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Aggregations of the opaque: Rethinking datafication and e-waste

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Abstract

This paper points to phenomena that are undeniably intrinsic to the datafied society, yet that themselves belie the dream/nightmare of total control through datafication: electronic waste (e-waste) and its recycling. In recycling industries and reverse logistics, invisibility, opacity, and uncertainty persist despite worldwide networks of surveillance, datafication, and algorithmic calculation. Mobilizing different technologies from RFID to big data, data assemblages enact particular regimes of visibility that cohere three "gazes": security's gaze, efficiency's gaze, and speculation's gaze. Yet along with these gazes come various forms of sightlessness, which I frame respectively as "blind eye," "blind spot," and "blindsight." Looking at datafication through e-waste teaches us that critique should not start from the presumption of increasingly all-encompassing datafication, but instead analyze the (constitutive) limitations and (productive) excesses at stake in data assemblages.

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Introduction

Media studies scholars have argued that we witness compounding datafication, namely the rendering into data of social processes and everyday life by means of (self)tracking in order to govern populations, markets, and cities (Cukier and Mayer-Schönberger, 2013). The prevailing critique of datafication revolves around the presumption of the omnipresence of data-centric governance in phenomena variably described as dataveillance, the quantified self, and the sensor society (Andrejevic and Burdon, 2015; van Dijck, 2014). Rather than the dream/nightmare of total control, this paper points to phenomena that are undeniably intrinsic to the datafied society, yet that operate rather differently. The reuse and recycling of electronic waste (e-waste) is marked by persistent sites of invisibility and opacity. E-waste matter is of a transient quality and often circulates in informal and illegal ways. It harbors multiple potential futures that vary from toxic hazard, second-hand device or product in secondary markets, refurbished *shanzhai* item, or salvaged raw material to be fed back into production processes.

This paper aims to, on the one hand, rethink the workings of datafication in the light of e-waste and, on the other hand, to reconsider e-waste and recycling in the light of datafication. It focuses on the ways in which logistical media (Rossiter, 2016) mediate the recycling process and especially data-centric apparatuses that inform discursive and material constructions of waste as well as the limitations of these apparatuses in terms of providing data-centric visibility and control. Many different terms exist to refer to waste in the recycling process (*e.g.*, surplus IT, de-commissioned IT, idled IT, e-waste, e-scrap) and the industry sectors dealing with it bear labels such as IT asset disposition, enterprise resource management, reverse logistics, and closed-loop (integrating forward and reverse) supply chain management. There are companies that simply offer software and platforms to their clients and ones that in addition provide services "on the ground" such as transportation, storage, and destruction. Their clients are original equipment manufacturers (OEMs) running take-back and returns programs such as Dell, HP, Apple; institutions collecting disposals such as municipalities and charity organizations; and individual firms, universities, hospitals, *et cetera*.

My questions are: what types of relations to waste matter does datafication afford? But also, what do the limits of datafication and the lack of data afford? How does the breakdown of electronics intersect with the workings and limitations of data-centric logistical media of e-waste recycling?

The overall aim of my article is to develop a conceptual and critical take on the role of continuing invisibility, opacity, and uncertainty amidst datafication. Hereby I neither resort to naturalizing supposedly "non-digital" or "extra-digital" phenomena, nor do I point to the incompleteness of datafication as a stage to be overcome by further technological innovation. Instead, in the below sections, I will discuss three types of socio-technical gazes, namely "security's gaze," "efficiency's gaze," and "speculation's gaze." Even though these gazes suggest intensifying datafication, they come with their own ways of cultivating sites of invisibility or opacity and uncertainty. Rather than failure, this indicates the systemic limitations and partiality of these gazes. Therefore, along with the aforementioned gazes, I analyze apparatus-intrinsic performances of sightlessness, variably called, "blind eye" (as in the phrasing "turning a blind eye"), "blind spot," and "blindsight" (the ability to respond despite not seeing visual information properly). The following section first introduces the conceptual framework of this study and proposes a methodological orientation on data assemblages in terms of their partiality and (constitutive) boundaries and limitations.

Mining data, mining waste

Waste is often understood as excess and residue and as that which does not have a social function and defies knowledge. Hence waste seems to come with a lack of data and information. After all, "There are no histories of residue, no atlases of abandonment, no memoirs of what a person was but could not be" [1]. It is remarkable how often waste statistics indicate what we don't know. For instance, the European Union provides the estimates of waste to be generated in particular years on the basis of sales numbers in previous years and then compares that to tracked disposal of electronics, for instance at collection centers. The difference between the two numbers is the estimated amount of waste that remains untracked, and its whereabouts remain unclear [2]. Reports from the security community raise further suspicions of the systematic smuggling, and hence disappearance from accounts, of e-waste. An operation by Interpol that was tellingly named "Enigma" focused on ports and customs in the Netherlands, Belgium, Germany, and the United Kingdom and found that one in three containers they inspected contained illegal e-waste exports [3]. Moreover, invoking the "unknown" forms part of environmentalist discourse, too. Various NGOs (nongovernmental organizations) have put out estimates of waste disappearing, whereby their variance and the wide margins cited underscore the prevailing uncertainty and hence the deficit of oversight over e-waste flows. Greenpeace has estimated that e-waste "disappearing" into informal and illegal circuits comprises 75 percent of all e-waste [4], while the United Nations Environmental Program (2015) has declared that globally only between 10 to 40 percent is disposed through formal channels. In addition, critical representations of waste in art and popular culture typically play on the aesthetic category of the sublime and produce sensations of awe in response to overwhelming magnitude and quantity. Even if numbers are provided, they may not alleviate the impact of such imposing magnitude. Instead, we ironically might experience the inability "to comprehend these numbers," as if waste renders meaningless the efforts of accounting and calculation [5]. Indeed, e-waste triggers the experience of the sublime both when we have "the data" and know "the numbers," and when we do not.

In these cases, waste remains unrecorded (without data), confirming the anthropological cultural-theoretical observation that waste is that which escapes our records and knowledge, social utilization, and human mastery over the world. Yet the situation I depicted finds a stark contrast in the logistical media of e-waste: your iPhone all of a sudden won't start anymore, or the screen keeps ghosting and you are unable to type. Actually, as this article discusses, such a moment is tracked, forecasted, and part of business models — I am referring to planned obsolescence and breakdown as monitored, anticipated, and calculated. When customers return used electronics to the company, waste is everything but a simple residue. Instead it is a resource to be secured and efficiently managed by means of an array of data-centric instruments.

In the reverse industries, e-waste makes part of what Gille (2010) calls *waste regimes* that govern the "production, circulation, and transformation of waste as a concrete material" [6]. Datafication is key to transforming waste from disposal into product, preventing it from going to landfills or becoming incinerated. There are different ways of using and processing data. Following a common tripartite distinction made in data science (see also Kitchin, 2014), *descriptive* technologies deal with data aggregation and mining focused on "what has happened," using historical data. In the case of e-waste, datafication is about tracking, sorting, and classifying waste in the name of "security." Second, *predictive* statistics modeling and forecast techniques are oriented onto "what could happen." Here different scenarios help render efficient the reverse supply chain. Third, *prescriptive* technologies afford agile adaptation by suggesting an optimized course of action in the light of probable and possible futures. Heterogeneous and real-time datasets allow one to compute a response to emergent situations by producing insights that are speculative in nature, yet actionable. Waste regimes involving descriptive, predictive, and prescriptive technologies raise the question of in what ways e-waste comes into being and transits into something else, be it an environmental hazard or a refurbished or new product. Historically, extraction refers to the mining of natural resources for precious minerals. Such mining provides a thought-provoking metaphor for the mining of data for the retrieval of information (Mezzadra and Neilson, 2017; see also Couldry and Mejias, 2018). In the case of e-waste, the two instances of extractivism are even interrelated: valuable materials are present in e-waste, including gold, palladium, and copper, and data is key to recovering this value and exploiting the potential inherent in e-waste.

So far in this paper, e-waste has appeared catastrophic, overwhelming, and beyond control *at the same time* that it is banal, calculated, and forecasted as part of business models and the rhythms of planned obsolescence. On the one hand, in line with the latter observation, this article could set out to rethink e-waste through datafication and emphasize the power of datafication and data-centric techniques of governance. I could follow scholars of technology who draw on the notion of the *dispositif* or apparatus, derived from Michel Foucault and further developed by Giorgio Agamben. Analyzing the government *of* material things as well as *through* things forming a "milieu," Lemke cites Foucault stating that "to govern means to govern things" [7]. Using 'apparatus' and 'assemblage' in intertwined fashion (Legg, 2011), Kitchin and Lauriault (2014) define data assemblages as — beyond the data system or infrastructure itself — "all of the technological, political, social, and economic apparatuses that frame their nature, operation, and work" [8]. Following the knowledge/power dyad, these assemblages are part and parcel of "strategies of relations of forces supporting, and supported by, types of knowledge" [9].

Nonetheless, e-waste remains a reminder of the persistent lack of control in the face of overwhelming quantities of transient matter that does not form a stable object but transforms as it circulates globally and enters into different relations. Following new materialists such as Bennett (2010), we can think of waste assemblages in a rather different way, namely as "ad hoc groupings of vibrant material of all sorts" [10], the properties of which are emergent and unstable. Moreover, in e-waste recycling, data does not necessarily enable abstraction, categorization, and transcendence of matter. Instead, data can resemble waste in terms of being overwhelming in quantity and heterogeneous and messy in quality. Hence, we need to account for the unruliness of data and material informational infrastructures themselves (Parisi, 2013; Pink, *et al.*, 2018; Tanweer, *et al.*, 2016).

How to combine these two lines of inquiry? I propose heeding the multiple and transformative materialities of e-waste together with datafication's inevitable incompleteness, manifested in persistent invisibility and uncertainty in data assemblages. Hence I consider data assemblages *in terms of their (constitutive) boundaries and limitations; and in the light of the systemic partiality of the technological "gaze" that they support*. Data assemblages enact particular regimes of visibility, or gazes, (Birchall, 2015, 2011; Halpern, 2014; Thrift, 2014), along with various forms of sightlessness, here framed as "blind eye," "blind spot," and "blindsight." I draw on Rossiter's (2016) methodological take on logistical media by considering the "discrepancy between the calculus of the plan and the world as it happens" and attending to sites at which "interoperability breaks down" [11]. However, my point is not to argue that the breaking down of seamless interoperability or the incompletion of datafication is resulting from the non-digital, or more specifically, the vibrant nature of e-waste matter, *per se*. Rather than pointing to the failure of data assemblages when confronted with the agency of matter, I inquire into the (constitutive) limitations and (productive) excesses of data assemblages. I do so by exploring the role of invisibility and uncertainty. Ultimately, I hold that looking at the articulations, co-constitutions, and parallels between e-waste matter and data encourages us to rethink waste and recycling as well as datafication.

Security's gaze: Blind eye

This first section attends to security technologies in recycling that focus on tracking waste items and their surveillance. It discusses these technologies in relation to the blind eye that they paradoxically cast. Security's gaze is oriented onto tracking e-waste and registering its whereabouts in a standardizing and integrated database that affords control over processes throughout the recycling process. The latest networks of logistics are also referred to as the "physical Internet" because of Internet of Things applications that allow objects to communicate with the Internet. The promise of datafication in this context is to ensure security by means of the ubiquitous tracking of goods as they travel through global logistical networks.

E-waste requires securitization both as a potential product and as a potential liability. Hence, concerns about the security of waste range from handling private and sensitive data stored on hardware, to theft of intellectual property of hardware design of original equipment manufacturers, and fines and damage to brand reputation deriving from exposure of illegal shipping of hazardous materials. The ITAD Works, for instance, warns that "70% of all data breaches result from the loss of data-bearing equipment" and "More than 95% of all equipment losses happen during the logistical process — many of them causing significant data breaches." [12] In response, The ITAD Works commits to continuous checking of the database against what exists "on the ground" by means of techniques such as *serialised reconciliation*, which compares the scanned inventory against the original service request. The "serial-number level" of granularity indicates what security's gaze is after: specific computers, hard disks, servers. In addition to serial numbers, barcodes, QR (quick response) codes, RFID (radio-frequency identification) tags, and GPS (global positioning system) trackers are used to track e-waste, either as individual items or as containers that are furthermore enhanced with tamper-evident seals.

Smartening of warehouses happens through automated means of cellular scanning, drones, cameras, sensors combined with actuators, and robotics. They assist with inventory assessment, classification, and sorting. The quality of items can be visually checked with the help of image recognition technologies that are constantly improved through machine learning, so that defects can be spotted by an automated "blink." [13] These smart solutions attempt to make the two orders of data and matter merge, with the promise that coverage will be increasingly exhaustive, affording control over waste as it proceeds through the global networks of the integrated (forward and reverse) supply chains.

Customers enjoy access to special platform interfaces to closely track their decommissioned hardware in real time. For instance, Cyclelution claims to be the "most popular ERP [Enterprise Resource Planning] utilized by over 150 OEMs, IT Asset Recovery, and Scrap Recycling Facilities in the US" [14] and among its clients are the OEM Dell and the non-profit donation chain Goodwill. It provides to clients a "tracking portal for real-time tracking, photo viewing, and pickup requesting" [15]. When data security is the concern, such interfaces, along with detailed reports, provide data about data erasure, perhaps to be considered metadata of obliteration.

Locative and smart technologies allow for control despite or even through mobility, following the Foucauldian idea of security that consists in governing rather than constraining mobilities (Amoore, 2013). They realize the advantages of proximity at a distance, supporting government of and through things (Lemke, 2018). This is to the benefit of corporations that desire control over goods while outsourcing and allocating production/recycling processes so as to benefit from comparative advantages across geographies (Amoore, 2013; Tsing, 2009). In her critical studies of logistics, Cowen (2014) identifies this spatializing approach as "systems thinking," which from the 1960s onward started to prevail and meant that logistics was not simply seen as transportation from A to B and an activity that merely follows production. Instead, logistics became about "spatial management." The opinion dominated that "the competitiveness of firms, nations, and supranational regions is contingent on their capacity to mobilize 'seamless' supply chains, to circulate *stuff* in a timely and reliable way" [16].

However, whereas the technological apparatus of security provides ubiquitous tracking, datafication, and informatization, it also engenders blind spots. The careful end-to-end barcoding and tracking of items and loads stops after the point that clients' data or corporations' intellectual property are not at risk anymore. That is for instance, after that items have been "de-branded" so as to avoid reputational harm in secondary markets. Whereas these items cease to exist as such and disappear from clients' interfaces, what continues can result in waste in less recognizable forms, increasingly amorphous and without any identifying logos. In other words, more anonymous objects and less or more sorted components: knots of wires, broken CRT (cathode ray tube) screens, motherboards, pieces of plastics, or everything mixed together. If e-waste is turned into raw materials, a new order emerges: plastics are sorted by type, while separated from steel, copper, and glass, or in the case of older equipment, from precious metals such as gold, silver, and palladium.

In these stages, recycling relies on a very different regime of visibility, revolving around certification. The recycling industry is certified by two main standards, R2 and E-Stewards (Pickren, 2014). Their *modus operandi* involves audits and inspections on the ground that are high-cost, low-tech, human-resource intensive and that merely provide sparse and momentary inspection rather than continuous monitoring and tracking. R2 was initiated by SERI (Sustainable Electronics Recycling International) in 2014 and according to its latest annual report, which dates back three years to 2015, it was working with an annual budget of just over US$530,000. Money was spent among others on educational activities, capacity-building, and independent audits of close to five percent of R2 certified facilities, which means that R2 relies heavily on self-governance and self-reporting by industry players. In fact, some recycling contractors play in on the inadequacy of certification to market truly "secure" recycling solutions. SSI writes on its Web site that "Many providers have R2 certification, but it's only a small part of the story," adding that R2 and e-Stewards "are minimum certifications. They are simply not enough to tell you what goes on inside a facility on daily basis, not to mention integrity." [17] Among the problems they list that auditors only spent a few days to check a facility, while they merely check paperwork most of the time. Recyclers might out-trick the auditors and the latter may not be trained well-enough to know standards in detail [18].

Given the limited and selective focus of security's gaze that turns a blind eye, waste might not need to be considered merely a "natural" frontier of human knowledge and control. The partiality of security's gaze functions in social histories, too. Anna Tsing [19] argues that "salvage accumulation" is a strategy of capitalism where the amassing of capital by a firm happens "without controlling the conditions under which commodities are produced." Instead of being brought under control and regulated in the process, the non-scalable, local, and informal are preserved because supply chains benefit from contexts' upholding a degree of either self-governance or non-governance. Following Tsing [20], barcodes — and can be added, RFID technologies and scanners integrated with decentralized computing — do not afford total control, but just the right degree of control. By the same token, they form technologies of neglect, too. Walmart pioneered with the use of UPCs (universal product codes), which is barcode, and later RFID. These technologies enabled control over products moving along the supply chain, reconciling mobility and security, effective contiguity and physical distance, yet they do so without the need to control the conditions of manufacturing and production entirely. This in turn enables non-governance (Rossiter, 2016), which manifests itself in labor and environmental violations that routinely remain overlooked — literally (see also Hoyng, 2018). Global integration and non-governance appear to be concomitant, and it is exactly their combination that affords wealth accumulation, though it also implies risks for the industry, including theft of intellectual property and reputational harm. What I call the "waste of waste" consists of externalities of the recycling process that include waste water, carbon dioxide and other fumes, and valueless residue, which results in the pollution of the soil, water, air, and ultimately in harmed lungs and tainted blood [21].

Efficiency's gaze: Blind spot

This section analyzes technologies of efficiency in reverse logistics, primarily databases that enable collaboration with, and control over, branches and partners across the globe. It highlights the blind spots of these management systems. In the context of recycling and reverse logistics, security discourses are complemented by efficiency discourses. Efficiency turns recycling into another production process, whereby waste is a potential product, be it in an aftermarket or as a type of salvaged material, and whereby managing the "lifecycle" of equipment "cradle to grave," to adopt business vocabularies, ties in disposal with retrieval. Efficiency means not wasting waste and instead finding out how to get the most value out of it or, if it has no value, how to dispose of it with the least costs. For instance, reverse logistics sets the goal to prevent electronics becoming outdated, and "going to waste" in that sense, while waiting on shelves in warehouses. This is a real threat given that, as some say, life cycles in the computer industry are "nearly as short as grocery life cycles." [22] Also, datafication is deployed to prevent waste caused by overproduction and to spare resources such as space in warehouses that store inventory. Moduslink, which lists on its Web site multiple consumer electronics OEMs and wearable brands, contends to provide "a highly streamlined reverse logistics management operation, one that eliminates costly handoffs and decreases inventory processing time, leading to an increase in value recovery." [23] Infor LN claims to work with nine out of ten of the biggest tech and electronics brands on manufacturing software including product lifecycle management that is "efficient": "With rapid product obsolescence and extensive outsourcing, high tech supply chains are difficult to manage." [24] Infor LN promises that their collaborative environment allows the client to handle "the complexities of mass customization and new product introductions through to aftermarket service and warranties." [25]

Streamlined software and integrated data architectures and cloud services enable collaboration and integration of processes across the global networks as well as functional units. Capabilities revolve around collaboration with as well as control over partners to whom tasks have been outsourced along the reverse supply chain. For instance, Makor, which is designed to handle IT asset disposition, resale, and e-waste, deploys a single core SQL (structured query language) database and uses this "centrality" to provide management with key "accurate real-time and historical data." Thanks to such a platform of communication, "Sales, Logistics, Production, Finance, and Fulfillment can now work together fluidly, with each group effortlessly feeding the next." [26] Data is communicated to a shared database in real-time, whereby degrees of access and authorization enact hierarchies among partners, employees, and decision-makers.

Efficiency subjects waste to decision-making through particular, automated decision-tree calculations that consider multiple variables, including for instance shipping costs and labor costs. The ITAD Works promises "efficiency by automating complex decision-making." [27] The accompanying illustration depicts pieces of a puzzle inscribed with various corporate objectives, including value, security and sustainability, all neatly fitted together, suggesting that the company's proprietary decision tree can solve this complex puzzle. Amoore [28] analyzes decision trees in terms of their ability to negotiate an array of possibilities as "multiple possible courses of events held open simultaneously." It is in this regard that efficient recycling/reverse logistics strike as flexible and open, as claimed by corporate promotional discourse. Yet Amoore argues that instead of cultivating some kind of entirely open-ended potential, decision trees aspire to the "actuality and the actualization of an array of possibilities" [29] that are rather particular and finite. They introduce a "numeric way of arraying alternatives, an already encoded systematization" [30]. In other words, though multiple, the options are not endless but delimited by the affordances of the system. For instance, for data stored in, and structured by, a SQL database, also called a relational database, key to the restriction is the initial finite columnar relation. As Dourish (2017) argues, columnar relations introduce a structure separate from the content so that operations within the database are uniform and fitting with this predefined structure. As a collaboration platform, the relational database offers "archival provisionality" in that the database can be extended and revised as contents are continually updated by multiple users. Yet, the structure of the relational database has to be pre-determined and defines the original terms in which the data are set. So "the structure of the schema largely defines and constrains the conditions of viewing, editing, and contributing" [31].

Such constraints are key to streamlined collaboration, yet they are necessarily also exclusive of other possibilities. Indeed, as *Reverse Logistics Magazine* writes, the decision tree structure is supposed to eliminate "the need for manual decisions by personnel on the reverse route." This is to prevent "poor decisions made by uninformed employees," while it "automatically dictate[s] the best destination and handling options" [32]. This quote conveys the belief in the superiority of the centralized and automated decision-making system over local insight. Following Star and Ruhleder [33], "an infrastructure occurs when the tension between the global and the local is resolved." In this regard, infrastructures can form "boundary objects" that reconcile shared systemic structures with divergent, local aims and practices and hence "allow different groups to work together without consensus" [34]. However, in the global networks of recycling, such a reconciliation between the system and the situated case, the global and the local, seems to be beside the point: management systems making use of relational databases and decision trees simply are intended to curtail local interpretation and action.

This insight prompts a further question: what possibilities remain foreclosed in the formal circuits' treatment of waste? What if local interpretation and more impromptu action in fact enact a form of efficiency in repurposing and recycling, too — one that is tactical and situated rather than strategic and systematic? Describing his observations of informal circuits of reuse and recycling at Huaqiangbei electronics market in Shenzhen, China, Adam Minter (2016) claims as much. He provokingly asks: "Need an Intel 486 CPU from the early 1990s? Someone at SEG Plaza can get it for you in bulk. Want the motherboard from a 2002 vintage Dell laptop? The man selling Dell motherboards will ask how many you need for tomorrow." Rather than being marked by a lack of security and compliance with environmental regulation, these circuits allegedly have been ahead of formal industries in seeking the (use and exchange) value in waste through reuse and recycling. Minter claims that "China and Ghana are looking less and less like electronic wastebaskets and more and more like leaders in a powerful, informal green economy."

Of course, informal recycling often compromises law enforcement and indeed e-waste smuggling has proven remarkably hard to control for crime investigators such as Interpol. It could be said that e-waste — despite new security technologies that penetrate matter ever deeper in order to foreclose supposed human errors, deviation, and wrongdoing — remains rather resistant to the spreadsheet of the relational database, the catalogue, the coding system. But likewise it could be said that the constitutive "law" or *nomos* of these systems, with their predefined structures, engenders its own opaque outside or remainder, while it produces "waste" according to stipulated waste regimes [35]. As efficiency becomes an encoded systematization, it renders invisible and marginalizes other possibilities and the tactical efficiency that Minter describes. This outside of datafied constructions of waste does not just consist in the items and loads of electronics that "disappear" off the radar, as crime investigation discourses frame the issue, but in the overlooked interpretative flexibility of waste and heterogeneous, dynamically evolving relations to waste matter.

Speculation's gaze: Blindsight

Speculation's gaze in reverse logistics and closed-loop supply chain management draws on big data applications. It revolves around action that does not follow clear and solid empirical evidence but intuition, estimation, and adumbration, therefore resembling the condition of blindsight.

The uncertainties and complexities of reverse logistics and the closed-loop supply chain are said to be much greater compared to forward logistics. The complexity stems from the large number of actors involved in the closed-loop supply chain (Guide and Van Wassenhove, 2009). Moreover, there is truth to Jackson's reinterpretation of Tolstoy: "All working technologies are alike. All broken technologies are broken in their own way" [36]. In other words, in reverse logistics items arrive in different conditions and will need different treatment. Last, the high degree of uncertainty derives from the volatility of global markets, including the aftermarkets for refurbished goods and markets for salvaged raw materials. In response to these conditions, a transition is on its way toward "agile" reverse or closed loop supply chains, rather than just "lean" and efficient ones. Whereas lean supply chains focus on planning and efficiency, guaranteeing minimally wasteful operations, agile supply chains focus on short-term projections and quick responses to ongoing developments (Agarwal, *et al.*, 2006; Carvalho, *et al.*, 2014) [37]. If waste matter, as it circulates globally, is transient and full of potential rather than inert and fixed, the latest logistical media are set to exploit this potential rather than constrain it. While the latter, typically big data technologies, are not yet standard in reverse industries, the fact that they appear in exploratory papers and are put to use by the most "innovative" players prompts the question of how these technologies mediate recycling processes and construct "waste."

New technologies in recycling do not only make use of historical data but also of real-time data, which allows for direct responses to emergent trends and events. Furthermore, they are aimed at coping with the lack of accurate information and troublesome integration of datasets and systems at a global scale. What the technologies discussed in this section share is that they produce "actionable knowledge" that supports acting amidst persistent uncertainty. That is to say, though a threat to security and efficiency, uncertainties are incorporated in computation and become the ground for speculation (see also Hoyng, 2018). Amoore [38] has argued about the deployment of similar technologies in anti-terror security efforts that the measure of success is not "ever greater degrees of accuracy and objectivity" but precision which is sufficient enough to engage the world. For instance, whereas big data technologies relinquish the ambition to produce final truths about external conditions, they are judged in terms of what is called *value* (the degree of usefulness of data) and *veracity* (the degree of reliability), which does not constitute a demand for absolute accuracy or truthfulness (in other words, information is either true or false and if it is false, it is worthless; Biswas and Sen, 2016).

Mediated by such technologies, the recycling process comes to consist in tactical intervention in the transient and aleatory flows of waste and in quick response to changing markets and circumstances. As one logistics company with a large Web presence writes, "Having the ability to foresee the future would be the ultimate power in business, but it is simply impossible. However, the next best thing is knowing what trends are occurring and adjusting output and operations to mesh well with these trends." [39] A paper by affiliates of the Calcutta Business School on the use of big data in supply chain management breaks down the use of analytics. It characterizes the data at stake as "Multiple data sources, different formats, lack of reliability in some data sources, presence of noise in the network communication" [40]. Subsequently, it hails the capacity of big data technologies for "intelligent decision[making] under uncertain situations thereby achieving the goal of a smart analytics under uncertainty or in absence of crisp raw input data" [41]. One example of big data technology that supports analytics is Hadoop. Together with the use of big data NoSQL (not only structured query language) databases and the programming model MapReduce, this software system serves to overcome the obstacle of lacking integration between different partners by arriving at workable formats and procedures, regardless of this circumstance. Unstructured and messy data that do not befit the format of the relational database or may not be fully accurate (due to measuring errors, inconsistencies in interpretation and classification, and conflicting information) are no longer inhibitive. Dourish [42] contends that "Software like Hadoop makes feasible computational services deployed across scalable clusters of computational nodes." It enables "the development of new sorts of cloud computing applications characterized by distributed access, low degrees of integration, and loose consistency" [43].

Several predictive and prescriptive technologies deal with uncertainty. Bayesian algorithms facilitate decision making processes under uncertain conditions, that is to say, when a situation is considered and modeled in terms of probabilities. They render estimations of the likelihood of multiple outcomes, giving insight into what different actions could be undertaken and what the various outcomes could be, while taking into account complex interdependencies among variables. In order to deal with greater degrees of uncertainty than standard Bayesian algorithms used to be able to handle, it has even been proposed to combine them with interval probabilities that reflect the margins within which something is estimated to occur as well as within which this condition is impactful. The idea is that this combination provides "a robust decision support approach based on imprecise probabilities" [44] and that it assists "the confidence of decision-makers compared to the traditional precise probabilistic reasoning" in acting in uncertain conditions [45]. Similarly, yet more widely present, fuzzy logics offer an instrument that supports decision-making and taking concrete action, while relinquishing the need for exact numbers and deterministic estimations. Fuzzy logics is used to reflect imprecise qualitative judgements in a quantitative manner. In reverse logistics, this is applicable in multi-criteria analysis or multi-objective decision making, so that the relevance of, for instance, security, sustainability, and cost-efficiency can now be weighed through quantified and automated means (Govindan, *et al.*, 2015; Nikolaou and Evangelinos, 2013; Pochampally and Gupta, 2009). Furthermore, already available on the market, Microsoft R Services in supply chain management assist in operating an ensemble of forecasting models together at once. Rather than using a single, "true" forecasting model, the underlying idea is to deploy a group of models that combined could provide more accurate forecasting, while one does not need to bet on any particular model working in isolation [46].

The construction of "waste" by these technologies of speculation can be contrasted to its construction by technologies of security. First, whereas the latter attend to the individual item or load, the technologies discussed here are not preoccupied with a disposed computer as an individual object. This is similar to social big data research not caring about the individual as such: if in social research it is not the single digital trail holding information about the individual that is important [47], in reverse logistics, the concern with waste as concrete, individual objects is replaced by the concern with waste flows in their emergent and possible qualities. Waste is conceptualized as flows of transient matter that is full of potential for different futures and transformative relations, unleashed through unrestricted circulation. Second, algorithmic big data technologies modulate the milieu in which they operate, rather than simply tracking, mapping, or diagnosing it. While drawing probable futures into present decision-making and modulating trajectories of transformation, such technologies preempt the future in which matter would ever materialize as residue or excess [48]. In the case of reverse logistics, while waste as residue is never to materialize, waste matter is always already on its way to becoming a new product.

However, while waste is always already a product, the electronic product is always already waste, too. Datafication supposedly is a tool to fight the problem of "aging" products and, according to IBM, it is key to accelerating the reverse supply chain and preserve value (Veerakamolmal and Gupta, 2001). Yet the datafication of waste overall forms in fact a *pharmakon* — medicine that is also poison — rather than a solution only. This is so because it enables feedback loops that add to planned obsolescence due to sped-up product renewal — now informed by real-time data about sales, returns, customer behaviors, social media chatter, *et cetera*. Likewise, datafication does not alleviate the volatility of markets as it merely stimulates actors to make tactical interventions without seeking further control, continuously adjusting their operations in response to the sped-up frequencies of business intelligence.

Last, as Clough, *et al.* [49] argue regarding big data computing, noise and excess in big data no longer form an obstacle and even become valuable to the extent that they allow for algorithms to revise themselves, creating continuous renewal in speculative intelligence. Hence algorithms including interval probabilities, fuzzy logics, *et cetera* produce actionable insight and this type of intelligence can be constantly renewed through machine learning in response to feedback and more and more data. Yet at the same time, noise and excess can speak to the unruliness of data and data infrastructures themselves. The threat of excess in e-waste is mirrored by the abundance of data, which is messy and unsorted (meaning unstructured), similar to e-waste trash itself. The value and utility of both resources remain to be settled. As the big data analytics software developer Optimal+ writes, electronics manufacturers collect "tens of terabytes worth of manufacturing data whose inherent value and bottom-line impact are lost, because it can't be acted upon [...]." Whereas Optimal+ promises a solution lying in technological innovation, a 2013 article in the *Journal of Business Logistics* on the issue of big data in reverse logistics warns that a "pure data mining approach often leads to an endless search for what the data really say" [50].

Conclusion

Rethinking e-waste through datafication shows the ways in which data assemblages enable tracking, calculating, and controlling that what used to be considered the outside of cultural knowledge and classification. The various "gazes" discussed in this article, namely of security, efficiency, and speculation, cohere the different sets of technologies, discourses, and interests at play in the constitutive mediation of waste. For instance, security, which pertains to intellectual property and data, is discursively and technologically constructed in ways rather different from efficiency or speculation. Waste regimes involving descriptive, predictive, and prescriptive technologies show us that, as Gabrys (2016) argues, there is not one version of materiality but many and our inquiries should attend to "the sorts of materiality that are addressed, the processes of materialization that are attended to, and the material relations that are animated or obscured" [51]. The aim of such critique is to open up the black-boxed processes of recycling and the all too homogeneous, often grossly misleading connotations of the term itself. For instance, the newest applications in reverse logistics focus on *ad hoc*, adaptive intervention to exploit e-waste, which is constructed as an elusive, aleatory, transient flow. To some degree, this approach compromises the commitment to disciplinary control over the mobility and transformation of e-waste, key to security and law enforcement. As I have elaborated elsewhere (Hoyng, 2018), given the importance attributed to waste mobility in scenarios of efficient and agile reverse logistics, e-waste disappearing off the radar *de facto* cannot be prevented. In line with the Foucauldian understanding of risk in economic circulation, waste flows are beyond strict control. Yet at the same time, uncontrollability functions as an ideological construct in discourses on the volatility of e-waste flows and it somehow resonates with the incorporation of uncertainty in data apparatuses associated with speculation's gaze. These new solutions appear as our best bet to tackle the problem of overwhelming, uncontainable quantities of e-waste — a problem that itself becomes taken for granted and naturalized. In this regard, my analyses call into question the pure naturalness of waste as a frontier of knowledge and control; along with the simple accidentalness of the huge amounts of e-waste disappearing off the radar, which ironically continues to happen in the very era of compounding datafication.

Rethinking datafication through e-waste inspires important insights about how data assemblages constitute, permit, or open up sites of invisibility, uncertainty and, therewith, uncontrollability. Paradoxically, sensing, tracking, calculating, forecasting, and speculating leaves room for invisibility and uncertainty. On the one hand, greater amounts of data do not necessarily mean more transparency and knowledge that affords control. Instead, data deluge, parallel to waste deluge itself, is a well-known phenomenon in supply chain management. On the other hand, whereas possessing more data does not necessarily amount to more knowledge, the absence of (clear and accurate) data is not necessarily incapacitating either. Instead, I have shown three more complex ways of understanding the role of invisibility and uncertainty in relation to datafication. First, the "waste of waste" is the result of neglect, which is inscribed in the politics of representation of security's gaze. It instantiates wherever security's gaze "turns a blind eye." Second, the constitutive "law" or *nomos* of apparatuses of "efficient" recycling is founded on predefined structures at the level of the database. It produces efficiency according to certain waste regimes, but also engenders its own opaque outside, or blind spot. In informal circuits of recycling, tactical and situated efficiencies derive from the interpretative flexibility and potential for heterogeneous futures inherent in waste matter. Third, speculation's gaze consists in intelligence supporting agile, tactical intervention and draws on messy, overwhelming amounts of data. Big data technologies incorporate uncertainty by relinquishing the need for strict accuracy in data and integrating estimations and imprecise qualitative judgement into the calculation. As uncertainty forms the very "ground" and milieu for speculation, it gives rise to adaptive, creative intelligence. In analogy, blindsight refers to a condition whereby one is able to somehow respond despite a lack of clear, empirical information.

Looking at datafication through waste teaches us that critique should not start from the presumption of increasingly all-encompassing datafication. Instead, it should consider the relation to datafication's outsides and the persistent role of invisibility and uncertainty in data assemblages.

About the author

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Notes

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