Kära läsare,

Denna text är ett väldigt tidigt och första utkast på ett stycke om varför och hur min forskning är tvärvetenskaplig. Jag skriver min avhandling på avdelningen för Industriell Miljöteknik som förvisso är en tvärvetenskaplig miljö, men som inte har det internaliserat i blodet på samma sätt som ni som deltar på det här seminariet. Med reservation för att ni möjligen läser den här typen av forskningsmotiveringar till morgonkaffet, är det från min horisont viktigt att kunna argumentera varför såväl som hur ens forskning är tvärvetenskaplig. Att den bör vara det är nämligen inte alls självklart där jag nu befinner mig (men ändå vanligt hos oss i relation till andra avdelningar på teknisk fakultet). Texten utgör vidare, vill jag mena, de teoretiska utgångspunkterna för kappan till min licentiatsavhandling.

Jag är intresserad av alla sorters kommentarer jag kan få, men kanske framför allt sådana som sätter den här texten i relation till det övriga innehållet i en licentiatskappa. Hur beskriver man tvärvetenskap i ett sådant sammanhang? Hur extensiv bör man bli i beskrivningen av teorier, metodval, informationsbearbetning etc., när dessa i ett tvärvetenskapligt sammanhang blir flerfaldigt många? Håller nivån som den nu ser ut över huvud taget, hur kan den förbättras?

//Björn

PS. För den som inte är insatt i vad jag vetenskapligt ägnar mig åt, börjar texten med en kortare redogörelse för mitt doktorandprojekt. Den som bevistade mitt seminarium i höstas kommer att känna igen denna del som skåpmat. DS.

1. Introduktion till mitt avhandlingsprojekt

Begreppet urban mining innefattar brett sett en rad verksamheter som på olika sätt försöker ta till vara på ansamlingar av material i och omkring vår byggda miljö. Avsaknaden av tydlig konsensus kring hur termen ska användas är emellertid uppenbar (SUM, 2012), vilket också har kritiserats (Johansson et al, 2012). En grundläggande ambition med urban mining är att genom att återföra exempelvis metaller och plast in i produktcykler eller återanvända och/eller återvinna dem i högre utsträckning, kan primärproduktion ersättas och på så vis minskar den samlade materialanvändningens miljöpåverkan. Istället för att på ett energiintensivt sätt bryta malm i berg, kan färdigprocessade metaller ”brytas” i våra samhällen. Det gryende intresset för frågan bör förstås inom ramen för att vi exempelvis redan kan ha passerat planetens kopparkrön och de stigande metallpriser som tillkommit som en följd av detta (ref.). Lägg därtill den samhälleliga resursineffektivitet som växande sopberg runtom i världen är ett bevis på, och frågan blir akut också ur ett strikt miljöperspektiv.

I vårt forskningsprojekt intresserar vi oss för bulkmetaller som aluminium, järn och koppar, och i enlighet med FN:s klimatpanel (2010) fokuserar vi på infrastruktur eftersom dess metallinnehåll är högt. Vi rör oss inom Sveriges gränser och är särskilt intresserade av de delar av infrastruktursystem som inte används men som ligger kvar under marken. Dessa urkopplade rör och ledningar benämns ofta som ”urkar”, eftersom det är så de betecknas på de flesta systemägares gamla papperskartor.[1]

I Norrköping, som utgör huvudsakligt lokus för våra studier, har vi i en inledande kvantitativ studie funnit att en femtedel av infrastrukturen är urkopplad sett till vikt, vilket motsvarar omkring 5000 ton järn, aluminium och koppar. Baserat på dagens svenska skrotpris skulle all koppar ensamt vara värt omkring 28 miljoner svenska kronor om den återvanns (Wallsten et al, 2012). Denna samlade malmkropp av olika sorters urkar under Norrköping är mitt avhandlingsprojekts tekniska artefakt och jag är specifikt intresserad av att kritiskt undersöka de sociala sammanhang som möjliggjort dess tillblivelse. Kvantitativa studier av miljövinsterna med att systematiskt plocka upp och återvinna urkar görs för närvarande av min doktorandkollega Per Frändegård.

Vår andra studie, ”Journey to the Center of an Urban Mine” (Wallsten et al, 2012, inskickad till Journal of Urban Technology), är en praktikernära intervjustudie som förklarar hur urkar kopplas ur och osynliggörs i samband med underhåll och om-/nybyggnation av infrastruktur. I Norrköping förvaltas infrastrukturen enligt den så kallade beställar-utförar-modellen, där ägarna av de tekniska systemen (exempelvis kommunen, E.On och Tele2), beställer in/upphandlar underhåll och om/nybyggnations-tjänster av utförare/entreprenörsfirmor (exempelvis Vattenfall och Skanska). I studien intervjuade vi beställare och utförare för fem infrastruktursystem i Norrköping (stadsgas, fjärrvärme, el,

[1] Urk är alltså en förkortning för urkopplad, och den använd(e)s av folk i branschen för att särskilja på de delar av systemet som är/var i drift och inte. För vårt syfte fungerar den utmärkt eftersom den till skillnad från ”rester”, ”skrot” eller liknande förhåller sig neutralt till begreppet avfall.

vatten- och avlopp samt gatubelysning), och kom bland annat fram till att den tids- och kostnadspress som uppkommer till följd av ökad konkurrens gör att det aldrig grävs en extra meter för att plocka upp och återvinna urkar ur marken.

Det är dessa två artiklar som utgör artiklarna i min licentiatavhandling, och det är dessas tvärvetenskaplighet som jag är ute efter att beskriva och motivera.

Inter-disciplinarity

Inter-disciplinarity is a research co-operation that strive towards the integration of theories, methods and/or results on equal terms between two (or more) scientific fields. Berner (2011) delineates between three different aims of inter-disciplinarity; the intellectual integration aim, the aim of generating innovation and the solving societal problems aim. Generating innovation is a common goal in projects where two scientific fields are so closely related that they can easily be merged, such as the case in medical engineering when developing new medical apparatus for diagnosis. While there is a possibility to meta-study a test case with a newly innovated urban mining-technology in the next year or so for my doctoral dissertation, creating innovation has not been the ambition with the first two articles. Left instead with the two inter-disciplinary strands of intellectual integration and solving societal problems, there is reason to bring both of them up to discussion. I shall return to both of these aims of inter-disciplinarity in later stages of this section.

First however, I found it useful to assemble a bibliometric analysis of the references used in the two articles included in the licentiate thesis. Given that such an analysis is capable of saying something about the cross-disciplinary nature of the performed work, I have categorized the references into two umbrella categories; Science and Technology Studies (STS) and Industrial Ecology (IE), with one sub-category for each of these: Infrastructure Studies (IS) and Material Flow Analysis (MFA).

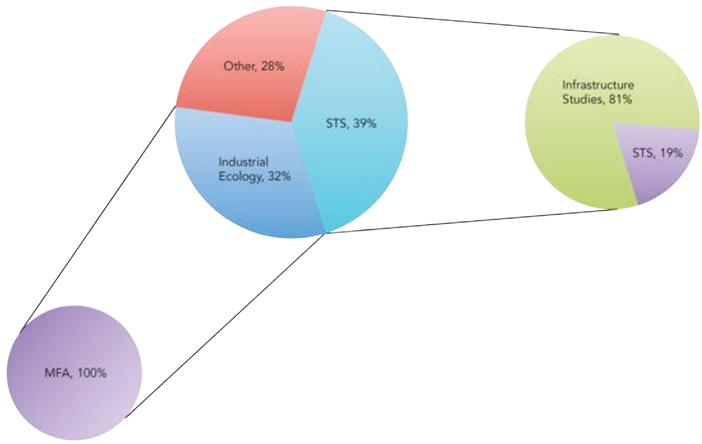

Figure 4. The references of the appended articles quantified with regards to sub-categories of Industrial Ecology and STS. Material flow analysis (MFA) and Infrastructure Studies, are shown as the two key research areas in this licentiate thesis. From this insight, a fruitful discussion with a sound basis in the actual articles can commence.

While it would indeed be an intellectual exercise worthy of the name to compare the umbrella terms, I am not yet ready to do indulge in such an endeavour. It would furthermore be outside the scope of a licentiate thesis. Instead and following from the ratios found in figure 4, the focus will be on Material Flow Analysis and Infrastructure Studies, two sub-categories which are arguably large enough in themselves. While the notion of equal terms is an important feature of inter-disciplinarity, the starting point is not a fifty-fifty match but the integrated approach between the disciplines at hand. The important question is: how were material flow analysis and infrastructure studies used and integrated in the articles?

I will therefore describe these two fields in the following and then use the notion of ”black boxes” as an entity for a comparative assessment. I believe the epistemological differences between Material Flow Analysis and Infrastructure Studies are fruitfully articulated in their view on black boxes, and my argument from there and onwards will not favour one over the other, but rather argue that their differences can be overcome and their respective strengths combined in fruitful ways. Actually performing this merging of the separate field has been an ambition with my project from the get-go.

No Flow Left Behind: The Lynchpins of Material Flow Analysis

Material flow analysis is an analysis of the throughput of organic or non-organic matter in the anthropogenic[2] processes of industrial society. Many MFA:s apply a systems or chain perspective and are thus based on accounts in physical units which quantify the inputs and outputs of such industrial processes. Like many engineering and environmental analyses, MFA:s are based on the methodological principle of mass balancing, which has the exact conservation law at its core; i.e. matter cannot disappear or be created spontaneously. By trying to account for all materials entering and leaving a system, the mass balancing principle enables an MFA to detect and identify material flows that would otherwise have gone unnoted or would have been difficult to measure without this technique. Through the use of flow charts, complicated process chains are simplified and divided into arrows and boxes, representing the flows and stocks of the material chosen for the study.

Figure 1. The exact conservation law gives at hand that any perfect determination of two out of the three components in the figure determines the other. If the blackbox in the figure represents the urban infrastructure of a city, the weight of the urban infrastructure can be estimated as soon as you've come up with reasonable estimates on the sum of the accumulated input and output flows of cables and pipes over time. How to acquire the underlying statistical data for such estimations, is the core endeavour of material flow analysis.

The spatial scale and the amount of stocks may differ, but typically the flowcharts include the extraction, transformation, manufacturing, consumption, recycling and disposal of the chosen material. The subjects of the accounting can be either chemically defined substances, natural or technical compounds or 'bulk' materials. (e.g. Bringezu and Moriguchi in Ayres and Ayres, 2002, Graedel and Allenby, 2010). A central aspect of an MFA is indeed this coupling of the very small; "in an elemental analysis, the emphasis is on the atom" (Graedel & Allenby 2002, p.245), and the very large aggregated flow chosen as the scale of inquiry. An MFA can for example account the global flows of nickel (Reck et al, 2008), the flows of steel and copper in Japan (Daigo et al, 2007) a set of different metal flows in a particular city such as Stockholm (Bergbäck et al, 2001), the flows of steel through the construction sector at large (Moynihan & Alwood, 2011).

Top-Down or Bottom-Up? MFA:s and Missing Masses

Data collection for an MFA can be done in roughly two methodological ways: using a top-down or a bottom-up approach. Possible combinations of the two are thinkable and can be rewarding for triangulation purposes to check the accuracy of ones results (cf. Zeltner, 1999; Wang, 2009). The top-down approach is the one I've described up until this point, where mass balances between the flow of new resources into use and the outflow of end-of-life

[2] Material Flow Analysis is typically based on a differentiation between human and natural resource cycles and so they separate between anthropogenic and biogeochemical stocks and flows. There are examples where both of these cycles are taken analysed within the same study (e.g. Rauch and Graedel, 2007), but the entities remain differentiated and thus fully represent a dualistic view of the world.

resources are compared. All resources that are not recycled are in such accounts assumed to amount in waste repositories which are estimated by integrating the mass balance between the rates of discard and recycling. Depending on the specific interest of a study and the spatial scale chosen to assess this, input and output information for longer periods of time can be hard to find. This is an often encountered problem of top-down MFA:s, which however can be resolved by using the bottom-up approach instead. A bottom-up approach furthermore enables the spatial distribution of stocks, which is interesting when you for example want to know where within a certain city a certain material is located.

The bottom-up approach begins with an inventory of different units that contain the material in question. It can for example be buildings, infrastructure and electronic gadgets. The material contents of the unit is found using engineering data and then multiplied with the number of units estimated to be in use in a certain geographic area. Census data is often the basis of such estimations (Graedel and Allenby, 2002; pp 245). In a study done on copper in Sidney, Australia, the number of buildings, cars, electric grids etc. where determined by using a GIS-informed census information, and then multiplied with the typical copper concentrations to arrive at estimates of the total copper stock and its location (van Beers and Graedel, 2007). The knowledge retrieved by such a spatial bottom-up MFA can be used for two purposes; either to inform the collection and re-use of the material at hand in the case of fore example copper, or to spatially anticipate environmental problems of a certain material if it is hazardous or toxic (Graedel and Allenby, 2002; pp 298). A weakness that has been found in practice using the bottom-up approach is that it yields less useful data on wastes, because of the lacking availability of trustful information on the content and extent of such repositories; i.e. landfills. (Graedel and Allenby, 2002; pp 245)[3].

The Policy Relevance of MFA

Summing up, the main interest of MFA studies lies in the overall characterization of the metabolic performance of the entity at hand. This is estimated in order to understand the volume and structure of the throughput and to assess the status and trend with regard to sustainability. (Bringezu and Moriguchi in Ayres and Ayres, 2002). MFA:s have in this sense supported policy makers in formulating goals and targets in relation to the resource debate (Bringezu, 2000). When it comes to minerals, the raw material strategies that the EU at large and several European countries have developed or are developing lately (Finland, Germany, Norway, Sweden, insert refs), are also grounded in MFA:s.

Increased recycling is mentioned as a societal goal in all of these documents, and this is also embedded within the EU waste hierarchy (EU, 2008). Chertow (2000) points out that MFA:s most often operate at the regional/global scale, and so it is no surprise that MFA so far has been most influential at the level of policy that correlate to the use of aggregated (i.e

[3] Not all bottom-up MFA:s are spatial. When writing this, the number of spatially informed MFA:s are easily counted.

national) data and scopes. If however, and as Graedel and Allenby (2002 p. 301-302) point out, the desired outcome of MFA studies is to further inform detailed recycling policy and improve the conditions also for practical implementation of recycling activities, then the accurate determination of both the size and spatial distribution of the stocks assessed is necessary.

Given this, the deficiencies of the two principal methods must be better addressed. The top-down approach can estimate the stocked amounts of waste but not where in society these are located. The bottom-up approach can estimate where in society the in-use material stocks are located, but not where or how big the wastes are. Due to this loophole which persist also when the two MFA methods are combined, *a spatially informed MFA which specifically focus on materials which are not in use* has not been done.

The reason for why such a study is interesting is that resources which are not in use are potentially available in their current state and location, there is no need to wait for their discontinuation. This was the main driver for us, when doing our first article, which I believe is the first of its kind in this respect.

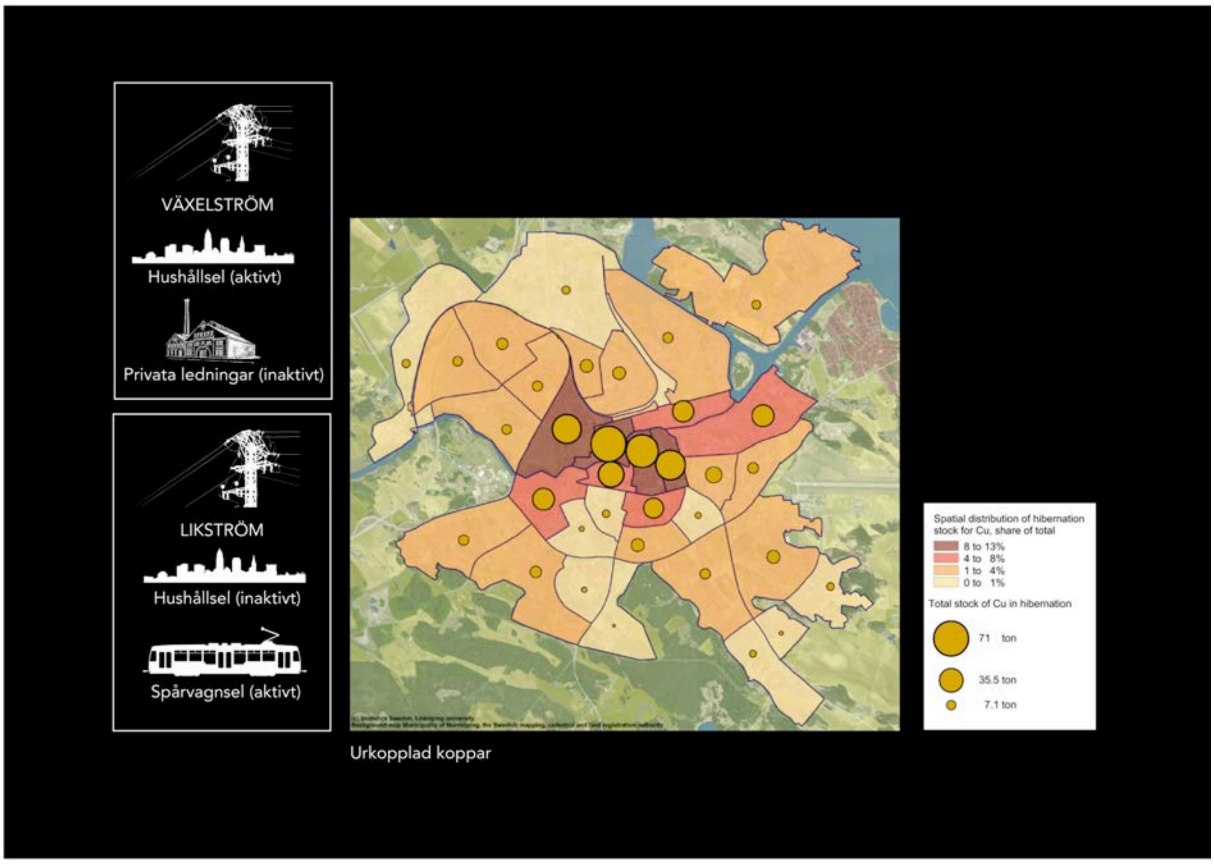

Figure 2. The amounts of disconnected copper and its dispersal underneath the streets of Norrköping. The systems incluced in the study are found to the left, and there is approximately 560 tons of copper worth 28 million SEK.

Infrastructure studies: an overview

Since the mid 1980's, there has been a more or less consistent flow of research devoted to infrastructure systems. One way of capturing this diverse field, is to follow the axis of edited volumes which have been published and continously reference one another on a more or less consistent frequency basis: "The Development of Large Technical Systems" (Mayntz & Hughes, eds. 1988), "Social Responses to Large Technical Systems: Control of Anticipation" (LaPorte, ed. 1991), "Changing Large Technical Systems" (Summerton, ed. 1994), "The Governance of Large Technical Systems" (Coutard, ed. 1999), "Urban Infrastructure in Transition: Networks, Buildings, Plans" (Guy, Marvin, Moss, eds. 2001) and "Shaping Urban Infrastructures: Intermediaries and the Governance of Socio-technical Networks" (Guy, Marvin, Medd, Moss, eds. 2012). Before the work of Thomas P. Hughes came along, the history of technology had mostly been interested in nuts and bolts with little or no interest in theory. Empirically driven case studies dominated the field, and few if any conclusions were written making generalist claims outside the scope of the studied cases (Berner, 2011). With the game changing "Networks of Power", Thomas P Hughes convincingly argued that the understanding of technological development is not possible without taking into regard the work of the so called 'system builders', and their context of politics, organisations, regulations etc. These must be viewed as an integrated whole. The system builder, always a white male engineer, was furthermore understood as heterogenous; i.e. he had to work with not only technology as such, "but on and through people, texts, devices, city councils, architectures, economics and all the rest" (Law, 1991). While this was not entirely new, Hughes' formulations on the *sociotechnological* order were. By this, Hughes meant that what appears to be purely technical is partly social and vice versa. Nothing can be purely technical, nor purely social and thus, these entities has to be understood as a integrated whole. Instead of studying them one at a time, the seamless web that they form, is best studied by following the actors central to the sequence of events one is interested in (Law, 1991). While Hughes does not explicitly formulate any such method, the person behind the idiom "follow the actors" is instead Bruno Latour, an absolute central person in science and technology studies (STS) and portal figure of actor-network theory (insert refs). The reason for bringing Bruno up is not that I'm about to endulge in a historiography of STS and go into explicit detail on how its central concepts, if indeed there are any, relate to the history of technology. The quite simple emphasis that I would like to make, which is the one useful for my purposes, is instead the one of their common traits.

As Sismondo notes, "Latour's networks and Thomas Hughes's technological systems bundle many different resources together" (2010, p.95). Nothing in their respective worldview can be reduced to only one dimension, the better picture is given by accounts that incorporate many different inputs. Any "technologist" must make use of scientific and technological knowledge, but material, financial, social and rhetorical resources are important as well. While I'm well aware that all of the involved researchers in the old but classic volume "The Social Construction of Technological Systems" (Bijker, Hughes, Pinch, eds. 1989) have developed along different trajectories in the last thirty years, I hastly argue that they would agree on that they share something of importance. In this, history of technology, ANT, infrastructure studies and all the rest fit under the same, albeit it wide, umbrella, which first and foremost represent a theoretical perspective; i.e. a way of looking at the world.

I'm making this claim since all the urban infrastructure studies used and referenced in my work are not explicitly using the LTS-perspective. Especially given that the managerial prerequisites for urban infrastructure have changed significantly since the days when LTS was developed as a theory, one needs different approaches to be able to say something about how infrastructure works in the world today. Many of these are informed by science and technology studies, and thus; the core of this theoretical perspective needed to be outlined here.

Key aspects and critiques

Following the lines of Berners argument (2011), Thomas Hughes theoretical ambitions was a turn away from the narrow focus of the systems' nuts'n'bolts often found in history of technology accounts. Hughes shifted the focus towards how large technical systems in general develop according to an inherent expansionist logic as a way to supply new customers with flows of system services. Hughes found LTS to develop according to different phases (1983, 1987), which were later elaborated by Kaijser (1994) to include: establishment, expansion and stagnation. Criticism has been raised against the flavour of technical determinism found in Hughes very development oriented descriptions, but even if this was formulated as early as in 1992 (Bijker & Law), the focus has remained one the extend-and-supply logic of systems flows also in studies of urban infrastructures that use other perspectives than LTS (Moss, 2008, p.445). There has been continued critique against how little we know about system decline in general (Gandy, 2005), and we are seldom if never served explicit accounts on how technological systems are discontinued or un-made (Weber, 2012). Perhaps tellingly, the most often referenced article on system decline describes how "Stagnation is, though, not an ending, declining phase; systems can end up in a stable mode or a revolution can start a positive trend again" (Gökalp, 1992 quoted in Magnusson, 2013). Infrastructures never seem to die in urban infrastructure research; the description of their decay is at least never mentioned. Although further assessment has to made for such an argument to hold, I'm thinking that this is a case of having lost the critical distance towards the object studied. This would then be in line of the critique that has been formulated towards LTS in regards to its focus on heroic, often male, actors engaged in system development, while neglecting other actors that might be of importance (Summerton 1998).

Even though they have been acknowledged as well as adressed to a certain extent there is reason to further investigate these critiques, especially with MFA-informed eyes. Interesting questions to pose would from such a perspective be: What happens after stagnation? What if we returned the focus away from the extend-and-supply-logic of system growth and towards the nuts'n'bolts instead? What would a maintenance and repair focus reveal about urban infrastructure waste (Graham & Thrift, 2007)?

I believe that MFA motivates these questions to be asked. I shall therefor turn to how I have co-used the two research perspectives outlined above in a more detailed way, and the inter-disciplinary gains that this has enabled. First however, I would like to elaborate a bit on the main epistemological differences between MFA and infrastructure studies. This is done to explain my ambitions of theoretical integration as well as how this can lead us closer to the solving of societal problems. As mentioned, these can both be drivers for why to engage in inter-disciplinary research in the first place.

Infrastructure Studies, MFA and the Black Boxes

A black box is in engineering terms a predictable device that is solely interesting in terms of its input-output characteristics. The inner workings of a black box need not to be known for it to be used (Sismondo, 2010 p.120). In a social scientists words, it is "a finalized entity with fixed boundaries that cut it off cleanly from other objects and social processes on its outside and endow it with a taken-forgranted (but unexamined) 'inside' that is assumed to account for its shape and stability" (Slater, XXX).

While there are different ways to perform a MFA, black boxes facilitate their quantitative assessment of material inputs and outputs. In MFA, black boxes are essential to formulate postulates of how the material flows of the world works (Bringezu and Moriguchi in Ayres and Ayres, 2002). Dependent on the chosen level of analysis and what compound's flow to assess, MFA can black box buildings, factories and vehicles (Graedel & Allenby 2002, p.245, assessing metals), mines, smelters, scrapyards and landfills (Reck et al, 2008 assessing nickel), countries and continents (Johnson & Graedel, 2008), the lithosphere (Johansson et al, 2012 assessing metals in general), or the Earth's orbit, the Moon and the Universe (Rauch & Graedel, 2007 assessing copper).

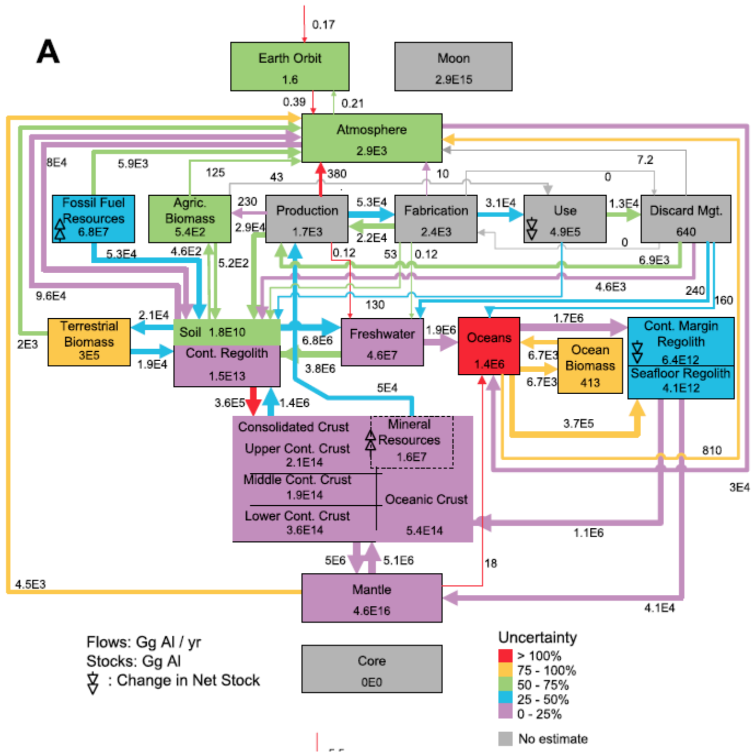

Figure 3. The Global flows of aluminium, in gigagram (Rauch & Graedel, 2007).

Were it not for black boxes, an MFA would have a much haFirder time to pinpoint how the material flows flow through our societies in a quantitative way. The huge amounts of data must be broken down into manageable sizes in some way or other; they are needed as necessary accounting devices to be able to assess the large flows of particular entities that MFA is set up to do. The processes inside any of the black boxes in an MFA are understood in accountant terms; i.e. which are the interesting material flows and stocks within this set of processes? If a black box as an example signifies cities, this includes that city's infrastructure, its buildings, its amount of technological gadgets etc. lumped together. While it is known *that* the flows exist and transfer through the black box in an MFA, it is not at all interesting *how* they do so from the strict MFA perspective. The "how something is/was assembled"-question, is however an absolute key to STS-informed research. As Galis notes (2006 p.48): "One of the most significant aspects of adapting a good social science-method as inspired by science and technology studies (STS) is that technology is not to be treated as an end-product, as a black box." The STS-informed analysis is thus instead directed towards opening black boxes and scrutinize their content and the way that interactions, relations and processes of co-production has lead to their wrapping.

This black box-discrepancy is the crucial nexus for the inter-disciplinarity of this licentiate thesis. It is here that the inter-disciplinar gains are revealed, and I emphasis that they were not used one after another in the research process, but intertwined in oneanother in a set of different ways[4].

I shall in the following argue for how and for what purposes I have merged the MFA and IS research perspectives. To the extent that it has to do with the two aims of inter-disciplinarity mentioned earlier: intellectual integration and solving societal problems (Berner, 2011), I shall mention this accordingly.

[4] Not all of the mentioned black boxes from the body of MFA-literature are examples of technological black boxes. The ones that are would to my understanding provide good topics for scrutiny for STS-studies at large and infrastructure studies in particular. Opening a MFA-black box with the purpose to inform it with a socio-technical understanding enriches MFA while the MFA in turn, provide infrastructure studies with a re-newed empirical focus; the materiality of the infrastructure's nuts'n'bolts. Second; it is indeed infrastructure that move all of Earth's material flows around.

Informing MFA with history of technology

As was pointed out in the previous MFA-section, no-one had ever conducted a spatial assessment of materials which are not in-use. In relation to this, Brunner goes so far as to say that ”amazingly little is known about” *where* (consumer and) capital goods end up after having been taken out of use, generally due to the lack of data on such information (2004). Knowing the answer to this to a larger extent, would be a first step towards solving a societal waste problem.

In our study, the empiric limitation of being interested in the city of Norrköping’s infrastructure and not in the buildings[5], enabled us to use empiric as well as contextual insights from the field of history of technology to assess the out-of-use stock of urban infrastructure in the city. As previously outlined, the top-down approach of MFA:s is not compliable with spatial questions at close range, and so we used the bottom-up approach to assess where in Norrköping the urban infrastructure had gained surplus weight, i.e. waste, over time. Even though bottom up-MFA:s are not characterised by flowcharts, arrows and boxes, they use black boxes which are assembled through the gaze of an accountant. An MFA accountant is interested in the material content of a certain entity and how many examples of that entity can be found in the geographical area of interest for the study. In altering the gaze to that of an historian of technology, we enabled contextual knowledge of the infrastructural history of Norrköping to play an active part in the study and put new sets of relevant data sources in play through altered methodological means. Furthermore, it allowed us to semi-analytically assess the generalizability of the results.

Archive Souls: An Historic Sensibility

Historians make sense of the world by studying historic source material, which need not be but are often found in different kinds of archives. The study of source material enables the historian to both describe and analysize a sequence of events that has occured. If you want to say something truly derogatory to a historian, you say that s/hes written a descriptive account of a certain sequence of events, i.e. without providing any explanations of why it occurred. The mere facts are of course necessary to provide an accurate account, but it is the explanations that the scientific field of history aim at (Ekman et al, 1993 p.25). In the first article of this licentiate thesis, we’ve been influenced by historical methods to inform the performed bottom-up MFA. We provide no thorough explanation for why and how the accounted metals were taken out-of-use[6], we’ve been interested in their accumulated weight and where they are located under Norrköpings streets as an outcome of a historic process. In this sense, the questions we ask to the source material is different than the one an historian would ask, and in the extension; the source materials were used for a different purpose. While the article thus is less than descriptive from a historians point of view, the

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[5] These are the only two interesting entities of any city in the eyes of an MFA researcher (see next chapter).

[6] This is the focus in the second article, which unfortunately is not explicitly historic either.

quantitative outcome has nevertheless been thoroughly informed by historic knowledge about the infrastructural city of Norrköping.

It is to this extent that the black box was opened in the article. Instead of the eyes of the accountant used in regular bottom-up MFA:s to make an inventory of all products containing the metal one is searching for in the current city (e.g. Drakonakis et al. 2007), we used the eyes of the infrastructure historian to find relevant stocks for our assessment. The delimitation stemming from that we only scrutinize the black box of urban infrastructure and thus get a limited picture of Norrköping's total metal stock, is countered by the possibility to include a neatly defined body of literature on the (infrastructural) history of Norrköping (Kaijser, 1984; Horgby, 1998; Hallberg, 2003), together with a set of infrastructure glasses to go to the city archives.

Starting in the self-explanatory assumption that the infrastructural setup of Norrköping is a result of the citys particular history, I went to the city archives for a reason. Following from an surveying interview with one of the responsible civil servants in the technical office at Norrköping Municipality (Gunnar, 2010), I had a tentative list of all infrastructure systems in the ground. Also knowing that the existing systems in Norrköping were once built by the municipality, the city archive were a good place to start since they archive the outdated documents from all the municipal bodies[7]. I went through all the interesting maps and other documents I could find where either spatial or quantitative material on disconnected parts and wholes of infrastructure systems could be assumed. While I could not find any maps of entire systems in this way, I was able to find maps of the "gas area", i.e. how spread out the town gas grid had been (insert archive ref.) and at what time it was the longest (Norrköping, 1938-1985) together with technical information on pipe dimensions from an engineering account of the history of Norrköpings gasworks (Ekdahl, 1951 p.). From these sources, triangulation could be performed to estimate where the iron masses of the derelict town gas grid are located. While this is not the place to extensively explain all the ways that data was collected by historically informed methodological means, I shall give just one more example.

Knowing from Hallström (2003 p.324), that Norrköping is "somewhat uncommon in the sense that there were many industries with their own water supply", and that many of those industries are located in the city center and were closed down during the 20th century (Horgby, 1989), I contaced the municipality assuming that those very industries perhaps also had their own private power systems. It turned out that the municipality had just started a project digitalizing all existing private cables laid in municipal ground (Sköld, 2011) and furthermore (Adolfsson, 2011); that I could have access to this GIS-information.

[7] As an example; the german power consortium E.ON now owns the electric and district heating grids once built by the municipality. At the time when I first went to the city archives, I had no access to their GIS-data nor archive. My idea was therefore to find old municipal maps of the electric and district heating grid from before it was privatised, and from those construct a bottom-up MFA. The maps

With these examples, the argument for using the historically informed data collection method for a solid bottom-up MFA:s, is the empiricist ideal found in the field of history: always consult the source material (Odén, XXX). The only information which is mandatory for infrastructure providers to report and send in to the central Swedish authorities is the total accumulated systems lengths. Thus; the only documents where one could find the taken out-of-use parts and components of Swedish infrastructure systems are the maps of the system owners. If these are not found in their operating GIS-systems, there is need to consult the archives whether those be in charge of by a private or public actor.

While the overall aim of the inter-disciplinar approach was to take a step forward towards the solving of a societal waste problem by spatially locating and determining the size of a set of metal stocks in Norrköpings infrastructure, this required intellectual integration of the two incorporated fields. Following from the infrastructural history of Norrköping, we knew it to be specific enough to not make any generalized claims about a infrastructure waste picture applicable for the rest of Sweden and based on a kg/inhabitant-indicator or the like. All we were left with was in fact the black box we had assembled; the ore body of urban infrastructure waste. A black box ready for further STS-scrutiny in a second article.

MFA and the city
The material flow analysis view of the city is one that consists of two broad material strands of inputs, stocks and outputs: the urban fabric and the urban biosphere. The urban fabric consists of the city's buildings and infrastructure (Douglas, 1983), while all the materials that people and other organisms consume constitute the flows of the urban biosphere (Douglas and Lawson in Ayres and Ayres, ed. 2002).[8] The input flows of materials to the urban fabric is mainly constituent of construction materials which are derived from different kinds of mining activities. Over time, the renewal of the urban fabric cause material waste which often remain in the city as it is used to level original building sites for new construction. Cities thus raise over the residues of past structures, and these residues continually become part of the 'urban deposit' (Wilburn and Goonan, 1998). Dumps of waste and from industrial transformation are also part of this urban deposit: "The urban fabric, and all the materials housed and stored within it, and the underlying and surrounding urban deposit make up the urban materials stock." (Douglas and Lawson in Ayres and Ayres, ed. 2002).

Poängen med fortsättningen av detta stycke är att beskriva den verktygslåda av olika infrastrukturstudierperspektiv för att kunna gripa av "hur"-frågan i relation till Norrköpings infrastrukturella malmkropp. Eftersom jag vill hävda att det med hjälp av MFA härledda skrotet är ett empiriskt nytt material inom infrastrukturstudier behövs ett antal teoretiska utgångspunkter. De befintliga räcker helt enkelt inte till, de kommer en bit men inte hela vägen. I det följande tänkte jag i det följande bara helt kort lista ett par av dessa. Tiden räckte dessvärre inte till för att beskriva dem fullt ut.

• Kaijser och Gullberg (2004) beskriver städer i sin city building regimes-artikel vars utgångspunkt är att "the morphological transformations of city regions can only be understood as a result of the interrelated dynamics of the landscape of buildgins and the landscape of networks" (p.15). Sammankopplat med Kallipoliti (2008), som menar att "urban transformations always result in material residue" så skapas ett analysutrymme för att exempelvis förstå och studera uppkomsten av infrastrukturskrot i relation till stadsomvandlingsprojekt.

• Timothy Moss (2003) beskriver infrastructure 'cold spots' som "zones of limited commercial opportunity". Urkopplad infrastruktur kan sägas utgöra "zones of non-existant commercial opportunity" och är kanske därmed att förstå som 'frozen spots' of infrastructure.

• Det gamla LTS-begreppet "stagnation" beskriver hur infrastruktursystem kan hamna i en negativ spiral till följd av ökad konkurrens från system som kan leverera samma sorts

[8] One is tempted to argue that this dichotomy is upheld by differentiating between organic and inorganic materials, but since wood as one of many possible examples is a commonly used construction material any such attempt is deemed futile.

systemtjänster men till ett lägre pris. För en förklaringsapparat till varför system tas ur drift i sin helhet är “stagnation” ett utmärkt begrepp (se dock s.7), även om det inte förklarar varför systemet slutligen tas ur bruk.

• Avslutningsvis använder vi oss av Graham och Thrifts (2007) artikel om städers djupa beroendeställning till underhålls- och reparations-tjänster. En poäng med den artikeln är att underhållstekniker sällan involveras som informanter i akademiska studier (jmfr. kritiken mot systembyggarfokus). I linje med hur Star har argumenterat för att arbete utgör nyckeln mellan osynligt och synligt, inkluderade vi underhållsarbetare (och infrastrukturägare) i studien, vilket innebar ett analytiskt tillskott och insikter i avfallspraktiker i relation till den urbana underjordens mycket speciella arbetsmiljö.