksal

1952:254). Far more serious was the dismantling and removal of power plants and machinery by the Soviet military immediately after the war, conducted primarily in the western sector before the arrival of the Allied authorities. The largest and most modern power plant in West Berlin – Kraftwerk West – was dismantled in its entirety. As a result, the generating capacity of the whole city was reduced by almost one half and of West Berlin by 90% (Brocke/Brüss 1953:113, Merritt 1986:159). At the time the blockade began, therefore, West Berlin had already experienced severe disruptions to its electricity supply and was extremely dependent on power supplied by the power stations in East Berlin. Not only the generating capacity, also most of the city's coal reserves were at the time stored at power plants in the eastern half of the city, notably at Klingenberg (Merritt 1968:170).

The stoppage of power supplies and coal deliveries from the Soviet sector and zone to West Berlin triggered a serious supply crisis. In response to the blockade the Allies rapidly established an airlift, flying in essential supplies to the beleaguered city, above all coal to keep the run-down power stations in operation. In a desperate effort to restore West Berlin's generating capacity whole generators for flown in for the rapid reconstruction of Kraftwerk West (Senat von Berlin 1964:736). To minimise the strain on the power plant, the military and civilian authorities in West Berlin imposed severe restrictions on energy consumption (see above). Ernst Reuter, then city councillor responsible for utilities and transportation, called on Berliners to support the efforts to reduce consumption:

> "Every kilowatt hour of electricity, every cubic metre of gas and every litre of water which is taken from our supply pipes costs coal. And new coal can only be provided by air." (undated, Senat von Berlin 1964:1482)

The organisational division of Bewag began immediately after imposition of the blockade (on the following, Merritt 1968:172-177). Between June and December 1948 a power struggle was conducted for control of the company and, in particular, of its headquarters located in the Soviet sector of the city. Interventions by the Soviet authorities to dismiss and replace senior company executives and to manipulate representation on the Bewag's workers council were countered by reprisals from the West. Bitter accusations and counter-accusations between the two sides succeeded in splitting the workforce along political lines. When pro-western staff walked out of the company headquarters on 6 December in protest at the dismissal of the Bewag director Strassmann and the appointment of the pro-Soviet Witte the split of Bewag into two companies was complete.

Following the end of the blockade on 12 May 1949 the immediate need of West Berlin was to reach agreement on the delivery of electricity from East Berlin, at least until the reconstruction of Kraftwerk West was complete. A contract was duly signed, on 18 July 1949, and over the next year Bewag-West received 457,000 Mwh, or ca. 56% of its gross output, from East Berlin and the Soviet zone (Merritt 1968:178). Disputes over the renewal of this contract led to electricity supplies from East to West being summarily cut and restored as East Berlin exploited its powerful bargaining position to extract maximum concessions. A more stable arrangement was reached on 16 November 1950 involving a three-way agreement for Bewag-East to supply Bewag-West, the Hamburg power utility to supply Mecklenburg (situated in the Soviet zone) and Bewag-West to reimburse the Hamburg utility. The following months were uneventful, indeed there were even cases of cross-border assistance following technical failures on both sides of the divide. In early 1952, however, the separation of West Berlin's electricity network took a further decisive step. On 4 March Bewag-East announced the impending termination of all electricity supplies to West Berlin, citing "disturbances in the East German power system". When offers of help from Bewag-West were ignored, the company had no alternative but to shut down the cross-border power lines:

> "Bewag-West did what it could. Its technicians took prompt action to recircuit Bewag-West's own electrical distribution, thereby forestalling a failure of the entire system of West Berlin. Until past two in the morning they cut, circuit by circuit, the lesser transmission lines of the grid that bound the two halves of the city together." (Merritt 1968:182)

Gas

The experience of division over the supply of gas was, on the surface, very similar to that of electricity. From the early days of the blockade the Soviet authorities gave orders applying to all four sectors of the city, they occupied the headquarters of the gas utility Gasag, also located in East Berlin, and disrupted communications with the company's West Berlin offices (Berliner Schicksal 1952:259). Following the dismissal of the company board of directors by the Soviet authorities on 26 March 1949 the Allied powers transferred the headquarters to West Berlin, marking the effective split of the utility (Merritt 1968:186). The physical connections were cut wherever possible. Where gas mains had valves on or near the border these were closed; where there were no valves the gas transfers in each direction were calculated and (after lengthy negotiations) billed to the other side (Berliner Schicksal 1952:260). By the end of 1950 the separation of the physical networks was complete: the service area of Gasag-West was henceforth almost wholly independent of the East.

Unlike the Bewag experience, however, contractual agreements between Gasag-West and Gasag-East were generally adhered to. This may be attributed to the much lower levels of dependency of Berlin as a whole on outside supplies and of West Berlin on East Berlin supplies. Even before the war Berlin had not been supplied by long-distance gas mains, despite intensive wooing by the national Reichswerke (Brocke/Brüss 1953:118). Gas was produced from coke wholly at its own gas works. Nor was East Berlin in a particularly strong bargaining position, lacking adequate production capacity itself and – without access to Ruhr coal – dependent on coal from Upper Silesia that was less suitable for coking. The case of gas supply will not be pursued further in this paper.

Water

During the war Berlin's water supply system, despite bombing damage, remained fully functional up until the Soviet military advance into the city. Even during the worst of the fighting in April 1945 water supplies were disrupted only for a short period of time and in certain areas (Bärthel 1997:188-189). The immediate post-war concern was to secure sufficient coal supplies to operate the waterworks. As most water pumps were driven by diesel or steam West Berlin's water supply was not immediately affected by the power cuts marking the beginning of the blockade (Senat von Berlin 1964:1459). Nor were water services initially subject to the arbitrary or sudden cut-offs in supply described above for the electricity and gas sectors. Drinking water continued to flow freely between the two halves of the city.

On 26 March 1949 the Berlin water utility was split into two, at the same time as Gasag, following the division of the city government (Merritt 1968:187; Bärthel 1997:194ff). From this time onwards conflicts arose between the two halves of the city over cross-border water transfers. As with electricity generation capacity the water supply situation was strongly asymmetrical in favour of East Berlin in the late 1940s. In terms of the water resources theoretically available to the waterworks scattered across the city East Berlin possessed twice the per capita capacity of West Berlin (Bärthel 1997:195). Considerably more water flowed from East to West than in the other direction and the East Berlin government sought to maximise compensation for the net water transfers to West Berlin. Prolonged negotiations over the price of these transfers during 1949/50 ultimately broke down. Frustrated by the lack of progress West Berlin officials disconnected all water mains linking the two halves of the city on 3 July 1950. This "precipitous action [...] by Western officials" (Merritt 1968:187) had a far more detrimental impact on West Berlin than on the East, revealing the greater dependency of the former on cross-border water flows at this time. The borough of Neukölln was left without water for days and needed to be supplied by emergency pipes laid specially from the neighbouring borough of Tempelhof. After three weeks an agreement over payment for water transfers was reached and the mains valves were re-opened.

Subsequent disputes over payments for water supplies led to less dramatic disconnections in April 1952 and again in 1957. The installation of water meters at border crossings in 1953, permitting exact calculations of water transfers, helped reduce conflict between the two sides over this issue. In a memorable incident on 7 July 1953, just three weeks after the East Berlin uprising, officials from the West and East Berlin water utilities met on the Späth bridge to successfully negotiate additional emergency water supplies for Neukölln and Tempelhof following a particularly hot spell. Relations between the two were, from 1958 onwards, largely conflict-free despite their partial interdependence on each others' water supplies.

Wastewater

In contrast to the water sector, Berlin's wastewater disposal system had been severely disrupted by the war. In 1945 all the city's sewage pumping stations were out of action and raw sewage was being disposed of in bombed-out sites and open watercourses. The effect on public health was dramatic: mortality rates from typhus reached pre-1870 levels (Bärthel 2003:168). War damage had largely been repaired by the end of 1946, however.

Any division of the sewer networks was - for physical reasons - far harder than with other sectors of underground infrastructure. Blocking up sewers at border crossings would require re-routing wastewater along alternative networks – a solution which generally was neither technically nor financially feasible. There were 97 cross-border sewers altogether: 66 flowing from East to West Berlin, 31 flowing the other way (Möhring 1991:7). An additional physical deterrent to separating the networks lay in the radial structure of the sewer network. Wastewater was collected at central points in the city and pumped out to irrigation fields or sewage treatment plants (STPs) lying largely outside the city. For this reason around 90% of West Berlin's sewage was treated or disposed of on sites located in the surrounding Soviet zone (Bärthel 2003:203).[1] Following the organisational division of the Berlin wastewater util-

[1] Merritt (1968:188) cites an even higher figure of 98%.

ity in December 1948 negotiations over payments for the transportation and treatment of sewage from West Berlin in the East produced an agreement on 12 December 1950 for a fixed sum of 1.3 million DM p.a. paid by West Berlin. This agreement remained in force until 1954 (Bärthel 2003:174). These payments for net transfers of wastewater were a welcome source of hard currency for East Berlin – and a constant reminder of dependency for the West Berlin authorities.

A peculiarity of the sewer network, as compared with the electricity, gas or water systems, lay in its potential function as a conduit for people seeking to pass from East to West Berlin. Even prior to the building of the Wall in August 1961 barriers had been erected in sewers, allegedly to prevent the passage of spies from the West. Following the building of the Wall the East German Ministry of State Security took over responsibility for the "underground border" (Bärthel 2003:199). By November 1961 all 41 of the cross-border sewers with a diameter of over 60cm had been rendered impassable for humans, with many equipped with sensors and alarms (Möhring 1991). Although the barriers were designed to permit the free flow of sewage, they were nevertheless responsible for frequent blockages and sewer overflows at the border.

2.3 Disconnected flows

To conclude this overview of the experiences of the division of Berlin's infrastructure systems it is worth reflecting on what different kinds of flows were truncated. The process of separation, from the blockade in 1948 to the building of the Berlin Wall in 1961, affected most obviously the underground flows of energy and natural resources along the city's networks of pipes, cables and ducts. As we have seen, flows of electricity between West Berlin and both East Berlin and the surrounding Soviet zone ceased completely in early 1952; the supply of gas across the political borders was effectively terminated by late 1950. Cross-border flows of drinking water and – to a greater extent – wastewater continued throughout the 40 years of separation, but at much reduced levels as both sides of the city tried to minimise dependence on the other.

Other flows of vital importance to the functioning of the city's infrastructure systems were also cut off or redirected as a result of political division: flows of information, lines of communication, movement of people and transfers of money. During the struggles for control over the utility companies prior to their division, the military authorities on both sides attempted to prevent the movement of machinery, equipment and documents from plants or offices located in their own sector. The Soviet authorities, in particular, were concerned to stop staff sympathetic to West Berlin from smuggling important files, plans and maps from the head offices in East Berlin to the West. When the dramatic split of the utilities came, chief executives who vacated the central office buildings left only with what they could carry.

Since most documentary material was left behind in the East Berlin headquarters and staff from the West were denied access to it the West Berlin utilities possessed wholly inadequate data about their own technical networks, hampering reconstruction work for years to come (Merritt 1968:176-177, 186-187). Bewag-West technicians had to reconstruct from memory the layout of their part of the network of underground cables. The water utility in West Berlin lacked adequate documentation on the water supply network and data on water consumption. Consequently, completely new plans had to be drawn up from scratch – a painstaking exercise which took around a decade to complete (Bärthel 1997:236-237). Some informal contacts were maintained across the political divide which helped cover some of the most urgent knowledge gaps on both sides. Such meetings between former colleagues were prohibited by the East Berlin utilities and had to be clandestine. These personal contacts tailed off, however, during the 1950s and were stopped almost entirely when the Wall was built. There remained subsequently only limited formal contacts between West and East, for example over the contractual agreements for cross-border transfers or monthly meetings of senior technicians from the two power utilities (Merritt 1968:190). The knowledge networks had been disrupted so severely that by 1968, in the words of Richard Merritt, "directors on both sides of the Brandenburg Gate learn about plans of the other side only through the press" (1968:194-195, footnote 60).

The division of the utilities and their staff affected not only information flows but also the skills and knowledge of the respective workforces. The general tendency in 1949/50 was for the more highly qualified and better paid staff to follow the West Berlin utility and for a larger proportion of workers to remain with the East Berlin company. As a result Bewag-West had a surfeit of office staff and not enough workers and technicians, whilst Bewag-East suffered from the loss of key management personnel, as well as retaining only two fifths of the total workforce. The damage of division to the workforce of the utilities well preceded the building of the Berlin Wall in 1961, in other words, when the flows of people were arrested completely. What immediate affect the Wall had on the workforce is unclear. One direct consequence was to delay the construction of a new waterworks at Jungfernheide in West Berlin by nine months, as most of the construction workers came from the eastern sector (Bärthel 1997:256).

Finally, we should also consider how the division of Berlin and its infrastructure systems was accompanied by the emergence of new flows of money across political borders. Compensation payments for the cross-border transfer of electricity, gas, water and wastewater proved essential for preventing the collapse of municipal services. This applied to the energy services during the critical early period of division and to the water/wastewater sector to areas close the border or wholly dependent on external infrastructure. Initially, the money transfers were primarily from West to East, reflecting the higher degree of dependence of West Berlin. However, as the West Berlin utilities increased the capacity of their technical networks during the 1950s and 60s, investing heavily with Federal Government support (another significant dimension to Cold War money flows), this asymmetrical situation was halted and even reversed in some sectors, with East Berlin making net payments. How this came to be is addressed in the following section.

3. Responses of the network managers

3.1 Securing the systems

The political division of Berlin had, as we have seen, dramatic impacts on the territorial integrity, technical functionality, organisational structure and socio-economic exchanges of the city's infrastructure systems. This begs the question of how those responsible – the utility managers, infrastructure planners, city and occupying authorities – responded to this immense and unique challenge. Looking beyond the immediate events of division surrounding the blockade – the era of de-stabilisation – we now turn to the efforts of the 'network managers' to safeguard and stabilise their systems within the new geopolitical reality of a divided Berlin. What notions of security guided their thinking when rebuilding the networks and how was this reflected in their coping strategies? How did they attempt to reorder their infrastructure systems technically, spatially and institutionally? Were these responses directed solely at creating self-dependent systems or did they keep other options open? These questions are explored here by looking at West and East Berlin in turn.

3.2 West Berlin

The immediate concern of West Berlin's network managers in the utilities and city planning departments was to secure the provision of a basic level of municipal services during and immediately after the blockade. The focus was on emergency measures to forestall network failure precipitated by unpredictable interventions by the Soviet authorities and/or system overload caused by demand outstretching the limited supply capacity. As the acute crisis receded in the early 1950s attention turned towards more strategic ways of safeguarding the infrastructure systems. The priority here was, undeniably, on reducing dependency on East Berlin and the Soviet zone:

> "The experience of the blockade made West Berliners insist on complete independence from the East with respect to most of these municipal services." (Merritt 1986:159)

A repeat of June 1948, when the vulnerability of West Berlin's infrastructure systems had been revealed all too painfully, had to be avoided at all costs.

It was no coincidence, therefore, that one of the first acts of city councillor Reuter following the end of the blockade was to call for the reconstruction of Kraftwerk West as a top priority. The speedy delivery of material and equipment and the establishment of substantial coal reserves in West Berlin were to act as a deterrent against similar Soviet interventions in the future (Senat von Berlin 1964:1554). By 1952 this flagship power plant had been restored to a capacity of 268 MW, already providing the lion's share of the total 382 MW at West Berlin's disposal (Brocke/Brüss 1953:114). As the generating capacity of Bewag-West grew, so did the company's bargaining position vis-à-vis the East. Negotiations for renewed cross-border electricity transfers in the summer of 1953 resulted in a much more advantageous agreement for West Berlin (Merritt 1968:183). By early 1955 Bewag-West had become self-sufficient in electricity generation. Not requiring electricity imports from the East any more, the agreement was not renewed.

The capacity of West Berlin's water supply network was similarly insufficient to meet demand (Bärthel 1997; Tessendorff 1995). West Berlin had only limited groundwater resources at its disposal and the network was dependent on a few large waterworks in the North-West of the city. The priority, as with electricity, was to raise supply capacity as quickly as possible. Major investments were made in extending the capacity of the waterworks at Beelitzhof in 1953 and, in subsequent years, at Spandau, Tiefwerder, Jungfernheide, Tegel and Kladow (Bärthel 1997:272ff). A programme of water mains repair reduced leakage substantially. The water utility also applied innovative techniques to increase drinking water reserves, notably extensive forms of groundwater enrichment. Already by 1953 dependence on water 'imports' from the East had been reduced significantly and contacts with East Berlin counterparts became less necessary. Several cross-border water mains were opened merely to keep the pipes clean. By 1978 the supply capacity of West Berlin's waterworks had increased by 227% against the 1949 figure (Bärthel 1997:278-279). The utility was able to cope with an unusually hot summer in 1975 without mishap.

Interdependencies between West and East over wastewater were more complex. On the one hand West Berlin disposed of only 10% of its wastewater on its own territory, at the irrigation farm at Karolinenhöhe, making it highly dependent on the surrounding German Democratic Republic (GDR). On the other hand the GDR had a vested interest in avoiding wastewater pollution of lakes and watercourses downstream of West Berlin. On 2 October 1951 the West Berlin Senate, as the city government was now termed, presented an internal report on various options for rendering the wastewater system independent of East Berlin and the GDR (Bärthel 2003; Merritt 1968). Interestingly, the one chosen was against provisional measures designed to provide immediate relief for the critical disposal situation and in favour of a long-term plan for structural autonomy. On the basis of this strategy the decision was taken in 1953 to build three completely new sewage treatment plants inside West Berlin, at a cost of 87 million DM. This scheme, which involved substantial re-routing of wastewater flows in the existing radial system, was implemented with the construction of the STPs Ruhleben (1957-63) and Marienfelde (1968-74). The third planned STP was never built. By 1989, when the Wall fell, only 28.3% of West Berlin's wastewater had to be disposed of or treated on East German territory – a major reduction from the 90% figure 40 years previously (Tessendorff 1995:555; Möhring 1991:5). Between 1950 and 1990 the sewer network was extended in length from 1,414 km to 5,169 km and the number of connected buildings more than doubled (Bärthel 2003:231). As with the drinking water system, the West Berlin utility invested heavily also in new technologies designed to meet the city's peculiar geography of wastewater disposal. The two new STPs incorporated special space-saving design features, the stormwater drainage system was expanded, including the construction of eight underground rainwater retention basins, and a novel technique of sludge incineration was introduced in the 1970s to permit sludge treatment within West Berlin (Tessendorff 1995:558-559).

West Berlin's strategy to maximise autonomy via major network reconstruction and expansion did have its price, however. Firstly, the investment programmes were very expensive. The reconstruction of Kraftwerk West alone cost $30 million, the new STP at Ruhleben $12 million (Merritt 1968:191). Total investments in the West Berlin wastewater disposal system between 1950 and 1989 amounted to around 3,800 million (Bärthel 2003:232). Richard Merritt estimated in 1968 that the direct and indirect costs for increasing network independence from the East for all infrastructure sectors amounted to some $250 million (Merritt 1968:191). This price tab was picked up not primarily by West Berlin consumers – who paid charges for their municipal services comparable with West German cities – but by the Federal Government, in the form of subsidies.

3.3 East Berlin

The East Berlin utilities also planned to re-orientate their supply and disposal systems around the particular needs of the GDR, despite being generally less dependent on the other side than West Berlin (Bärthel 1997:200). However, the plans to repair, extend and reorder the technical networks failed to be implemented. Applications for funding from the state planning system fell on stony ground throughout the 1950s and 60s, despite repeated warnings from those closely involved of the dire consequences of underinvestment for the condition of the physical infrastructure and the quality of municipal services (Bärthel 1997:205). Planning priority for major programmes of industrialisation and housing construction resulted in meagre funding for the technical infrastructure (Möhring 1991:5). This hit the water/wastewater sectors particularly hard. The supply capacity of East Berlin's waterworks fell significantly between 1949 and 1970, from 715,000 m^3/day to 525,000 m^3/day (Bärthel 1997:233). A decision made in 1956 to build a new STP at Falkenberg was not implemented until 1963. In the 1950s, but increasingly in the 1960s, the technical networks were subject to technical failures, such as mains bursts, significant drops in water pressure and malfunctions to sewage pumping stations and irrigation farms (Bärthel 1997:205; Bärthel 2003:179). As water supply capacity failed to keep pace with growing demand areas were subject to supply cutoffs and rationing. In the summer of 1970, when demand exceeded supply capacity by an estimated 50,000 m^3/day, large parts of the city centre were without water (Bärthel 1997:204-205). At the same time as West Berlin was investing heavily in upgrading and reordering its technical infrastructure, in other words, East Berlin's own infrastructure was being starved of funds, causing the city to lose many of the comparative advantages it had possessed in the early 1950s.

Only after the 8th Party Conference of the Socialist Unity Party and the announcement of a major housing programme in 1973 was higher priority given to upgrading the infrastructure systems in East Berlin (Bärthel 2003:190ff). For the first time, substantial investments were allocated to improving wastewater treatment, resulting for example in the completion of the STP at Münchehofe in 1976 and the construction of a new STP at Schönelinde in 1979-87. By 1980 the supply capacity of East Berlin's waterworks, at 810,000 m^3/day, well surpassed 1949 levels (Bärthel 1997:133). As an expression of growing recognition by the planning authorities of the importance of technical infrastructure to the city's development, a general plan for the future development of all technical networks (*Generalplan Stadttechnik*) was adopted in 1980 (Bärthel 1997:212). Despite these improvements the renewal and upgrading of the technical networks was generally not able to keep pace with the needs of urban expansion and growing demand (Bärthel 1997:226; Bärthel 2003:201-202). When the Berlin Wall fell in 1989 most networks were in a poor state of disrepair.

3.4 New spaces of flows

Having made some general observations at the end of the previous section on the kinds of flows disrupted by the division of Berlin, we can draw some conclusions here on the nature of the spaces of these reordered flows. In so doing we can present some interim conclusions on how an act or process of division can alter the relationship between urban territories and networked spaces. Infrastructure systems are generally attributed an important function in contributing to the territorial cohesiveness of a city (Graham/Marvin 2001:15). At the same time they interconnect and bind the city to spaces beyond city limits, drawing for example on natural resources in the surrounding region. Since the spaces of socio-technical networks generally do not correspond to the territorial space of a city, the relationship between urban and infrastructure systems is often a contested one.

In the case of post-war Berlin the level of contestation over urban and infrastructure spaces was extreme. Physical and social connections across space were abruptly cut off, in the case of energy supply systems completely. Boundaries between the two sectors of the city and the Soviet zone, previously invisible from an infrastructure perspective, suddenly became areas of tension between two opposing regimes, where connections were closed off, underground barriers erected and residual flows scrutinised to determine transfer payments. Behind the physical boundary spaces each political system sought to corral its own infrastructure networks around the territory over which it had control.

This reordering of the spaces of flows around the new geography of the city was not immediate but developed in intensity during the 40 years of division. West Berlin's electricity supply system, cut off from the national grid and East Berlin's generating capacity, was reoriented around the political-administrative territory of the western sector, generating all its own power by the mid 1950s. New water mains were built on a West-East axis to compensate for the loss of supply from waterworks in East Berlin (Bärthel 1997:238-239). The siting of West Berlin's new STPs similarly reflected the spatial reordering of wastewater flows across the city, minimising dependence on the GDR (Bärthel 2003:215ff). East Berlin and the GDR, confronted with a significant 'hole' in their networks left by West Berlin, responded by reordering their mains electricity, gas and water systems so that they circumvented the western sector, as clearly demonstrated in the *Generalplan Stadttechnik* of 1980 (Stoll 1995:241; Bärthel 1997:1997:212). In an effort to "disentangle" the sewer network close to the border to West Berlin the East Berlin authorities even built a number of "border pumping stations" to redirect wastewater flows away from the West, primarily as a means of avoiding transfer payments (Möhring 1991:7).

These parallel strategies of infrastructural separation seriously undermined the territorial cohesion of the city as a whole. At the same time they were promoted on both sides of the divide as a means of protecting their own territorial integrity. The rhetoric of infrastructure as a key building block of the city was retained, but it was applied to the newly truncated territorial units and in a far more political sense as an instrument of political and economic security. In what ways, though, did this reordering of networked spaces mark a turning point in the development of the city's infrastructure systems and how irreversible did the changes prove? Furthermore, did East and West Berlin's infrastructure systems pursue different development pathways following division, or do the similarities outweigh the differences? These questions guide our investigation in the remainder of the paper.

4. Trajectories and turning points: a conceptual framework

4.1 Introductory remarks

The severity of the political division of Berlin and the experience of separating the city's infrastructure systems creates notions of major upheaval and radical transformation, which – it might be assumed – marked a departure from established development pathways and a complete reorientation around the new geopolitical situation. Similarly, the huge differences between the two political regimes of East and West Berlin and the ways in which technical infrastructure was used to safeguard and support each political unit might lead us to expect that the city's infrastructure systems subsequently developed along divergent pathways in East and West. On the other hand, clearly, there were elements of Berlin's technical systems which survived the experience of division, such as much of the physical infrastructure. Nor was it self-evident that differences in political orientation produced diverse infrastructure policies. So what did change as a consequence of division, and what did not? Which components of Berlin's large technical systems proved resilient, and which adaptable to the new circumstances? How far did resilience prove an asset in securing vital energy and water services during the years of separation? And, finally, how irreversible did the changes prove with the benefit of hindsight post-1989?

In order to analyse the Berlin case with these questions in mind we need to have a general understanding of what infrastructure systems comprise, how they change and how key events affect the development of large technical systems. To this end we draw here on two bodies of literature to provide a conceptual framework for the subsequent interpretation: on large technical systems and on path dependency.

4.2 Large Technical Systems

Research on large technical systems (LTS) is valuable to us in explaining what constitutes large technical systems, what phases are characteristic of their development and how they change. Following Thomas Hughes' pioneering book "Networks of Power" (1983), a field of research has developed to investigate the complexity and dynamics of large technical systems of electricity supply, transportation, telecommunications and so on. Drawing on perspectives from the history of technology, science and technology studies and – more recently – urban studies, researchers have sought to uncover the social and technical components of these systems and interpret the interrelationship between them (e.g. Hughes 1987, Summerton 1994, Coutard 1999). Avoiding both a technologically determinist and a social determinist conceptualisation of the development of large technical systems they understand infrastructure systems as constituting a complex web of physical artefacts, techniques, organisations, regulations, established practices etc.. Indeed, the relational nature of large technical systems – that is, the interdependence of their social and technical components – is central to this understanding. Each component is part of a larger whole, upon which it depends. It follows that "[i]f a component is removed from a system or if its characteristics change, the other artifacts in the system will alter characteristics accordingly" (Hughes 1987:51).

Hughes provides several useful concepts to describe how large technical systems evolve. The "system builders" – initially inventors and financiers, subsequently managers and engineers – seek to develop and then continuously reinforce their system in a changing environment. They possess the ability "to construct or to force unity from diversity, centralization in the face of pluralism, and coherence from chaos" (Hughes 1987:52). Following an initial phase of invention and a subsequent phase of accelerated development and innovation successful large technical systems enter a phase of stabilisation or consolidation, characterised by greater resilience against competing systems and stronger dynamics of self-perpetuation. In this stabilisation phase large technical systems adapt to changing circumstances, where possible, by incorporating new requirements into the existing established system. Where radical change occurs, this is as a result of a "reverse salient"; that is, a component which falls behind or is out of phase with the large technical system. A reverse salient can be some technological inadequacy or incompatibility, but equally a social problem, such as a negative externality or a political conflict (Summerton 1994:14). The division of Berlin's infrastructure systems after the war clearly constitutes a major reverse salient. Of particular interest to our questions is, in addition, Hughes' concept of momentum, or trajectory (Hughes 1987:76-80). The relative durability of artefacts and knowledge supporting a large technical systems is suggestive of the notion of momentum, defined by Hughes as "the persistence of acquired characteristics in a changing environment" (Hughes 1987:77). This momentum applies not to technical artefacts alone but to the combination of social and technical components which characterise a large technical system. Momentum – Hughes warns us – is not to be confused with autonomy. Systems of high momentum often give the appearance of autonomy, i.e. being impermeable to external influence, but this is deceptive, as events of political upheaval reveal. The metaphor of momentum, by contrast, "encompasses both structural factors and contingent events" (Hughes 1987:80). It allows us to consider how these "black-boxed" systems, though appearing highly stable, are inextricably tied up in wider social, political and cultural forces exercising contingent effects in different times and at different places (Tarr/Dupuy 1988; Graham/Marvin 2001). This makes the concept particularly suited to studying the impact of the political division of Berlin on the longer-term development of the city's infrastructure systems on both sides of the divide.

4.3 Path dependency

For the literature on path dependency these notions of momentum and contingent events – more usually termed trajectories and turning points or critical junctures – are the central objects of analysis. In LTS research these concepts emerge out of the study of the evolution of technical systems as an instrument for explaining persistence and change. The path dependency literature, by contrast, is targeted at investigating the nature of these phenomena in their own right, using technological innovation as a fruitful topic for empirical verification. It is helpful for us here in explaining the nature of change and persistence and how past events shape subsequent development trajectories and options for action.

The concept of path dependency was originally developed in the mid-1980s by economic historians to explain how events in the past can place constraints on options for action at a later date. It was applied first to a variety of technologies (Arthur 1989; David 1988) and subsequently to institutions (North 1990). More recently it has been taken up by political scientists and applied as an instrument of policy analysis (Pierson 2000; Deeg 2001). Path dependency is concerned at how current events are shaped by past events and, thus, how social and material structure can act as "carriers of history" (Araujo/Harrison undated:3). A path dependent process is characterised by a self-reinforcing sequence of events; it begins – and ends – with specific triggering events which retrospectively take on the significance of "critical junctures" (Pierson, cited in Deeg 2001:8). Chance events can have huge long-term consequences if they succeed in tipping societies or technical systems along a different development pathway (Arthur 1989, David 1988).

Early research on path dependency has been criticised for being too fatalist in its interpretation, focussing narrowly on cases of suspected 'lock-in' of sub-optimal technologies, according too great an importance to so-called "positive feedback mechanisms" and, as a consequence, underestimating the influence of agency and the spatial-temporal contingency of trajectories. More recent studies by political scientists suggest that path dependency, though limiting options, in no way predetermines future events (Deeg 2001; Araujo/Harrison undated). The operation of causal mechanisms is not automatic but contingent on contextual circumstances. Araujo and Harrison argue, therefore, that "path dependence is best understood as a general framework to understand how temporal-relational contexts of action are formed and how specific events can contribute to their reproduction or transformation" (undated:1).

From this broader perspective trajectories are understood as interdependent sequences of events which coerce processes along a particular path with the ability to absorb minor variations without an appreciable impact on the overall direction of the trajectory (Araujo/Harrison undated:4). Turning points are events with the potential to redirect trajectories along new paths, whereby this capacity may well only become apparent at a much later time. How path dependency works in practice is illustrated by Araujo and Harrison as follows:

> "This temporally oriented definition of agency reinforces the notion that actors have always got a foot in the past, the present and the future. They adjust their temporal orientations in relation to changing circumstances in more or less reflective or imaginative ways. They selectively engage with routines and habits from the past, evaluate present possibilities and project hypothetical new paths in to the future. Their temporal orientation may also change in response to specific circumstances (e.g. more past or future oriented) and structural contexts." (Araujo/Harrision undated:6)

5. New trajectories to Berlin's infrastructure systems?

5.1 Introductory remarks

Did the division of Berlin's infrastructure systems during and after the blockade mark a turning point in their development, setting in motion a departure from an established trajectory and the emergence of a new path or paths? If so, in what ways did these new paths differ from the old? Which components of Berlin's large technical systems proved resilient to change and which more adaptable? Finally, what degree of influence did the key actors possess to shape the further development of their systems?

Following a socio-technical understanding of large technical systems we need to look for path dependency in the various components of an infrastructure system. Evidence of persistence and change must be sought not only in the physical and technical artefacts of a system, but also in the network spaces, organisational structures, operational strategies of network managers and institutional logics which frame their actions. We might, for example, expect technical/physical artefacts to display greater persistence than institutional or social components, but this initial assumption might be ill-founded. An in-depth, systematic analysis of the path dependency of a large technical system is, thus, a complex task and one beyond the scope of this paper. Here, we highlight instead selected areas of persistence and of change to Berlin's infrastructure systems and provide a more differentiated picture of path dependency than might at first sight be expected.

5.2 Persistence and change in Berlin's infrastructure systems

When considering the physical/technical dimensions to the path dependency of Berlin's infrastructure systems it is worth recalling the great importance attributed at the time to their resilience during the war. A much-cited study on the condition of Berlin's underground infrastructure undertaken in 1946/47 by Ernst Randzio revealed an astonishingly high rate of survival (Randzio 1951). Whilst the value of buildings and other surface infrastructure in the city had fallen by 27.6% between pre-war levels and 1946, the value of the underground infrastructure had declined by a mere 1.2% (Randzio 1946 in Geist/Kürvers 1989:242-243). The figures in detail were: wastewater sewers and pipes 1.1%, gas pipes 2% and electricity cables 6.1%. Only the house connections for water and wastewater (19.2%) and public lighting (gas 36%, electricity 25%) suffered notable damage (Randzio 1951:15). Berlin's largely undamaged networks of pipes, cables and ducts became a prime asset in the city's recovery programme. Besides the fact that, in most cases, they did not need to be repaired, their survival enabled urban reconstruction to build on the existing infrastructure, literally and figuratively. The "structural inertia" (Storbeck 1964:10) of the technical infrastructure proved a powerful argument for retaining the city's pre-war urban structure and resisting the initiative of some urban planners to reorder Berlin's urban design (Randzio 1951). Here was a dimension of path dependency which was widely regarded not as a constraint, but as a major benefit for the city's development.

This physical infrastructure remained in place following political division in 1948/49 and, for the most part, continued to function as before. What changed radically as a result of division were the territorial boundaries of the technical networks and the embeddedness in wider technical systems. West Berlin's technical networks were either cut off from surrounding systems entirely (electricity, gas) or had the flow of natural resources controlled at the border (water, wastewater), with the effect of reducing cross-border flows in the longer term. This spatial constriction caused West Berlin's existing system to be reordered so as to secure adequate supply for the city, with some sections of the network taking on new functions and others (e.g. near the border) losing importance. This physical-technical reordering, involving the construction and upgrading of major plant (STPs, waterworks, power stations), the introduction of new technologies and the redirecting of flows, constituted a radical shift in the spatial orientation of the city's infrastructure systems. In East Berlin similar spatial reorientation took place but to a lesser extent, partly because of the continued connections to the surrounding Soviet zone and later GDR and partly because of a lack of investment opportunities. The restructuring was directed at circumventing West Berlin and was closely linked to urban development priorities on the eastern perimeter of the city from the 1970s onwards.

It is indicative of the extent of change to these physical structures following division that concerns were raised about their irreversibility and the risks this posed for the potential reunification of the two cities at some time in the future. Referring to the physical restructuring of Berlin's technical networks Richard Merritt described the threat as follows:

> "The infrastructural aspects of a political community […] exhibit remarkable durability and tenacity in resisting change. The very tenacity of the infrastructure, however, suggests that, once change is initiated, its reversal will be very difficult. The developments [in post-war Berlin] thus portend an ever growing divergence of West and East Berlin, respectively, from the old centre of Greater Berlin, and increased solidification of each around its new core area." Merritt (1986:163)

Merritt's concerns were shared by many at the time, and infrastructure planning did, especially in the early years of division, take possible reunification into consideration to a limited degree (Bärthel 1997:281-282). However, the risk of establishing structures which might be difficult to reorder following any reunification was generally deemed less significant at the time than the danger of not being able to safeguard municipal services. Minimising dependence on the other side of the city was accorded a much higher priority than keeping the reunification option open. Merritt, on the basis of his research in the 1960s, criticised West Berlin's network managers for paying lip service to reunification while "enhancing the city's invulnerability to threats to its independence" (Merritt 1968:193). He charged both sides with "pass[ing] up chances for fruitful cooperation – primarily for the sake of increasing the viability of the utilities in their own sectors" (Merritt 1968:191).

Merritt paints a picture of divergent pathways between East and West driving a rift between the two sets of infrastructure systems which reduced the prospects for their reunification. He could point, correctly, not only to the physical/technical and spatial reorientation of infrastructure systems in East and West Berlin but also to the highly diverse organisational structures and institutional arrangements on either side of the divide. The West Berlin utilities were responsible to the city government but had considerable autonomy over investment plans and operative management. Significantly, they received significant funding from both city and Federal governments, permitting extensive reconstruction and expansion programmes without placing undue financial burdens on consumers. By contrast, the East Berlin utilities were institutionally weak. They came under the powerful influence first of the Soviet authorities and subsequently of the state planning bodies and suffered at least until the 1970s from the low priority accorded to infrastructure refurbishment in the planning system. As a result they were continuously under-funded.

Yet if we look closer at the strategies pursued by network managers in East and West and at the underlying logics or rationales for their actions we can detect some strong parallels. On both sides of the divide the network managers were intent on repairing, modernising and expanding their technical networks to meet rising demand. Their prime concern was to ensure maximum connection to municipal services, adequate supplies of electricity, gas and water for all consumers at all times and failure-free operation of the networks. Whether in West or East Berlin network managers subscribed to the logic of infrastructure management predominant since the late 19th century which Graham and Marvin have termed the "modern infrastructural ideal" (2001:43ff.). In the very different contexts of East and West Berlin this ideal was pursued with different results, but this can largely be attributed to asymmetries in the availability of resources. The rationales motivating the network managers and guiding their strategies were, essentially, the same. It is in this sense that we can speak of strong path dependency relating to the underlying logics of infrastructure management which survived both the immediate division of Berlin's infrastructure networks and, as we shall now see, the forty years of forced separation.

6. Reunification of Berlin's infrastructure systems post-1989

6.1 Introductory remarks

To what extent were the concerns raised at the time over the incompatibility of the infrastructure systems in East and West Berlin justified? The reunification of Berlin and its infrastructure systems following the fall of the Wall in 1989 offers a rare opportunity to test the case of irreversibility of altered trajectories. It allows us to revisit the thesis of divergent pathways, exploring the legacy of division from the perspective of experiences made in reunifying the infrastructure systems post-1990. Areas where reunification proved difficult might point to components of the systems which had grown apart during the 40 years of separation. Conversely, problem-free aspects of the reunification process could be construed as expressions of underlying similarities which had survived separation. When investigating persistence and change in the reunification process we need to distinguish between short-term impacts and longer-term implications of division. In addition, we need to consider the political asymmetries of reunification and be aware that a rapid process of reunifying the infrastructure systems may be indicative as much of the dominance of the West Berlin model as of any lasting compatibilities between the West and East Berlin systems.

6.2 Physical and organisational reconnection

Reconnecting the networks physically proved a relatively straightforward task. This was particularly so for the wastewater systems, which had – for technical and financial reasons – never been completely separated, and for the water supply systems, where the connecting pipes had not been dismantled but only closed off. Valves in the water mains were reopened and barriers blocking the sewers removed in early 1990, even before formal political reunification. For technical reasons the reconnection of West Berlin's electricity supply system to the regional distribution networks took considerably longer. In 1994 West Berlin was reconnected to the East European grid and a year later eastern Germany was connected to the West European grid (Stoll 1995:243). During the whole reunification process there were no notable instances of network failure in any of the infrastructure sectors.

Organisational restructuring of the utility companies proved also, at least at first sight, straightforward and conflict-free. Following the fall of the Berlin Wall contacts were quickly established between management on both sides of the city to discuss reconnections and, subsequently, the amalgamation of utilities in East and West (cf. Bärthel 1997). As early as 1990 the two water/wastewater utilities – Berliner Wasserbetriebe (BWB) in West Berlin and Wasserversorgung und Abwasserentsorgung Berlin (WAB) in East Berlin – were placed under joint management prior to full amalgamation on 1 January 1992. The rapidity and ease of these formal acts of reunification mask, however, some serious operational difficulties experienced in bringing the utilities together under a management structure and business culture based wholly on the model of the West Berlin utilities. Organisational restructuring was, in the words of the then technical director of the West Berlin water utility, "a particularly difficult process" (Tessendorff 1995:556). In the case of the water utility, the existing organisational structures and procedures of the BWB were transposed onto the united utility without adaptation to reflect the traditions and needs of the East Berlin WAB. Almost all senior management posts went to staff from the West Berlin utility. This was recognised at the time as being a sub-optimal solution but was justified on the grounds of the urgency of the tasks confronting the reunited water utility (Tessendorff 1995:556). Furthermore, staff from the WAB accustomed to operating under the state planning system had to acquire new skills rapidly, in particular in marketing and business management. The remarkably smooth process of formal amalgamation, effectively involving the takeover of the East Berlin by the West Berlin utilities, therefore papered over areas of tension within each company relating in particular to managerial structures and practices.

6.3 The logic of "the modern infrastructural ideal" confirmed

Where there was widespread agreement was over the need for major investment in upgrading, modernising and, where necessary, extending the technical networks in the eastern part of the city. Infrastructure managers in East Berlin had, ever since the 1950s, documented for the state planning authorities the serious deterioration of the physical networks as a result of neglect and under-investment. The reunification of the city created the opportunity to implement the improvements which they had – largely in vain – called for under the GDR. At the same time infrastructure planners from West Berlin were keen to upgrade the eastern Berlin networks to West European standards and to meet the needs for the projected population growth of Berlin from 3.5 to 4.2 million inhabitants. Over the modernisation of East Berlin's infrastructure there was, therefore, a meeting of minds between East and West.

The BWB presented its first investment plan in the spring of 1992, envisaging expenditure of 12.8 billion DM by the year 2000. Within a year the figure had been revised upwards to 20 billion DM for the period 1993-2003, once a detailed survey of the state of the networks in eastern Berlin had revealed the full extent of the problem (Tessendorff 1995:557). The utility's annual capital investment rose from ca. 350 million DM in 1990 to ca. 1,300 million DM in 1994, two thirds of which was spent in the eastern half of the city. In 1995 Bewag planned investments of ca. 6 billion DM over the following 5 years, primarily on upgrading and modernising the utility's 13 power plants in the city. The sheer scale and importance of these investment programmes placed huge demands on the planning and coordination of infrastructure development and, in particular, on the interaction between infrastructure and urban development planning in Berlin. To meet this need the city authorities drew up a special Urban Development Plan for Technical Infrastructure (*Stadtentwicklungsplan Ver- und Entsorgung*) in 1998 (SenSUT 1998; Stoll 1995).

What is significant about these substantial investments and planning exercises in infrastructure development from a path dependency perspective is that they are expressions of the survival – with renewed vigour – of the traditional logic of network managers to build up and extend their technical systems as a means of avoiding network failure and meeting projected growth in demand. Reunification did not, in the immediate term, challenge this dominant rationale for action. On the contrary, the self-evident deficits of the East Berlin networks reinforced and reinvigorated the response of infrastructure managers to expand and upgrade their networks in response to current and potential threats to the secure provision of municipal services.

6.4 The logic of "the modern infrastructural ideal" challenged

Other legacies of the years of division worked in the longer term, however, to seriously undermine the "extend-and-supply" logic of Berlin's infrastructure managers. The creation of two fully operational, but separate, networks for each of the municipal services had produced a network structure and capacity level for the city as a whole which was, from a technical and economic perspective, sub-optimal in many respects. The construction of considerable additional electricity generating, sewage treatment and water abstraction capacity in West Berlin had made a lot of sense during the years of division, but left the reunified city with potentially obsolete plant and excess capacity. Similarly, the spatial reorientation of the technical networks during separation had resulted in new spaces of flows which were not compatible with the needs of the reunified city, despite the persistence of many pre-war structures. The overriding concern of the network managers for protecting their respective systems from failure had, in addition, encouraged the creation of security reserves in network capacity – particularly in West Berlin – to avoid dependency on the other side.

The legacy of spatial re-orientation and capacity expansion would not have posed such a problem if demand for energy and water in Berlin had risen as predicted in the early 1990s. Difficulties arose, however, when the city, rather than enjoying rapid growth following reunification, experienced major socio-economic restructuring as state subsidies dried up, industrial production collapsed and many businesses and residents turned their back on the city. As a result, electricity consumption was stagnating by the mid-1990s and – far more serious – water consumption in Berlin dropped by over 40% between 1990 and 2002. For the first time in the city's history network managers were confronted with the problem of serious over-capacity in all or parts of their networks. In response, the ambitious investment programmes were revised downwards from the mid-1990s onwards: in the case of the BWB's ten-year plan from 20 to 12.8 million DM. By 2003 the company had closed down 7 of its 16 waterworks and three of its sewage treatment plants (Adlershof, Marienfelde and Falkenberg), requiring the complete reorientation of some wastewater flows to a remaining STP along a newly constructed 18 km mains sewer. This ongoing experience of adapting to declining or stagnating demand and over-capacity is requiring network managers to re-think some of the basic assumptions underpinning their strategy of service provision and network management. This readjustment can be seen as a direct consequence of the legacy of urban development and infrastructure development in East and West Berlin during the era of division.

What makes this process of readjustment so difficult is a second challenge to the "modern infrastructural ideal" in recent years: the growing commercialisation of infrastructure management in the city. This development is not a product of political division, at least not a direct one. Since the mid-1990s Berlin's utilities have come under increasing pressure to raise efficiency, cut costs and compete with other service providers externally and – in the case of Bewag – on its own service territory. These requirements are in part the consequence of the liberalisation of the German energy market but in part also a product of the budget crisis confronting the city. In order to pay off huge debts the city has privatised all its utilities, either fully or in part, in recent years. To raise revenue the Berlin government is demanding from the utilities higher payments for concessions to supply the city. It is these two developments in the recent history of infrastructure management in Berlin – commercialisation and over-capacity – which, arguably, are posing a much more fundamental challenge to the dominant logic of "extend-and-supply" than the division of the city ever did. This, however, is a story which reaches far beyond the scope of this paper.

7. Conclusions

What conclusions can we draw from our analysis of the division of Berlin's infrastructure systems following the blockade of 1948/49? One set of observations relates to the nature of the crisis and the interdependency between a city and its infrastructure which it revealed. The network failure which Berlin's infrastructure systems suffered in the late 1940s and early 1950s was not the result of forces endogenous to them but of the geopolitical conflict of the Cold War, with Berlin as the principal pawn. Technical networks played a central role in this proxy conflict. Severing West Berlin's electricity supply was one of the first acts of the blockade, quickly followed by the retaliatory stoppage of cross-border gas supplies by the Allies. Subsequently, municipal services on both sides of the city were seriously disrupted by political and economic division. Beyond the flows of gas, electricity, water and wastewater the division of the city stopped or curtailed other, less obvious flows of central importance to their functioning, most notably of people, equipment and information. The infrastructure systems were not merely passive victims of division but were often enrolled in the protection of one political regime against the other, creating structures of supply and disposal crucial to the survival of each city.

A second set of conclusions addresses the responses of the network managers to this crisis and the security concerns which these responses reveal. We have observed how, during the early period of the blockade and political division, the prime concern of the network managers, above all in West Berlin, was to maintain essential services in the face of interventions and reprisals from the other side. Emergence measures were targeted at ensuring the provision of basic – if heavily restricted – supplies of electricity, gas and water. The experience of the blockade and the extreme dependence on external powers which this uncovered prompted West Berlin's authorities to seek to maximise self-dependency for all municipal services. The strategy shifted rapidly from stop-gap measures to the spatial reordering of the networks, a strategy which gradually came to be mirrored in East Berlin. Restructuring the technical networks to reduce external dependency and create sufficient reserves to withstand an assault like the blockade became the top priority for the West. This strategy took precedence over concerns at the negative consequences which restructuring might have on any future reunification of the city and its infrastructure systems.

This raises issues relating to a third set of conclusions on whether or not the division of Berlin marked a turning point in the established trajectory of its infrastructures systems and on the extent to which we can detect two divergent development pathways in East and West. In some important respects, the blockade and the reactions of the network managers to it did represent one of those "critical junctures" which change the direction of a large technical system. We have observed how the spatial structures of the networks in East and West altered substantially for the following forty years, how the organisational structures and institutional influence of the utilities differed significantly and how the higher level of technological innovation and network modernisation in West Berlin rendered the two systems increasingly asymmetrical. On the other hand, some elements the pre-war systems proved very resilient to change. This applied most obviously to the large part of the physical networks which survived the war – and the blockade – unscathed and continued to provide the backbone of Berlin's infrastructure systems in both East and West. Less tangible, but just as important, was the persistence of the traditional logic of "extend-and-supply" amongst network managers. Whether operating in East or West Berlin the network managers adhered to what Graham and Marvin have termed "the modern infrastructural ideal". Where they differed was primarily a result of the different level and quality of resources available to pursue this common goal.

This interpretation would appear to be supported by the experience of reunifying the infrastructure systems post-1990. The "extend-and-supply" logic fitted neatly to the task of repairing and modernising the technical network in eastern Berlin. The prospect for East Berlin infrastructure managers to have access to sufficient funding and influence to upgrade their systems after so many years would appear to have offset many of the tensions and difficulties associated with the rapid reunification process. What is currently proving far harder to adapt to is the combination of over-capacity in the networks and growing commercialisation of utility management. These two challenges strike at the core of the belief system which has underpinned infrastructure management in the past: the rationale of "extend-and-supply". It would appear that Berlin's infrastructure systems – after the experiences of division and reunification in the past – are today experiencing a third turning point of unknown outcome.

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