# Chapter 10
# On Uncertainty in Ethics and Technology

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**Abstract** The article aims to examine uncertainty in technology development and its subsequent ramifications for ethical technology assessment. Although uncertainty is a pivotal feature of complex technologies, its importance has not yet been fully appreciated within the field of ethics. Hence, the purpose of this paper is to study uncertainty in technology development and its consequences for ethics. Going on the insight of other scientific disciplines such as environmental studies or economics the concept of uncertainty is disentangled and a typology of uncertainty is proposed and introduced to ethical theory. The uncertainty typology results in a series of questions with regard to the collection of information about the object of assessment (i.e. complex technologies and their development) and the framework of assessment (i.e. ethical theory and its practical aim of guiding the assessment of technology development). What is more, the uncertainty surrounding technology development has ramifications for ethical technology assessment. Any attempt to provide an account of ethics of technology may seem daunting given the fact of uncertainty, because uncertainty results in a lack of information to guide our moral decision-making. In order to deal legitimately with uncertainty, I claim that any adequate ethics of technology needs to account for *both* substance and procedure. The paper concludes with requirements for any future ethics of technology under uncertainty.

**Keywords** Technology development · Technological innovation · Uncertainty · Typology of uncertainty · Uncertainty management · Ethical technology assessment

## 10.1 Introduction

Going on the insight of various scientific disciplines, such as economics and environmental studies, I will argue that uncertainty is a pivotal concept in many contemporary debates, notably that of technology development and its ethical evaluation.

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However, within the field of moral philosophy the concept of uncertainty is a notion not fully explored and scrutinised. This is noteworthy as we observe that technology has become increasingly more complex, pervades nearly every sphere of life, and involves far-reaching and often unforeseen and unanticipated consequences for human beings and the environment. Consider, for instance, environmental concerns like non-degradable plastics or carbon dioxide emissions; IT-related issues such as the influence of the Internet on communication and social relations; issues with regard to surveillance-enabling technologies like CCTV and RFID. Another example is the technological programme of 'Towards Ultra-fast Communication' (hereafter TUC), which aims at improving and increasing the speed of data transmission. (See Chapter 2) The speed of data transmission, which has increased over the past years, is however determined and constrained by aspects like the speed of the client, the capacity and the use of the data line, the routing, and the speed of the server. With current technologies sending packets of information over the Internet is rather unproblematic. However, two trends might compromise Internet traffic. First, there is an increase in data transmission over the Internet as new possibilities open up, such as streaming media and 3D movies. Second, the number of people engaging on the Internet is still significantly growing. For example, Africa, the Middle East, and Asia, which are in terms of percentage regions with the lowest penetration of Internet usage but have enormous populations, display a usage growth between 2000 and 2007 of 643, 495, and 282% respectively. (Internet World Stats, 2007). These trends will ultimately impact on the capacity of the Internet. While sending packets of information over the Internet at very high speed is unproblematic with current technologies, restraining factors are the nodes at which information is processed. At this moment these nodes are incapable of processing information optically. These nodes route information electronically, which is significantly slower than photonics. In order to overcome future problems of congestion engineers have engaged in this technological program of developing optical switches to provide for ultra-fast communication in the future without congestion. TUC aims at creating faster and more effective use of information and communication networks. This endeavour does not seem risky in itself or to raise any moral dilemmas at the outset. Nevertheless, what about future applications or consequences of such a complex technology? The issues mentioned, which surround complex technology development, have led to many a debate on the desirability and moral acceptability of new, complex, and possibly disadvantageous or even catastrophic technologies. Since the issue of uncertainty is underappreciated in such debates, the question of how we should deal ethically with new, uncertain technology developments is the focal point of this scrutiny.

The aim of this paper is to study uncertainty in technology development and its subsequent ramifications for ethical technology assessment. Uncertainty is to be distinguished from risk. Risk, which I leave outside this paper, refers to situations in which probabilities can be assigned to known possible future states of the world. Conversely, uncertainty has to do with situations in which probabilities cannot be attributed to future states, which are often indeterminate themselves. In this paper I will argue for the necessity of ethics to reflect upon uncertainty. This will involve a theoretical analysis, conceptualising uncertainty via a typology formulated in other scientific disciplines. I will then show that this scrutiny is insightful for the debate on ethics of technology. Uncertainty is paramount, particularly in the field of technology development and its ethical assessment. Although the typology also applies to existing complex technologies, the paper focuses on the specific endeavour of technology development. The uncertainty surrounding technology development has ramifications for the ethical assessment. Any attempt to provide an account of ethics of technology might seem daunting given the fact of uncertainty, because uncertainty results in a lack of information to guide our moral decision-making. In order to deal legitimately with uncertainty, I claim that any adequate ethics of technology needs to account for *both* substance and procedure.

In Section 10.2 I attend to the underlying question of how to deal ethically with complex, uncertain technology developments. This brings to the front fundamental questions about ethics, ethical theory, and its aims. Section 10.3 is concerned with uncertainty in the field of technology development. Uncertainty within technology development relates to the characteristics of complex technology development, which include among other things multi-agency, opaque R&D trajectories, and substantial indeterminacy regarding use and impact. The complexity and uncertainty of developments stand out as special compared to ideal-typical cases in ethics that are straightforward, linear-causal, unequivocal, and calculable. As a systematic reflection on uncertainty is lacking in ethics of technology, I discuss and introduce in Section 10.4 a typology of uncertainty that differentiates between its nature, levels, and locations. In Section 10.5 I argue that by introducing this typology into the field of technology development we arrive at a clearer picture of uncertainty in technology development and its ethical assessment. The different dimensions of the typology prove to be insightful for working towards a methodology for morally evaluating complex technology developments. In the concluding Section 10.6 these insights will facilitate the identification of problems and requirements for any adequate ethics of technology.

## 10.2 The Aims and Adequacy of Ethics

The rationale behind this scrutiny is the difficult issue of how to deal with complex, new technologies that are surrounded by uncertainty. This difficulty underlies the practical and wide-ranging question 'How are we able to deal proactively with complex technology developments that are characterised by uncertainty from an ethical perspective?' that I take to be one into the nature and scope of ethical theory. This question can be decomposed into several subquestions of which I will address two. First, the question, which I only briefly touch upon, is a research into ethical theory as a philosophical discipline that aims at discovering, justifying, and applying right-making criteria. What are the nature and scope of these right-making criteria within ethical theory? Are these criteria coherently presented and how are they accounted for and justified? How are the principles related to the object of which they purport to say something about? The object of evaluation pertains to the second subquestion and entails research into the uncertainty of new and emerging technologies. In this paper I concentrate on the second question, but I will commence with briefly reflecting upon the first question.

The central question is one that goes straight to the heart of the nature of ethical theory and raises questions on different levels as it regards the *question of what agents which interests should be taken and how this can be justified*. With Timmons I distinguish two complementary and necessary aims of ethical theorising that make up for the *adequacy* of ethical theory – the theoretical and the practical aim. Concerning the first aim, I recognise, in accordance with Gewirth, that the 'most important and difficult problem of philosophical ethics is whether a substantive moral principle can be rationally justified.' (1978, ix) The *theoretical aim* of the justification of right-making criteria generates three central questions: the distributive, the substantive, and the authoritative question. (Gewirth, 1978, 3) The distributive question relates to the question of whose interests other than and in addition to their own agents should consider. Any ethical theory should have a justified theory with regard to what agents they include in the realm of relevant agents of which account should be taken. Questions in this area concern issues such as whether 'I' am the only agent whose interests count as egoists will argue, whether foetuses have moral status, or whether we should include animals in the domain of relevant agents. The substantive question concerns the issue of which interests of relevant agents account should be taken. Do all preferences of relevant agents count, only particular preferences, or perhaps even none? The authoritative question of moral philosophy aims at tackling the question why one should be moral, in which the 'should' refers to a criterion other than the criterion of moral rightness whose obligatoriness is in question. (Gewirth, 1978, 3) What is more, with Parfit I agree that we need reason-giving facts for following certain rules and requirements set forth by an ethical theory. (Parfit, 2006, 72) Where there are no reasons given *why* we are obligated and required to follow certain moral rules, we will be reluctant to give them priority over other considerations, even non-moral considerations. 'To be able to make significant claims about the relative importance of moral requirements and requirements of [. . .] other kinds, we need some non-moral, neutral criterion.' (Parfit, 2006, 73)

The second level pertains to what Timmons calls the *practical aim* of ethics, namely applying right-making criteria to judge and evaluate persons, actions, state of affairs, and the like (Timmons, 2002, 3). It aims at demonstrating *how* these right-making criteria are practicable in moral issues, which is different from us being able *to* apply these criteria, for instance, under conditions of uncertainty. The latter entails, as I argued elsewhere, that the adequacy of ethical theory is independent from a contingent aspect or circumstances such as the uncertainty of technology developments (See, further, Sollie, 2008). For an adequate theory there is no problem *how* to apply right-making criteria, but there may be a *problem for us to apply* these criteria, which is ultimately a problem of our epistemic indeterminacy, our limited knowledge and capabilities. So, it is one thing — although certainly not a minor and easy thing — to satisfy the theoretical objective of ethical theory by forwarding and justifying right-making criteria, yet it is quite another thing to meet the practical aim of ethics by guiding correct moral reasoning. According to Gewirth, ‘an ethical theory should not only set forth a justified principle that grounds moral rights and duties; it should also show how the principle serves to resolve moral conflicts, including conflicts between the duties it grounds.’ (Gewirth, 1984, 249) Both the requirements of justification and practicability need to be satisfied for an ethical theory to be considered as adequate.

The application of right-making criteria, often formulated as principles such as the Kantian Categorical imperative or the Consequentialist principle of utility, is not without problems as I will demonstrate more extensively below. For the present purpose, it suffices to state two main issues in view of the practicability requirement. First, one of the aspects that I will highlight at this point concerns the disagreement between proponents of different ethical theories. They may disagree about the legitimacy of the right-making criteria forwarded in a theory. How should we deal with the fact that agents may hold diverging beliefs about morality when trying to resolve moral issues in practice? This issue bears directly on the theoretical objective of ethical theory, namely the underlying justification of right-making criteria. In this sense the practical aim is dependent on the theoretical aim. Second, even if all agents endorse one particular ethical theory, this theory still may leave room for conflicting requirements or duties within that specific moral framework. For this reason, any adequate ethical theory must specify *how* it will adjudicate such theory-intrinsic conflicts.

To sum up, any adequate ethical theory should be able to deliver the theoretical aim of ethics by answering the authoritative, distributive, and substantive question as well as the practical aim of guiding correct moral reasoning by demonstrating *how* right-making criteria apply. The *adequacy* of ethical theories is measured by the extent in which both the theoretical and practical objectives are satisfied. *Both* requirements of justification and practicability need to be satisfied for an ethical theory to be considered as adequate.

## 10.3 Complex Technology Development

In this section I take up the issue of uncertainty that surrounds many new and complex technology developments. Uncertainty is a concept less scrutinised in ethics than risk, of which exists an extensive literature. Despite the apparent reluctance to address this question, uncertainty proves to be a matter central to many a debate on ethics and technology.

Complex technology developments are characterised by uncertainty. Uncertainty seems to be reducible to empirical observations such as the changing nature of technology development over the course of history or the complex development trajectories with unpredictable outcomes. Without presenting a historical perspective on technology development, it is not unreasonable to argue that contemporary technology development is fundamentally of a more complex nature than in the past. One of the main reasons is that in the past technologies were to a great extent within human comprehension. Technology was related to core human actions and its main purpose was to relieve or better coordinate certain human activities. Technologies merely comprised of the same activities as humans were concerned with, but technologies made these easier, lighter, faster, and so on. For example, the wheel enabled people to travel or transport things faster and more easily; a hoisting apparatus to move heavy objects with less force; or, windmills to manufacture certain products more efficiently and faster. Without attempting to trace a specific point in history, over time technology development became more complex. TUC, for instance, is a difficult to comprehend technological program as it starts off from fundamental research on materials to discover the material or constellation of materials that best suit the goal of switching light optically. New scientific discoveries, such as Newtonian mechanics, molecular physics, and quantum mechanics, definitely contributed to this change and opened up the possibilities for new sorts of technologies, which are more complex of nature and exceeding human measure and intellect.

The most important factors of uncertainty that surround technology development pertain to the unpredictable, unforeseen, and unanticipated nature of complex technology development trajectories, that is from research and development to the subsequent user application and consequences of the artefacts (See Healy 2006; Tenner, 1996; Brown et al., 2000; Cilliers, 2005; Verbeek and Slob, 2006; Von Schomberg, 2007). Telling examples are the Internet (developed for decentralised and secluded military and academic information transfer and now utilised as a multipurpose worldwide network), the telephone (originally designed for business purposes — Bell could not imagine people having and using such a noisy apparatus at home — and now every single person has a cell phone and can be contacted anywhere and anytime), or SMS (developed for telemetric purposes, i.e. the measuring and reporting of user information to providers and/or designers, while it is now being used by people to text messages to each other). The uncertainty arising from unpredictable, unforeseen, and unanticipated nature of technology development has many reasons (Sollie, 2005). To begin with, the examples indicate that, while technology is designed for specific purposes, it often ends up being used for completely different activities. This also relates to what Moor (1985, 269) has coined the logical malleability of technology; technology can be shaped to do any activity that can be characterised in terms of logical operations. Moreover, the development trajectories are often opaque (see, for instance, Brey, 2001, 52) for a variety of reasons. To begin with, there is the fact of multi-agency. The research and development trajectories consist of many agents from different disciplines who are all involved in various parts of the process. Each individual phase of development might be so recondite that other agents cannot fully comprehend what has been done in previous phases or what will be done in next phases. Not infrequently, agents take over products or artefacts from previous phases as a black box, i.e. a closed system of a technological artefact, which they then continue to work on. Next, uncertainty also arises from the unprecedented pace of technological developments (See, for instance, Johnson, 1997, or Osborn, 2002, 37). There is a continuous drive from science, the market, politics, and so on, to develop new and improve on existing technologies; for instance to produce faster technologies, to increase efficiency, or to innovate and introduce new technologies. This technological race obstructs our trying to react adequately to and to get grip on these developments. Moreover, uncertainty is triggered by the scale on which technology is being developed; global and international developments interact with local and national developments. These are complex processes in which influence is exerted on different levels, in which local and global treaties and laws play important roles; not to mention cultural and moral pluralism.

These developments and observations are also what David Collingridge infers in his Control Dilemma: 'attempting to control a technology is difficult, and not rarely impossible, because during its early stages, when it can be controlled, not enough can be known about its harmful social consequences to warrant controlling its development; but by the time these consequences are apparent, control has become costly and slow.' (1980, 19) In the early phase, during the design and development of a specific technology, it is still possible to control and steer this development. Controlling and steering necessarily presupposes relevant information on for instance application, consequences, and impact. However, the information on basis of which one can perform a (moral) evaluation and subsequently steer the technology is lacking in early phases of development. Only in later phases of technology development and during its embedding and stabilising in society it is possible to collect relevant information on the application and consequences, but at that point it is extremely difficult and expensive to adjust an already existing and embedded technology.

A contemporary example of uncertainty of technology development concerns nanotechnology, which is an umbrella term for the fabrication of devices on atomic and molecular scale. Nanotechnology is an interdisciplinary field of disciplines like physics, engineering, chemistry, biology and computer science. It is a trumpeted area of technology development that is accompanied by huge promises such as powerful quantum computers and long term life preservation. It is nevertheless also fraught with uncertainty. As nanotechnology is in its early phase, 'it is still quite uncertain which options will be developed and which applications can and will be materialized. Nanotechnology is mostly promise, and sometimes pure speculation.' (Rip, 2006, 270) '[T]he future science and technology is still uncertain, let alone the future world in which these functions may have effects.' (Rip, 2006, 275) It is far from certain what will be possible in nanotechnology, which applications will be developed, how they will be used, and how they will impact on human beings and the environment. Nanotechnology is a particularly illustrative example of an uncertain technology development because of its complexity, its current merely speculative state, our inability to predict future applications and consequences, and the connected fears of catastrophic scenarios that it is accompanied by. (See for such possible applications and catastrophic scenarios, e.g., Weckert and Moor, 2006 and Clarke, 2005).

To conclude, many new technologies are surrounded by uncertainty due to opacity, complexity, multi-agency, long development trajectories, orientation at the future, global character, impact, and the fact that technology often shifts in application. These reasons contribute to the fact that uncertainty is an essential concept in modern, complex technology development and, consequently, it needs serious attention from those involved in ethics of technology.

## 10.4 A Typology of Uncertainty

Although uncertainty is central to complex technology, the question of what uncertainty entails is still unexplored. Over the course of the past decades, the concept of uncertainty has gained a lot of attention in many different scientific disciplines, like economics and environmental, management, and innovation studies. Numerous articles and books have been published trying to describe and conceptualise the concept of uncertainty. For example, one of the first major contributions to the study of uncertainty was by Frank Knight trying to incorporate risk and uncertainty into economical theory in his seminal 1921 *Risk, Uncertainty, and Profit*. In moral philosophy or, more specifically, ethics of technology, the importance and relevance of uncertainty for its discipline has not yet been fully recognized. Uncertainty has a rather new and un(der)developed position within ethical theorising. Ethical theories often put forward ideal-typical cases to show how these right-making criteria can be applied in the practice. The ideal-typical cases are generally linear-causal consisting of well-defined borders, a small and fixed number of stakeholders, and so on. For example, is it morally justified to steal bread to survive when poor? Should I kill one Indian to rescue nineteen others? Is it morally permitted to treat a mother with uterine cancer if this results in the loss of her embryo – when not treating her would result in the death of both? Is it allowed to steal medicine from an apothecary to save my sick mother? What these classical cases have in common is that they are rather surveyable. The cases consist of rational, acting, and evaluating agents that are capable of overlooking, calculating, and evaluating from a normative framework a limited subset of future states of the world of which one has substantial information regarding the range of possible actions and their consequences.

Although ideal-typical cases are well suited to show the adequacy of an ethical theory for guiding our moral reasoning in practice, this is only so theoretically. Complex, real life cases are of a different, more intricate nature and are misrepresented if treated as ideal-typical and linear-causal. As a result, ethical theories should be more robust and be tested against more complex issues. More specifically, coinciding the advent of complex modern technologies, uncertainty entered the domain of ethics when people found themselves called upon to morally evaluate these developments. If ethics aims at evaluating technology (not only retrospectively, but also proactively), then it has to account for the inherent uncertainty of technology development. This concerns an intrinsic problematic aspect of ethical theory, namely the application of theory to real life cases, which are always contextual and exceed the complexity and linearity of scholarly cases. I argue that, whereas many traditional theories have presented right-making criteria (e.g. principles) that were well suited for the assessment of relative well-calculable, unequivocal, and transparent objects of evaluation, complex technologies thwart both the practical and theoretical aims to a greater extent, because of the features surrounding complex technology development. Complex technology developments do not suffice the descriptions of traditional, ideal-typical ethical cases due to the uncertainty of future consequences, impacts, and applications. The following complex questions should be dealt with. Who are the agents that are involved in a particular technology development? What are the consequences of particular decisions during the R&D trajectories? What are possible applications and consequences of new technologies? Who is affected and to what extent? What status do stakeholder values and opinions have and how are these integrated in ethical analysis? For example, although engineers of TUC have specific goals in mind, various decision during R&D, such as about the materials, model structure, or algorithms, influence implicitly or explicitly the final product and thereby open up or close down potential applications. Moreover, it is not yet determined how results of TUC will materialise, how it will be implemented, how it will be applied by end-users, or what consequences it will have for society. Unlike traditional ethical cases, the variables for the ethical evaluation of new, complex technologies are vague and unclear, which poses serious problems for ethics when trying to evaluate these technologies. Since uncertainty is un(der)developed in ethical theory, it is worthwhile to study how uncertainty has been conceptualised in disciplines other than ethics and how ethics might benefit from this.

### *10.4.1 Three Dimension of Uncertainty*

Before turning to a conceptual analysis of uncertainty it is important to recognise that uncertainty is a fact of life that we have to deal with when making decisions in all sorts of domains. The fact that certainty is a utopian perspective might yield to inertia, but there is no need to throw in the towel too quickly. In case of decision-making, therefore, we would better try to understand what uncertainty is, because when we have an enhanced understanding of its dimensions and implications for decision-making, we are opening up the way for constructively dealing with a complicating fact of life. If we acknowledge this, then the first step is to conceptualise uncertainty. With Walker et al. I take uncertainty as 'any departure from the unachievable ideal of complete determinism.' (Walker et al., 2003, 8) For various reasons, uncertainty is not simply the absence of knowledge. First, uncertainty can prevail even in situations where a lot of information is available. Second, new information does not necessarily increase certainty, but might also augment uncertainty by revealing the presence of uncertainties that were previously unknown or understated (See, e.g., Beck, 1999, 6). Third, there might even be situations of uncertainty that are indeterminable and which for the reason of the nature of that situation cannot be reduced by acquiring knowledge. Such indeterminable situations are related to, for instance, the behaviour of other agents. These aspects show that uncertainty is more a multifaceted concept than it might seem at first glance. For that reason, I will advance by elucidating its different dimensions by reconstructing a typology of uncertainty. This typology of uncertainty (Walker et al., 2003) involves a three-part distinction between the nature of uncertainty, the levels of uncertainty, and the sources or locations of uncertainty.

With regard to the first dimension of uncertainty, the *nature* of uncertainty, Walker et al. distinguish between two types of uncertainty, namely knowledge or epistemological uncertainty and variability or ontological uncertainty (2003, 13–14).

This distinction contributes to identifying and assessing the nature of uncertainty of the phenomena that are studied, in casu technology development. Epistemological uncertainty is uncertainty that is related to the properties of agents and the collection of knowledge. Epistemological uncertainty results from the lack of information or the complexity of the situation that needs to be assessed. In principle, this type of uncertainty can be reduced by acquiring knowledge, more measurements, and better models. Other terms used for epistemological uncertainty include weak, internal, secondary, or substantive uncertainty (See Meijer et al., 2005, 8). Ontological or variability uncertainty pertains to the uncertainty that is inherent to the variability of the system and which cannot be reduced. Many empirical variables that are the input for the calculus or assessment are instable. They change and vary over space and time and are beyond human control, simply due to the nature of the phenomena involved (Walker et al., 2003, 13). Ontological uncertainties are attributes of reality. Decisions within a framework or system generate a large number of potential and possible outcomes, decreasing the confidence in predictions. Strong, fundamental, stochastic, random, primary, external, aleatory or procedural uncertainty are synonyms for ontological uncertainty (See Meijer et al., 2005, 8). According to Walker et al., one can identify four aspects that might contribute to ontological uncertainty (2003, 13–14). First, the inherent randomness of natural processes. Second, the unpredictability and variability of human behaviour, such as irrational behaviour or discrepancies between what people say, feel, think, and what they actually do. Third, the unpredictable nature of societal processes stem from social, economic, and cultural dynamics. Fourth, technology development not rarely entails technological surprise, such as breakthroughs in technology, unexpected consequences, and side effects (See also Tenner, 1996). Meijer et al. contend (2005, 8) that the distinction between epistemological and ontological uncertainty is not a sharp one. Ontological uncertainty contributes to knowledge uncertainty, because, due to its variability, perfect knowledge and certain predictions are anyhow unattainable. But epistemological uncertainty can also exist in deterministic processes, e.g. due to a lack of communication, inexact measurements or too high a complexity.

The second dimension of uncertainty involves the *levels* of uncertainty, which according to Walker et al. (2003, 11) pertain to the question of *how* uncertain something is. The uncertainty of something can be classified in different stages ranging from deterministic understanding, also called the ‘know,’ to complete ignorance, the ‘no-know’. They identify four levels of knowledge on the spectrum, from determinism to indeterminism. (Walker et al., 2003, 11–13) First, statistical uncertainties entail uncertainties that can adequately be expressed in terms of probabilities. Second, uncertainties that cannot be depicted adequately in terms of probabilities, but which can only be specified in terms of possible outcomes are called scenario uncertainty. The methods for assessing the probabilities are, however, not correctly understood, which makes it more indeterminate than statistical uncertainties. Third, recognised ignorance involve uncertainties with regard to the relationships and mechanisms of which we realise in some way or another that they are present, but of which we cannot establish any useful estimate; for instance, due to limits of predictability, knowledgeability, or due to unknown procedures. The fourth level connects to total or complete ignorance. These uncertainties are most indeterminate; the so-called ‘unknown unknowns’.

The third dimension comprises the *sources or locations* of uncertainty that are an identification of where uncertainty manifests itself within the model or framework. This dimension, Walker et al. argue (2003, 9), refers to the model in which it is possible to pinpoint the various sources of uncertainty for a specific domain. The source or locations might yield to uncertainty in two ways; uncertainty in systems, frameworks, or theories and uncertainties arising in particular domains or spheres of human life and action. On the one hand, the locus of uncertainty is based on the uncertainty in systems or theories. Subsequently, the location of uncertainty is an identification of where uncertainty manifests itself in the complex of decision-making. Walker et al. distinguish the following locations of uncertainty with respect to the model (2003, 9). First, the context, which has to do with the framing of the problem, including the choices determining what is considered inside and outside the system boundaries, as well as the completeness of this representation in view of the problem at hand. This involves the identification or setting of the boundaries of the system to be modelled and, accordingly, the aspects of the real world that are inside the system, the aspects that are outside, and the completeness of the system. Second, Walker et al. identify model uncertainty, which is associated with both the conceptual model (i.e. the variables and their relationships that are chosen to describe the system located within the boundaries and thus constituting the model complex) and the computer model, in casu the practical framework of ethics. Model uncertainty can be divided in model structure uncertainty (uncertainty about the form of the model or framework itself) and model technical uncertainty (uncertainty arising from the practical implementation of the model). Third, inputs that are associated with the description of the reference system and the external forces that are driving changes in the reference system. It is sometimes useful to divide the inputs into controllable and uncontrollable inputs, depending on whether the decision-maker has the capability to influence the values of the specific input variables. Fourth, parameter uncertainty relates to the data and the methods used to calibrate the model parameters. Fifth, model outcome uncertainty is the accumulated uncertainty associated with the model outcomes of interest to the decision-maker.

On the other hand, the sources or locations of uncertainty relate to the specific domain about which the decision-maker is uncertain. The source of uncertainty depends on the context. Different sources of uncertainty are distinguished by Meijer et al. (2005, 10), such as technological uncertainty, resource uncertainty, uncertainty regarding labour and market, consumer uncertainty, competitive uncertainty, political uncertainty, and supplier uncertainty. I will focus on the domain of technological uncertainty. Technological uncertainty can be subdivided in three elements, Meijer et al. say. (2005, 11) First, uncertainty about the technology itself. Decisions we make are influenced by the perception of the technology itself. Moreover, the uncertainty concerning individual technological innovations is influenced by the complexity of the technology. Second, uncertainty about the relation between the technology and the technological system, i.e. the complex of technologies that it is part of. Third, uncertainty about the availability of alternative technological solutions, which connects with both technologies that are already available as well as technologies that might become available in the future.

In the final two sections I will illustrate how this typology might improve on the understanding of uncertain technology developments and their ethical evaluation. Introducing the typology of uncertainty sets the scene for two important insights and conclusions that will be addressed. First, in Section 10.5 it is demonstrated that uncertainty relates to the whole of the situation that is to be evaluated, namely the object of evaluation (i.e. the technology), the subject of evaluation (i.e. the actor), and the framework of evaluation (i.e. ethical theory). Section 10.6 concludes with some closing remarks that purport to be an outline for any future ethics of technology that is able to deal with uncertainty.

## 10.5 The Uncertainty of Ethics

In this chapter I observed that uncertainty is a concept un(der)developed in ethics. As argued in Section 10.2 the practical aim of ethics is to guide correct moral reasoning by demonstrating *how* right-making criteria apply to objects of assessment, in casu complex technology developments surrounded by uncertainty. Where ethical theories generally focus on rather static and calculable ideal-typical situations to demonstrate their practicability, complex, real life cases seem to obscure and frustrate this aim. Complex technology developments do not suffice the descriptions of ideal-typical ethical cases due to the uncertainty of future consequences, impacts, and applications. In view of this uncertainty, complex technology developments lack substantial information that is needed for the ethical evaluation. This deficiency in information fundamentally frustrates the practical aim of ethics. Should we infer from this that only a retrospective type of ethics of technology is feasible for technology development, or is there any potential to work towards an ethics of technology that allows for proactive, *ex-ante* moral evaluations of technology development? Is an ethics of technology able to incorporate a proactive perspective on uncertain situations; and, if so, to what extent? In retrospect of this study the prospects for an ethics of technology seem discouraging, but the question raised might benefit from insights of other scientific disciplines, in which uncertainty is a central topic of debate and reflection. The typology of uncertainty is useful for ethical theorising in relation to technology development (but might also prove to be interesting for existing technologies and other complex cases).

This typology and its three dimensions will be examined in relation to the case of complex technology development. At the start-off of every new development, an agent *x* (either individual or collective) is called upon to morally evaluate and justify the proposed development. Hence, at time $t^1$ agent *x* is to decide whether to develop a specific new technology, such as TUC, for which different development trajectories ($o^1$, $o^2$ … $o^n$) are possible. It is at $t^1$ expected of *x* to provide a proactive moral evaluation of an intended new technology which entails an overview of the different, potential development trajectories, the possible applications or uses, and its impact and consequences at $t^n$, resulting in a well-considered judgment on its moral permissibility. The uncertainty of such situation relates to at least three aspects of ethics; namely to the agents or subjects (they are not omniscient), to the object of assessment (the uncertainty of future use and impact of technologies), and to theoretical issues (the uncertainty of the ethical framework used).

The first factor of uncertainty connects to *agents* who are not omniscient persons, but who are nevertheless confronted with the need to evaluate a new technology on basis of the information available; the information of which it is also the question whether agents correctly understand and interpret it. As argued in Section 10.3, facts like the involvement of many agents with different skills and from different disciplines or the long duration and opacity of development trajectories are central to many technology developments. In TUC many agents are involved in R&D; some are concerned with the conceptual design of optical switches, some with fundamental research in materials, and others with making proto-types, and so on. Accordingly, technology development is often too complex to be fully understood by a single agent. This first feature of uncertainty lies within agents themselves. The nature of this uncertainty is epistemic.

The second factor of uncertainty pertains to the *framework* of evaluation. In case of ethical theory the location of uncertainty is an identification of where uncertainty manifests itself in the framework of evaluation. The evaluative framework, consisting of rules, principles and/or values, is the starting point for reflection and judgement. This framework is not an objective or a perfect representation of reality. By this I mean that, although ethical theory purports to set forth statements with truth value about for instance the nature and status of moral judgments, it has an inherent uncertainty attached to it. For example, which data or inputs are accepted as relevant for the evaluation within a specific theory or meta-theory? In consequentialist theories only data are accepted that relate to the consequences of the actions and the central good that needs to be maximised. With regard to the theory itself, uncertainty might arise in applying certain principles and values to evaluate new technology developments. In connection with meta-theory, uncertainty relates to the foundations of theory. Choosing a meta-theory, in casu meta-ethics, necessarily implies certain presuppositions on the nature and status of moral judgements. It is important to clarify and explicate this uncertainty. The nature of this uncertainty is ontological, i.e. it is inherent to a specific framework and/or reality.

The third factor of uncertainty concerns the object of assessment, such as possible *development trajectories*, which connect to the levels of uncertainty. As we have seen, technology developments, especially complex variants, are characterised by uncertainty. This uncertainty is, however, not always of the same level. For certain developments it might be reasonably argued that trajectories $o^1$, $o^2$, $o^5$, and $o^7$ are likely on basis of available information, but that $o^3$, $o^4$, $o^6$, $o^8$, and $o^9$, are improbable. For example, research in optical switching and ultra-fast communication is a specific area in complex technology development in which engineers are able to foresee that in the future Internet traffic will increase (notably with the advent of (3D) video streaming). This specific information implies that certain trajectories are likely, but that others are moot. Other technology developments might involve greater uncertainty, or might even be indeterminate. Fundamental research into materials to investigate which materials best conduct current under suboptimal circumstances is such an example. In this case we are confronted with a high degree of indeterminacy. The level of uncertainty is not an absolute measure, but represents different stages of (in)determinacy; on the one side information is available (determinacy) and on the other it is lacking (indeterminacy).

Uncertainty is wrongfully underappreciated in ethics, but by introducing this typology and its distinctions we arrive at a clearer picture of the concept of uncertainty for ethics. This is not to imply that uncertainty has become unproblematic. For a variety of reasons, this typology is a first contribution in overcoming this deficiency. It contributes to conceptual clarity about the dimensions of uncertainty and it shows the nuances of uncertainty in order to prevent uncertainty to be black boxed and reduced to risk. It shows where and how uncertainty manifests itself in the complex of technology development and its ethical assessment. It results in a better comprehension and overview of the role of uncertainty in ethics and technology. Uncertainty is, for instance, not simply the lack of knowledge, but it also relates to the inherent uncertainty in frameworks and reality. These insights about uncertainty raise fundamental questions — for instance with regard to the subject, the object, and the framework of evaluation — for any ethical framework that purports to assess new technology developments. Some of these questions with regard to the framework of evaluation will be outlined in the final section.

## 10.6 The Ethics of Uncertainty – An Outline for Any Future Ethics of Technology

Based on the previous sections, I will propound a number of questions as to what consequences uncertainty yields for the framework of evaluation, in casu ethical theory in its practical aim of proactively evaluating new technologies and in its theoretical aim of justifying theories and principles. One of the most pregnant questions relates to how uncertainty, that is among other things a lack of information, bears upon the practical aim of guiding correct moral reasoning. I will scrutinise the possibilities for ethical theory to deal legitimately with uncertainty, that is, even in the absence of relevant information for the ethical evaluation. I will argue that both pure substantive and pure procedural theories fail to guide proactive moral reasoning under conditions of uncertainty and that, as a result, we should endorse a substantive theory that incorporates a procedural solution.

To arrive at this conclusion I will first discuss uncertainty in relation to substantive and procedural theories.[1] So, how does the distinction between substantive and procedural ethical theories bear upon our aim of ethically evaluating uncertain

[1] For a more detailed exposition of (1) the relation between uncertainty and ethics and (2) the nature of and differences between substantive and procedural ethics, see Sollie (2008) and, especially, Sollie (forthcoming 2009).

technology developments proactively despite our lack of information? First, the lack of information, as a resultant of uncertainty, to apply right-making criteria foremost connects to *substantive* ethics. Substantive ethical theories specify what is right in terms of duties, rights, and values in relation to the object of assessment that are to be satisfied independent of any decision-making procedure. Substantive theories are theories for which *we* are in need of information to be able to evaluate technologies. Information is a prerequisite for us to be able to generate determinate answers when applying substantive right-making criteria to objects of assessment — provided the ethical theory has been able to demonstrate its practicability of *how* the right-making criteria apply to the object of evaluation. Without information substantive accounts are rather unsuccessful to guide our proactive assessments. Pure substantive theories fail in this regard, not because they are inadequate (they need not be), but because *we*, as subjects of ethical theories, require information to apply right-making criteria in practical moral reasoning. Hence, it is not so much a problem of the inadequacy of substantive ethics as it is a problem for us to apply substantive principles under conditions of uncertainty; there is no inherent failure or shortfall in substantive ethics in this regard. Any attempt to provide such an ethics of technology based on a substantive ethical theory may seem daunting given the fact of uncertainty. The lack of information frustrates the aim of guiding proactive moral reasoning. Without information we are rather handicapped in using substantive accounts to guide pro-active assessments. For example, consequentialists require information for calculating and maximising the utility of different, possible states of the world. However, if in circumstances of uncertainty substantial information is lacking about the possible states of the world then we face serious problems in trying to realise our practical aim of guiding correct moral reasoning via consequentialism. Under uncertainty it is not only consequentialist theories that are subject to the limitations of a substantive approach, any substantive ethical theory is.

Does this imply that we should turn to pure procedural ethical theories in situations of complexity and uncertainty? Pure procedural ethical theories solely attend to the process of moral decision-making instead of focusing on the substance. One could therefore argue that in absence of information we should resort to pure procedural theories. The problem with using pure procedural theories to assess uncertain technology development concerns the fact that such theories only focus on the procedures of communication and debate without regard to the substance. It cannot guide action without being supplemented with a material principle, which, in fact, draws our attention to the need for a substantive account. In the end, it is only able to guide the way in which the debate is carried out by providing communicative tools and instructions for moral deliberation, but these do not bear on the substance of the debate. Despite the fact that the lack of information is less a concern for procedural ethics as it is for substantive ethics, pure procedural ethics can only say something about the structure of debate and not about the substance. It is not able to make moral judgments by guidance of moral principles based on the content of the subject matter. An additional problem accompanying pure procedural theories is of a moral-psychological nature. Why would people agree to the outcome via a procedural solution that is independent from any content? How will we trust a procedure that is not grounded in any substance? We have no reason to trust a procedure without substance.

These are major deficits in procedural approaches and therefore I maintain that we should strive for a substantive theory that is able to justifiably and legitimately include a procedural approach. The substance is required for guiding moral judgments, while the procedures can be invoked in cases in which we are confronted with uncertainty. Any future ethics of technology should therefore also be procedural of nature, not only substantive. A proactive evaluation under uncertainty necessitates a procedural turn. The upshot of this analysis is that pure substantive accounts are unsuitable for *us* to evaluate uncertain technology developments due to the lack of information. This still leaves unanswered the question as to what procedure is to be invoked and how this is legitimised and authorised. The problem with uncertainty *is* its uncertainty, its resultant lack of information and, for this reason, it is not so much a question about finding the right answer to uncertainty as it is to discovering an authorised and legitimate way of dealing with uncertainty within ethical theory that incorporates both a substantive and procedural approach. As said, uncertainty is not an intrinsic problem of the adequacy of ethical theory, but it prevents *us* from applying right-making criteria to complex cases *directly*. Consequently, the previous argument for a dual approach of substance and procedure is to present an *indirect solution*.

For this indirect solution to work and to be legitimate, any ethics of technology needs to show how procedures are justified within the ethical framework and how it conceives of the relation with substantive principles. Moreover, it needs to be demonstrated which procedure best fits the specific nature of technology development. In view of the central research topic, the scrutiny so far amounts to the formulation of three questions that any future ethics of technology needs to address and cope with in order to be adequate. The first two questions address the adequacy of ethical theory and the third questions stems from our aim of finding a legitimate approach that allows for a proactive assessment of technology developments that are characterised by uncertainty.

1. Theoretical aim of ethics: What right-making criteria underlie ethical theory and how are these right-making criteria justified?
2. Practical aim of ethics: How do these right-making criteria guide practical moral reasoning?
3. How does ethical theory deal with complexity and uncertainty, that is, how does it construe a justified relation between a substantive and procedural approach that is able to legitimately deal with uncertainty in a proactive manner?

This is the direction I am convinced an ethics of technology should be directed, because substantive accounts by themselves will inevitably prove to be insufficient to guide the assessment of complex and uncertain developments. Hence, what is required is a theory that satisfies all the demands put forward in this analysis. The aim of this article is not to present an answer — although I believe Gewirthian ethics to be a promising candidate for such an approach (Gewirth, 1978; Beyleveld, 1991; Beyleveld and Brownsword, 2007) as is further explored in Chapter 13 — but to lay down arguments for the necessity of this research, the inevitability to scrutinise and take serious uncertainty in ethical theorising, and the subsequent consequences and requirements for any future ethics of technology.

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