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Maintenance and Repair Work

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Abstract: This essay review evaluates recent contributions in the field of maintenance and repair studies with a focus on a special issue of *Tecnoscienza* on this research field and a volume edited by Ignaz Strebel, Alain Bovet, and Philippe Sormani entitled *Repair Work Ethnographies: Revisiting Breakdown, Relocating Materiality*. These two publications provide important insights into empirical investigations of maintenance and repair work which raise stimulating questions for engineering studies, where these activities are often overlooked.

Keywords: engineering practices; maintenance; repair; ethnography

Neglected activities in engineering studies

As James Trevelyan noticed ten years ago, engineering studies is still focused on design and problem-solving, which tend to frame the field's understanding of engineers' identities.[1] Such studies have contributed to our understanding of engineering practice. However, our knowledge of other aspects of engineering practice remains tenuous. In fact, we still know very little about engineering and technical work.[2] Some activities are relegated to such an inferior status that they are unseen even though they are critical in obtaining technical performance, efficiency, and robustness.[3] Among these neglected activities are maintenance and repair work. Some authors have, of course, noticed that repair and maintenance are included in the tasks assigned to engineering organizations such as the Corps of Engineers (e.g. the French Corps des Mines, or the US Army Corps of Engineers) – alongside their more famous charge to design and supervise the construction of roads, bridges, canals, drains, military works, and royal factories.[4]

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[1] Trevelyan, "Reconstructing engineering from practice," 177-178.
[2] Barley, "What We Know (and Mostly Don't Know) About Technical Work," 376–403.
[3] Trevelyan, "Reconstructing engineering from practice," 186.
[4] Massa-Esteve, Roca-Rosell and Puig-Pla, "'Mixed' mathematics in engineering education in Spain," 235.

Scholars such as Emily Blosser have also observed that maintenance and repair structure engineers' experience of time: in chemical plants, for instance, jobs often require quick turnaround, especially when a plant shuts down for maintenance and repair, which means engineers have to work long, sustained periods without time off.[5] However, this part of engineering practice has largely escaped the field's notice.

Even in the journal *Engineering Studies*, maintenance and repair still are absent from the scope. Very few papers talk about these issues, even in articles focusing on post-breakdown and post-disaster case studies such as the aftermath of earthquakes and the repair of piped water systems.[6] Disaster, failure, and breakdown themselves are still neglected situations in engineering studies that focus on technological progress, industrialization, the rise of technical professions, and high-risk systems. Within the larger, related field of Science and Technology Studies (STS) more attention has been paid to disasters, post-disaster hearings, and tools for risk evaluation and management. In looking at societal expectations for technological safety, this subfield of "disaster studies" investigates codes of ethics, professional standards, engineering education, and liability calculations.[7] However, *maintenance and repair studies* (MRS) are not yet a key subfield in engineering studies.

On another side, Cyrus Mody advocates that we interpret engineering studies in a broad sense to include user innovation, citizen science, lay expertise, hackerspaces, DIY culture, crowdsourcing, and "maintainers," in order to avoid focusing too exclusively on the credentialed members of the engineering profession. He suggests we can learn about the engineering profession by also studying "crafters, hobbyists, user communities, indigenous experts, and others who make do with uncredentialed technological knowledge."[8] Maintenance has drawn little attention even though it involves exactly this kind of diverse cross-section of many people: users, technicians, managers, *and* engineers. As Lee Vinsel and Andrew Russell note, most engineers are employed in various forms of maintenance, not innovation.[9] These maintainers can be credentialled or uncredentialled, and the involved engineers are sometimes not considered as engineers. Thus, maintenance is the kind of issue that demands, as Mody recommends, that we continue asking "who is an engineer" and "what is engineering."[10]

Looking at engineering activities, we find many working situations for which there are engineering issues regarding maintenance and repair. First of all, there are episodes of breakdown, accident, and failure which stimulate practices of saving, repair (e.g. in a building after a fire like the recent destruction of the roof of Notre-Dame cathedral in Paris), or re-design (e.g. after the Challenger explosion or the recent crashes of two Boeing 737 Max aircraft). These are spectacular breakdowns, but there are many "small" accidents (e.g. with cars) or failures (e.g. bugs in software) which generate feedback or complaints from users and clients, and lead to a lot of work to fix the problems or to undertake a re-design (e.g. functional re-dimensioning). Within software engineering, for instance, debugging represents a substantial part of the job and therefore constitutes a significant technical and economic issue.

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[5] Blosser, "Gender Segregation Across Engineering Majors," 38.
[6] Sheller et al, "Participatory engineering for recovery in post-earthquake Haiti," 159-190; Knowles, "Engineering Risk and Disaster," 227-248.
[7] Knowles, "Engineering Risk and Disaster," 230.
[8] Mody, "New Editor-in-Chief Editorial," 8.
[9] Russell and Vinsel, "Let's Get Excited about Maintenance!", 2017.
[10] Mody, "New Editor-in-Chief Editorial," 8.

Moreover, the software industry is not an exception; many productive activities in industry and construction face many production hazards which require repair, rectification, adjustment or re-design, and sometimes conservation to restore "authentic" appearance or operation.[11] On assembly lines, Robert Linhart documented a senior worker retouching bumpy car doors before reintroducing them into the production line.[12] In industrial engineering, similar situations occur, as Jean-Philippe Neuville demonstrated for "just-in-time" production management.[13] In fact, a lot of work on assembly lines consists in "adjusting in time" and *re-doing* just-in-time (repair, replacement, negotiating changes and quality) in order to avoid stopping the production. Furthermore, re-doing is not limited to building and production, but is also involved in design activities: in design departments in firms, much work consists in product modification, re-design, and re-dimensioning products already launched on the market, following production incidents, after-sale servicing, and client feedback.[14] This activity is also neglected in design studies that focus on the design of new products. There is a pro-innovation bias both in design and engineering studies, just as in innovation studies.[15]

The same is true of user studies, which tend to over-value innovation relative to the repair work that users themselves relate to. Some evidence of users' affective relationship with repair can be found in a fictional source, Robert M. Pirsig's *Zen and the Art of Motorcycle Maintenance*.[16] In Pirsig's book, the driver of an old motorcycle pays continual attention to it and engages himself in diagnose, maintenance (e.g. a ritual to adjust the valves on the cycle's engine), and repair work (e.g. rectifying some pieces, installing new components), as well as learning from his observations, essays, and experiences. The book became a best-seller, creating a philosophical manifesto regarding life, through motorcycle maintenance, with arguments like: if there is no doubt, there is neither dedication nor learning; the maintainer is in the scene (paying close attention to what is going on), not just watching it; to remain grounded at all times, even when things get too complex.

All these restorative practices deserve to be investigated in order to further feed collective reflection on this part of technical and engineering activity, which is important in establishing sociotechnical performance and maintaining a sociomaterial order. However, there is much more to study than repair after breakdown, adjustment, re-design, and ordinary maintenance. In some technical sectors, there are special major maintenance practices, which require a complete stoppage in use and production in order to make a general revision and restoration. This is the case for airplanes, which have to pass through regular overhaul checks or heavy maintenance checks (D-check, every 4 to 5 years), in addition to their daily check (after 24 to 60 flight hours), A-check (every month or 500 flight hours), B-check (every three months), and C-check (every 12 to 18 months). The heavy maintenance check is performed in a maintenance hangar and lasts at least two weeks to three months, depending on the type of aircraft, its age and the number of flight hours.[17] All its components are inspected and repaired if necessary.

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[11] Edensor, "Entangled agencies," 238–252; Jones and Yarrow, "Crafting authenticity," 3–26.
[12] Linhart, *Etabli*, 1981.
[13] Neuville, *Le modèle japonais*, 1997.
[14] Guffond and Leconte, "La modification de produit," 31-40.
[15] Godin and Vinck, *Critical studies of innovation*, 2017.
[16] Pirsig, *Zen and the Art of Motorcycle Maintenance*, 1974.
[17] http://archive.wikiwix.com/cache/?url=http%3A%2F%2Fwww.airworthiness2011.com%2Faircraft-maintenance-checks%2F, last consultation 16 may 2019.

There, an airplane is exposed to a systematic check, including of any part of its structure. The heavy maintenance check also offers an opportunity to install the latest improvements or to make changes in response to staff and user feedback. It involves the performance of more than 10,000 complex, precise, and strictly regulated tasks. Thus, the check is important engineering work in itself, requires substantial planning, and, of course, costs several million dollars.

Similar work applies as well to boats with their large fairings, and to nuclear plants, and the chemical and petroleum industry. Maintenance implies shutdowns and stopping production for weeks or month; this requires anticipation, precise methods, a specific organization of the work, etc. In some sectors, such as the nuclear industry, these heavy maintenance procedures present an opportunity to repair and to make continuous improvement every ten years. For instance, in France, legislation requires the operator to improve the safety level at each inspection, in light of scientific and technical knowledge and taking advantage of feedback from accidents (e.g. Chernobyl and Fukushima) or incidents. Furthermore, there is a vast industrial program to strengthen facilities, aimed at extending the possible operating life of nuclear power plants beyond the designed-for 40 years by adding a further 30 years more. Here, maintenance *combines* with innovative operations.

Finally, I would point to another type of repair which involves engineering: retrofitting. This activity is sometimes organized as a productive activity more than a reaction to damage. This is the case for a subsidiary of the French national railway company (SNCF), managed for a time by Peggy Louppe, an engineer and PhD in sociology, which retrofits locomotives with a staff of 750 mechanics, boilermakers, welders, electricians, polyester technicians, painters, and handlers. These people dismantle diesel-electric locomotives at the end of their use, rectify every component, and build a new locomotive, mobilizing more than 60 years of know-how and memory of failures, incidents, and repairs. Retrofitting or redevelopment is also a common practice in various other sectors of activity, including construction, not to mention road, distribution, or drainage infrastructure.

These activities are unexplored by engineering studies. As they represent an important part of the ordinary work of engineers and could shed a different light on engineering, engineering studies therefore needs to pay more attention to maintenance and repair.

Maintenance and Repair Studies (MRS)

Within the nearby field of STS, maintenance and repair practices have been attracting growing attention from scholars since the ground-breaking works of Susan Leigh Star on knowledge infrastructure and Marianne de Laet and Annemarie Mol on adapting technology.[18] A new research field has emerged which explores overlooked practices, sheds light on invisible and unnoticed workers, and points to issues such as material vulnerability. These are the kinds of topics that appear in a recent special issue of *Tecnoscienza* on maintenance and repair, edited by Jérôme Denis, Alessandro Mongili, and David Pontille.[19] The introductory article gives a very good representation of MRS

[18] Star, "The ethnography of infrastructure," 377-391; de Laet and Mol, "The Zimbabwe bush pump," 225-263.

[19] Denis, Mongili, and Pontille, "Maintenance & Repair in Science and Technology Studies," 2015.

as a dynamic research field, while the four papers are each based on an in-depth case study focusing on contrasting sites and workplaces (electronic waste mending, anticipation of failures during design of advanced driver assistance systems for "autonomous" cars, daily maintenance of a building, repair of an industrial plant) with their specific occupational communities. This special issue of *Tecnoscienza* is particularly valuable in laying the foundation for a research program in engineering studies.

MRS addresses major topics relevant for engineering studies

The four empirical articles in the special issue show that MRS addresses larger topics which concern engineers: planned obsolescence, durability and tinkering; anticipation of maintenance and repair work in and after the design of new technologies; involvement of a variety of actors in maintenance and repair work; distribution, negotiation, and organization of the activity among those actors; and the ascription of responsibilities and recognition of all the actors' work in sociotechnical networks.

The first article highlights the material vulnerability of our world and questions how people experience this vulnerability. In "Vulnerability Tests: Matters of 'Care for Matter' in E-Waste Practices," Blanca Callén and Tomás Sánchez Criado explore the diversity of the ways in which vulnerability is experienced in practice when people are mending, fixing, or maintaining computers. The authors show that there are different kinds of "vulnerability tests" (sensing matter, setting up informal experiments, and intervening) which together enact vulnerability through specific "care for matter" practices and sustain an alternative ethical and political order that resists the on-going e-waste regimes and their focus on obsolescence. The reading of this paper questions how prior studies have understood how engineers approach fragility; how they experience sociotechnical vulnerabilities; whether they consider maintenance and repair work as anything other than the restoration of a pre-existing sociomaterial order; what kind of care for matter they engage, and which ethical and political orders they explore and develop.

With the second article, "Instances of Failures, Maintenance, and Repair in Smart Driving," Oana Stefana Mitrea questions the designers' point of view on failure and maintenance and repair when they design advanced driver assistance systems. The paper shows that, in "autonomous" car experiments, repair is perceived as complex technological activities aimed at monitoring and controlling humans, where the humans are considered major causes of failure. The alternative, i.e., seeing humans as helping technologies to achieve their full functionalities, is disregarded by designers. This case allows us to question engineering practices and the symmetrical or asymmetrical consideration of the components involved in the "distributed correction process." The paper shows the importance of considering the broad ecology of maintenance and repair in and after the design of new technologies and the ways that failures or weaknesses are attributed in sociotechnical structures.

The third article is an ethnomethodological study of the daily accomplishment of maintenance and repair in mundane interventions of building caretakers. In "Reassembling Repair: Of Maintenance Routine, Botched Jobs, and Situated Inquiry," Philippe Sormani, Ignaz Strebel, and Alain Bovet investigate maintenance and repair as a practical issue and the methods professionals (plumbers) and laypersons (tenants) engage to identify and fix particular housing problems. The authors show that repair work draws upon the coordination of different participants, including users, who negotiate and configure the site, the problem, the method, and the solution. This article

could help to question the ways engineers and other people involved in a situation interactively shape problems, methods, and acceptable solutions.

With the last article of this special issue, "Repair in Socio-Technical Systems: The Repair of a Machine Breakdown That Turned into the Repair of a Shop," Cynthia Colmellere addresses the issue of crisis in repair in the case of an industrial pharmaceutical plant. This paper examines the implications of a major breakdown occurring in a large sociotechnical network, the negotiations among actors trying to identify the need for repair, establish a reliable diagnosis, and designate the actors entitled to repair. Thus, the author shows maintenance and repair are distributed activities, embedded within an organizational framework, filled with power and social relations, technological issues, contingency management, and bricolage. The article raises questions regarding the visibility and recognition of the engagement of the different actors.

All these articles should stimulate empirical and theoretical investigation in engineering studies. However, in order to understand their real importance, it is worthwhile to situate them in a broader panorama of what is going on in MRS. In this regard, the introductory article of Jérôme Denis, Alessandro Mongili, and David Pontille is very helpful. The authors outline a genealogy of MRS in STS and point to a few main topics: sociomaterial ordering of places; material vulnerability and agency and the corresponding sociomaterial work; and innovation emerging from maintenance and repair practices.

Sociomaterial ordering of places

In STS, since the end of the 1970s, authors such as Bruno Latour and Steve Woolgar have stressed the literary and material side of the scientific work involved in the production of scientific facts.[20] Laboratory studies has tended to focus on the numerous documents, inscriptions, instruments, animals and chemical substances composing daily work in science. Following these material components in the scientific endeavor, ethnographic lab studies, but also social history of science have pointed to technicians and their role in terms of building, preparation, and maintenance of instruments, and in the arrangement and adjustment of experimental settings and the sociomaterial ordering of places.[21] These technicians, sometimes including large numbers of credentialed engineers in fields such as high energy physics, remain largely invisible in scientific accounts, even if they play a crucial role in design, calibration, and repair of instruments, as well as in fixing problems in order to avoid the failure of experiments and accidents. Caretaking, maintenance, and repair is a major concern for technical devices (e.g. glassware and pipette tips which must be cleaned, sterilized, and preserved from degradation). In life science, these technicians also take care of living organisms (e.g. a colony of chimpanzees with AIDS) and prepare them for experimental manipulation (e.g. their boronization before submitting them to neutron beams produced by a nuclear fission reactor in order to design and test a Boron Neutron Capture Therapy) or circulation within scientific cooperative networks.[22]

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[20] Latour and Woolgar, *Laboratory life*, 1979.

[21] Shapin and Schaffer, *Leviathan and the Air-Pump,* 1985; Barley and Bechky, "In the backrooms of science," 85–126.

[22] Vinck, "Accessing Material Culture by Following Intermediary Objects," 89-108.

We can identify many of these unnoticed workers as engineers, no matter if they were trained in engineering or if they are employed as research engineers after their PhD training in scientific disciplines that are normally not included within the scope of engineering studies (e.g., the life or social sciences, design methods, instrumental and experimental physical science). As MRS analyses within STS have shown, part of their work also consists of caretaking practices which requires organizational and boundary work between scientists (who produce new questions, hypotheses, and concepts) and the technical workers or research assistants that perform the protocols and manipulate instruments. In STS, the focus on maintenance and repair led to critiques of the disembodied representation of scientific thinking; these could be similar to critiques of genius innovators or creative engineers within engineering studies. Looking at these practices would help us to emphasize that engineering is also embodied in technical work, instruments and intermediary objects, and the distribution of work.[23]

MRS also points out that the division of work is related to a moral division of labor, with a distribution of prestige and credentials and some engineers charged with the "dirty work" while others receive all the recognition. Taking its inspiration from the interactionist sociology of work, these studies of science shed light on the invisible part of scientific and technical activities and have led to a new research field – *infrastructures studies* – which considers the role of mundane practices and sociomaterial ecologies that are often "taken-for-granted."[24]

This new research field further points to the dynamics of knowledge within occupational communities, such as the maintainers of photocopy machines, and that dynamic's resistance to attempts at rationalization due to the crucial role of material and bodily commitment.[25] MRS scholars have focused their attention on the cognitive processes of manual work and the work of invisible hands on which the information society depends.[26] This domain inherits ethnographic surveys such as Douglas Harper's *Working Knowledge* which investigated the repair shop of a do-it-yourself mechanic who repairs cars and farm machinery for his rural community.[27] His work is described as a material commitment of a thought that communicates with what this mechanic sees and manipulates in his workshop filled with tools and materials accumulated over time. The practical knowledge and DIY culture reported by Harper is seen as a form of resistance to industrial rationality. On the contrary, Julian Orr's survey of photocopier maintenance technicians reports on how they organize themselves, talk about their work, customers, employers, and machines, and how they share knowledge. Their skills and actions are not limited to the implementation of repair protocols. Furthermore, in the event of breakdowns, they initiate investigations to understand the problem, interpret the situation, and define a way of proceeding.

Material vulnerability and agency, and the corresponding sociomaterial work

The editors of the special issue of *Tecnoscienza* also point out that MRS expands the assumptions of interactionist sociology and ethnomethodology in considering social order not as "a given, but the vulnerable outcome of a ceaseless process which draws on

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[23] Vinck, "Accessing Material Culture by Following Intermediary Objects," 89-108; Vinck, "Taking intermediary objects and equipping work into account," 25-44.
[24] Star, "The ethnography of infrastructure," 381.
[25] Orr, *Talking About Machines*, 1996; Henke, "The mechanics of workplace order," 55–81.
[26] Denis and Pontille, "Workers of writing, materials of information," a-s.
[27] Harper, *Working Knowledge*, 1987.

mundane 'remedial interchanges' and on conversation repair."[28] The authors in MRS broaden the focus of conversation analysis from face-to-face interactions between humans to material commitments within a material environment. They also connect with actor-network theory and feminist approaches considering human and nonhuman relationships.[29] The sociomaterial order is then the result of the perpetual accomplishment emergent from everyday practices of material maintenance and repair which face instability and failures, but also different social worlds that enact various and sometimes conflicting normativities.[30]

Material fragility and vulnerability appear then to be key characteristics of the sociotechnical arrangements engineers, among others, are designing and building. Thus, scholars now concentrate on the material fragility of things, following authors like Annemarie Mol and Maria Puig de la Bellacasa (2011) in their consideration of the logic of care that "starts from decay and vulnerability instead of denying them" and the "constant necessity of taking care of them."[31] This new focus led to reconsidering technology and engineering work from a radically different point of view (e.g. what could be learned from engineers in charge of software security and reliability); far from being defined by their original design and their material inertia, technologies depend on a logic of care that engineering studies still need to explore.[32]

Innovation emerging from maintenance and repair practices

MRS also challenges the dominant representation of innovation as defined by invention and engineering design articulating a technology and its function via a top-down process in which the design and its materiality are determined, and in turn determine the diffusion of the novelty, its use, and its impact. Here, there is an opportunity for MRS to combine with STS and engineering studies, since those fields have already demonstrated that heterogeneous actors enter into an indeterminate technological dynamic with specific agendas and resources. Thus, the resulting technology, its dissemination, uses, and consequences are path-dependent. With MRS, we can add the further point that many actors engage themselves in maintenance and repair work in addition to the classical loci of design, diffusion, use, and impact. Some authors, such as Julian Orr and Steven Jackson, have even pointed to the challenge faced by maintainers and the inventive activity that challenge elicits.[33]

However, the innovations of maintainers largely go unnoticed. As Cyrus Mody has advocated, we can learn a lot about engineering by also studying crafting, user

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[28] Goffman, *Relations in Public*, 1971; Garfinkel, *Studies in Ethnomethodology*, 1967; Schegloff, "Repair after next turn," 1295–1345; Schegloff, Jefferson and Sacks, "The preference for self-correction," 361–382; Denis, Mongili, and Pontille, "Maintenance & Repair in Science and Technology Studies," 7.

[29] Haraway, *Simians, Cyborgs, and Women*, 1991.

[30] Gregson, Metcalfe and Crewe, "Practices of object maintenance and repair," 248–272.

[31] Connolly, "The 'new materialism' and the fragility of things," 399–412; Mol, *The Logic of Care*, 2008; Puig de la Bellacasa, "Matters of care in technoscience," 85–106; Jackson, "Rethinking repair," 2014; Denis and Pontille, "Material ordering," 338–367; Denis, Mongili, and Pontille, "Maintenance & Repair in Science and Technology Studies," 8.

[32] Barad, "Posthumanist performativity," 801–831; Ingold, "Materials against materiality," 1–16.

[33] Orr, *Talking About Machines*, 1996; Jackson, "Rethinking repair," 2014.

communities, and maintainers.[34] Because they face the fragility of technology, change components, make piece-by-piece adaptation, and learn from experimentation, they have to invent solutions – sometimes more so than designers who, under production pressure, often recycle and assemble existing solutions, avoiding taking too much risk with something new. They ensure the integration of off-the-shelf elements and ground their engineering in existing infrastructures, databases, and solution portfolios.[35] On the contrary, repair is often a site that implies articulation, reconfiguration, reassembling, and invention.[36] So, MRS, taking the breakdown of technological objects and vulnerability as a starting point, focuses on the challenge occurring in innovative sites that are otherwise overlooked.[37] Thus, the editors of the special issue of *Tecnoscienza* postulate that innovation occurs during maintenance and repair work because it is the place for challenging articulation, occurring every day, but often invisible, including where sociotechnical networks are extended toward unplanned situations, e.g. in the Global South.[38] The ordering processes appear not to be limited to design and development but also occur when people face vulnerabilities of the technology-in-use, crises and breakdowns. Then, through disassembling and reassembling, maintenance, and repair enact new realities.

Repair work ethnographies

With MRS, repair work has attracted the attention of many authors who associate it with different issues such as (the work of) care for things and people, sustainable development and reuse of products, ecological alternatives to the innovative *fuite en avant*, the (counter-)culture of tinkering, revolutionary or nostalgic "do it yourself," the conservative regression, or even a "broken world" way of thinking.[39] So far, though, published works in MRS have sometimes strayed far from the ethnographic work that initially focused attention on repair work in urban areas, at home or at work, sometimes falling instead within the field of infrastructure studies. From this point of view, the book edited by Ignaz Strebel, Alain Bovet and Philippe Sormani, is refreshing, as it offers the reader a beautiful collection of stimulating ethnographies on repair work.

Engineering studies would benefit from detours through ethnography

With *Repair Work Ethnographies: Revisiting Breakdown, Relocating Materiality*, Ignaz Strebel, Alain Bovet, and Philippe Sormani usefully stimulate reflection on disturbances of sociotechnical arrangements and on the work that is involved in repairing situations.[40] They articulate a materialistic vision of work with concern for social complications. They use Dewey's notion of inquiry to account for the situated work undertaken by the involved people to identify the problem and to fix it.[41] The series of

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[34] Mody, "New Editor-in-Chief Editorial," 8.
[35] Mongili, "Designers as users," 2014.
[36] The concept of articulation derived from interactionist approach. It is defined as a work done in real time to accommodate unanticipated contingencies. Bowker and Star, *Sorting Things Out*, 1999.
[37] Suchman, "Agency in Technology Design," 2009.
[38] Denis, Mongili, and Pontille, "Maintenance & Repair in Science and Technology Studies," 9.
[39] Jackson, "Rethinking repair," 221-239; Godin and Vinck, Critical studies of innovation, 2017.
[40] Strebel, Bovet and Sormani, *Repair work*, 2019.
[41] Dewey, *Logic: The theory of inquiry*, 1938.

ten case studies is very helpful to give a precise idea of what could be learned when going back to the field.

Repair Work Ethnographies makes reparation work an ordinary practice of particular interest not only for the study of science and technology in society, but also potentially for engineering studies. The authors account for what is important for the persons, in their ordinary practice, and the need to study it *in situ*, without confining them to the borders of a site. The book documents the inquiries people are conducting into the situation and its networks.

After an introductory chapter, "When Things Break Down," in which the authors situate the book with respect to the state of the art and identify the issues they highlight, in particular the notions of improvisation and inquiry, ethnographic case studies are grouped into three subsets according to whether they shed particular light on the settings, the networks, or the policies.

Settings: understanding in situ action when things break down

The first section presents three ethnographic and videographic studies inspired by pragmatism, ethnomethodology, and conversation and interaction analysis. They pay attention to the details of the repair work, the practical inquiries conducted by people, and the intelligibility which emerged from these inquiries.

Cornelius Schubert in his chapter titled “Repair Work as Inquiry and Improvisation: The Curious Case of Medical Practice” studies the inquiries nurses and medical doctors undertake into the causes and consequences of material equipment failures in hospitals. The author highlights the constitutive dimensions of the inquiry “for the sake of maintaining” and the improvisation of repairs based on redefined priorities *in situ* and in emergency, and combining routines and flexibility, partial repair work, and “ways of going on” without fixing the problem, as well as situated workarounds aimed at maintaining a stable order and re-purposing of available resources. The chapter shows that common sense inquiry and improvisation from the involved people demonstrate competent situational adjustments which require a high level of training. Improvisation then does not mean doing something without preparation, but requires knowledge and experience. Fixing problems appears to be very different than applying scientific or technological knowledge, but depends on them. This ethnographic investigation regarding nurses and medical doctors confronted by uncertainty and emergency would complement an analysis of engineers’ situated action on the spot when faced with many small incidents or a major failure. What could we mean by engaging in *in situ* inquiries and improvisation when we talk about engineering? Would that be different from what nurses and medical doctors do? Are there any specificities?

In his chapter “‘A Good Enough Fix’: Repair and Maintenance in Librarians’ Digitization Practice,” Moritz Fürst studies how librarians fight against the deterioration of books, which constitute cultural heritage and national identity, while making them available to the public. He reports on the work research librarians carry out on the properties of books, their materiality (including their digital materiality), and the care they take of them.[42] He shows they assess the vulnerability, the damage, the historical value of the objects, the conservation state of a specific document with respect to its place inside a collection as a cohesive whole. Regarding repair, librarians deploy a range of actions ranging from restoring the authenticity of the document to securing it

[42] Camus and Vinck, “Unfolding digital materiality,” 17-41.

with a "good enough" solution. This chapter also underlines the multiple enactments of an object leading to different versions of it, a consideration that differs from the idea of artifact stability. Similar situations could be encountered in engineering when a series of machines starts to differentiate according to their personal history of breakdowns and repair, their wear and tear and their maintenance; after a while, each machine gets a personality, which people sometimes document (like librarians with their cultural heritage) because this generates specific knowledge useful for further maintenance and repair. Thus, the question is also what is going on in engineering with these historical accounts and descriptions of machine "personality?" The ethnography of repair work of old books gives some fruitful indications for how to investigate more conventional engineering work with aging machines.

With the third chapter of this section, "Job Done: What Repair Does to Caretakers, Tenants and Their Flats," Alain Bovet and Ignaz Strebel study the work of building caretakers and focus attention on the different ways to closure of an intervention followed by residents when caretakers came to repair damaged things. The chapter, which is based on the same study as the article by Sormani, Strebel and Bovet discussed above, reports on the specific sociotechnical entanglements that are at play in these repairs; the damage situation concerns both things and people, thus repair also concerns both. Sometimes, repair thus means taking care of people even if the damaged things are not (really) fixed. This implies building caretakers (or engineers) have to inquire into both the materiality and sociality of situations. This point has a huge heuristic potential for engineering studies.

Networks: expanding the situation and the notion of inquiry

The volume's Networks section focuses on how human or material entities intervene in repair work, thereby expanding the situation into sometimes unexpected ramifications and assembling complex sociotechnical and institutional networks. These extensions emerge either from the fact that local resources are not sufficient to understand and solve breakdowns, thereby extending the inquiry, or from the distributed nature of the sociotechnical assembly to be repaired.

Lara Houston's ethnography in Uganda, "Mobile Phone Repair Knowledge in Downtown Kampala: Local and Trans-Local Circulations," discussed the global networks on which repair workers depend to access knowledge about constantly evolving technologies. She thus extends the notion of situated action. Focusing on repair knowledge, she sheds light on the process of learning repair connecting to ecologies of knowledge. She reflects on two main trans-local sites (online libraries of firmware files and a virtual community of technicians) where people search for information about breakdown (because a symptom can point towards multiple failures) and repair. Repair work requires knowing multiple devices, but also locating firmware files specific to each phone model and version, and tools to intervene. However, manufacturers share this information on design and engineering knowledge about how devices are designed to operate, and how they normatively behave when working, only with authorized workshops. Lara Houston shows how repair practice limits are at stake and how independent repair workers overcome the challenge of asymmetrical ecologies of knowledge engaging collaborative sharing and pooling of information about practices. She documents the extensive work of searching information and locating accounts of breakdown, and solutions that have been tried. The notions of extended situated action and asymmetrical ecologies of knowledge would be relevant to explore how engineers learn to repair machines and plants.

The ethnographic description of Jérôme Denis and David Pontille, "The Dance of Maintenance and the Dynamics of Urban Assemblages: The Daily (Re)Assemblage of Paris Subway Signs," investigates the maintenance of the signage of the Parisian metro. It reflects its role in the creation of an urban assembly and in the intelligibility of the network, which depends on these workers' concern for the visibility of the signs and their durability. What about the intelligibility of productive or other technological networks in which engineering is involved? With the chapter of Martin Tironi, "Inquiring and Experimenting with Urban Ecology: Pragmatist Lessons from Public Bicycle Repair," we can learn that maintenance and repair agents, looking at the Parisian transport network made up of self-service bicycles, carry out social and technical surveys on things as well as on users, places, and schedules. In a similar way, engineers in charge of information systems security look at users and organisation as well as software and machines. Such work would be relevant to document in order to get a better understand of engineering practices. Monitoring sociotechnical systems is a widespread activity which is overlooked by engineering studies.

The last chapter of this section presents Christophe Lejeune's participant observation study, "Interruptions, Lunch Talks, and Support Circles: An Ethnography of Collective Repair in Steam Locomotive Restoration," of a network of steam engine restoration enthusiasts. It examines the living and extensive nature of the social network involved in deliberations on the causes of failures and mutual assistance in devising solutions. Remote specialists, working in firms, also involve themselves to support these passionate fans of old machines. Steam engines are, however, not an exception; preserving and keeping alive old computers, software, video games, cars, and other machines also occupy technologists. They present interesting challenges for engineering regarding maintaining functional technologies while materials, components, and infrastructures are constantly evolving. Thus, the notion of inquiry would reveal an interesting variety of activities regarding such different extensive sociotechnical assemblages.

Politics: addressing issues of responsibility and participation in engineering

The Policy section brings together research that questions the politicized nature of restorative work. For instance, Christopher Henke's chapter, "Negotiating Repair: The Infrastructural Contexts of Practice and Power," shows that reparation takes place within a physical infrastructure and a social order where all kinds of question are at play: what should be repaired or not, by whom and how, whether it is well repaired or not, where the repair is satisfactory or not for the user. This sometimes leads to extensive negotiations and the uncovering – or shifting – of power relations. In "Inside the Bicycle: Repair Knowledge for All," Tim Dant studies DIY videos that circulate on the Internet and that offer repair as a way to empower users of technologies and to find alternatives to obsolescence. Reading these chapters raises questions about the politics of engineers' negotiation of technological priorities and solutions, and what would happen if non-engineers were empowered to look for alternative developments. Finally, in "Repair for the Masses? Gender and Care Work in the Fixers' Collective," Meg Young and Daniela Rosner look at the participatory culture of repair and the obstacles and discrimination that prevent women from playing an active role, a question already studied in engineering studies.[43]

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[43] Faulkner, "Doing gender in engineering workplace cultures," 3-18 and 169-189;

In the conclusion, "Repair as Transition: Time, Materiality, and Hope," Steven Jackson highlights tensions within the materialist turn, between vibrancy and precariousness, and questions the hope brought by reparation and the different perspective on old things it engages.

Strengths and limits of existing works

The strength of *Repair Work Ethnographies* lies not only in the richness and quality of its empirical work, but also in the conceptual questions it raises for engineering studies. Those questions range over the notions of inquiry and improvisation regarding the materiality and sociality of extended situations, the heuristic potential of material disruption, and the negotiation, participation, role differentiation, empowerment, and responsibility (allocation) that form the foundation of a sociomaterial order.

Almost all of the contributions concern repair situations in response to breakdowns that have occurred, i.e., disturbances in the sociomaterial order of things. These are singular disruptions, but they are sometimes so frequent that repair becomes a component of ordinary activity (healthcare personnel confronted with multiple breakdowns, the deteriorating archives, building caretakers in buildings with multiple inhabitants, mobile phone repair workers, etc.). This qualification raises the question of whether, in essence, repair activity is not also, simply, a component of any engineering activity with its flow of "small" ordinary failures. It would be useful to have a new look at engineering taking that component into account.

Repair Work Ethnographies has shown that the diagnosis of failure, repair, and the verification of results are opportunities to produce and transform knowledge. Such inquiry produces data, causal relationships, representations, and models of undetermined situations. Practical reasoning is sometimes the subject of explanation and deliberation, especially when a circle of people is involved in the process. Participants explore the properties of objects and materials, develop distinctions and categories, classify phenomena and objects, and integrate knowledge. They experiment, test hypotheses, read and interpret traces, verify data or results, and establish evaluation criteria. These cognitive activities could be investigated by engineering studies. The literature teaches us that incidents, accidents, and failures are valuable opportunities to learn about complex sociotechnical systems.[44] When it comes to repair, knowledge focuses on materials, their properties and behaviours, techniques and effective ways of doing things. It also concerns gestures, skills, dexterity, and the body. However, some of the studies presented in *Repair Work Ethnographies* highlight that they also concern the circumstances of the breakdown, and the situation in which the people affected find themselves. Jérôme Denis and David Pontille have shown that the staff of the transportation network operate on sociomaterial assemblies that allow for the intelligibility of the network. Martin Tironi has described the attention maintenance agents direct towards users. Christopher Henke concluded that reparation is also about social order, which means getting to know more about the social order is central to the practice of engineers and maintainers alike. Knowledge in repair work also concerns people, their relationships, their power relations, their relationship to organizations and society – all of which could be worthwhile to look at for engineering practices. Furthermore, repair work is oriented by an aim, namely to restore normality; but what this normality consists of should be an object of questioning.

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[44] Vinck, "Learning thanks to innovation failure," 221-239.

The special issue of *Tecnoscienza* and *Repair Work Ethnographies* should stimulate engineering studies to engage ethnographic, historical, sociological, and other empirical investigations into maintenance and repair in engineering practices. There is plenty of stimulating work for our research field to do on that topic.

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