Rathenau Instituut

Shaping socio-technical innovation through policy

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Content

Introduction

Assignment

The Department of Knowledge, Innovation and Strategy of the Dutch Ministry of Infrastructure and the Environment is in the process of drafting the Strategic Knowledge and Innovation Agenda (SKIA) for the Ministry for the period from 2016 to 2020. One issue with which the department is concerned is, by its own account, “policy in times of singularity”. Having noted a sharp increase in the number of technological innovations with a high speed of development and a significant impact on society, their question is what implications this has for the Ministry’s policies and regulations.

The Rathenau Instituut has conducted an analysis into the ways in which innovation and regulation impact one another (Maclaine Pont & Deuten, in progress). This analysis focuses on what are known as “key technologies”: technologies which could potentially create an acceleration in many different research and application areas, while at the same time little is known about the societal challenges involved. As part of the project, a number of case studies were conducted into nanomedical innovation and EU regulation, the internet and copyright, synthetic biology and right of ownership, and automated vehicles as system innovation. These analyses have shed light on the types of challenges to policy presented by complex and difficult-to-predict innovations.

The Knowledge, Innovation and Strategy department of the Ministry of Infrastructure and the Environment has commissioned the Rathenau Instituut to draft a memorandum in order to be able to develop the theme of “policy in times of singularity” in the new Strategic Knowledge and Innovation Agenda. Specifically, we were asked to provide the following: suggestions for reformulation of, partial answers to, and paths of enquiry for knowledge requirements relating to challenges in dealing with unpredictable innovation specific to the Ministry of Infrastructure and the Environment. On account of the limited scope and turnaround time for the assignment, the Ministry does not expect any detailed analyses or specified knowledge requirements.

Problem and approach

Policymakers have noted that technological advances are becoming less predictable. Above all, there is considerable uncertainty regarding key technologies such as information technology and nanotechnology, which generate a wide variety of new applications. The trends and developments are fast-moving, but it is unclear how these innovations will affect society at large: what opportunities are created and what are some of the challenges we face? This uncertainty poses a problem, since it means the consequences for the policy areas of the Ministry of Infrastructure and the Environment also remain unclear.

The question as to the role of policy in innovative trends and developments is not new: the Ministry of Infrastructure and the Environment has many years of experience with innovation issues that call for a new role, and in many cases this has resulted in innovative new policies. Examples of such innovations include the construction of the Delta Works, innovative outsourcing by the Directorate-General of Public Works and Water Management, technology-independent regulation for vehicle

types, participation in experiments involving automated vehicles, and the participation-based regulatory approach to nano-materials in the workplace.

On a national level, there is a growing focus on the conflict of interest between innovation and policy. One example is the “Futureproof Legislation” programme, which is being developed by the Dutch ministries of Economic Affairs, Security and Justice, and the Interior. The main objective of this programme is to “create room” for innovation, so as to prevent legislation from unnecessarily blocking innovation. Several ministries are also concerned with the question as to the role of the government in a changing society. One example of a new framework is the report titled *Leren door doen* (“Learning by Doing”) by PBL Netherlands Environmental Assessment Agency and the Netherlands School of Public Administration (NSOB) (Steen et al, 2014).

While policymakers are challenged by innovation, they also have extensive experience in dealing with innovation. The primary question at present is which of these numerous and complex trends they need to address, and what role they need to adopt. This essay creates a framework for the demand for knowledge that innovative trends and developments might provoke when it comes to policymaking. The focus is on determining the extent to which innovation does or does not present a challenge to policy and the type of response required. In drafting our document, we drew on cases investigated by the Rathenau Instituut (including MacLaine Pont & Deuten, in progress; Royakkers & Van Est, 2016) and additional research conducted as part of this project.

Summary

Chapter 1 provides a framework for thinking about innovation. In this essay, we focus on innovations facilitated by technological trends; however, other contributing factors are economic, social or legal in nature. Innovations are created as part of an “innovation system” in which companies, research and educational institutions, governments, financiers, insurers and other social institutions interact with one another. As such, we might regard innovation as a socio-technical process, and the central government and its policies and regulations constitute an essential part of this process. Rules have an impact, for example, on the decisions made by technology developers and innovative companies. When technological innovation leads to innovations which are not (or do not appear to be) consistent with existing policy frameworks, this creates uncertainty regarding the permissibility of the innovation and/or applicability of the regulations. The challenge for policymakers, then, is to deal productively and responsibly with the conflict of interest between innovation and policy. Next, we demonstrate that socio-technical innovation can affect policy at three different levels. Innovation can present a challenge to policy instruments, to the organisation of a regulatory regime, and to policy objectives and conditions. At each of these levels, it may be necessary and/or desirable to modify the policy in various gradations.

In Chapter 2 we describe three cases: drones, Uber and automated vehicles. These cases illustrate what type of knowledge would help improve insight into the potential policy challenges involved. This, in turn, enables policymakers to pre-empt the question of whether new policy is required and what type of policy innovation is appropriate in this case: is the existing policy adequate, are other instruments required, does the regime need to be updated – for example by redistributing roles in

regulation and supervision among stakeholders – or are the terms of the policy affected and/or is there a need for a new set of objectives?

In the final chapter, we extend the framework based on the cases discussed. As innovation becomes more rapid and complex, we perceive a growing uncertainty about the permissibility of innovations and the effectiveness of existing policies and regulations. This uncertainty is permanent, and the challenge is to find a productive and responsible way of handling it. An initial step would be to clarify for policymakers and other stakeholders what type of challenge innovation presents to policy and what types of policies should be created in response. Seeking and acquiring knowledge will become a more important part of the process of improving the responsiveness of policy and regulation. The question, however, is how do you put this into practice? For each of the policy levels, we outline the types of informational needs involved, along with examples of policies created in response. The chapter concludes with a diagram that integrates these various insights and which serves as a guideline for defining more targeted knowledge requirements and follow-up measures in specific policy areas.

1 Innovation and policy

Contemporary policymakers are faced with a wide spectrum of new technological trends and developments, ranging from nanomaterials and facial recognition systems to the emergence of self-driving cars and killer robots. There is a wide awareness of the rapid pace of current technological advances, and some new technologies even follow an exponential growth curve. For example, there are the integrated circuits which for many decades have been following Moore's Law: the observation that the number of transistors in a dense integrated circuit doubles approximately every 18 months. The rapid changes in technology raise the question as to the extent to which policy must be adjusted in order to accommodate advances in technology.

This chapter provides a framework for thinking about the relationship between technological advances, the innovations this creates, and policy. The first paragraph discusses the growing unpredictability of technological advances, while the next paragraph demonstrates that innovations facilitated by technological advances are also shaped by all types of economic, social and legal factors. Innovation is a socio-technical process, being driven not only by technological possibilities, but also by the interaction between companies, research and educational institutions, governments, financiers, insurers and other social organisations. The third paragraph discusses the policy challenges that might be involved in groundbreaking socio-technical innovations. We identify three levels at which socio-technical innovations may challenge policy.

1.1 Technological advances

Technological advances tend to be erratic and unpredictable in nature. There are at least three factors which contribute to this unpredictability. First of all, technology development is an evolutionary process in which new options are explored all the time. This tends to result in incremental innovations, where existing products, processes or services are improved gradually, in a series of stages. Note that incremental innovation can occur at an exponential pace, as shown by the example of Moore's Law cited above. In some cases, however, we witness technological breakthroughs which lead to radical innovations, involving the launch of brand new products, processes or services. These breakthroughs can potentially end up transforming existing markets and business models.

A second factor contributing to uncertainty is the fact that technologies converge, and it is at this point of convergence that many technological breakthroughs occur. Innovations of this kind do not build on existing products, processes or services, but rather represent a new class of applications which could potentially give rise to new value chains and markets. An example of this is the use of extremely powerful digital light sensors in cameras, which have made cameras both easier to operate and more affordable and which constituted a disruption to the camera market.

A third cause of the uncertainty is standardisation and what is known as "platformisation" in which highly complex technologies can be integrated into relatively simple building blocks. Digital

platforms, in particular, provide a generic basis on which, thanks to interface standards, various applications can be developed by a variety of parties. This has facilitated a more complex division of labour, whereby users and smaller businesses can also play a role in innovations within modules. The lowering of the threshold for technology means that the development can make more unexpected leaps. Smartphones are one of those platforms for which different types of companies all contribute to innovation. Integrated digital cameras, for example, have changed the social practice of photography beyond recognition raising questions both for professional photographers and with regard to social communications, privacy, and so on.

These trends are particularly conspicuous in key technologies such as nanotechnologies, biotechnologies, artificial intelligence and cognitive sciences (NBIC). They are developing rapidly and converge in a wide variety of research areas, including nanocomputing and nanomedicine. NBIC technologies are also converging into whole new fields such as artificial intelligence, robotics and synthetic biology. Many developments are also created in the form of platforms. In summary, we are seeing a wave of new technologies and building blocks, with technological advancement taking on a highly nonlinear nature. However, the innovation dynamics can only be understood if we look at technological innovation alongside other processes, including policymaking.

1.2 Socio-technical innovation[1]

Innovation is not only driven by technological possibilities but also by social, economic and societal factors. Innovative applications become successful if they manage to connect with their environment; that is to say, if they become integrated into existing systems and technologies, are permissible and fit within regulatory frameworks, and are accepted by users and society at large. Companies therefore anticipate user requirements and involve consumers in the design and marketing process. For example, businesses attempt to influence the legal permissibility and public acceptance of their products with legal affairs and public affairs departments. In addition, innovation is created by changing socioeconomic conditions. Consider, for example, how new needs are created as a result of growing consumer power, emancipation or climate issues – or the estimates made by businesses or policymakers in relation to these topics. It is this interaction between technological and social aspects that constitutes innovation.

In other words: innovation based on technological advances also constitutes a socio-technical process. Innovations are created as part of an interaction between businesses, research and educational institutions, insurers and other social institutions. This interaction determines the way in which technological possibilities are shaped and the chances of survival of applications. In addition, the success and societal impact of technological innovations tend to be determined by integration with innovations in the organisation, marketing or business models. A classic example of this is the T-Ford model. Innovations in the production process (the assembly line) and the business model (a

[1] The technological framework for this essay is related to the social studies of technology, focusing on the interaction between advances in technology and other processes in society. A central notion in this process is the “social construction” of technology systems. Important works exploring these ideas include: Bijker, Hughes & Pinch (1987), Bijker & Law (1992), Callon, Law & Rip (1986) and Hackett et al (2007).

focus on affordability and user-friendliness) resulted in a mobility revolution. The sharp growth in car ownership led to more roads, an increase in interregional traffic (including trade), alternative city planning, changes in town planning procedures, and so on.

In this essay, we focus primarily on the role of policy and politics in the innovation dynamics. The government plays a variety of roles, for example: demanding user, financier of science and technological advances, regulator, supervisor and guardian of public interests. There are many ways in which policy can influence innovation. Regulation can lead to socially desirable innovation: for example, the strict emission standards for vehicles or the (implicit) ban on light bulbs. Regulations can also work against controversial innovations, e.g. the ban on cloning.

Since policy plays such a multifarious role in innovation, it is not sufficient to merely “adapt” to trends and developments, because policy and regulations are among the factors that determine the innovation dynamics and the chances of survival of innovations. In the introduction, we noted that the Dutch Ministry of Infrastructure and the Environment is aware of this: in all cases, it explains its role as a legislator, provider of government subsidies/grants, customer, project executer, partner in innovative projects, or director of a governance network. Policymakers can start by charting the role policy has played so far in innovation and by charting the forming of innovation paths.

The challenge is subsequently to determine how the government intends to be part of the innovation dynamics. As innovation becomes more complex and advances more rapidly, policymakers feel there is a greater urgency to take action. This calls for a wide perspective on innovative trends and developments, with a specific focus on the role of policy in this process. On this basis, an analysis can then be made of the types of challenges facing policymakers. One of the follow-up measures to be taken is to make clear to other parties involved what they can expect from the government, for example by explaining how policymakers intend to manage uncertainties relating to permissibility and public acceptance.

Policymakers are experienced in dealing with innovation and have developed a wide spectrum of instruments. The central issue right now is to determine which of the many complex innovations call for attention and a policy response. The paragraph below sets out a framework for making a distinction between the ways in which innovations and policy affect each other and the type of response required.

1.3 Framework for policymakers

As described above, policies and changes to these policies are part of the dynamic of socio-technical innovation. The current regulatory frameworks guide innovative developments: they determine what room developers will be given (or think they will be given) and how policymakers regard innovation, what the responsibilities are of public and private parties, and what the purpose is of regulation. It is precisely because of the guiding effect of existing policy that it is necessary to survey such interactions early in the process in order to prevent socio-technical innovation and the regulation thereof from becoming trapped on an inflexible trajectory.

In the political debate, there is a strong focus on the administrative pressure which laws and regulations can create: this would stymie innovation. As noted above, regulation also plays a stimulating and guiding role in technological innovation. Stricter requirements for the handling of farm animals could potentially result in the development and use of more animal-friendly technologies in cattle farming. It is this encouraging and directional aspect of regulation that is central to the framework developed in this essay.

The many ways in which socio-technical innovation presents a challenge to existing policy also form part of the framework. We identify three levels (gradations) of policy challenges. Innovative developments may be at odds with policy instruments, policy strategies or the objectives and basic conditions of policy.

1. Policy instruments

“Instruments” here refers to the way in which policies are operationalised in terms of measures.This includes, for example, the exact design of laws and regulations, but also covers the design of implementation instruments such as inspection or certification protocols, subsidies, or stimulus measures.

A tension arises between innovation and policy instruments when innovations do not align with the categories, concepts, specifications, requirements or conditions defined in the measures. One example of an innovation which challenged the statutory categories was the Segway: an electric scooter for use in pedestrian areas. Types of vehicles were defined based on technical specifications, and this required that a specific description be included for each new vehicle type, or else the law would not be properly applicable.

2. Policy regime

The regime in which policies are designed refers to the manner in which duties, roles and responsibilities are divided and delegated and the arrangements within which regulation is conducted. In organising a regime, policymakers consider the playing field of a policy domain as a whole. A large number of players are active in any one domain and can play various roles in defining and adapting/updating rules, implementing policies, supervision and enforcement and liability. In dividing duties and responsibilities, for example, the division of duties between public and private parties, access to information, the balance between market players (market power) and the extent to which the regulatory approach is predictable all play a role.

Socio-technical innovation can challenge a regulatory regime, because the form in which duties are delegated does not function properly; an example of this would be copyright on the internet. If a copyright infringement takes place online, there is essentially a legal ground for a legal case, and the laws currently in place are legally valid. However, it turns out to be impossible to enforce the rules, since those violating the laws are difficult to identify and prosecute, particularly when the violations are committed abroad. Companies responsible for managing internet traffic (internet service providers) can play a role in protecting copyright. They typically only cooperate when ordered to do so by the court, a situation that undermines the legal certainty of copyright.

3. Policy objectives

This level refers to the objectives envisioned by policies and the principles underlying them. The government develops policies based on various public and political responsibilities, which are embodied by duties and policy objectives. In other words, the implementation of objectives is based on a number of administrative and political considerations. With regard to the principles, this concerns the grounds on which trade-offs are made between goals, and how government policy is legitimised within a specific domain.

Innovation challenges policy goals when the balance between considerations changes and/or when two policy areas are connected in which assessments of such matters are typically made in a different way (manner). Alternatively, innovation can also challenge policy goals if it challenges the foundations of the policies and the legitimacy of the legislation. An example of the latter is the regulation of genetically modified organisms (GMOs) in agriculture. The EU has made safety its main priority, but there are other factors at play in society at large in terms of the desire to permit or stop GMOs.

Using concrete cases, we can use the framework outlined here to form an idea of the type of challenge that innovation presents to policy and the type of response this implies. Gathering insights into the type of policy challenge involved is an initial step in determining concrete knowledge requirements and taking on a more conscious role. The framework described above is hierarchical in nature. As policy is challenged at a higher level, the questions as to which innovations are permissible and how the government must manage this from a political and policy point of view become all the more pressing.

2 The cases

This chapter sets out the framework outlined above based on three mini-cases. Using practical examples, we illustrate how innovation presents a challenge for regulation and policy. We draw on examples of innovations related to drones, Uber and automated vehicles. The cases do not purport to provide a complete picture of the complex ways in which innovative developments have created tensions with existing policy frameworks and the manner in which policies have or have not been able to respond adequately. The purpose of these cases is to provide compelling examples of the various levels of policy challenges involved.

The cases demonstrate that it is possible to anticipate the challenges to existing policy even though there remains a great deal of confusion and uncertainty regarding innovation. Since the reality in which policymakers operate is so complex, it helps, for example, to prioritise challenges. In addition, the proposed analyses also support the process of identifying the different roles the government plays or intends to play. Using this as a foundation, it is then possible to make decisions regarding the measures that must be taken (i.e. are necessary or desirable) and/or how to implement them. By reflecting on these challenges at an early stage, policymakers can start dealing with radical socio-technical innovation even when there is a high level of uncertainty involved.

2.1 Commercial drones[2]

In this mini-case, we briefly outline the development of commercial drones, the ways in which they challenge existing policy frameworks, and how this issue has been addressed to date. We also describe the challenges that might be expected in the future, based on this outline. A more detailed analysis of the innovation dynamics in relation to commercial drones will provide a more comprehensive picture of the policy challenges involved. The objective is to provide several examples of the various levels at which policy can be challenged by innovation.

Socio-technical innovation

We have seen an emergence in recent years of Unmanned Aerial Vehicles (UAV) – also known as Remotely Piloted Aircraft Systems (RPAS) or, more commonly, drones. Unmanned aviation is facilitated by a convergence between mechatronics and artificial intelligence (AI). Mechatronics a multidisciplinary field of engineering that includes a combination of systems, mechanical, electrical, telecommunications, control and computer engineering – makes it possible to build “aircraft” that are simple, economical and reliable. In combination with sensors technology and AI such aircraft can largely operate themselves AI: the drone owner (remote pilot) only needs to give orders.

[2] Below is a list of the sources used for this case. For an overview of the trends and challenges, see: Royakkers & van Est, 2016. For the old regulations and discussions on this topic: see the roundtable meeting of the Parliamentary Committee on Security and Justice, 12th September 2013, and the Bulletin for the Environmental and Transport Inspectorate, 1st July 2013. For the new situation, refer to Parliamentary Papers 30806 #31 and #33 and reports on the website of the Dutch national government.

The development of drones for military use began in the early 1990s. The use of drones saves the lives of pilots and makes it possible to operate more effectively in remote, difficult-to-access war areas, e.g. the mountains in Afghanistan. Scientific research also promotes the development of drones: Delft University of Technology, for example, developed the DelFly in order to better understand how insects and birds fly. This resulted in the creation of a dragonfly-like drone: this "world's most lightweight drone" is currently being developed further for use by fire departments and other first-response providers. The amateur community was also working on developing antennae and camera stabiliser systems at an early stage, in order to improve the flight qualities of non-military drones. Private companies subsequently noticed that camera footage and other sensors facilitated a variety of new applications, such as the inspection of roof-gutters and aerial photography.

The ease of operation of commercial drones increases the group of potential users significantly, since compared to flying radio-controlled aircraft and helicopters, flying most commercial drones is relatively simple. Since production costs are low, some drones can literally be found in the toy aisle of retailer stores. This is what makes drones disruptive: they make innovative functions available to a large group of people at a low price, thereby opening up a whole new market. As a result of these developments, an airspace filled with self-propelled objects is no longer science fiction.

There has been a great interest in the various ways in which drones can contribute to solving some of the challenges facing our society. This includes the use of drones by fire and police departments, or for the inspection of windmills and dikes, or in order to deliver goods or provide services in underdeveloped or densely populated areas. However, economic purposes also promote the development of drones. In agriculture, for example, they lend themselves to the purposes of precision agriculture, while drones were also used at an early stage in journalism. In addition, companies such as Amazon and Domino's Pizza have ambitious plans involving logistics drones. The use of such drones potentially increases accessibility and speed of delivery, but also raises questions regarding security, inconvenience and privacy. These types of questions become all the more pressing when there is a sharp increase in the use of drones by private individuals. Drones are expected to become popular – particularly among young people – as a tool used for a variety of recreational uses, e.g. creating videos for social media or tracing sports performance.

A problem of a different kind altogether is the recreational, professional or semi-professional use of drones for hunting, (civilian) espionage, or criminal activities such as smuggling, hacking other people's drones, and terrorist activities. Then there is the related use of drones by law enforcement agents, security firms or private individuals to combat misuse. This raises questions not only about the relationship between the state and its citizens ("Big Brother"), but also about citizens who spy on each other using a variety of technologies ("little brothers").

The development pathways for drones, then, are determined by technological possibilities, as well as by economic, social and societal aspects and participants with a variety of interests. This not only creates different uses, but causes tension as well. The challenges this poses to policy are addressed in the section below.

Challenges to policy

Based on the insights presented in the previous paragraph, we will outline several policy challenges in this section, how they were handled and which challenges have remained. Note that this discussion is not exhaustive, but rather serves to illustrate the first step of the policy process. Once challenges have been identified, it can be evaluated how they relate to political and administrative priorities and assessment frameworks.

1. Policy instruments

Prior to July 2015, drones were not classified as a separate category in aviation regulation. There were two categories of aircraft: radio-controlled aircraft and manned aircraft. The first category involved small aircraft with a limited action radius for recreational use. This is subject, for example, to specific rules for flight altitude, the distance to the pilot and the avoidance of specific zones. The manned aviation category is highly diverse and maintains a strict and comprehensive regulatory regime. In addition to laws and regulations, for example, there are authorities and institutions for the certification of aircraft and pilots, for traffic management and for inspection and enforcement. Furthermore, the civil aviation industry uses a dedicated infrastructure, including airports and the flight paths set by air traffic controllers.

As long as drones were not subject to specific guidelines, they were incorporated into the aviation regulations in the manner described below. The recreational use of drones was subject to the guidelines for radio-controlled aircraft, while the use of drones for professional purposes was prohibited, unless an exemption was applied for for each individual flight, which required three different procedures. The practical effect of this development is described below. Small-scale recreational use was in compliance with the rules. Since technology tends to greatly improve access, the use of recreational drones could increase sharply, while the rules did not provide sufficiently for possible noise nuisance caused. However, regulations turned out to be a hindrance for businesses. Due to the exemptions required, for example, professional flights needed to be scheduled well ahead of time, thus thriving companies were faced with a substantial administrative burden. The introduction of drones has occurred in fits and starts so far, and has been incremental in nature.

In recent years, policymakers have been involved in amending the aviation regulations. This is a complex issue, not only as a result of the developments described above, but also because there is a need for international coordination. The European Commission is currently in the process of aligning drone regulations, but the Dutch government found it necessary to speed up these changes, amending its rules effective 1st July 2015. Recreational use remains subject to the regulations for model aeroplanes, but these have since been refined. New measures were adopted for professional use, which essentially involve a relaxation of the existing rules. Some have expressed criticism of the modifiedrules. The use of drones for professional purposes remains subject to strict requirements in the Netherlands, requiring, for example, three certificates: one for the pilot, one for the drone, and one for the operator (i.e. the company). Another complication is that there was a lack of clarity in the drone industry up to several months before these changes were implemented. Various private sector companies have stated that this has had a restrictive effect on their investments.

Yet a number of measures were taken in order to keep the modification process open. For example, the proposed rules were open to feedback from internet users, providing all members of the public the opportunity to voice their opinion. The regulations were eventually significantly amended based on this feedback. There is currently also an open debate on the questions and challenges to regulations in the future (e.g. Parliamentary Letter 30806 #31). It is this process of communicating propositions and asking questions that can contribute to managing expectations.

2. Policy regime

The description above of socio-technical innovation demonstrates that drones will eventually also challenge the way policy is organised. The regulation of air traffic control, for example, is a process with a central and hierarchical organisation, putting it on par with traditional aviation. Aircraft are expensive and difficult to operate and require a specific infrastructure and specific facilities. Since pilots or the people operating the aircraft are themselves invested in organising the facilities and the airspace, it is easier for air traffic control to set requirements and supervise operations. At the same time, we are seeing a shift in traditional aviation towards decentralised organisation: on account of the higher traffic volumes and increasingly sophisticated technologies, companies have been working for years on developing a regime in which aircraft organise their own aviation.

Drones have radically changed the balance within aviation organisations. For one, there is less of a need for extensive infrastructure, and secondly, drones are very inexpensive and easy to operate, which means the proportions in aviation can change within a short space of time. If anyone can launch a drone from their balcony at home, aviation takes on a more decentralised nature, similar, in some ways, to the internet. Regulation by central authorities is more likely to come under significantly higher pressure than is already the case in traditional aviation, which affects not only safety, but mobility as well. So how do we ensure that our airspace remains both safe and mobile? This issue calls for new forms of coordination and cooperation between organisations at both the national and international levels.

Another challenge to the regime of aviation regulation is liability. For the professional use of drones, this liability depends on compulsory insurance, where companies are required to take out drone insurance. The Dutch government has conducted an extensive investigation which led to the conclusion that the liability laws currently in place are adequate, but must be evaluated on a regular basis. This creates the room to acquire additional experience, for example with practical safety and security issues which might occur, as well as with the manner in which the insurance market is organised. However, inspection for incorrect use or identifying the owner of a drone which is causing damage can be a significant challenge, particularly when it comes to recreational drones. An interesting measure by the European Commission is the recently adopted proposal to equip new drones with ID chips containing ownership details. This would not only solve the problem of implementing laws and regulations, but also places the responsibility for safety and security squarely with drone owners. This, in turn, is expected to have an impact on the use of drones itself. We are currently seeing changes in the regulatory regime.

3. Policy objectives

While drones are subject to a country’s aviation regulations, they also collect all manner of data, which touches on different policy issues altogether, including privacy, ownership of the data and

market power, and the nature of the information flows. This is governed by a separate set of rules, which, in turn, are challenged at the level of the instruments and the regime. The first question to ask is whether the rules currently in place for data flows and privacy laws also adequately cover drones, and whether people who purchase a drone from their local toy shop, for example, are aware of what is and isn't permitted when using drones. Secondly, drones are changing the nature of data collection, which has implications for the regulatory regime. In other words, there are several regulatory domains that merit appraisal at different levels.

The fact that drones integrate different regulatory domains produces a third effect. The balance between the public objectives safeguarded through these rules is disrupted and needs to be reassessed. Drones raise issues regarding the safety of air and ground traffic, the privacy of private individuals, the ownership of data flows, the economic power positions of companies, and so on. This calls for an integrated evaluation. The current policy emphasises this aspect: there is a focus on all forms of use, opportunities and risks, along with different regulatory aspects. The Dutch government has also been proactive when it comes to defining the roles they want to play in this sector (see Parliamentary Letter 30806 #31).

The main question here is what shape these considerations should take within the complexity of existing regimes. The exploratory policy approach is a good start in that sense, as well as communications about plans and issues and cooperation with the parties involved. It is as yet unclear whether the fundamental issues are being addressed, e.g. the question of whether we really want our airspace to be filled with drones, and what applications are acceptable in this case. This calls for a comprehensive public debate.

Level	Challenge?	Policy innovation
Policy instruments	Recreational use: compliant with the rules; challenge in the event of strong growth.	(Moderate) tightening of existing rules, based on feedback provided by consulting users through the internet.
	Commercial use: limited opportunities for use; regulatory burden.	New measure, based on feedback provided by internet users.
Policy regime	Central, hierarchical organisation of aviation clashes with the decentralised nature of drone traffic.	*Coordination between the various stakeholders in aviation: "self-regulating flights"*
	Liability is difficult to determine	Proposal from EU Commission: ID chips to identify owner
Policy objectives	Drones produce big data: this raises issues regarding privacy, ownership and market power.	Full assessment of objectives: safety, privacy, market power, economic opportunities, etc.

Table 1. Examples of policy challenges for drones

2.2 Driverless cars[3]

In this mini-case, we briefly outline the development of driverless cars, the ways in which they challenge existing policy frameworks, and how this issue has been addressed to date. We also describe the challenges that might be expected in the future, based on this outline provided. A more detailed analysis of the innovation dynamics in relation to autonomous or driverless cars will provide a more comprehensive picture of the policy challenges involved. The objective is to provide several examples of the various levels at which policy can be challenged by innovation.

Socio-technical innovation

As with drones, trends and developments relating to mechatronics and AI have produced a vehicle that operates without human intervention. There are a number of ways in which "self-operation" can be organised; we discuss three archetypes below. The first of these is the "autonomous car": a vehicle that can drive without human intervention, controlled by on-board computers. The most renowned example of a driverless car is the Google Car. A second form of automated driving is based on "intelligent infrastructure", where highly developed information systems along the side of the road control traffic. In this case, the car itself does not need to be "intelligent". A third form of automated driving is "cooperative intelligence", where roadside systems and on-board systems inside the vehicle are integrated with what are known as "nomadic devices" such as smartphones and GPS systems. This helps to create an intelligent network. Figure 1 shows the various innovation pathways.

The future trends associated with driverless cars are invariably positive: traffic will be safer, roads will be used more efficiently (i.e. less congestion), more people will have access to cars (i.e. more potential users get to benefit) and fuel consumption will be reduced (i.e. more efficient driving behaviour). However, it is unclear at this stage how exactly this will develop, as there are significant differences between the innovation pathways outlined. What automated driving will actually look like depends on how these innovation pathways relate to each other.

A large number of parties are involved in the development of intelligent systems. Car manufacturers are always working on improving driving features, e.g. automatic transmission, cruise control, anti-lock braking systems and support during reverse parking. The main motivations in developing these features are driver ease and comfort. This also serves as the basis for the development of automated cars: car manufacturers attempt to maintain their market position and win customers' loyalty. Established companies can sometimes benefit by managing their own technologies: autonomous functions provide support, or platforms established as part of the partnership. Dominant market players are better able to maintain their position if automated driving is rolled out on an incremental basis, while smaller and new players can strengthen their position by adopting innovations on an accelerated basis. This is the strategy adopted by Tesla, which is currently the leader in automated driving.

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[3] This case is based to a large extent on research conducted for the purpose of the Rathenau report *Innoveren door te reguleren* ('Innovation through Regulation') (Maclaine Pont & Deuten, *2016 - in progress*) and the case contained therein prepared by Bonno Pel. In addition, we have drawn on the work of Timmer & Kool (2014).

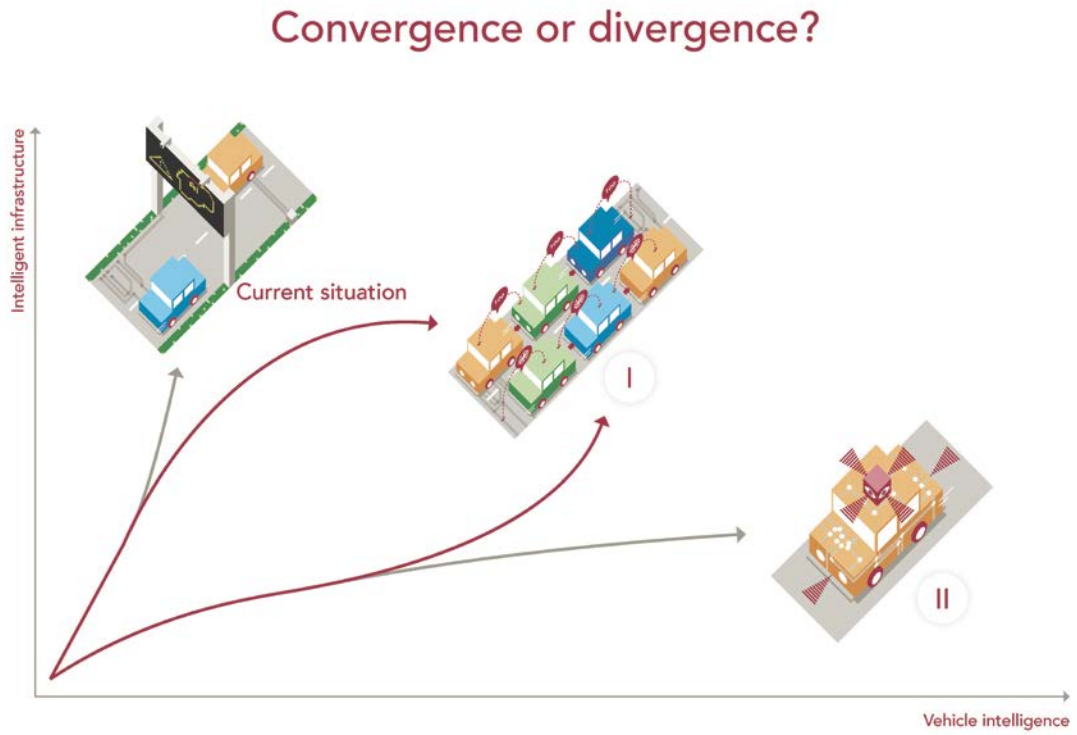

Figure 1. Potential innovation pathways for driverless cars (source: Timmer & Kool 2014)

Google is in the vanguard of the development of driverless cars and has been pursuing its own strategy: rather than improving cars – the cars themselves are not manufactured by Google – it integrates data. The integration involves the creation of a new system, in which “hard” components such as the car itself and sensors are ‘mere’ building blocks. It is essential that Google has access to metadata, the intelligence required to navigate traffic, and this, along with equity capital, explains how the Google Self-Driving Car could be developed in such a short period of time. This development can be regarded as disruptive, since it has the potential to seriously upset the balance in the automotive market.

Google and Tesla pose a threat to existing market conditions and the automation of driving functions has resulted in a significant improvement in safety: this represents a key innovation. It could potentially also result in a reduction in fuel consumption. Yet driverless cars represent incremental innovations in road traffic, as long as they are not integrated into the traffic system. There are various ways in which this integration can be achieved. When cars are controlled by a traffic system, traffic flows can be centrally managed. In the Netherlands, the national government is a key player in intelligent road traffic, with the Directorate-General for Public Works and Water Management involved in the development of traffic management systems. This can theoretically serve as a basis for developing a system to let road traffic drive in convoy on Dutch motorways, thereby avoiding accidents and making more efficient use of road capacity. A system based completely on “roadside operation”, however, does require that vehicles have specific equipment on board. From a practical point of view, it would make little sense to develop a scenario in which the

Directorate-General coordinates everything, even though this can be implemented at a technical level. For one, it does not align with other trends and developments.

Traffic users themselves can also arrange to drive in single file as part of a cooperative system. Over the years, the traffic information duties of the Directorate-General for Public Works and Water Management have become open to private companies in the form of public-private partnerships. We are currently seeing a large number of companies operating in the market for traffic intelligence and geolocation data, ranging from TomTom to smartphone apps (including, once again, Google). These companies are engaged in developing services for vehicles, rather than for publicly managed systems we refer to as “roadside systems”. As the number of road users employing these discrete systems increases, the driverless vehicle based on network intelligence becomes more of a reality. This has essentially made the possibilities for driving in formation more flexible. In addition, it also creates new opportunities for driverless shared vehicles (i.e. new public transport models). The extent to which cars will actually cooperate depends on which systems can communicate with each other and what type of information is exchanged. This is a question more related to the socio-technical organisation of the (new) traffic system than of automated driving itself: it calls for persuasive communication standards and reliable network governance.

Challenges to policy

Based on the concise ideas outlined in the paragraph above, we can describe the policy challenges below for illustrative purposes. How these challenges relate to political and policy-related priorities and assessment frameworks represents the next step in the policy process.

1. Policy instruments

Driverless cars are vehicles which are capable of navigating and operating without the need for a driver to take control, and the laws and regulations currently in place do not provide for this category. However, this does not mean that the use of driverless vehicles is prohibited. The Ministry of Infrastructure and the Environment is currently exploring opportunities to integrate driverless cars into the current framework, based on a creative use of various key rules and facilities. However, it is not just the laws and regulations, but also the implementation instruments which are adapted to the current situation: drivers are required to take a competency test at the Central Office for Motor Vehicle Driver Testing (CBR), while vehicles are inspected by the Netherlands Vehicle Authority (RDW). The easiest solution would be to request both certificates for driverless cars, although this would increase the regulatory burden. The Ministry of Infrastructure and the Environment is therefore exploring opportunities to design legislation and vehicle acceptance on an adaptive basis so as to create room for future – unexpected – developments, while still keeping safety a priority.

Instruments do not just need to “factor in” innovation; they actually help to define it. The criteria applied in vehicle inspections, for example, include safety and fuel efficiency. The latter helps to achieve environmental targets: the evaluation of carbon emissions is one of the factors used to determine the amount of road tax paid. Car manufacturers are therefore encouraged to focus on making environmental improvements. In addition, it is also possible to incorporate new policy objectives into the vehicle requirements, for example by checking the capacity for driving in formation.

Another issue is liability; under the current legislation, individual legal entities are held responsible. The driver is always held liable for car accidents, and in some cases the manufacturer may also be held liable. However, it is presently unclear who is legally responsible for driverless cars. Several car manufacturers have recently claimed full responsibility for driverless cars; however, it remains to be seen whether this is compatible with the legal framework in place. Legal proceedings may be able to shed light on this. In order to increase legal certainty, another possibility is to translate the statements made by car manufacturers into a set of guidelines. Presumably, this is possible from a legal perspective as well as being politically expedient. For example, cases tried in criminal courts could turn out to be problematic.

2. Policy regime

The question has been raised as to whether a regime involving two “gatekeepers”, i.e. one for vehicles and one for drivers, would be adequate in terms of efficiency and effectiveness. In addition, there are questions relating to liability. A common concern is that the timing for decision-making has changed. Drivers on the road make all sorts of decisions: what route to take, how they deal with specific traffic situations, their driving behaviour, and so on. This must be programmed into the automated driving system. But how do you organise decision-making processes in an effective way?

To some extent, this problem is solved by “the market”: it is obviously not in manufacturers’ best interests to develop a reputation for being unsafe. However, as the number of parties involved increases, it will no longer be possible to rely on “self-regulation” to the same extent. The Netherlands Vehicle Authority (RDW) may impose additional requirements, but as a larger number of functions depend on networks, it will become more difficult for a single entity to control the design requirements. Cooperative systems require that regulation be organised differently; that is to say, automated driving consists of a number of different innovation pathways, each of which comes with its own opportunities and limitations. When making an analysis, it is important to look at innovation pathways as comprehensively as possible, including the possibilities and limitations in terms of the traffic system, as well as the various ways in which responsibilities can be assigned in this process, for example. The numerous questions that this raises can then be integrated into experiments involving driverless cars, for example by testing different liability models.

3. Policy objectives

The Minister of Infrastructure and the Environment is investing in driverless cars with the specific objective of improving both traffic safety and mobility. The description of the socio-technical innovation shows that there are significant differences between innovation pathways for automated driving, particularly in terms of how they contribute to the mobility objective. A cooperative system is best capable of letting cars drive alongside each other in a variety of locations and under a variety of conditions. In this sense, policy designed to improve mobility would do well to promote the development of a cooperative system, yet at the same time a cooperative system is also the most difficult to implement. By actively focusing on this, another policy challenge is created in the form of platform governance. One way to organise an open platform is by developing standards, while another way to keep a platform open and promote innovation dynamics is market regulation. It takes a solid communication platform to accommodate a large number of participants. However, the

strength of a platform depends on the governance strategy used: it is difficult to manage a process when the intelligence is fragmented. The Ministry of Infrastructure and the Environment has therefore taken this one step further: as an innovation partner, it is actively involved in developing a cooperative system.

The shift of decisions from driver to car also raises psychological, social and moral issues. Are people actually willing to lose their autonomy behind the wheel? Could this potentially lead to types of behaviour that have not been anticipated so far? Also, what are acceptable practices, for example in an accident, when the danger to the passengers must be considered against that of other traffic users? Normative issues may also be part of experiments involving automated driving, not only by incorporating socio-scientific research into research and system design, but also by involving users.

Level	Challenge	Policy innovation
Policy instruments	Integration of the "human-operated vehicle" category.	Incorporation into existing (special) regulations and implementation instruments.
	Policy objectives of automated driving: environmental, cars driving in formation.	Delegation through acceptance or inspection requirements.
	There is a lack of statutory guidelines for liability: this is to be decided by the courts (on a case-by-case basis).	*Claims from car manufacturers regarding the assignment of responsibility through guidelines.*
Policy regime	Changes in the timing for decision-making: this affects the organisation of supervision and responsibility.	*Analysis of each innovation pathway: integral experiments, e.g. by assigning duties and responsibilities.*
Policy objectives	A cooperative system is preferred, but (more) difficult to implement.	Network governance. Active participation in innovation (i.e. the DAVI project).
	Automated driving raises new social and normative questions.	Investigating/assessing social aspects. *Giving users a more active role in experiments.*

Table 2. Examples of policy challenges associated with driverless cars

2.3 UberPop[4]

In this mini-case, we briefly outline the development of the UberPop platform, the various ways in which it challenges existing policy frameworks, and how this issue has been addressed to date. We also describe any challenges that might be expected in the future, given the brief outline provided. A more detailed analysis of the innovation dynamics in relation to UberPop and other digital platforms will provide a more comprehensive picture of the policy challenges involved in the changing taxi market. The objective is to provide several examples of the various levels at which policy can be challenged by innovation.

Socio-technical innovation

The innovations facilitated by Uber can hardly be considered technical; these are services provided by an intermediary between supply and demand, commencing with the market for passenger transport. These services immediately caught on in the United States and subsequently in other countries, since the majority of locations do not have taxi companies. The launch of US-based company Uber went relatively unnoticed in the Dutch market, because there were already taxi companies operating in the Netherlands and TCA, Amsterdam's largest taxi company, already had an app of its own. Uber's taxi services did not position themselves as competitive in terms of rates, but rather as an improved service, and in this particular context represented a highly incremental type of innovation.

Intermediaries such as taxi companies and Uber improve the taxi market, thereby facilitating more efficient transactions. For one, they offer a more user-friendly method of securing a cab than hailing one in the street, as well as improving the chances of a fare for the providers of the service. An additional benefit of these services is that they create more "information equality". The relationship between taxis and customers is essentially unequal: for street taxis, for example, it is difficult for customers to compare rates and quality, and customers are unable to check if the driver is taking the correct route when they find themselves in an unfamiliar setting. An intermediary can help customers navigate the services available, as well as create trust. In addition, intermediaries also offer economies of scale to individual businesses thereby lowering the barrier to enter the market. In principle, this helps to create healthier competition.

Uber's services as an online platform go beyond those provided by traditional taxi companies. For one, customers can directly exchange experiences with each other; this appears more trustworthy than a taxi company which is merely viewed as a provider (in some cases, there may even be associations with an alleged "taxi mafia"). Secondly, an online platform reduces the chain between supply and demand, resulting in lower transaction fees. Uber's taxi services (UberBlack and

[4] A key source for this particular case is the report *Internationale vergelijking taxiregulering en Uber* ("International Comparative Study of Taxi Regulation and Uber"), published by the Kennisinstituut voor Mobiliteitsbeleid (Research Institution for Mobility Policy), March 2015. We also drew on the study *De kracht van platformen* ("The Strength of Platforms") (Kreijveld, Deuten & Van Est 2014), the study of a debate on the sharing economy on Cato Unbound, from the US-based think tank Cato Institute, and from the 19th November 2015 edition of Dutch news daily *NRC Handelsblad*.

UberLux) do require that drivers pay a fee, but this may be lower than those charged by taxi companies, since some administrative fees can be avoided.

Whereas Uber's taxi services represent incremental innovations, particularly in the Dutch market, UberPop is a different story altogether. UberPop does not purport to be a taxi service, but rather a ride-sharing platform that allows consumers to make arrangements with each other for sharing one another's chauffeured vehicles. In reality, however, these "mutual arrangements" tend to serve as commercial rides, while the platform serves as a taxi company. In other words, UberPop was launched in the market based on a disruptive business model.

A key aspect of the innovation dynamics is the platform model: Uber's closed model enables it to operate independently, while at the same time creating a power imbalance. First of all, the company operates in a large number of countries, which means it can generate substantial revenue even if it keeps its rates low. However, what is more important is the lock-in situation created by platforms: once drivers and customers have joined Uber, they are not likely to opt out – particularly if a community of participants has already been formed. Combined with Uber's closed platform model, this creates a very strong market power. Uber can now easily expand into other areas, in the process gaining access to a growing amount of valuable – and sensitive – data.

Challenges to policy

Based on the concise ideas outlined in the paragraph above, we describe the policy challenges below for illustrative purposes. How these challenges relate to political and policy-related priorities and assessment frameworks represents the next step in the policy process.

1. Policy instruments

The criticism focuses mainly on the fact that UberPop is – deliberately – sidestepping existing regulations, with providers serving as taxis on the pretence of an exchange of services. The problem here is not so much the rules, but rather their applicability, in the sense that the service has evaded the taxi industry regulator. The court was able to ban the service based on its actual function. A policy innovation designed to prevent future problems would be the proposal of goal-oriented regulation. However, UberPop has gone much further in terms of policy challenges. The policy plans demonstrate that the Ministry of Infrastructure and the Environment has also taken into account changes in the division of roles.

2. Policy regime

The taxi market is regulated in order to correct market failure. This concerns the high investment costs involved, the inequality between the customer and the provider and the low chance of drivers with "bad intentions" getting caught when the market is particularly saturated. In order to remedy this market failure, price, capacity and quality are all regulated in the Netherlands. However, an online platform such as Uber solves various aspects of this more efficiently and effectively than the measures currently in place. Instead of relying on taxis having taxi meters and rate cards on board as required, customers can gather information instantaneously in order to set a reasonable fare and route, and the same applies for quality. The review system appears to be more effective than a

system involving certification and checks by being less bureaucratic and increasing competition in the taxi industry based on the need for companies to present themselves as favourably as possible.

However, UberPop also creates a different type of market failure in that, although the courts have suspended the UberPop service, it is difficult to deactivate it, making it hard to regulate. When drivers get caught they receive a personal fine, although Uber has stated its willingness to cover these fines. There is also a lack of inspection of drivers' working conditions, their social security and the safety to passengers and other traffic users. On 19th November 2015, Uber came forward with a solution: the company would suspend its UberPop service in the Dutch market.

An innovative policy response is the intention of the Ministry of Infrastructure and the Environment to develop a new strategy – in addition to target regulation – in which achieving these targets is increasingly left up to the market. The intention is to address this by gradually implementing a series of measures. A first measure would be to change a number of requirements so as to make it possible to set prices using an app: this would open the market to providers who have no intention of evading taxi laws. For example, TomTom, the Netherlands-based manufacturer of automotive navigation systems, has been planning to do this for years.

Yet the effects of these changes would extend further: apps have shifted the responsibility for information and fair prices and services to the customer. This could potentially also affect the responsibility for other types of "market failure", such as drivers' working conditions. This, in turn, could raise questions regarding legitimacy, for example as to who is responsible for public interests such as working conditions: the Ministry of Infrastructure and the Environment, the Ministry of Social Affairs and Employment, the taxi industry, Uber – or the consumers looking for the lowest-priced service? These questions inevitably affect the organisation of the regime as a whole.

3. Policy objectives

A challenge in terms of the policy objectives in this case is the taxi market becoming connected to the domain of digital platforms. Platforms theoretically provide a solution to different aspects of market failure in the taxi industry and to the government failure associated with conventional taxi regulation, such as the required equipment and devices. At the same time, we have also witnessed the new problems created by UberPop. In order to be able to set policy objectives, the innovation dynamics of platforms need to be considered, and this intention is outlined in the Parliamentary Letter titled *Ruimte voor vernieuwing* ("Room for Renewal").

When taxi platforms are approached as digital platforms, this presents a whole new set of challenges. Apps such as UberPop generate substantial amounts of data. How is privacy guaranteed? Who owns the data? In order to answer these questions, discussion is needed in addition to research with regard to the question as to which types of platforms are desirable, and how this relates to other public objectives, e.g. the notion of "free internet traffic".

Level	Challenge	Policy innovation
Policy instruments	UberPop promotes its taxi service as a form of exchange, thus evading the law.	Court ban imposed. Intention of target regulation.
Policy regime	Uber platform solves market failure relating to price and quality information more efficiently than the current regulatory regime in the taxi market.	Intention to transition to new regime: start by permitting apps.
	Uber creates new market failure: misuse is difficult to control.	UberPop suspends services (in the Netherlands).
	Decision-making shifts to consumers: this affects the responsibilities for other public objectives, e.g. drivers' working conditions.	*Radical reorganisation of the regulatory regime: reduce the role of the government.*
Policy objectives	Apps link the taxi industry with the "digital platform" domain.	Intention to create policy for digital platforms. *Linking the objectives of the taxi market with those of the platforms.*

Table 3. Policy challenges for Uber

3 Knowledge requirements

The major uncertainty and changes associated with technological advances have raised the question among many policymakers as to how they can adequately make policy decisions. This essay demonstrates that innovation is socio-technical in nature: innovations are created through interaction between technological, social, economic, cultural and political aspects. At the same time, policy also forms a part of innovation: while it cannot completely determine the direction of this innovation, it can certainly influence it.

The challenge for policymakers, then, is to learn more about the role policy plays in innovations, the ways in which innovation affects policy, and what the relationship should be between the government and the innovations in question. It is useful to acquire information on this topic at the earliest possible stage and to develop the knowledge base from there. The insights will gradually become more precise (at least to some extent) while continuing to change at the same time. Some uncertainty will always remain, including questions such as: which specific aspects are uncertain, and how will this affect the shaping of the policy objectives, regime and regulatory instruments?

The mini-cases discussed in the previous chapter show that when we view innovation based on the socio-technical framework presented in this essay, this produces a rich and complex picture. Based on this image, we can then gain an idea of the policy innovations that are necessary and/or desirable, and, in so doing, take initial steps towards setting more stringent knowledge requirements. Bearing in mind the cases outlined, we will return to the framework in this chapter and will shed light on the types of knowledge requirements that arise at all policymaking levels with regard to innovative developments.

3.1 Insights gleaned from the cases

Anticipation: technology is merely a starting point

Technological advances tend to attract attention, and applications based on technologies such as synthetic biology, robotics and artificial intelligence, in particular, conjure up images of the future that both create high expectations and cause considerable anxiety among the public. Advances in technology can serve as an excellent basis for anticipating innovation. The cases reviewed also demonstrate that a variety of innovation paths are created that are only partially shaped by technological aspects. There are a variety of other aspects that play a role as well, including the way technologies are shaped into application and the related market expectations and business models, the way in which users are involved and the interests and expectations based on which they act, market competition, the scope offered by existing regulation for new applications, and the associated policy objectives and public interests. Table 4 outlines a number of knowledge requirements that might arise in the process of charting the dynamics of socio-technical innovation.

	Mapping technology
Knowledge requirements	• Which technologies and technological systems play a role? • At what stage of development is the innovation? • How rapid are the advances in technology? • What views and expectations play a role? • What are the technological alternatives?
	Identifying the parties involved
Knowledge requirements	• Who is driving innovation? • Who are the users? • Who are the technology regulators? • Are there opponents, and what are their views and interests? • How do proponents and opponents relate to each other?
	Charting social issues
Knowledge requirements	• What are the opportunities and risks involved? • What values are being compromised? • Which social objectives play a role? • How urgent are the issues concerned? • What is the status of the public and political debate?

Table 4. Several knowledge requirements that shed light on the socio-technical innovation dynamics.

When using policy to respond to innovation, it is important to identify the various socio-technical innovation pathways involved. First of all, thisprovides a basis for anticipating the policy innovation required, as we will explain in more detail below. Secondly, the socio-technical innovation dynamics identify relevant and perhaps new sources of knowledge. Based on this information, policymakers can then extend their knowledge networks and determine how to address specific issues. In the Uber case outlined above, for example, our concise analysis notes the importance of expertise in platforms and internet governance. Thirdly, developing an understanding of socio-technical information can help make stakeholders' expectations more realistic. Policymakers can reduce the uncertainty for themselves and others by highlighting what is and is not (or not yet) clear, what strategies to pursue in order to eliminate some of this ambiguity, and what implications this will have for the immediate future. In the Drones case, for example, we can attempt to determine who will be liable for any accidents caused when it turns out to be impossible to identify the owners. This provides a framework for the ID chips for drones proposed by the European Commission.

At the same time, the cases also demonstrate that knowledge is never complete: developments continue, technologies and applications converge, and the innovation network as a whole influences the direction in which innovation pathways unfold. Another factor is feedback (or lack thereof) from policymakers. While the uncertainty does not actually disappear, it does change, and dealing with uncertainty in innovation is a learning process. The paragraph below addresses the question of how this learning process can be organised.

Learning: the knowledge requirement per policy level

In the policymaking arena, the process of building and acquiring knowledge and adopting specific viewpoints is an ongoing concern. In this essay, we explain that policy challenges exist at three levels: policy instruments, the regime under which policy is implemented, and the objectives and basic principles of policy. The knowledge requirements vary at each of these three levels.

At the level of policy instruments, the question to ask is: how effective are the laws and regulations, subsidy policies or other policy measures in place, what burden do they create, and how might the situation be improved? The cases demonstrate that two dimensions need to be examined. The first question is whether the measures implemented achieve the desired results in an efficient manner, even when circumstances change due to innovation. For example, is the separation between vehicles and drivers useful when approving driverless cars for the market? A second question that arises concerns the impact that existing measures have (unintentionally or otherwise) on innovative developments, e.g. the impact of aviation regulations on the commercial use of drones.

At the level of the regulatory regime, the question concerns how efficiently and effectively the duties have been assigned, whether the division of responsibilities is legally sound, and what alternatives there are for regulating a specific domain. We first look at the extent to which the regulatory regime manages to achieve the policy objectives, or whether the organisation might be improved in this regard. In the Uber case, technology enables us to assign responsibility for information to users, thereby enabling more efficient regulation of the market.

In addition, the potential impact of the policies implemented on innovation are outlined, for example, the impact of the way road user liability is organised on the gradual introduction of automated driving. In order to determine whether the regime needs to be changed, it is important to develop an idea of the possibilities and limitations of the domain as a whole. In order to explore opportunities for changing policy and, by extension, changing the division of duties between the various participants in society, active consultation is required, since stakeholders must be both willing to accept their responsibilities and have the ability to perform the duties concerned.

At the level of policy objectives, the knowledge question is: how legitimate are the proposed objectives used to regulate innovation, are there new public objectives that call for policy, and/or have there been any political or social shifts in values? Firstly, this allows us to examine whether innovation causes changes with regard to the policy objectives in the policy area(s) concerned. The driverless car, for example, makes it possible to improve traffic safety and accessibility, provided that automated driving meets specific requirements, which the Ministry of Infrastructure and the Environment subsequently sets out to meet. The next step is to assess the legitimacy of the policy objectives and basic principles in light of changing standards in society. Determining the objective of drone policy, for example, requires an understanding of how the public weighs issues such as noise nuisance and privacy in relation to aviation safety. Developing an understanding of objectives and basic principles requires both internal and external dialogues. Within the government, policymakers from the various departments and ministries evaluate these issues on a regular basis, for example by consulting a panel of experts. In some cases, they meet to discuss the implications for various policy areas. At the external level, specific normative issues are explored which concern specific

sections of society. Any signals resulting from this may prompt the parties concerned to initiate dialogue on a smaller or larger scale.

Doing: preparing to define the next steps

The learning process created by this approach is iterative in nature: the picture is never complete; new informational needs arise constantly and new decisions need to be made on a regular basis. Policymakers would do well to adopt a specific position at the earliest possible stage, since policy is part of the innovation process and because innovation can potentially have implications for government responsibility. The basis for determining one's position is not to demand or provide certainty; the key is interpret as closely as possible what is already known, to identify where uncertainties remain and determine which issues merit – and will receive – attention. As it becomes more clear, then, what role policy plays in innovation and what implications innovation has on policy, it also becomes possible to determine what is politically expedient.

The role currently played by the government and the role it can or intends to adopt in the future depends, first of all, on a number of responsibilities. The government has a number of specific constitutional responsibilities, such as safeguarding public values, preventing problems associated with collective action, and meeting the standards of effective governance. In addition, it also holds a number of political and policymaking responsibilities, as represented by government plans, the priorities and assessment frameworks for the policy issues of the various ministries, and in terms of handling new political and social trends and developments.

Furthermore, there are decisions to be made in determining the role of the government, or the role it intends to play. In the introduction, we provided a number of examples of ways in which the Ministry of Infrastructure and the Environment has been involved in innovation through its various roles. There are various references we can draw upon in methodically examining these roles. The World Bank (2002) provides an instrumental framework, for example, for four different roles the government can adopt with regard to a specific innovation. These roles are: 1) Mandating (i.e. setting requirements): for example by applying minimum standards for laws and regulations; 2) Facilitating: by promoting developments in a specific area, with instruments being used to further facilitate the process, e.g. targeted programmes, subsidies, tax measures, laws and regulations, or public procurement (launching customer); 3) Partnering: based on strategic considerations to achieve their own objectives, governments can work together on innovations in a variety of ways, as coordinators, equal participants or moderators; 4) Embracing: by advocating or providing a platform for innovation.

Alternative guidelines for government roles are provided in the report titled *Leren door doen* ("Learning By Doing") (PBL & NSOB, 2014), which identifies four different *approaches* to roles: the legal government, the performing government, the networking government and the participating government.

3.2 Working framework: policy challenges and areas of innovation

As the process of innovation becomes more dynamic, policymakers are faced with greater uncertainty. This context calls for a highly active knowledge strategy based on which policy can be amended on a regular basis. The question is, however, how do you put this into practice? The Ministry of Infrastructure and the Environment and other Dutch ministries currently have a number of programmes and instruments in place designed to deal with innovation, while at the same time we have also noted a need for a more systemic approach to innovation.

To conclude this essay, we will provide an overview of the policy challenges, types of informational needs and learning processes relevant at all policy levels, along with examples of the types of amendments that can be made through policies. The table below can serve as a source of support in analysing specific cases. An initial step is to identify and outline the relevant technological changes, who plays a part in these changes, and the social issues arising as a result. Table 4 provided an overview of the various informational needs which can provide an insight into the socio-technical innovation dynamics. Once the innovation pathways created have been outlined, along with the role that policy plays in this process, Table 5 can help us to define the specific knowledge requirements for each of the three policy levels.

The process of defining these requirements is a permanent part of the policymaking process. Innovation creates new uncertainty all the time, and the government will continue to be faced with new challenges. Table 5 contains a number of proposals for integrating the learning process required into the policies. The working framework is specifically designed as a first step in a conceptual exercise to answer the question of how policy can be organised so as to deal with uncertainty more effectively.

Table 5 Working framework for determining policy challenges

Policy instruments	**The measures used to operationalise policy: laws and regulations, grant schemes and programmes**
Challenge	Is innovation consistent with the manner in which measures have been designed?
Knowledge requirements	How effective are the measures implemented? What type of burden do they create? What alternative instruments are possible and/or necessary for innovation?
Learning process	• Measuring and monitoring for the effects and burdens of measures. • Changing requirements for innovation: comparison with measurements and monitoring results.
Administrative assessment	Do measures achieve the desired results in an efficient manner? What are the unintended consequences?
Political assessment	What effects are favorable and how do these measure up against the burden or unintended side effects?
Cooperation	Internal and external information sources; internal evaluation. Cooperation requires a foundation of trust.
Type of response	Variation within the existing system (“controlling the buttons”).
Examples	Amending existing measures/modifying existing implementation processes, for example: • revision of laws and regulations • setting requirements for taxes and subsidies • setting requirements through procurement and tendering • soliciting online feedback in the review of regulatory proposals Incorporating adaptive capacity, for example through the use of: • goal-oriented legislation • sunset clauses • Right-to-Challenge • Experimental legislation (see also: policy objectives)

Policy regime	How a regulatory regime is organised and how tasks, roles and responsibilities are assigned
Challenge	How effectively does the regime function? Does innovation legitimise a different form of organisation?
Knowledge requirements	To what extent are policy objectives achieved under this regime? What are the intended and unintended effects on innovation? How effectively and efficiently are tasks assigned? How legitimate is the division of responsibilities? What alternative forms are available to regulate a specific domain?
Administrative assessment	To what extent does the regulatory regime meet the policy objectives? How can this be organised differently/more effectively?
Political assessment	To what extent are the various stakeholders willing and/or able to take on specific roles?
Learning process	• Integrating internal lessons (i.e. learning capacity) and comparing them with external reflections. • Information exchange and evaluation between the various participants. • Creating institutional properties and facilities in order to deal with change.
Cooperation	Joint knowledge production; internal and external evaluation. Creating best-efforts obligations. Integrating third parties (i.e. independent entities) into the regime.
Type of response	Amending or redesigning a regulatory regime in conjunction with other parties (and their roles and responsibilities).
Examples	Linking ministerial responsibilities and regulatory areas. Modifying the institutional organisation. Other forms of cooperation or division of responsibilities, for example: • Safe Innovation (Nanomaterials) • EMA and EPTN translation hub (nanomedicines) • Platforms for supply and demand (i.e. open taxi apps)

Policy objectives	**The objectives envisioned by policies and the principles underlying them**
Challenge	Does innovation challenge/compromise existing policy objectives? Does it give rise to other public interests? Does innovation lead to new considerations? Are prevailing standards and values under discussion?
Knowledge requirements	How legitimate are the proposed objectives? What public objectives are affected – is there a change in how these objectives are balanced against each other? How do the various stakeholders view current/future trends and developments? What changes could and/or would they make?
Administrative assessment	How do the various public or political objectives relate to each other in light of the changes that have occurred?
Political assessments	How desirable and/or legitimate are the policy objectives or basic principles? What type of government role is desirable or legitimate?
Learning process	• Evaluation criteria are up for discussion; assessing the existing regime against wider questions regarding public interests and standards. • Reflective capacity from outside of the (direct) regime: independent critical insight. • Need for institutions with gravitas/mandate.
Cooperation	Open dialogue. Involving a larger group of participants, also beyond the immediate stakeholders.
Type of response	Reassess objectives and basic premises in conjunction with stakeholders (in the broad sense of the term).
Examples	Reassessing regulatory objectives. Exploring normative principles, for example: • public debate on nanotechnology. Integrating experimental legislation at the instrument level helps to acquire knowledge in anticipation of regime change and policy objectives.

Table 5. Working framework for determining policy challenges

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Who was Rathenau?

The Rathenau Instituut is named after Professor G.W. Rathenau (1911-1989), who was successively professor of experimental physics at the University of Amsterdam, director of the Philips Physics Laboratory in Eindhoven, and a member of the Scientific Advisory Council on Government Policy. He achieved national fame as chairman of the commission formed in 1978 to investigate the societal implications of micro-electronics. One of the commission's recommendations was that there should be ongoing and systematic monitoring of the societal significance of all technological advances. Rathenau's activities led to the foundation of the Netherlands Organization for Technology Assessment (NOTA) in 1986. In 1994 this organization was renamed 'the Rathenau Instituut'.