The Structure of (Information) Infrastructure: Origins, History, and Theory of the Flow Chart

Markus Krajewski, *University of Basel*,
ver.1.0:2017-06-23

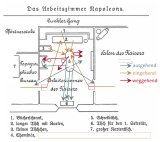
1 Mobilization

The center of power is wooden and round [●]. At first, it looks like a plain old, somewhat bulky table standing on six legs mounted on a pedestal, a table that in some respects resembles a dresser with all its storage space. The table top is shaped like an ellipsis. The piece of furniture is made of simple plywood adorned with some rosewood inlays, and is stabilized with copper inserts and framing. »The table top is made of thin, polished, green marble.«[1] At second glance, however, the static, plainly ordinary design is set in motion. The rounded table top can be separated into parts, pulled out, or expanded with a quadratic surface concealed in the middle. A shelf can be pulled out and turned into a chair, while compartments for inkwell, quill, and other writing utensils can also be pulled out of the inside. [●]

The object was custom made for none less than the French Emperor, Napoleon Bonaparte, manufactured by a cabinetmaker named Sacci in Florence following a design of *l'empereur* himself. The handy, highly mobile smart desk that the generals called the *bureau de campagne* accompanied Napoleon and his generals on most of their campaigns. More than anything, the desk was a site where information flows met, coagulated, and interacted with one another in order to be sent back out in altered form, in a different order, in other directions. In short: Napoleon's

[1] Knight and Wulpi 1931, p. 53.

desk was a communications center. Information and command flows from the most divergent places came together here, were classified, separated, and rerouted. This was true both for the periods between campaigns and for the lengthy phases spent traveling: everywhere he went, Napoleon was accompanied by his governing apparatus with all its instruments.



Napoleon's office was always set up according to the same logic [●]: A long table for maps along with a smaller table were placed before a bookshelf. On the other side of the room, the Emperor's secretary sat at a smaller desk with his back to the open room so that he could quickly take down the Napoleon's dictations, copy them, and archive them. In the middle is a desk with a chair, at which, however, the Emperor rarely sits. Instead, he walks back and forth like a peripatetic while dictating his orders and commands so that he can keep his maps in sight and regulate the flow of information.

None of these pieces of furniture—or, better, none of these media of governance—can be dispensed with on a campaign. Everything is brought along on every journey: The Emperor's desk, the secretary's desk, the books on the bookshelf, and, of course, the whole cartography center in the adjoining room with its maps and map tables. It's no wonder that—alongside multiple wagons and about 400 horses—Napoleon's baggage train and that of his closest generals and assistants consisted of more than forty mules »that carried or pulled tents, field beds, offices, lockers, medicine, silverware, kitchens, a wine cellar, and a blacksmith's shop; further, the group was made up of secretaries, officials, servants, cooks, and stable grooms as well as about 130 horses for the Emperor and his adjutant generals.«[2] These are the things that make up the infrastructure of a smoothly running communications system, which, as history in general and the history of media in particular teach us, is indispensable for successfully governing an empire.[3]

How did Napoleon use these media of governance that outfitted his (mobile) command center, which was called the »Palais« even in the

[2] Zamoyski 2012, p. 122. [3] Vgl. Siegert 2003.

field?[4] He normally showed up to the office around eight in the morning to sign documents that had already been prepared for him. Then he read the most up-to-date news and classified it within his hierarchically organized information system:

> Any documents that were not in need of further attention Napoleon tossed on the floor; these documents were called »le repondu«; documents that needed to be processed were placed *upon* the desk and were called »le courant«; finally, the documents that could be dealt with later on were put together and were called »le suspens«. Napoleon himself implemented this system of classification and he held fast to it.[5]

Thus, every piece of information is placed on a different level in a vertical hierarchy depending on its urgency and significance. At the bottom with the pencil shavings are documents that can be ignored, while only the urgent messages ever even land on the Emperor's desk, where he literally reads and processes them. In other words, the information contained in these documents was—in consultation with maps when necessary—really translated into troop movements, marching orders, and other commands. The flow of information then changes direction, and the inbox turns into an outbox. However, Napoleon didn't actually write his responses himself, but delegated the writing to his secretary, the reason being that even Napoleon himself could only read his own handwriting with considerable strain. »Thus, he used the hands of others to dictate his thoughts. His secretaries were primarily occupied with writing down his thoughts.« But Napoleon spoke very fast. »Because he didn't allow himself to be interrupted and didn't repeat himself, he could only find few people—he called them ›machines à écrire‹—who could follow his dictations.«[6] In situations requiring haste, three or four of these writing machines were used to ensure a continuous flow of commands. The constant arrival of important dispatches and unexpected news made the Emperor's work flow rather unorderly, even if it was still carried out with all necessary speed. Though renowned for his ability to multitask, he often lost track of things, giving contradictory orders and forgetting things

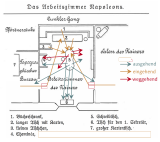
[4] Giehrl 1911, p. 7. [5] Ibid., p. 4. [6] Ibid., 4 f.

in the hustle and bustle, so that his assistants had to constantly be on the lookout for misplaced papers in order to keep the information flowing and the files in order.

> This diligence went so far that every morning assistants went on a search for letters, documents, or notes that might have been left in Napoleon's clothes or lying on the mantle or bedside table in his room. In the same way, the doormen looked through the salon after the Emperor had held a meeting. If they found a letter, note, or piece of paper, they picked it up and returned it.[7]

Thus, Napoleon always left a literal trail of paper behind him that awaited his dutiful servants. His trace is of paper, a trace gathered up, read through, and processed by his secretaries. In other words, the *flow* of information is much closer to actually resembling the metaphor than one might initially believe. It is not comprised of individual bits of news coming in one by one like drops, but by countless, swirling, non-linear, turbulent pieces of information that disseminate in different speeds, with different relations to one another, sometimes interacting, sometimes wholly unrelated, and sometimes contradicting one another and giving each other a new trajectory.

If we transfer this logic of flows that determines the stream of commands and information to the topography of the command center, we get the following diagram: [●]. [Explain briefly] By adding a second visual layer that marks the command flows and information vectors, we turn what at first seems to be nothing more than a schematic overview of Napoleon's office into a diagram that tells us quite a lot about the Emperor's communications apparatus. It is an organigram of power and its media as they appeared about 200 years ago.



* * *

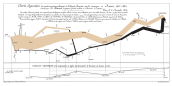
Diagrams visualize connections and relations that would otherwise be difficult to grasp.[8] Filling in the command flows turns the simple

[7] Ibid., p. 7. [8] Among the countless definitions of what a diagram actually is see Schneider, Ernst, and Wöpking 2016, p. xx.

schema of the office into something new. Rather than just depicting the arrangement of rooms, it now tells us about work flows around a central piece of furniture, a desk oddly shaped like an ellipsis. It makes visible the spatial order and disorder at the head of the Napoleonic Empire. Diagrams are instruments of illustration that fuse heterogeneous elements and overlapping levels into a single image, all with the aim of making clear the relations between things that might have at first seemed to have little to do with one another. Diagrams use structures to make infrastructure visible, whether it be in my diagram of Napoleon's desk and the flow of information churning around it or in another diagram that has a not insignificant relation to it. I'm not just talking about any old diagram here. I'm talking about the diagram that Edward Tufte called "the best statistical graphic ever drawn."[9] But I'll show you what I'm talking about in a just a second. . .

2 Description of a Battle

How can such a massive project—and I mean project in the full sense of a bet, anticipation, or, even more literally, projectile—how can such a massive organizational undertaking like Napoleon's 1812 invasion of Russia be translated into a single image? And I'm not talking about the many drawings made by eye witnesses [●],[10] or the rather conventionalized paintings of battles [●]. I mean, how can an image be made that captures the entire megalomaniacal venture and its failure and makes it comprehensible in a single glance? In 1869, Charles Joseph Minard succeeded in doing just that. He produced a depiction of the French invasion of Russia in a form that enabled the imagination to grasp the troops' movements over territory and the dynamic of losses in a detailed and at the same time comprehensive manner. His seminal graphic ultimately came to exert a great influence on nineteenth-century cartography and the fledgling discipline of infographics [●].



[9] Tufte 2001, 40. Tufte makes this rather remarkable claim without providing any reason for it. He simply says it after giving a brief description of the diagram.. [10] Zamoyski 2012.

What do we see here? First, we can see that there are three distinct, overlapping horizontal levels: in the upper quarter of the image there is a block of text that contains both the title and the graphic's legend, while the lower quarter is taken up by a diagram with a few different axes. Between them is a geometric figure that looks kind of like a lizard's tail whose color changes at the right edge of the image from reddish brown to black, winding back to the left side with its girth greatly diminished. The otherwise austere layout is filled out with a scale, a few tiny numbers and city names, and topographical elements that represent rivers. From west to east, we see squiggly lines that represent the Neman, the Berezina, the Dnieper, and the Moskva, which transform the image into a map, heavily reduced in its graphic form and in the way it encodes information. Attached to the thinner, black shape are eight vertical lines that connect it to the diagram at the bottom, which turns out to be a graphic representation of the temperatures recorded on the route between October 18 and December 7. The temperature record runs east to west, against the left-right orientation of French readers, while the reddish-brown shape represents the move from west to east. Indeed, both the reddish-brown and the black shapes trace the Grande Armée's path during the campaign. And the width of the shape—graded rather than continuous—symbolizes the strength of the army, which, with few exceptions, constantly shrinks. Numbers are given on the edge of the shape to help orient the reader. Thus, the map gives graphic form to the losses incurred on the trip from the Neman to the Moskva and back, losses that saw an army 422,000 strong dwindle to a force of only 10,000 soldiers.

What does Minard's diagram show us aside from the scale and the temperature chart, the geography of the land covered and the political situation? Without using arrows or the like, the shape that represents the flow of troops over the land and their constantly diminishing numbers clearly moves in two directions. The shape is a minimalist, symbolic depiction of an abstract narrative, a story without words. The shape also shows the flow of time spread over the space covered. From left to

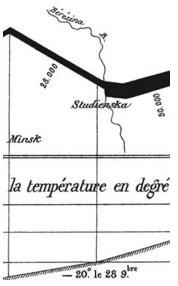
right, it depicts in a color somewhere between mud brown and blood red the march to Moscow, which didn't see much fighting and thus wasn't all that bloody. And from right to left, it traces the return to France on the same axis in funeral black, an axis that thus tracks two spans of time that run contrary to one another. The identification of a single axis with two temporal directions is the map's somewhat concealed visual statement: the diagram does not operate with a continual time flow. Rather, the time flow is broken up, proceeds in leaps and bounds. Put differently, the direction of time turns around in Moscow, where the flow of time folds back on itself. The singular, dwindling geometrical form is given shape by a long flow of commands that—rather provisionally and desperately—holds the Grande Armée together. The diagram doesn't say anything about the different modalities of loss, whether it be through desertion, illness, fighting, or the weather.

Strictly speaking, the diagram represents anything but concrete processes. Put in extreme terms, one might say that it doesn't represent a timeline at all, but simply two points in time. Because with its 600,000 personnel (including the rear guard), thousands of wagons and horses, etc., the Grande Armée itself took up a huge expanse of land. The same goes for the individuals within the army: even a good estimate of the number of personnel can't tell us the exact geographic location of the army, simply because it took up so much space and can't be reduced to a single point. Put bluntly, the campaign was a gigantic, international traffic jam whose supplies were being fed in from as far away as Prussia. But the traffic jam (as opposed to traffic flow) wasn't stable. It spread out over the roads—the key element of infrastructure—and into the surrounding towns, where the soldiers had to go to find food and accommodation. This, of course, led to problems, especially in sparsely populated areas. So, even the directions and paths outlined on the graphic only match up with the army's actual location in a rather schematic fashion.

It is the diagram's very schematic nature that makes us ask: what else can't we see here? What remains suppressed, covered over, or merely

implicit? The most important thing to keep in mind here is that the representation of the ever-diminishing stream of people covers over the infrastructure that supported that very stream. No roads can be seen, and there are no dots that might signify a city. The image is dominated by the natural flow of rivers and the symbolic and temporal flows of armies. The structure of information flows relies on an infrastructure of invisible roads and visible rivers. Thus, the graphic is literally a flow chart.

A quick question for thought: What is infrastructure? – Infrastructure is what we normally don't pay attention to because we take it for granted. Who thinks about the street when driving? Who thinks about the overhead cables, signal lights, and parallel tracks when riding in a train? Who sees the radio beacon when flying in a plane? It is no matter of coincidence that the word was coined in an 1875 tract on French railways. In the tract, it refers to those stationary structures necessary for mobility like rail beds, bridges, tunnels, etc., in contrast to the so-called superstructure made up by rails and the like. But it would take another 80 years before NATO's use of the concept would make it an important part of discourses on transportation and mobility.[11]



Minard's map makes visible the special relation between structure and infrastructure with a telling detail [●]: At the point of the famous crossing of the Berezina in November 1812, when Napoleon lost about half of what was left of his army, two heterogeneous flows meet. On the one hand, there is the Berezina River. 613 kilometers long, it flows into the Dnieper west of Homel. Because of its depth, it can support ships and can thus be used for transport; in other words, it can be used as infrastructure. But in this case, the river, which flows from north to south, is a kind of natural border that has to be crossed using structures like temporary bridges, pontoons, etc. On the other hand, there is the flow of soldiers, war machines, and entourage called the Grande Armée, which is about to come into contact with the natural flow of the river, with fatal consequences. The depiction of two flows crossing one another using the same medium—two simple black lines—turns the map into a

[11] Laak 1999, p. 281.

diagram, which is constituted at the moment heterogeneous elements are set in relation to one another.

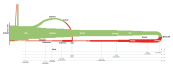
Designed two years before his death, Charles Minard's (1781–1871) remarkable, imaginative map might be seen as a kind of resume of his wide-ranging skills as a cartographer (it is worth noting that he completed a considerably less famous depiction of Hannibal's similarly catastrophic journey through the Pyrenees in 218 BCE around the same time). But it cannot be adequately understood without a discussion of, on the one hand, Minard's expert knowledge of canals, rivers, and other bodies of water, and, on the other, his mastery of the art of cartography. How did Minard come to be such an expert? Born in Burgundy in 1781, Minard left his home in Dijon at the age of fifteen to study at the École Nationale des Ponts et Chaussées in Paris, where he primarily focused on learning about the construction of canals and methods of land improvement, which is to say, the very disciplines that would eventually give birth to the concept of cultural techniques. After his first experiences working on the construction of a canal between Brussels and Charleroi, he took part in other canal projects in Belgium, where he not only managed to escape being conscripted for the invasion of Russia, but also witnessed first-hand the Prussian occupation of Antwerp in 1814. ‹ Back in Paris, he worked as a university teacher and in city administration, where he had to grapple with large-scale logistics problems like moving tons of cobblestones, a project for which he orchestrated his own lines of transportation that combined trains and river ships. This work familiarized him with setting up supply chains and transporting goods over long distances.

Alongside his career as an engineer, teacher, and administrator, he also started working as a cartographer in 1844. Better put, he became a sort of autodidactic cartographic ›nerd‹ who developed his own visual language, most likely without much assistance from others. Thus, in 1845, he designed a *carte figurative* that depicted the number of train passengers traveling on various lines between Mulhouse and Dijon [●]; like with most of his 51 maps, he self-published it and distributed it among his

co-workers.[12] Minard's remarkable maps garnered considerable attention at the Third Conference of Statisticians in Vienna in 1857, but the extent to which they continued to receive recognition (at least before Tufte's praise mentioned above) is unclear, and this despite the fact that none less than Étienne Jules Marey stated in his 1885 *La méthode graphique* that their brutal visual eloquence puts all historiographic description to shame.[13]

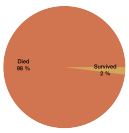
And indeed, Tufte's claim that Minard had already made the best infographic ever in 1869 seems to invite disagreement. One can, indeed, think of a few ways in which the graphic might be improved:

- In this revised version [●], not only are the now established color codes red and green used to tell the story of march and retreat; the erratic path that the army took over the terrain is now streamlined.



- This next version [●] is much more structured than the original; events and processes are clearly demarcated; the timeline organizes the events and shows how the campaign could have been optimized. Its title is: »If only Napoleon had used Omniplan«.

- In the last example [●], the graphic is pretty much reduced to the basic idea of an economic paradigm: 98% dead, 2% survived.

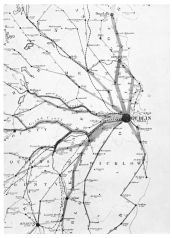


3 Frozen Flows

According to cartographer and cartographic historian Arthur Robinson, the way maps were drawn underwent considerable changes between the Biedermeier era and the era of the World's Fairs, that is, between 1835 and 1855. During this period, maps came to be loaded with all kinds of information, using new graphic elements like circles of varying size to signify different quantities or lines of varying width to signify

[12] This brief summary of Minard's biography and his accomplishments in the field of cartography largely relies on Arthur H. Robinson 1967, 96–98, for a list of Minard's maps see ibid. 106–108. [13] Marey 1885, p. 73.

the movement of people and goods in a gradually globalizing world. It was during this »golden age«[14] that the so-called »thematic map« was born, which might be understood as a »graphic geographical essay.«[15] Because Minard's 1845 flow diagram depicting train passenger travel between Mulhouse and Dijon comes relatively late in this periodization, one might ask if there was someone earlier who might be identified as the inventor of this graphic form. The statistician Maurice Block, a contemporary of Minard, writes that the Belgian cartographer Alphonse Belpair had designed a similar carte figurative depicting train passenger travel between different regions.[16]



The earliest map we know of that connects topographic information with statistical information[●]—tracing the use of infrastructure to boot—was designed, however, by the Irish engineer and civil administrator Henry Drury Harness (1804–1883). Seemingly without knowing it, Harness had come up with »a new design.«[17] In 1837, the Irish Railway Commission conducted a study on railway passenger travel and hired Harness to make a map to accompany it based on surveys they had done for that very purpose. The idea was to provide a simple, yet convincing representation of »information concerning the movement of goods« in order »to exhibit [. . .] the relative number of travellers [. . .] conveyed in different directions throughout Ireland.«[18] But in order to complete his task, Harness had to develop a wholly new visual vocabulary that used shading, circles, and other devices to represent the Irish population, a technique that would later be taken up by August Petermann.[19]

So, what's so special about flow diagrams? »With just a glance, flow line maps give readers an immediate impression of both the direction of

[14] Arthur H. Robinson 1955, p. 440. [15] Arthur H. Robinson 1967, p. 95; on the history of thematic maps, and statistical maps in Paris in particular, see Schöning 2018. [16] Block 1878, p. 382. [17] Second Report of the Commissioners appointed to consider and recommend a General System of Railways for Ireland, Presented to both Houses of Parliament by Command of His Majesty, H.M.S.O., Dublin, 1838, quoted in Arthur H. Robinson 1955, p. 441. [18] Ibid., S. 440, 441. [19] Arthur H. Robinson 1955, p. 448; as well as Felsch 2011, ??

something in motion and also the volume of its flow.«[20] Graphic elements like the width and direction of the shape in Minard's representation of Napoleon's invasion of Russia tell users everything they need to know in a split second. The flow chart has a direction insofar as it prescribes the direction it should be read in. Just go with the flow. Cartographers don't always need to use things like arrows. Minard dispensed with them because he could rest assured that the direction of the invasion was common knowledge. Moreover, a flow on a chart can have two or more directions, in contrast to natural flows.

Because Minard's diagram dispenses with arrows, the shape as a representation of the course of the march is relatively homogenous: while its width varies, its basic form pretty much remains the same. As a statistical aggregation based on provisional calculations, it does not distinguish between individuals. The suffering of individual soldiers, the pains of crossing the Berezina, the bullets piercing French and Russian uniforms, all this is omitted for the sake of translating the campaign into a set of clear numbers and a simple graphic.

And yet, hidden in the shape that contains everything in reduced form there is a secret center that travels along. Even if it were made visible, it would still only be about the size of a pinhead. The little sign would flow along in the viscous stream of soldiers and supplies towards the east and then, much quicker, would turn back towards the west. This sign is imaginary, and yet, it is also the point where all the information flows run together. It cannot be made visible because it does not represent a loss. Rather, it *generates* losses. It is that oddly bulky ellipsis, the sign for Napoleon's field desk [●].

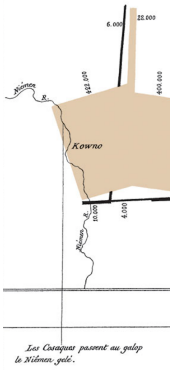
As a piece of furniture, desks are at once mobile and stable, and this is even more true for Napoleon's field desk. Although it can be moved, it is temporarily solid, standing in one single location. As a node, it has an address, and in Napoleon's case, it is the address where all the information in the flow runs together. – The flow diagram is at once mobile and stable

[20] Kraak 2014, p. 18.

too. It sets infrastructure and structure in relation, producing relative movement between them.

But what do they set in motion beyond the mobile desk? Maps, and topographic maps in particular, are generally stable. They serve as the foundation for flow maps. A map represents a territorial order. For this reason, it can be used as a means of control. But it can also be used as a strategic instrument. For instance, French or Prussian generals might use maps not only to see the location of their troops, but also to simulate and plan future maneuvers by moving around symbolic placeholders.[21]

Maps, at least on paper, are always static, but their static appearance conceals a powerful dynamism. They depict infrastructure (stationary elements) and superstructure (buildings, etc.) as the unshakeable order of things in a place. But maps become diagrams the minute they start working with time, the minute they begin representing things that move at different speeds and change places. Still, no paper technology, at least not a single piece of printed paper, can depict real movement. Thus, in Minard's chart, all movement is fictive, the flows are frozen because their speeds can't be represented. And so, it is up to the viewer to imagine the movement. It is no coincidence that there is a ninth vertical line on the left edge of the map accompanied by a sentence that might have been taken from a Tolstoy novel: »Les Cosaques passent au galop le Niémen gelé.« [●] Nature forges an alliance with the map. Both come to a standstill. The frozen flows—natural and symbolic—remain suggestion and have to appeal to the imagination, for instance by means of literature. The act of reading flows of people, goods, and information on a map is an act of the imaginary.[22]



[21] On such tactical and strategic war planning see Hilgers 2000; Hilgers 2012. [22] This figure of thinking inevitably brings Jacques Lacan's famous distinction of the symbolic, the real and the imaginary to mind. However, I am more interested in the notion of the imaginary what Michel Foucault 1998, has discussed, see »The domain of phantasms is no longer the night, the sleep of reason, or the uncertain void that stands before desire, but, on the contrary wakefulness, untiring attention, zealous erudition [. . .] The imaginary now resides between the book and the lamp. [. . .] The imaginary [. . .] is a phenomenon of the library.« 105-6.

4 Flow Chart of Flow Charts

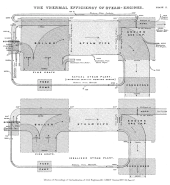
Flow diagrams serve as a medium for getting an overview of things when administering, controlling, or organizing large, complex processes that are in a state of constant movement, processes whose internal dynamics are much more complex than what you might find in a paper mill or a pin factory. True, these sites of production also work with moving machines, but their movements aren't subject to constant revision and change. Things are altogether different when we start talking about armies or large organizations where everything is always in motion and where every change requires the administration to adapt. Thus, it's no surprise that flow diagrams came into prominence around the turn of the twentieth century. After all, this was the era when big corporations and conglomerates were beginning to develop. And in particular, it is no surprise that companies working in the fields at the heart of the so-called Second Industrial Revolution like electricity and petroleum, fields that themselves are based on the flow of materials and energy, began using flow diagrams to represent the complex organization of things, whether it be in administration, research, or production. And, of course, it is no surprise that the military kept up.

Frank Gilbreth and his wife Lilian are usually credited as the inventors of flow charts, even though it is always difficult to draw clear distinctions between similar graphical techniques like the flow map, which also incorporates cartographic elements, or process charts, statistical maps, thematic maps and other kinds of diagrams that employ vectors and other elements that give direction.[23] It all depends on what one considers to be a flowing entity. As long the diagram depicts movement and represents time in

[23] While in the flow map the fundamental plane is usually a geographic map to which other geometrical structures are to be inserted, a flow chart – the etymology of lat. Charta as a rigid leaf (from the papyrus) suggests it – sets on a neutral background unequally abstract symbolic systems in relation. These can generally consist of character groups, font, geometric structures such as representations of organizational units, networks, or even temporal processes that are displayed.

some way, then it's a flow diagram. Henry Drury Harness' depiction of railroad passengers traveling from Dublin to the suburbs is one of the earliest examples of a diagram that represents the relationship between multiple elements, including territory. This was then followed by Charles Minard's works, among them his famous flow map of Napoleon's 1812 invasion of Russia.

If the way in which flow diagrams place structure and infrastructure in relation to one another is what makes them unique, constituting a new method for representing flowing, mobile, ephemeral entities, then the same can be said of Irish engineer Matthew Riall Sankey's inventions and the diagrams he published in 1898, which sought to visually represent and thereby minimize the loss of heat in a steam plant [●]. The flow diagram turned out to be a powerful tool for depicting the movement of materials and the transfer of information, precisely because it forces the designer to place things that are in reality complex entities in time and space onto a flat surface like a sheet of paper. In short, the flow diagram is a medium of efficiency: it is a paper technology[24] capable of abstracting and thus simplifying complex processes.



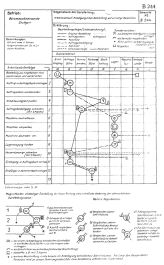
So what does the genealogy of flow diagrams look? In the beginning there was, as far as we know, Henry Harness (see fig. 1), who, if he did not serve as a model, was at least a forerunner of Minard and Belpair. The next connection between the three and Sankey is less apparent, because the things they sought to represent are markedly different. Sankey's drawings are no longer based on maps, but rather on the energy flow of machines, even if the graphic vocabulary—the width of flows as indicator of quantity—is similar to that of the thematic maps. The original purpose of Sankey's diagram was to optimize and give an overview of energy flows. Thus, we can draw a line from it to the personnel organization of the first half of the twentieth century.

In their seminal paper »Process Charts,« presented at the Annual Meeting of the American Society of Mechanical Engineers in 1921, the trailblazers of the new field of ›scientific management‹, Frank and Lilian

[24] Dommann 2008.

Gilbreth, proposed using a set of graphical symbols to depict processes like commercial orders or the act of cocking a rifle. Their aim was to improve the organization of each action in relation to the process as a whole. The process charts led them to develop a graphical language called therblig[s], a palindrome of Gilbreth. The language facilitated the optimization of production and administrative actions. Not only did it help managers improve efficiency (a common task at that time); it also gave them an abstract representation of how certain processes should be organized. The therbligs serve as a visual aid to help others see what is going on, what agents are involved, and what the purpose of the whole set up is. What made it really attractive to managers in the following decades, however, was its underlying claim that there was »the one best way to do work.« No doubt, the process chart was the medium of the move towards making complex processes more efficient and bringing them under control.

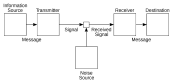
The Gilbreths' work complemented and influenced the management theory of Frederick Taylor, and they had contact with the engineer Henry Gantt, who developed his own diagrams.[25] Their work was quite influential. Thanks to the efforts of the workplace reformist Irene Margarete Witte, their work became a part of discourses on management and administration in Germany,[26] where it was later taken up by Fritz Nordsieck and made into a widely popular tool for optimizing bookkeeping and business under the heading »Schaubilder,« or charts [●].[27] In American management theory, Allan ›Mogy‹ Mogensen[28] and his students Art Spinanger and Ben Graham are seen as pioneers of the use of flow diagrams as a method of management. Together with Lilian Gilbreth, Mogensen developed an early form of business consulting based on the notion that everything can be optimized.



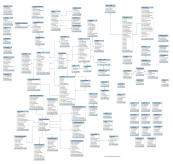
It's only a small step from the discourses on workplace management of the 1930s to the data organization models developed by mathematicians and computer pioneers working at Bell Labs or on the Manhattan

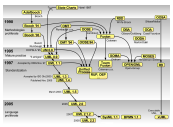
[25] See Hoof 2009; Hoof 2015, p. 110. [26] See Krajewski 2002, ?? [27] Vgl. Nordsieck 1956. [28] See Dommann 2011, pp. 89–94.

Project, where John von Neumann[29] and Claude Shannon also used flow diagrams. Indeed, Shannon's visualization of communication in his signal-flow graphs [●] might be seen as the paradigmatic form of representing different stages of the flow of information.



Then come works like Nassi and Shneidermann's *Structured Flow Charts* [●] from 1973 and David Harel's »Statecharts: A Visual Formalism for Complex Systems.« Finally, the graphic presentation of algorithms was turned into the contemporary system for modelling software processes, the Unified Modeling Language or UML, whose genealogy can, of course, be well presented in a flow diagram [●].





The UML (and other computer languages can be directly linked to the graphical language of scientific management. However, the connection is very abstract, since the so-called »activity diagrams« used in programming languages like the Object Modeling Technique (OMT), Unified Modeling Language (UML), and the Nassi-Shneiderman diagrams all give the graphical representation and formalization of best management processes an algorithmic structure. Their main purpose is to develop and control the flow of information, the objects modeled in software, coding patterns and data structures within an algorithm. A historical reconstruction of the depiction of data flows in charts, maps, and diagrams should enable us to systematically compare the achievements, lacunas, and restraints of each type of flow chart with recent theoretical approaches in diagrammatics (Krämer 2014; Bender and Marrinan 2010; Schneider, Ernst, and Wöpking 2016) and cultural techniques (Schüttpelz 2006; Gethmann and Hauser 2009; Maye 2010; Siegert 2011; Siegert 2015). However, due to the lack of time, I have to stop at this point. To sum up this long genealogy in one brief sentence, one could argue: Designing flow charts has always been based in algorithmic thinking, because every step within a process has to be identified and placed in relation to its neighbors and competitors.

[29] For the transfer of the process charts from Gilbreth to the early software development, as by John von Neumann see Hellige 2003, pp. 62–64.

The flow chart is a technology used for controlling movements, processes and organizations, developing logistics, and pursuing strategic aims. In a flow chart, the mobile elements always move to certain destinations, and thus have to be known in advance. The design of the flow chart mobilizes strategies, certain media practices (paper technologies) and cultural techniques such as abstracting, representing, visualizing, and transmitting, in order to facilitate organizational decisions and reformulate work flows. In the remaining part of my paper, I will widen the scope of this rather economical concept and broaden this historical reconstruction of the flow chart as a medium of reflection by undertaking a critical discussion of the metaphors employed in their development and use.

5 Why Flowing? – Conclusion

Allow me to finish with a very brief and critical discussion of the metaphors used to describe flow diagrams. This will enable me to shed light on the media technologies and cultural techniques at stake (a theoretical concept that is itself derived from basic water logistics and land improvement, as mentioned before). The main question is: what does it mean to describe (data) transmission as a flow?

Flow charts, flow maps, flow diagrams are all based on a—at least at first sight—very common process: Flowing. But what are the implications of this? Where is this concept derived from? The answer sounds simple: Rivers. But what are the implications when such a fundamental, supposedly natural structure like a river is used to describe data transmissions? Is this an apt terminology? After all, genealogy allows room for different branches and bifurcations. A river usually does not bifurcate. It flows steadily in one direction until it reaches its delta with its many forks. What are the epistemological consequences of juxtaposing natural flows[30] with transfer media, communication processes, in short: the complex and

[30] It turns out that there have been no natural rivers since the Early Modern era: All rivers, especially in industrialized nation states, are highly technological and cultural entities.

Figure 1: A flow chart of the history of flow charts showing a flow in one direction (no bifurcations) and a denial of a more complex historiography.

highly technical transmission of data, where such a common thing like water would do nothing but disturb?

Since the early modern era at the latest, the great rivers of Europe, such as the Danube, the Elbe, the Rhine, and the Volga, have become something altogether different from natural phenomena. They are shaped by culture in complex ways and have been subjected to various human uses and adaptations. Human interventions into and regulation of the flow of water constitute a genuine *cultural technique* that controls and ensures the functioning of rivers through things like land improvement, transportation techniques, trade measures, and international political agreements. Large, transnational waterways are studied not only by geographers, but also by historians, because they bring together politics, economics, culture, and social relations. Over the last two decades in particular, historical river research has been enjoying increased attention: while some researchers follow the trail blazed by Lucien Febvre's classic 1935 study on the Rhine like Cioc (2002), Blackbourn (2007), Mauch and Zeller (2008), Etzemüller (2012) or Rau (2010), others take a perspective more informed by popular science like Küster (2007), Rada (2013), Magris (1988). In disciplines like literary studies (e.g. Cepl-Kaufmann and Johanning 2003) or cultural history (e.g. Tümmers 1999), biographies of individual rivers have long been a literally mainstream topic.[31]

The notion of rivers/flows/streams discussed here allows us to trace the pathways from the local to the global (e.g. from Basel to Rotterdam and further on to Copenhagen or via Grenada here to Venice), as I have discussed in more detail in a historical analysis of world traffic in the nineteenth century (see Krajewski 2014). In that study, I took up Bruno Latour's claim from his book *We Have Never Been Modern* that networks are the key to understanding how we get from local points to global destinations. Furthermore, the concept of flows makes it easier to bridge the gap between the digital and the analog. The use of flows and their graphical representation to analyze the relationship between structure

[31] See, as the most recent approach the exhibition *Der Rhein* at the Bundeskunsthalle in Bonn, Plessen 2016.

and infrastructure provides evidence for the various ways in which the digital and the analog, far from being a rigid dichotomy, actually have a lot of similarities that, indeed, flow between them.

References

Bender, John B. and Michael Marrinan (2010). *The Culture of Diagram*. Stanford, Calif.: Stanford University Press.

Blackbourn, David (2007). *Die Eroberung der Natur. Eine Geschichte der deutschen Landschaft*. München: Deutsche Verlags-Anstalt.

Block, Maurice (1878). *Traité théorique et pratique de statistique*. Paris: Guillaumin et Cie.

Cepl-Kaufmann, Gertrude and Antje Johanning (2003). *Mythos Rhein. Zur Kulturgeschichte eines Stromes*. Darmstadt: Wissenschaftliche Buchgesellschaft.

Cioc, Mark (2002). *The Rhine. An eco-biography, 1815-2000*. Weyerhaeuser environmental book. Seattle: University of Washington Press.

Dommann, Monika (2008). "Papierstau und Informationsfluss: Die Normierung der Bibliothekskopie." In: *Historische Anthropologie* 16.1, pp. 31–54.

— (2011). "Handling, Flowcharts, Logistik. Zur Wissensgeschichte und Materialkultur von Warenflüssen." In: *Nach Feierabend. Zürcher Jahrbuch für Wissensgeschichte* 7, pp. 75–103.

Etzemüller, Thomas (2012). "Romantischer Rhein – Eiserner Rhein. Ein Fluß als imaginary landscape der Moderne." In: *Historische Zeitschrift* 295.2 (Oktober), pp. 390–424.

Felsch, Philipp (2011). *Wie August Petermann den Nordpol erfand*. München: Luchterhand Literaturverlag.

Foucault, Michel (1998). "Afterword to The Temptation of Saint Anthony." In: *Aesthetics, Method and Epistemology. The Essential Works of Michel Foucault 1954–1984*. Ed. by James D. Faubion. Tr. Robert Hurley et al. Vol. 2. Harmondsworth, Middlesex: Allen Lane, Penguin, pp. 103–122.

Gethmann, Daniel and Susanne Hauser, eds. (2009). *Kulturtechnik Entwerfen. Praktiken, Konzepte und Medien in Architektur und Design Science*. Bielefeld: transcript Verlag.

Giehrl, Hermann (1911). *Der Feldherr Napoléon als Organisator. Betrachtungen über seine Verkehrs- und Nachrichtenmittel, seine Arbeits- und Befehlsweise*. Berlin: Ernst Siegfried Mittler und Sohn.

Hellige, Hans Dieter (2003). "Zur Genese des informatischen Programmbegriffs: Begriffsbildung, metaphorische Prozesse, Leitbilder und professionelle Kulturen." In: *Algorithmik - Kunst - Semiotik. Hommage für Frieder Nake*. Ed. by Karl-Heinz Rödiger. Heidelberg: Synchron, pp. 42–73.

Hilgers, Philipp von (2000). "Eine Anleitung zur Anleitung. Das taktische Kriegsspiel 1812–1824." In: *Board Game Studies* 3, pp. 60–77.

— (2012). *War games. A history of war on paper*. Ed. by Ross Benjamin. Cambridge, Mass.: MIT Press.

Hoof, Florian (2009). "Film – Labor – Flow-Charting. Mediale Kristallisationspunkte moderner Managementtheorie." In: *Medien in Raum und Zeit. Maßverhältnisse des Medialen*. Ed. by Ingo Köster and Kai Schubert. Vol. 34. Medienumbrüche. Bielefeld: transcript Verlag, pp. 239–266.

— (2015). *Engel der Effizienz. Eine Mediengeschichte der Unternehmensberatung*. Konstanz: Konstanz University Press.

Knight, E. Vernon and Meinrad Wulpi (1931). *Furniere und Sperrholz. Furniere und Sperrholz in Möbeln und Panelen vom Altertum bis zur Gegenwart und ihre Holzarten*. Ed. by L. M. Cohn-Wegner. Berlin: M. Krayn.

Kraak, M. J. (2014). *Mapping time. Illustrated by Minard's map of Napoleon's Russian Campaign of 1812*. Redlands, California: Esri Press.

Krämer, Sybille (2014). "Schrift, Diagramm, Programm. Kulturtechniken der Inskription." In: *Programm(e). Medienwissenschaftliche Symposien der DFG*. Ed. by Dieter Mersch and Joachim Paech. Berlin: Akademie Verlag, pp. 159–174.

Krajewski, Markus (2002). *Zettelwirtschaft. Die Geburt der Kartei aus dem Geiste der Bibliothek*. Vol. 4. copyrights. Berlin: Kulturverlag Kadmos.

— (2007). "In Formation. Aufstieg und Fall der Tabelle als Paradigma der Datenverarbeitung." In: *Daten*. Ed. by David Gugerli et al. Vol. 3. Nach Feierabend. Zürcher Jahrbuch für Wissensgeschichte. Zürich, Berlin: diaphanes Verlag, pp. 37–55.

— (2014). *World Projects. Global Information Before World War I*. Electronic Mediations. Minneapolis: The University of Minnesota Press.

Küster, Hansjörg (2007). *Die Elbe. Landschaft und Geschichte*. München: C.H. Beck.

Magris, Claudio (1988). *Donau. Biographie eines Flusses*. München: Carl Hanser Verlag.

Marey, Étienne Jules (1885). *La méthode graphique dans les sciences expérimentales et principalement en physiologie et en médecine*. 2. tirage, augm. d'un supplément sur le développement de la méthode graphique par la photographie Auflage. Paris: Masson.

Mauch, Christof and Thomas Zeller, eds. (2008). *Rivers in history. Perspectives on waterways in Europe and North America*. Pittsburgh, PA: University of Pittsburgh Press.

Maye, Harun (2010). "Was ist eine Kulturtechnik?" In: *Zeitschrift für Medien- und Kulturforschung* 1.1, pp. 121–135.

Nordsieck, Fritz (1956). *Die schaubildliche Erfassung und Untersuchung der Betriebsorganisation*. 5. Auflage. Vol. XV. Die Bücher: Organisation. Stuttgart: C.E. Poeschel Verlag.

Plessen, Marie-Louise von, ed. (2016). *Der Rhein. Eine europäische Flussbiografie*. München: Prestel Verlag.

Rada, Uwe (2013). *Die Elbe. Europas Geschichte im Fluss*. München: Siedler Verlag.

Rau, Susanne (2010). "Fließende Räume oder: Wie läßt sich die Geschichte des Flusses schreiben?" In: *Historische Zeitschrift* 291, pp. 103–116.

Robinson, Arthur H. (1955). "The 1837 Maps of Henry Drury Harness." In: *The Geographical Journal* 12, pp. 440–445.

— (1967). "The Thematic Maps of Charles Joseph Minard." In: *Imago Mundi* 21, pp. 95–108.

Robinson, Arthur Howard (1982). *Early thematic mapping in the history of cartography*. Chicago: University of Chicago Press.

Schneider, Birgit, Christoph Ernst, and Jan Wöpking, eds. (2016). *Diagrammatik-Reader. Grundlegende Texte aus Theorie und Geschichte*. Berlin: Verlag Walter de Gruyter.

Schöning, Antonia von (2018). *Die Administration der Dinge. Technik und Imagination im Paris des 19. Jahrhunderts*. Zürich, Berlin: diaphanes Verlag.

Schüttpelz, Erhard (2006). "Die medienanthropologische Kehre der Kulturtechniken." In: *Archiv für Mediengeschichte* 6, pp. 87–110.

Shneiderman, Ben (May 2003). *A short history of structered flowcharts (Nassi-Shneiderman Diagrams)*. www.cs.umd.edu. URL: http://www.cs.umd.edu/hcil/members/bshneiderman/nsd/.

Siegert, Bernhard (2003). "Translatio Imperii. Der cursus publicus im römischen Kaiserreich." In: *Archiv für Mediengeschichte* 3, pp. 41–60.

— (2011). "Kulturtechnik." In: *Einführung in die Kulturwissenschaft*. Ed. by Harun Maye and Leander Scholz. UTB. München: Wilhelm Fink Verlag, pp. 95–118.

— (2015). *Cultural Techniques. Grids, Filters, Doors, and other Articulations of the Real*. Ed. by Geoffrey Winthrop-Young. New York: Fordham University Press.

Tümmers, Horst Johannes (1999). *Der Rhein. Ein europäischer Fluß und seine Geschichte*. 2., überarb. und aktualisierte Auflage. München: C.H. Beck.

Tufte, Edward R. (2001). *The visual display of quantitative information*. Cheshire, Conn.: Graphics Press.

Laak, Dirk van (1999). "Der Begriff 'Infrastruktur' und was er vor seiner Erfindung besagte." In: *Archiv für Begriffsgeschichte* 41, pp. 280–299.

Zamoyski, Adam (2012). *1812: Napoleons Feldzug in Russland*. München: C.H. Beck.