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Maintenance and Its Knowledges: Functional Exploration, Biographical Supervision, and Behavioural Examination

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Abstract

This introductory article to the thematic collection entitled “Maintenance and its Knowledges” makes a significant departure from breakdown-centred studies. It foregrounds the epistemic virtues of maintenance, a practice that cultivates *continuity*, by examining a still underestimated and unexplored dimension: the forms of knowledge associated with maintenance activities. A twofold aim guides such an exploration. First, repair and maintenance interventions are examined as particular sites and moments of *knowledge generation*. Second, building on the scholarship dedicated to improvisation and learning dynamics in the Global South that has structured numerous works on maintenance, this article considers how it can be extended towards the Global North. Recalling that maintenance has been mostly investigated from the question of *how*, it stresses out the various tools involved in knowledge generation, the organisation of tasks at play in different settings and their politics. It then goes beyond the *how* question to embrace a more ontological perspective, focussing on *what* people do properly maintain, and *what kinds of knowledge* emerge at this particular moment. Such a line of inquiry opens up three directions towards which the production of knowledge is oriented in maintenance: functional exploration, biographical supervision, and behavioural examination.

Keywords

knowledge; maintenance; practice; continuity; modes of knowing

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Knowing Beyond Breakdown

In science and technology studies, the epistemic virtues of breakdown can be traced back to the turn from science practices to technology and engineering initiated in the late 1980s and early '90s ([Woolgar 1991](#)). In such a move, focusing the analysis on particular moments of destabilization such as failures, accidents, and breakdowns has a proven heuristic method to offer revealing effects.¹ In these approaches, accidents, failures and breakdowns are considered as moments of 'unblackboxing' that provide an epistemic and political opportunity to reconsider the taken-for-grantedness of the world that comes with every object, machine or infrastructure. They all are occasions to make unseen aspects of technological objects visible, intelligible, and debatable. Such a perspective is directly inspired by Martin Heidegger's ([\[1927\] 1962](#)) distinction between the transparent handling of artefacts under routine conditions and the destabilization generated by their malfunctioning, which suddenly troubles the way their users relate to them. It is also in line with Gilbert Simondon's ([\[1958\] 2017](#)) consideration for the strangeness of objects, and the crucial role of knowing their nature and essence to avoid any kind of alienation. Whether the moments of destabilization are small failures, dramatic accidents or even disasters, the epistemic virtues of breakdown lie in disruption. In this perspective, what is foregrounded are situations contrasting with the ordinary course of collective or individual life. Put differently, the revelatory effect comes from an event disturbing the flow of routine.

This thematic collection makes a significant departure from such a perspective to question the epistemic virtues of maintenance as a practice that cultivates *continuity* ([Denis and Pontille 2023a](#)). In breakdown-centred studies, repair and maintenance interventions are seldom examined, essentially considered as transitory, unproblematic operations linked to the exceptionality of an event they are supposed to close. Conversely, a research interest in repair and maintenance has been growing over the last fifteen years, which explicitly takes a step aside from moments of destabilization, and supports a gradual shift towards the mundaneness of pervasive repair operations ([Henke 2000](#); [Graham and Thrift 2007](#)) and "cultures of repair" ([Graham 2010, 19](#)). One such scholarship has been exploring a multitude of objects and configurations, like ICTs ([Jackson, Pompe, and Krieshok 2012](#); [Rosner and Ames 2014](#); [Cállen and Sánchez Criado 2015](#); [Houston and Jackson 2017](#)), art works ([Domínguez Rubio 2020](#)), large infrastructures ([Ureta 2014](#); [Anand 2017](#); [Barnes 2017](#); [Baptista 2019](#); [Henke and Sims 2020](#); [Denis and Florentin 2022](#)), software and information systems ([Cohn 2016](#); [Fidler and Russel 2018](#)), urban environments ([Strebel 2011](#); [Denis and Pontille 2014, 2021](#)), heritage buildings and sites ([Edensor 2011](#); [Jones and Yarrow 2013](#)), domestic consumption ([Gregson, Metcalfe, and Crewe 2009](#); [Rosner 2014](#)), and even corpse preservation ([Yurchak 2015](#)). What this scholarship foregrounds is not only the diversity of repair and maintenance practices, but also how the focus on maintenance pervasiveness offers opportunity to reconsider object uses, labour activities or regulation policies ([Denis and Pontille 2022](#)). As such, it resonates with Steve Jackson's ([2014](#)) invitation to 'rethink repair', not as an isolated and momentary part of a disruption, but as a continuous

¹ For further elaboration of this argument see: Denis and Pontille ([2023a](#)).

activity in an always broken world. In so doing, most of these studies considerably deflate the eventfulness of repair as an intervention dedicated to bringing back situations and technical objects in order.

The articles in this thematic collection share such an analytical consideration for the continuity of repair and maintenance operations by examining a still underestimated and unexplored dimension: the forms of knowledge associated with maintenance activities. A few aspects of this topic have already been touched upon in some previous studies. Improvisation and bricolage as pivotal practices in repair and maintenance are surely the ones that have been emphasized the most. Taking the form of interventions of copier repair technicians ([Orr 1996](#)), fuelling the operations performed between technicians and their work settings in a large American state university ([Henke 2000](#)), or being an imperative at the core of medical work ([Schubert 2019](#)), improvisation composes an already well-described dimension of maintenance and repair expertise. Similarly, bricolage has been identified in many work settings, whether it takes a crucial part of the “war stories” circulating in communities of copier repair technicians traced by Julian E. Orr ([1996](#)) or, more recently, of the trans-local knowledge across geographically extensive technicians’ communities in phone repair shops highlighted by Lara Houston ([2019](#)) in Kampala. In this perspective, some works have insisted on the physical dimension of knowledge production, emphasizing the role of embodied skills in maintenance practices. In his pioneering contribution, Christopher Henke ([2000](#)) for instance described the body of repair workers as a ‘networked body’, challenging thereby the internalized conception of body that separates it from a web of technologies and foregrounding the material and cognitive interdependencies of repair work. Tim Dant ([2008, 2010](#)) has also pointed to the role of corporal engagement in the various forms of knowledge at play in car repair. He has notably emphasized the importance of what he called a ‘sensual knowledge’, stressing out how mechanics engage in a regular interaction with car components, by touching, hearing, and smelling them to appraise their composition and condition ([2010](#)). More largely, this form of body engagement has been quite integral to the understanding of various maintenance operations, such as the analysis of the careful collection and removal of discarded and sometimes dangerous materials by street cleaners in urban nocturnal settings ([Shaw 2014](#)). This corporal knowledge actually makes explicit how repair and maintenance practices are a locus of learning dynamics. The exploration provided by Syed I. Ahmed and his colleagues ([2015](#)) of the knowledges shaping expertise in the mobile phone repair markets of Dhaka, Bangladesh, is particularly telling in this regard. As they showed, learning to fix articulates overlapping networks and activities through which various forms of knowledge (explicit, tacit, craft-based, and social) gradually emerge that are elaborated, transmitted and reproduced.

This thematic collection extends these previous studies with a twofold aim. First, repair and maintenance interventions are examined as particular sites and moments of *knowledge generation*. May they take the forms of ‘best practices’, oral stories, tacit skills, theories, standards, doctrines, maintenance practices often represent distinct ‘modes of knowing’ ([Law and Ruppert 2016](#)) sometimes articulated, sometimes considered as antagonistic. In their different settings and around their specific objects, the series of articles documents how knowledge both gives shape to, and is being shaped by, maintenance practices. Instead of considering the variety of knowledge as stabilized resources at the disposal of (some) actors, such an analytical gesture focuses the investigation on the forms of knowledge generation at the core of maintenance practices, echoing Stewart Brand’s idea on the upkeep of buildings that ‘maintenance is

learning' ([1994, 127](#)). Hence, the thematic collection's ambitions to highlight how far the production and mobilization of knowledge is an integral part of maintenance, *and* knowledge-in-maintenance. It also suggests that, in some configurations, knowledge generation is not only a moment in a maintenance operation, but a maintenance practice in and of itself—that conditions the maintainability of things and can consequently foreclose its perennality or even its existence (knowledge as maintenance). Since maintenance is deployed to make things last, which goes through continual explorations of their state and transformations, maintenance assembles a set of practices which contribute to sustaining the very existence of things. Hence the cultivation of such continual existence goes with an endless and recursive generation of knowledge amongst the people in charge of these objects, technologies, and infrastructures.

The contributions also gathered in this collection resonate with previous studies that apprehend improvisation, bricolage and learning dynamics as specificities of sites in the Global South, in which things would necessary be always in the making ([Anand 2017](#); [Baptista 2019](#)). Building on this scholarship that has structured numerous works on maintenance, this collection shows how it can be extended towards the Global North. Indeed, the series of articles considers the concern for continual work and learning is also key in situations and configurations in the northern hemisphere, and applies to infrastructures and objects well beyond their supposed state of “made (once and for all)” and “finished”, echoing Prince Guma's work on how infrastructures are always incomplete ([2022](#)). Put differently, it is worth asking whether the heuristics of breakdown mentioned above, in which major failures come with their revelatory effect and knowledge, remains a north-centred tropism, while constant failures and the “always in need for maintenance” state of technology, from machines to infrastructure is mainly put to the fore in studies situated in the Global South.² By contrast, in this thematic collection we aim at preventing any hasty geopolitical separation and essentialisation of ‘ordinary’ knowledge and maintenance issues as properties unique to the Global South.³ Indeed, recent studies in transportation history have for instance underlined the span of geographies of expertise, knowledge circulation and hierarchies involved in the repair and maintenance of fleets of ships during long-distance travels, activated through cross-cultural exchanges and between different locations ([Margócsy and Brazelton 2021](#)). We thus envision maintenance and its knowledges as an analytical circulation operator between the North and the South, without ignoring inequalities and power issues related to the infrastructures of maintenance ([Rosner and Ames 2014](#)) nor the geopolitics of discarded objects ([Houston 2019](#)). And we make ours the claim made by Stephen Graham and Nigel Thrift that, once we have acknowledged the heuristics of ordinary maintenance activities, ‘they become one of our chief

² Obviously, literature on Global South configurations do not overlook the issue of breakdown (see [McFarlane 2010, 131](#), or [Silver 2015](#); they look at the production of continuous disruption), but does not make it a revealing moment and a source of knowledge generation, and rather considers it an ordinary state of (dys)functioning.

³ The contributions of this collection widely illustrate, in this respect, how the six features isolated by Ghautam Bhan as representative of specifically “Southern” characteristics of urban practice – namely being ‘incremental, uncertain, temporally fluid, speculative, transversal and rooted’ ([Bhan 2019, 653](#)) – equally apply to a lot of activities of repair or maintenance in the Global North.

means of seeing and understanding the world' (2007, 5) and allow to go beyond "the always oversimplified distinctions between the cities of the global North and South" (ibid., 11).

In this article we want to offer a reading of the articulation between maintenance and its knowledges. So far, maintenance has been mostly investigated from the question of *how*. Maintenance operations have generally been apprehended as practices that are explored and documented – an approach reinforced by investigations based on shadowing techniques and ethnographic fieldworks. Asking how maintenance occurs and is actually performed allows scholars to examine the various tools involved in knowledge generation, as well as the organisation of tasks and the division of labour at play in different settings. We obviously acknowledge how these lines of work are fruitful: showing how the texts gathered in this collection flesh out debates on the modalities of knowledge generation *in* and *as* maintenance practices more broadly (section two. But, and this is our second reading: by going beyond the *how* question a more ontological perspective can be embraced. When people maintain, *what* do they maintain exactly, and *what kinds of knowledges* emerge at this particular moment (section three)?

How Do Maintainers Know?

Even though nurtured by documents, doctrines and manuals, the knowledges at play in maintenance practices are always situated. They unfold and emerge through the modalities of attention and contact operated by those in charge of concrete maintenance operations (Jones and Yarrow 2013). Throughout these material encounters (Denis and Pontille 2023b), knowing and learning are a matter of both routine and improvisation (Orr 1996), articulating 'a set of predictable repertoires of restoring relations between bodies and things' and the 'dynamic and constant exercise of creativity and innovation' (Anand 2017, 233).

Furthering such perspectives, this thematic collection emphasizes – that attending to these situated knowledges of maintenance entails questions that go beyond the individual relationship between a human being and an artefact. They invite us to investigate the variegated forms of instrumentations that equip the mobilisation and generation of knowledge. They also show that knowledge processes participate in more or less formalised and uneven forms of labour organisation which, in return, may facilitate or constraint them. Finally, and as consequence, they remind us that the knowledges of maintenance are also governed in specific manners and thus can take part in reconfiguring power relationships.

Maintenance activities rest on a fairly peculiar interaction between the maintainers and the maintained thing, which passes through various *forms of contact*. This interaction has been analysed as a way to 'make matters speak' (Sanne 2010, 54), or to 'sense matter' (Cállen and Sánchez Criado 2015); we could even call this a form of generative dialogue, through which what the materials express (signs, clues ...) meets the maintainers' attention and reaction. This dialogue is a moment of both knowledge mobilisation for maintenance and knowledge generation. Knowledge in maintenance practices goes with a sensitive and sensorial relationship to the maintained thing.

The articles of this collection illustrate both the situated and sense-based character of knowledge in maintenance. In their analysis of an environmentally-friendly wastewater experiment with algae, Mandy de Wilde and Fenna Smits (2023) detail the various senses mobilised to understand how the sociotechnical system is functioning and how some signs prompt actions of maintenance. In this ecological prototype, smell and sight are integral to a correct maintenance of a system: a rather smelly yellowish water is a good

testimony of the low levels of chlorine or ammonia whose presence could kill the algae that are cleaning the water; alternatively, the colour of the algae are cues of their state hence of the experiment's state, green algae being synonymous with vitality due to the presence of chlorophyll while orange being considered a sign of stress and cells disintegration. In a similar vein, Roman Solé-Pomies (2023), in their exploration of road asset management practices illustrate the various forms of diagnoses used to assess the level of degradation of the infrastructure. The multisensorial plays an important role in this, from the observation of cracks to the feeling of irregularities of the surface caught through the jolts of a street sweeper in charge of road cleaning. These manifestations of 'matters speaking' are not only felt, but recorded (i.e., at least remembered), and furthermore shaped as moments of knowledge generation. It is worth noting – in the majority of the cases investigated in the thematic collection – the multisensorial engagement does not stop at diagnoses and pertains to various forms of interventions. For instance, the mobile phone maintenance practices documented by Nicolas Nova and Anaïs Bloch (2023) – where repairers keep dismantling and reconstituting phones to update their knowledge on how the system has evolved and should be fixed – thus indirectly dialoguing with the practice of tutelage, as analysed by Malini Sur (2020) around cargo cycle repair activities in Kolkata. Yet, the purpose of maintenance can lead, in certain configurations, to the display of non-interventionist forms of knowledge: this is for instance the case in the maintenance of sealed biological samples analysed by Vololona Rabeharisoa and Florence Paterson (2023). They show that the limitations of interventions on samples is crucial to preserve their legal status in potential future judicial cases, while the careful observation of the samples is also decisive in keeping the samples capacity to 'speak' when summoned.

While the multisensorial remains essential in the production and mobilisation of knowledge in maintenance activities, the contact with the maintained thing often passes through mediations, which contribute to equip and improve maintenance interventions. Maintenance practices thus rest on a complex apparatus of techniques of preservation, which constitute forms of accumulated knowledge. In line with other works by Alexei Yurchak (2015) on body conservation techniques, Rabeharisoa and Paterson (2023) for instance detail the multifarious instruments used by the administration to preserve the integrity of living samples and combat their constant and rapid degradation. They thereby epitomise both the unruliness of things (Dominguez-Rubio 2014) and new forms of knowledge developed to enact this preservation. The importance of these mediations of contact between the thing and its maintainers largely echoes what Mace Ojala and Marisa Leavitt-Cohn name "tooling" (2023); that is, the manners through which the knowledge accumulated on a thing is (re)animated and used to test the state of the thing. In their case, as they pay attention to software maintenance, the tooling moments can be seen as a trial of the code, to test its functioning and define the boundaries of what is maintainable and what should not or could not be maintained anymore.

Among these various mediations the tools are often used as signals of repair the subject if it isn't repair. They can take the forms of a sole handwritten note to warn about the fragility or 'dangerosity' of a thing, or a more elaborated system of sensors, like the various instruments to regulate the heating system of a university depicted by Alex Reiss-Sorokin (2023) or the signal boxes of a railway system analysed by Tobias Röhl (2023). In these cases, knowledge is not only the outcome of an observation, but also a matter of concern, often linked to the fact that the contact with the maintained thing can be indirect. The

development of these intermediaries like sensors between the thing and the maintainer puts to the fore the idea that these instruments and tools are ‘partner(s) in inquiry’ ([Szymanski, Smith, and Calvert 2021](#)). They can take non-technological forms and even living ones, in a naturecultural perspective such as the one adopted by Mandy de Wilde and Fenna Smits ([2023](#)) where the algae acts as a sensor. These signals may also entail important transformations, which can result in forms of tensions, like the ones described by Reiss-Sorokin ([2023](#)) between subjective sensations and objective metrics (of feeling cold or hot in the case she studies), showing ambivalences in the knowledge that is generated as well as potential discrepancies between the attention to user and sensor. Maintenance practices thus mirror complex assemblages of tools, instruments, and sensoria which are constitutive of highly situated forms of knowledge, emerging and circulating through heterogeneous sociotechnical cognitive systems ([Hutchins 1995](#)).

However equipped, situated, and heterogenous the forms of knowledge in maintenance can be, they are also integral to a certain *organisation of labour*: they are a part of collective work ([Orr 1996](#)), and participate in organising it. Maintenance activities rest on a cumulative and collective effort, acting as a chain of knowledges. Through this work, some elements are negotiated to assess what is deemed acceptable or maintainable. As Gaston Bachelard suggests,

... comprendre quelque chose n’est pas seulement le reconnaître, mais le considérer comme la suite de quelque chose qu’on connaît déjà.

... *understanding something is not only acknowledging it, but considering it as the rest of something already known.* ([Bachelard \[1927\] 1968, 15](#))

... insisting thereby on an accumulation of knowledge as a source of understanding. Ojala and Leavitt-Cohn ([2023](#)) show this in an illustrative manner through the works of software maintainers, which is per construction a distributed task, and, in that sense, also a sort of collective elaboration of knowledge. Though often left to juniors or poorly performing programmers ([Ensmenger 2014](#)), the chore of maintaining code creates contact between a series of maintainers of code, who collectively decide the sufficient level of knowledge that is necessary to ensure the good functioning of the software, thereby enacting a form of negotiated endurance ([Rosner and Ames 2014](#)). If the world of code and software offers a somewhat horizontal form of negotiation, some of the other articles rather insist on the idea of a chain with people in charge of translating knowledge ([Yanow 2004](#)) from one person in the organisation of the maintenance to the next. Some maintainers and specifically supervisors, through various guidelines, signs and training, make the thing knowledgeable to other maintainers and together make sense of these ‘heterogenous infrastructure’ ([Vertesi 2014](#)).

Knowledge then is not only a way to share concerns about a thing, but a way to organise maintenance activities. Even if a part of them consists of constant adjustments, forms of improvisations ([Orr 1996](#)) if not innovations ([Anand 2017](#)), they also constitute distributed and sometimes even planned forms of labour. The production of knowledge may act as a tool of planning for maintenance and an instrument organising the temporalities and rhythms of interventions. This is particularly eloquent in the case of road maintenance analysed by Solé-Pomies ([2023](#)). The latter shows how, in a small French city, a diagnosis tool not only contributed to a better understanding and knowledge of the level of roads deterioration, but also

had a transformative impact, changing the decision-making process of maintenance activities. While refurbishment strategies were mainly dictated by local political decision-making, the knowledge tool produced by local technicians has reordered the prioritisation of public works. In a similar vein, Reiss-Sorokin (2023) narrates how supervision and maintenance activities act as work organising time and classifying times of interventions, defined situated forms of maintenance according to variegated processes of knowledge production and mobilisation.

The ability of different forms of knowledge to organise and distribute maintenance activities also highlights that the articulation of knowledge and maintenance is the locus of certain *politics of maintenance*. Four facets characterise these politics. First, maintenance activities can be an arena of conflicting knowledges and distributed forms of power. The practices of maintenance can be torn between their essential improvisatory nature and the ambition to prevent breakdown through predictive means. Tobias Röhl (2023) gives an illustration of that phenomenon through the debates animating the community of maintainers within a Swiss railway company. While the rapid diffusion of sensors and tools was expected to contribute to the automation of knowledge production for maintenance purposes, this process creates tensions with the practical knowledge cherished by the maintainers of rail tracks. As Röhl demonstrates, automated signals of fragility often result in contradictory injunctions for interventions, knowledge tools becoming in this case a source of disorganisation instead of an enabler of fluid labour planning. What Röhl's case illustrates is actually the tension that arises between breakdown-oriented activities and maintenance activities; the automated knowledge produced in the case of this Swiss railway company pertains to the organisation of repair, which happens to the detriment of the organisation of maintenance.

Secondly, the articulation of knowledge and maintenance also reveals other forms of conflict, highly intertwined with both the often marginalised or invisibilised situation of maintainers in the modalities of knowledge production in maintenance. The coexistence of different modes of knowing (Law and Ruppert 2016) often leads to conflicts between incorporated knowledge and 'objectified' knowledge. Solé-Pomies' article (2023) epitomises this tension with the knowledges produced in road maintenance: those who are in direct embodied contact with the defects of the road have a hard time demonstrating and convincing their managers and decision makers to transform their maintenance policy schemes according to these situated, oral knowledges, illustrating both the political sensibility of the road surface (Denis and Florentin 2022), and the invisibilisation of certain types of knowledge in maintenance, including marginalised forms of maintenance labour with a gendered dimension – as showed by works on maintenance in sanitation services (Alda-Vidal et al. 2023; Truelove and O'Reilly 2020).

Thirdly, the politics of knowledge and maintenance should not be restricted to the conflicts raised by their tricky articulation. Though possibly ambivalent, knowledge in maintenance has also an emancipatory dimension, and contributes to a form of empowerment of maintainers. This is precisely what we learn from the article by de Wilde and Smits (2023), where they insist on the capacities of supervision to repoliticise and reconfigure everyday relations to objects, enabling a sort of ownership of the 'thing' (be it an algae used for a greener sanitation system or something else), and a dowry to delegate and translate to those in charge of interventions.

Lastly, this emancipatory dimension is also framed and potentially limited by the commensurability (or lack thereof) of knowledge in maintenance. Whereas some of the articles in this

thematic collection insist on the ways to make maintenance issues knowledgeable to various actors intervening on a production process or a thing, a few also stimulatingly reverse the perspective and question the issue of the unknown, unknowable and its possible articulation with the non-maintainable. Ojala and Leavitt-Cohn (2023) explain how recognising the boundaries of the unknown is quite essential in software maintenance activities, as it delineates what is maintainable and the level of acceptable unknown that does not alter the functioning of the software. At another level, the unknown can be constrained by other means: in their text on the maintenance of biological samples, Rabeharisoa and Paterson (2023) recall the limits conservation has to reckon with, be they in terms of space, time, but also of financial means to ensure the perennality of the maintained thing.

Knowledge of What?

Even though the articles in the thematic collection essentially focus on *how* knowledge is organised, distributed and equipped, they nonetheless question the object of this knowledge and examine what is known *for* and *through* maintenance practices. They extend previous forays into the modes of existence of things, and by doing so, enrich our understanding of the ontological dimension of maintenance. As shown in early maintenance and repair studies, any attempt to preserve a thing, or make it last a little longer, draws on a more or less explicit definition of what counts for this specific thing to remain ‘the same’ (Jones and Yarrow 2013; Domínguez Rubio 2016; Barnes 2017). To maintain an object implies to identify and intervene on particular components or features that are deemed to constitute this object. This implies, like care (Puig de la Bellacasa 2012), that maintenance is always twofold. While maintenance strives to cultivate or perpetuate specific constituents of a thing, it simultaneously ignores or neglects other properties that some people would consider critical to this very thing. This selective process, which is intrinsic to every kind of maintenance and repair, invites to pay attention to the generative dimension of maintenance and, consequently, of the knowledge it both draws on and generates. It also prompts to explore its diversity: different forms of maintenance carry out different ontological enactments (Denis and Pontille 2017). This is precisely what this thematic collection of articles proposes, documenting and confronting varied, sometimes contrasted, ‘modes of knowing’ (Law and Ruppert 2016) in maintenance practices.

These ‘modes of knowing’ are not toolkits that could be gathered in a comprehensive catalogue, though. In these articles, knowledge is anything but a stock of stabilised information, and the verb *to know* does not discriminate between two clearly separated states (knowledge and ignorance). Rather, knowledge is the drive of a constant and uncertain endeavour – a quest. Maintainers know less than they seek to know. And the various knowledges of maintenance are the provisory outcome of never-ending inquiries. Like maintenance itself (Denis and Pontille 2023a), they have to be done again and again, always in the present time. More than a list or a table of ‘pieces of knowledge’, this thematic collection draws the broad lines of a landscape of various concerns:

- What has to be known about a thing to maintain it?
- What kind of expertise and understanding its ability to last does require?

Circulating among the different ways these questions are articulated and addressed, one can identify three main issues through which maintenance and knowledge are intertwined, three ways of apprehending and

investigating the things that are maintained. These issues can be expressed in terms of three simple questions:

- How does the thing work?
- What has happened to it?
- How does it behave?

These questions reflect three different directions towards which the production of knowledge is oriented in maintenance: functional exploration, biographical supervision, and behavioural examination.

Functional exploration is at stake when maintenance knowledge consists in documenting and understanding mechanisms and when what is maintained is apprehended as a complex set of pieces and workings. Getting to know how different technical components of a heating system work is for instance central for the team of maintainers studied by Reiss-Sorokin (2023). Such knowledge is directly connected to hierarchical autonomy. By monitoring and supervising the HVAC of which technicians are in charge, they are able to organise and prioritise their work, as well as negotiate the pace and nature of their interventions. Through their different forms of interventions, be they formalised or not, these maintainers make the employees of the customer service, who are in direct contact with infrastructure users, knowledgeable of the infrastructure. Interestingly, in his paper on railway maintenance, Röhl (2023) notices that the use of sensors and partially automatised tools for diagnosis multiply this kind of knowledge issues and their organisational consequences. Instead of providing legible accounts and allowing the setting up of “predictive” maintenance, these technical “solutions” add another layer of uncertainty and a need for further functional explorations: in addition to understand how every switch in the system works, the technicians have to get to know the sensors and their algorithms.

In these situations, as in others where maintainers work with HVAC systems (Henke 2000), photocopiers (Orr 1996), mobile phones (Houston 2019), water networks (Anand 2017) or spacecraft (Cohn 2016), knowledge relates to operating processes. What has to be known, and thus investigated, is a set of dynamic and intertwined working components. Such knowledge cultivates a mechanical ontology. The thing that is taken care of is apprehended as machinery: a complex assemblage of parts that operate both independently and in relation to each other.

This contrasts with another mode of knowing highlighted in this collection, which we propose to name as ‘biographical reconstitution’. Here, what is at stake is not how things work but how they have evolved. More precisely, maintainers try to know what has happened to the things they take care of. As shown in Rabeharisoa and Paterson’s article (2023), this knowledge of a more or less distant past is sometimes at the core of maintenance. It is, in their case, the very condition in which the sealed biological samples can be treated in a legal setting in the future. Knowing what these seals have gone through is essential to the preservation of their integrity, and thus to their ‘judicial potential’. Knowledge in this configuration is less something that participates to maintenance practices (knowledge in maintenance) as it is a form of maintenance in itself, a form of knowledge as maintenance. Such knowledge is anything but easy to organise and stabilise, though, as shown by the various attempts of the lieutenant-colonel Rabeharisoa and Paterson (2023) interviewed at creating a ‘science of sealed biological samples’. A science that would reinforce the traceability of every event in the concerned objects’ lives so that the marks these episodes left on them can be identified and separated from the ones the seals originally bore. Biographical reconstitution is also at play

in Ojala and Leavitt-Cohn's (2023) investigation of software maintenance. Among what the programmers try to know about software, how the code has changed over time is indeed critical. To do so, they notably use 'version control systems' that provide a comprehensive 'genealogy' in which every change is recorded. As the authors write themselves, 'each body of code thus develops its own biography' (*ibid.*). The collective knowledge long-term software maintenance draws on is largely focused on such biography. Similarly, some of the road technicians studied by Solé-Pomies (2023) rely on biographical elements to organise maintenance works. They especially use a spreadsheet whose certain rows and columns represent the 'temporal cycle of decay and refurbishment' of each road they are in charge of (*ibid.*). Made of diagnoses, results and written traces of previous maintenance interventions, these records allow the technicians to gather numerous formalised cyclical biographies they can compare with each other to make hierarchies, prioritise matters of concern, and sometimes debate future interventions.

Through extremely different settings, these cases share the same concern for a form of knowledge that grasp things as historical entities whose maintenance goes through the understanding of what has happened to them during what maintainers investigate as their 'social life', in a similar vein to Appadurai's (1986) use of the term. Such historical ontology fully acknowledges the transformations and interferences the things encounter over time, how they sometimes gain accretions or, conversely, lose components or "layers" as time goes by. If these mutations are not problematic in themselves, a precise knowledge of them is critical, though, since it is through the identification and sometimes detailed analysis of its potential modifications that a specific thing is maintained as "the same".

Finally, several articles in this collection highlight a form of knowledge that nurtures maintenance with *behavioural examination*. What maintainers strive to know in that configuration slightly differs from the idea of a "social life" made of events that would have certain consequences on objects. Behavioural examinations focus on the inner life of things and their own actions. This is an important aspect of most maintenance activities. Far from apprehending objects as inert and crystallised assemblages of matter, maintainers engage with a world of living materials of which they have learned to become aware (Denis and Pontille 2023b). Trying to know how objects behave is an important challenge of maintenance, and symmetrically, maintenance offers opportunity to explore not only discrete features and functionalities, but what Karen Barad (2007) has called 'intra-actions'.

These efforts to understand how things act are particularly noticeable in the article de Wilde and Smits (2023) devoted to the exploration of the maintenance of a wastewater treatment prototype in the Netherlands. Based on an algae-based treatment, this prototype needs various forms of care, and above all, require that engineers and inhabitants learn to understand the behaviour of the three species of microalgae in-situ. Such knowledge is crucial to the success of the experiment and – from a more practical perspective – to the smooth running of the water treatment infrastructure. As the authors show, maintaining the latter implies supervising, and getting to know, three kinds of behaviour from the microalgae: the way they act when they're hungry, stressed, and/or dying. Most importantly, none of these behaviours are known in terms of value (i.e., information that would be only recorded and formalised in order to properly set the parameters for the overall system). This knowledge on how things act is cultivated in terms of interspecies 'response-ability' (Haraway 2008), that is as a way for engineers and inhabitants to interact ethically with the microalgae in a form of collective 'diplomatic' maintenance (Denis and Pontille 2022). Behavioural

examination is also crucial in the conservation of sealed biological samples studied by Rabearisoa and Paterson (2023). As a close counterpart to the biographical investigations, which would record all that has happened to the seals, the lieutenant-colonel in charge of the maintenance of the biological samples calls for developing a “science of sealed biological samples” that can also generate knowledge about the behaviour of the seals themselves. Understanding how these complex and extremely diverse assemblages evolve, how the various materials they are made of mutate, and how each previously independent parts end up reacting to their respective transformations, generating hybrids, is crucial for the seals to remain over time as intelligible legal objects. Perhaps more surprisingly, behavioural examinations are also at play in software maintenance. As Ojala and Leavitt-Cohn (2023) explain, they are key in the use of automated tests, which allow technicians to regularly ‘check that the primary software still behaves as before’. Above all, these tests, done through executable programs, document these technical behaviours, generating a stabilised and up-to-date form of knowledge about parts of the code that remain otherwise unexplored, that are literally ignored.

The knowledge at stake here can be articulated to theoretical discussions in anthropology and philosophy. What behavioural examination looks at, indeed, is akin to what scholars have investigated in terms of material agency (Barad 2007; Bennett 2010), sometimes even of ‘entangled agencies’ in the sense of Tim Edensor (2011), when things are not only apprehended as individual ‘agential’ beings, but through processes of melting or differentiation.

As the short descriptions we have given here have hopefully made clear, the three modes of knowing present in these articles do not draw on stabilised sets of procedures, methods, or even articulated questions. While some configurations may imply formalised practice and automated tools for the production of knowledge, what the articles portray are mostly knowledge issues and concerns, which trigger inquiries and never totally get away with uncertainty. Obviously, they do not claim to be exhaustive either. There is no doubt that the ways through which knowledge might be articulated to maintenance can rest on other concerns than things’ functioning, biography and behaviour. These three problems give a first glimpse at how ambitious and overwhelming the cultivation of knowledge *for* and *from* maintenance can be, as mundane as it may seem in the first place. Most of all, they show the extent to which maintenance knowledges remain attached to things, without ever discounting their singularities entirely, or disregarding the myriad of connections that bind them to other things, people and their milieu.

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