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Maintenance, function, and malfunction in technology

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Abstract

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This paper takes a new look at the concept of maintenance through the notion of function and malfunction. I propose that different maintenance strategies have contrasting philosophical approaches about the nature of technology. I claim that the main difference between reactive and predictive maintenance is that the latter holds an underlying deterministic approach. On the one hand, the assumption behind predictive maintenance is that we can predict how technology works and even progresses, and because of this, we can predict when will malfunction appear. On the other hand, reactive maintenance is based on unpredictability, and it is led by the appearance of failure. Thus, the central notion in both strategies is the concept of malfunction.

By reverse-engineering different predictive maintenance and reactive maintenance strategies, I point out a different notion of malfunction in these two strategies. In order to highlight the philosophical nature of maintenance theories, first I discuss how failure has been identified within philosophy of technology, and present how malfunction is related to and connect both the concept of function and maintenance. Although different maintenance descriptions can be highly technical, I claim that each method has an underlying philosophical idea behind it.

1. Introduction

Technological devices are usually described by their particular function. Thus, human-made objects all have specific descriptions of what they do and how they do it. However, occasionally technical artefacts cannot achieve the purpose they were designed for, and malfunction (including failure, and gradual degradation) appears as time goes by. In order to prevent malfunction, thus to keep artefacts functional, many different maintenance strategies exist within technology. Maintenance as a practice could mean restoration to its original functionality of the artefact, preserving, repairing, or even improvement of an object. Often maintenance tends to be studied as a more technical question, rather than a practice with philosophical implications. However, the paper argues that we cannot separate underlying theoretical assumptions about the nature of technology from practical maintenance measurements.

Central to every maintenance strategy is the notion of malfunction. Essentially, human do maintenance to avoid malfunction, thus to prevent gradual degradation, breakage, or sudden failure, and to keep artefacts well functioning for a more extended time. Broadly speaking[1] , there are two[2] significant types of maintenance[3] strategies: reactive maintenance and preventive maintenance . These refer to, on the one hand, different stages of the life-cycle of artefacts, and on the other hand, to diverse methods of preventing malfunction and possible degradation. These major strategies hold different premises regarding the relationship between technology and malfunction.

What reflects particular engineering and design choices in a technological object? Who is responsible for malfunction and failure in a technosystem? What happens when components of an object one by one get replaced? This paper takes a new look at the concept of maintenance through the notion of function and malfunction. I claim that the main difference between reactive and predictive maintenance is that the latter holds a deterministic approach. On the one hand, the assumption behind predictive maintenance is that we can predict how technology works and even progresses, and because of this, we can predict when will malfunction appear. On the other hand, reactive maintenance is about unpredictability, and it is led by the appearance of failure. By reverse-engineering different predictive maintenance and reactive maintenance strategies, I point out a different notion of malfunction in these two strategies.

The aim of the paper is to point out that the philosophical assumptions behind maintenance strategies can lead to practical consequences. Thus, theoretical assumptions and pragmatic manners cannot be separated in maintenance. Because of this, the paper relies on both philosophical works and more technical descriptions of technology. I analyse the relationship between various maintenance strategies and the notion of malfunction, to highlight the connections between function, malfunction, and maintenance. I propose that different maintenance strategies have contrasting philosophical approaches about the nature of technology[4]. Although different maintenance descriptions can be highly technical, I claim that each method has an underlying philosophical idea behind it. What they all share is some type of assumption about the notion of malfunction, which I argue is a crucial factor in technology.

Preventive maintenance strategies have a deterministic approach towards technological trajectories, while reactive maintenance holds a less predictable notion about the nature of technology. Reactive and preventive approaches are inherent to maintenance strategies as they serve as the philosophical basis of any maintenance method. The paper examines these two strategies in order to trace back the specific relations between practical outcomes and philosophical implications in major maintenance attitudes.

[1]There are many different ways authors differentiate maintenance strategies. For the purpose of the paper, I use Mobley's categorisation consequently.

[2] There are subcategories as well, but for the sake of brevity I examine the two major categories of maintenance, as these two represents the two different basic assumptions about the nature of technology.

[3] Keith R. Mobley, Maintenance Fundamentals (Burlington: Elsevier, 2004).

[4] The already existing deterministic-indeterministic distinction is applied to maintenance in order to examine the theoretical assumptions behind various maintenance strategies.

In order to highlight the philosophical nature of maintenance theories, first I discuss how failure has been identified within philosophy of technology, and present how malfunction is related to and connect both the concept of function and maintenance. In the next section, I discuss the general goals of maintenance, and then the underlying assumptions behind reactive maintenance strategies. In the last section, I examine the deterministic approach behind preventive maintenance strategies.

2. The notion of failure

The fundamental concept in any maintenance theory is the notion of failure and malfunction, because the primary goal of maintenance is to restore or to keep functionality, thus to make and keep the technological device be able to perform its intended function. Although the term *intended function* has some controversies[5] around it, but for the purpose of this paper, I use *required function*[6] as the intended, designed function of a technological device, thus a feature created by engineers and designers. In case of malfunction, only this *required* aspect of functional features is relevant. This also means that the required function is an accessible feature, and the user and the designer agree[7] about what the device supposed to do. While a lot of different functional features can be attached to one artefact beside its required function that could all work simultaneously, malfunction as a concept is rather settled in this sense. Thus, if a person would keep adding new usages now and then to an object, for instance, practical purposes or symbolical meanings, that would not cause any problem in the artefact's structure, but only add new layers to it. Functional features are extensible, but these do not add malfunctional features to the object at the same time.

Preston argues that artefacts tipically need to be 'maintained in order to continue to perform their functions effectively'[8]. Although, sometimes performing the required function results in need for maintenance (e.g., routine car maintenance), and in other cases the material of the object will degrade even without use (e.g., certain materials get rusty), and thus maintenance needs to be done. Hence, even normal functioning can result in malfunction and need of maintenance.

Although, at first sight, failure – especially from a user's perspective - seems to be a simple concept, but in reality both in philosophy of technology and in engineering failure

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[5] For a new take on the concept of intended function see Public Artefacts, Intentions, and Norms in Maarten Franssen et al., Artefact Kinds: Ontology and the Human-Made World, Artefact Kinds: Ontology and the Human-Made World, 2014, 45–62, https://doi.org/10.1007/978-3-319-00801-1., and for another discussion of the problem see Beth Preston, A Philosophy of Material Culture. Action, Function, and Mind (New York: Routledge, 2013).

[6] Some authors, like Preston uses the terms proper and non-proper functions Preston, A Philosophy of Material Culture. Action, Function, and Mind.

[7] There are cases in which the user requires different purposes from the device than what the designer intended, and this causes malfunction and failure in the object, but for the sake of brevity in this article I do not go into details about these type of anomalies.

[8] Beth Preston, "Philosophical Theories of Artifact Function," in Philosophy of Science and Engineering Sciences, ed. Anthonie W.M. Meijers (Amsterdam: North Holland, Elsevier, 2009), 217.

as such is a wide-ranging phenomenon. Franssen gives a profound definition about malfunction that states that 'x is a malfunctioning K" expresses the normative fact that x has certain features f and that because of these features, if a person p wishes to achieve result of K-ing, then p has a reason not to use x for K-ing'[9]. Implementing maintenance into this formula would add a certain temporary element to the framework. Firstly, because a correct maintenance routine can prevent an artefact from being broken and stay a completely functioning object, e.g. car maintenance. Secondly, a maintenance routine in many cases can repair a failed artefact, or even improve the overall quality of a technological device, e.g. software maintenance. Thirdly, maintenance means in some cases transforming an object into a different artefact, e.g. old wooden furniture transformed into a new tool. In these cases, the person has a choice to use the object for an entirely different purpose.

These processes are led by the type of malfunction in each case. Indeed, there are clear cut cases in technology when something is considered a failure. Still, failure also can be partial, subtle[10] and unnoticed for an extended time. Birolini classifies [11] four causes of failure that maintenance has to account. The first is when an error is the symptom 'by which a failure is observed' [12]; the second is an intrinsic malfunction caused by human misuse. The third type accounts for different levels of failure, thus error of the device and failure at a higher level. The last kind is a physical process failing. A standard, less detailed differentiation[13] of failures is the ones caused by humans, and failures caused by design fail, aka equipment malfunction. As technology progresses, we tend to think that as designers are creating more and better equipment, structures, buildings and all kinds of technological devices, the chances of a disaster, failure, and accidents are getting lower and lower. However, the reality of our age cannot be further than this. Henry Petroski, author of *To Engineer is Human. The Role of Failure in Succesful Design* argues that in recent years there were many technological severe accidents, and he questions whether there is real technological progress at all [14].

The connection between failure and maintenance has been emphasised from a life-cycle perspective by many researchers. The lifespan and particular features of an artefact '(…) is now considered to be the designing engineer's concern, up till the final stages of the recycling and disposal of its components and materials, and the functional require-

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[9] Maarten Franssen, "The Normativity of Artefacts," Studies in History and Philosophy of Science Part A 37, no. 1 (2006): 47, https://doi.org/10.1016/j.shpsa.2005.12.006.

[10] In design, there is a strange phenomenon between malfunction and users. We tend to adapt quickly to uncomfortable situations and barely operating objects. For instance, our car has several failed parts, and as time goes by, there is more and more error. However, we get used to the – among other things - malfunctional airconditioning, the failed window electronics, and so on. As soon as a stranger arrives in the car, she immediately notices all the failure in the vehicle.

[11] A Birolini, Reliability Engineering: Theory and Practice (Springer, 1999), 3–4.

[12] Birolini, 3.

[13] Indeed, there is also failure caused by nature, such as tornados and extreme weather conditions, but this aspect of the topics is skipped here for the sake of brevity.

[14] Henry Petroski, To Engineer Is Human: The Role of Failure in Successful Design (New York: Vintage Books, 1992), 2, https://doi.org/10.1086/354258.

ments of any device should reflect this.'[15] Thus, the responsibility of the engineer does not end with creating and selling a design but includes the afterlife of the object, including the maintenance instructions as well.

3. Maintenance types

According to the European Standard, a basic definition of maintenance is that it is a 'combination of all technical, administrative and managerial actions during the life-cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function'. [16] Malfunction refers to, on the one hand, retaining a technical artefact in a preferred state before any type of malfunction occurs, and on the other hand, recover the object after malfunction occurred. Required function refers to the function or combination of functions of an item which are considered necessary to provide a given service connected to the artefact. Thus, required functions specify what activities the object must be able to fulfil.

The main goals of maintenance are (1) the reduction of the chances of failure, (2) to give information about the object's ideal use, and (3) about the stage of the life-cycle of the artefact, (4) to minimise the amount of time spent with inactivity because of failure occurrence, (5) to be cost-effective, and (6) to make the best out of an artefact's performance. Namely, to have a technical device operating for as long as possible. Altough sometimes conflicting, these aims are always densely interwoven, especially in the case of sophisticated devices and technological systems. 'The complexity of a device will affect how difficult it will be to maintain or repair it, and ease of maintenance or low repair costs are often functional requirements.' [17]

Maintenance can be divided into many different[18] categories [19], for example, *online versus on site* maintenance. It can also be approached from a professional and a non-professional, thus from a user's perspective. In this paper, I use the two traditional broad maintenance categories: reactive and preventive, maintenance for the sake of brevity. These diverse types of maintenance strategies refer to different approaches towards artefacts, and also to practices aimed at different life stages of objects.

[15] Ibo Franssen, Maarten, Lokhorst, Gert-Jan and van de Poel, "'Philosophy of Technology', The Stanford Encyclopedia of Philosophy (Fall 2018 Edition)," 2018, https://plato.stanford.edu/entries/technology/.
[16] EN 13306:2010, "European Standard – Maintenance Terminology," 2010, 5.
[17] Franssen, Maarten, Lokhorst, Gert-Jan and van de Poel, "'Philosophy of Technology', The Stanford Encyclopedia of Philosophy (Fall 2018 Edition)."
[18] See for instance Neil Bloom, Reliability Centered Maintenance. Implementation Made Simple (McGraw-Hill Companies, 2006)., Luca Del Frate, "Failure of Engineering Artifacts: A Life Cycle Approach," Science and Engineering Ethics, 2013, 913–44, https://doi.org/10.1007/s11948-012-9360-0.
[19] Mobley, Maintenance Fundamentals.

3.1. Reactive Maintenance

Mobley calls the reactive approach run-to-failure management, [20] as the logic of it is just to react and try to solve the problem when disaster and failure appear. This method is the oldest of maintenance strategies. However, in practice, this is a no-maintenance-maintenance, as this approach does not require any planning beforehand, unlike the rest of the maintenance methods. Proven that reactive maintenance is the most expensive [21] of all the maintenance strategies, it runs counterintuitive that it is still widely used in technology. There are many problems with reactive maintenance. The first issue is the cost-benefit ratio: in these terms, reactive maintenance is surprisingly inadequate. 'The major expenses associated with this type of maintenance management are (1) high spare parts inventory cost, (2) high overtime labour costs, (3) high machine downtime, and (4) low product availability.' [22] Spare parts are crucial as reactive maintenance supposed to be prepared for different possible malfunctional occurrences. In the case of reactive maintenance, the type of failure determines how we treat a technological device and what kind of actions have to be done.

How can we reverse engineer reactive maintenance strategies? As opposed to preventive maintenance, reactive maintenance is driven by malfunction, meaning that reactive maintenance only happens once failure appeared. It implies a more chaotic, less deterministic approach towards technology for two reasons. The first is the intuitive premise that nobody would let failure happen if he knows that it will happen for sure. That is to say, if an engineer knows the chances of a malfunctional occurrence within a technological system, and the possibilities are quite high, it is more than likely that he would want to prevent any failure before it happens. Reactive maintenance exists only because in many cases, humans just cannot predict what will happen with a technological invention, or more precisely how technology will progress. The other reason behind reactive maintenance is as simple as it gets: the lack of detailed knowledge about technology, interfering throughout systems, or in some cases about the properties of particular materials. With reactive maintenance, the term can be divided into two different aspects of malfunctional occurrences: (1) failure caused by humans, and (2) failure caused by different actors (e.g. natural disasters).

The first type of malfunction can also be subcategorised: failure caused by the engineer (designer), and the ones caused by users[23]. They all essentially form risk management. However, there are cases when different levels of responsibility and failure are intertwined. This happened with one of history's most severe disasters, the Chernobyl Nuclear Power Plant accident. In that case, engineers were planning to do maintenance. Still, before that, they were running tests 'to study the possibility of utilisation of the mechanical energy of a turbogenerator after the cut-off of steam supply, in order to ensure

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[20] Mobley, 2.

[21] Laura Swanson, "Linking Maintenance Strategies to Performance," International Journal of Production Economics 70, no. 3 (2001): 238, https://doi.org/10.1016/S0925-5273(00)00067-0.

[22] Mobley, Maintenance Fundamentals, 2.

[23] Another example of reactive maintenance is when the actual design of an artefact dictates how maintenance can be done, for instance with Apple products.

the power requirements in a case of a power failure' [24]. According to various studies, the cause of the Chernobyl disaster is varied: on the one hand, it caused by design mistakes of the reactor and misinformation about safety regulations, and on the other hand, mistakes made during the testing of the generators [25] by inadequately trained staff. In this case, test before even doing the real maintenance caused a disaster that requested quick reactive strategies from the team.

3.2. Preventive maintenance practices and their implications

The primary characteristic of preventive maintenance strategies[26] is that they are all time-driven and have a specific deterministic character. They need to be done at fixed intervals that are based on particular criteria, let it be daily, monthly, yearly maintenance, or any other fixed range. The point of preventive maintenance is to decrease the probability of error, failure, or any kind of malfunctional occurrence of a yet functioning item. The basic idea behind preventive maintenance is that there is a sometimes undetectable 'cause-and-effect relationship between scheduled maintenance and operating reliability' [27]. This assumption is based on two hypotheses: the first one is the intuitive belief that the older an object gets, the chances are higher of failure, and the second is that replacing older parts of an object would prevent failure.

Predictive maintenance is a specific type of preventive maintenance strategies. The most commonly used definition of predictive maintenance is the following: 'condition-based maintenance carried out following a forecast derived from repeated analysis or known characteristic and evaluation of the significant parameters of the degradation of the item.'[28] Predictive maintenance can be described as a means of improving systems and particular devices, and in general greater technosystems. Usually, predictive maintenance consists of different tools[29] that produces factual data on technology, and in many cases, predictive maintenance prevents sudden, unscheduled breakdowns of machines [30]. The underlying philosophical assumption behind this maintenance strategy is that it is possible to detect malfunction before it occurs. Thus, if objects are being analysed regularly, the chances of failure can be reduced. A well-established predictive maintenance

[24] Mikhail V. Malko, "The Chernobyl Reactor. Design Features and Reasons for Accident," 2016, 16–17, https://inis.iaea.org/search/search.aspx?orig_q=RN:48080457.

[25] Malko, 11.

[26] NASA also uses the so-called Reliability-Centered Maintenance that encompasses PM, Predictive Testing and Inspection, Proactive Maintenance and Repair at the same time in order to minimise the chances of malfunction. The discussion of this strategy is skipped here for the sake of brevity. For a detailed description, see NASA Reliability-Centered Maintenance Guide for Facilities and Collateral Equipment.

[27] "NASA Reliability-Centered Maintenance Guide for Facilities and Collateral Equipment," 2008, 2–1.

[28] 13306:2010, "European Standard – Maintenance Terminology," 12.

[29] Mobley claims that there are five techniques of predictive maintenance: vibration monitoring, process parameter monitoring, thermography, tribology, and visual inspection. The analysis of these more technical questions is skipped in this paper.

[30] Mobley, Maintenance Fundamentals, 5.

strategy 'utilises the most cost-effective techniques in a combination to obtain the condition of critical equipment.' [31] The data gathered through the different monitoring activities provide sufficient information about the state of the device.

Contrary to reactive maintenance practices, the underlying assumption behind preventive maintenance strategies is a deterministic approach. This is based on the idea that technology as a system and the advancement of particular devices hold trajectories, and humans can know and manipulate these paths for the better. However, technology is continuously shaped by influences from different actors, such as users, designers, and economic factors. The effects of these different spheres are profoundly interwoven. Broadly speaking, in the field of philosophy of technology[32] researchers divided technological changes into two different categories: technology-push, and demand-pull approach. The first emphasises social forces as crucial factors in technological change, while the latter defines technology as an autonomous entity. Although, Dosi claimed that these categories are inadequate for understanding and explaining technology, and he argued for a different approach based on scientific paradigms [33].

Inspired by Thomas Kuhn's *The Structure of Scientific Revolutions*. Dosi explained that technology has particular trajectories, similar to "normal science" period in Kuhn's theory and that these trajectories also define in which direction science progresses. Dosi described technological trajectories as a 'cluster of possible technological directions whose outer boundaries are defined by the nature of the paradigm itself' [34], meaning that there can be stronger and weaker trajectories as well as complementarities between trajectories. Dosi's framework has strong instrumental values in contextualising technological problems. Predictive maintenance strategies often imply a determined trajectory to technological progress. In many cases, they do not count with random factors such as in the case of the Chernobyl Nuclear Power Plant accident. Nearby technological trajectories can diverge or slowly move away from each other because of several reasons. Are trajectories a real feature of technology, or they only have instrumental value?

Summary

Even though malfunction is a crucial feature of technology, its role and status in particular devices and higher systems are still unclear. What causes is that in the majority of technological failures, engineers and average users can only retrospectively investigate the nature

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[1] Gustav Fredriksson and Hanna Larsson, "An Analysis of Maintenance Strategies and Development of a Model for Strategy Formulation – A Case Study" (CHALMERS UNIVERSITY OF TECHNOLOGY, 2012), 31.

[32] For a review and bibliometric analysis of the role of demand in technology and innovation see Technology Push and Demand Pull Perspectives in Innovation Studies: Current Findings and Future Research Directions Giada Di Stefano, Alfonso Gambardella, and Gianmario Verona, "Technology Push and Demand Pull Perspectives in Innovation Studies: Current Findings and Future Research Directions," Research Policy 41, no. 8 (2012): 1283–95, https://doi.org/10.1016/j.respol .2012.03.021.

[33] Giovanni Dosi, "Technological Paradigms and Technological Trajectories," Research Policy 11, no. 3 (1982): 147–62, https://doi.org/10.1057/978-1-349-94848-2_733-1.

[34] Dosi, 154.

of certain malfunctional occurrences. With new technologies, new failures appear as well, and in many cases detecting the exact cause of failure is a tricky thing. Among many other technological error[35], software engineering is one of the most common sources of failure nowadays. The goal of the paper is to point out that different philosophical assumptions behind maintenance strategies can have practical consequences as well. The effects of the deterministic nature of preventive maintenance strategies are that it can easily lead to simplistic notions of technology. Because of this, it can overlook serious problems concerning artefacts.

In this paper, I claim that the main difference between reactive and predictive maintenance is that the latter hold a deterministic approach. On the one hand, the assumption behind predictive maintenance is that we can predict how technology works and even progresses. Because of this, we can predict when will malfunction appear. On the other hand, reactive maintenance is about unpredictability, and it is led by the appearance of malfunction. By reverse-engineering different predictive maintenance and reactive maintenance strategies, I point out a different notion of malfunction in these two strategies. Identifying theoretical assumptions behind maintenance strategies can help reduce the chances of failure, and also to lay the foundations of a comprehensive understanding of the notion of malfunction.

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[35] For a selection of failures in technology in 2018, see The Biggest IT Failures of 2018 Robert N. Charette, "The Biggest IT Failures of 2018," 2018.

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