Revista Guillermo de Ockham
Research article Open Access

# Assessing Value-Laden Technology

## *Evaluar la tecnología cargada de valor*

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**Received:** 03/14/2024

**Revised:** 05/12/2024

**Accepted:** 05/30/2024

**Cite as follows:** Niiniluoto, Ilkka. (2024). Assessing value-laden technology. *Revista Guillermo de Ockham, 22*(2), pp. 5-17. https://doi.org/10.21500/22563202.6983

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**Declaration of interests:** The author has declared that there is no conflict of interest.

**Availability of data:** All relevant data can be found in the article. For further information, please contact the corresponding author.

**Funding:** None. This research did not receive any specific grants from funding agencies in the public, commercial, or nonprofit sectors.



## Abstract

Technological innovations—tools, artefacts, and processes—open up new possibilities of human action and thereby increase the domain of our positive freedom. Technology is inherently value-laden, since such an intended increase of freedom may be a good or bad relative to human values. The use of tools may also involve unintended and unwanted by-products and side effects. Therefore, technology should not develop in a deterministic or random manner but should be guided by reasonable democratic principles. *Technology assessment* (TA) is a pattern for the evaluation of technological projects and products by their costs and benefits, risks, and profits. Using philosophical distinctions and arguments as its method, this paper explains, elaborates, and illustrates Niiniluoto's formula TA = 6E + S for TA. The first E is *effectiveness*, the ability of the new tool or solution to produce its intended effects. This is the main concern of the engineer. The second is its *economic* profit, based on the monetary exchange value of the product. This is the domain of economic theories. Effectiveness and economy, and efficiency as their combination, are not the only relevant dimensions of TA. As products of design, artefacts have *esthetic* qualities, studied today in applied esthetics. The relations of tools to the health of their users are studied in *ergonomics*. The relations of human technologies to the health of the natural environment and sustainable development are treated in *ecology*. Technical tools and their effects can always be evaluated by *ethical* standards which concern their moral worth. Technological systems have also an impact which is *social* in the broad sense, since they can lead to changes in the communicative, legal, institutional, and political spheres of society.

**Keywords:** ecology, economics, effectiveness, ergonomics, esthetics, ethics, freedom, quality of life, social impact, technology assessment, tools, values.

## Resumen

Las innovaciones tecnológicas –herramientas, artefactos y procesos– abren nuevas posibilidades de acción humana y, por tanto, aumentan el ámbito de nuestra libertad positiva. La tecnología está intrínsecamente cargada de valores, debido a que este aumento de la libertad puede ser bueno o malo en relación con los valores humanos. El uso de herramientas también puede conllevar subproductos y efectos secundarios no deseados. Por tanto, la tecnología no debe desarrollarse de forma determinista o aleatoria, sino guiarse por principios democráticos razonables. La *evaluación de tecnología* (TA, por su sigla en inglés) es un patrón de evaluación de proyectos y productos tecnológicos por sus costes y beneficios, riesgos y beneficios. Utilizando como método distinciones y argumentos filosóficos, este artículo explica, elabora e ilustra la fórmula de Niiniluoto TA = 6E + S para la TA. La primera E es la *eficacia*, la capacidad de la nueva herramienta o solución para producir los efectos previstos. Es la principal preocupación del ingeniero. La segunda es su beneficio *económico*, basado en el valor de cambio monetario del producto. Este es el ámbito de las teorías económicas. La eficacia y la economía, y la eficiencia como su combinación, no son las únicas dimensiones relevantes de la TA. Como productos del *diseño*, los artefactos tienen cualidades estéticas, estudiadas hoy en día en la estética aplicada. Las relaciones de las herramientas con la salud de sus usuarios se estudian en *ergonomía*. Las relaciones de las tecnologías humanas con la salud del entorno natural y el desarrollo sostenible se tratan en *ecología*. Las herramientas técnicas y sus efectos siempre pueden evaluarse con criterios *éticos* relativos a su valor moral. Los sistemas tecnológicos también tienen un impacto *social* en sentido amplio, pues pueden provocar cambios en las esferas comunicativa, jurídica, institucional y política de la sociedad.

**Palabras clave:** ecología, economía, eficacia, ergonomía, estética, ética, libertad, calidad de vida, impacto social, evaluación de tecnologías, herramientas, valores.

## Is Technology Out of Control?

According to Benjamin Franklin and Karl Marx, "man is a tool-making animal." Ever since the first wooden and stone tools of our ancestors about three million years ago, the advent of agriculture about 10 000 years ago, and the Industrial Revolution in the 18th century, the intentional design and use of technical tools and artefacts have been a major driving force of human culture (Bugliarello & Doner, 1979). Technological progress with science-based development of new products and systems has been a crucial factor influencing industrial economies. This situation is not changing in the "post-industrial" society with Big Science, high tech, information technology, computers, automatization of production, artificial intelligence, mass media, and content industries. Technology continues to be the source of the wealth and competitiveness of nations. It is, therefore, natural that most developed countries have established national systems of science and technology policy to promote and accelerate technological invention and innovation. For example, since 1983 this program has been led in Finland by the Science and Technology Policy Council (later Research and Innovation Council), which formulated its conception of "the national innovation system" in 1993. And to gain more power in this task, small countries have joined forces to build larger economic and political units like the European Union. The Horizon programs and structural funds have aimed at ensuring the global competitiveness of EU industries.

On the other hand, technology also has harmful effects on the natural and social environment. Many of them have been unintended by-products of the employment of new technical tools and machines. No one could foresee the revolutionary social consequences of steam engines, spinning wheels, work lines in factories, cars, plastic, computers, and smartphones. The damaging effects of our technological form of life on the health of nature (such as waste of resources, pollution of air and water, greenhouse effect, climate change, loss of biodiversity, etc.) have only gradually been realized in the last decades. Since the 1970s, the scientists in the Club of Rome have argued that there are limits to the growth, and visionaries like Georg Henrik von Wright have expressed their concern about the dangers of technology (Niiniluoto, 2017). Many governments have endorsed the goal of sustainable development in their fight against climate warming: Finland aims to be carbon neutral in 2035, and the EU in 2050. Technology, together with natural and human sciences, is also expected to contribute to "grand challenges" by finding solutions to "wicked problems" like climate change, energy supply, water resources, ageing, healthcare, and poverty.

It is thus clear that there is an urgent need to direct and *control* technological change, both to promote and accelerate it in profitable directions to assess its effects and to inhibit its dangerous growth (Niiniluoto, 2022a, pp. 337–354).

Both tasks, acceleration and assessment, presuppose that technology is under human control. This view may be called *technological voluntarism*, as it claims that the emergence and change of technology depends on human will, i.e., can be influenced and directed by human evaluation and intervention (Niiniluoto, 2020).

There are strong trends in the philosophy of technology which deny voluntarism. Some of them are based on the "romantic" idea that modern technology has become an independent system or monster which follows its own "inner logic" and directs "technological imperatives" to us. Such *technological determinism* has been formulated, as a horror picture, by Jacques Ellul (1964). In a milder form, Langdon Winner (1977) has defended the thesis that technology has become "autonomous," and today determines politics, rather than vice versa. But determinism has also been advocated by the spokesmen for *technocracy*, who suggest that for ordinary citizens it is simply the best to accept and passively follow the advice of the technical experts who know where technology is going by its inner necessities. Technological determinism, divided into pro and contra positions, can be seen today in the opposite attitudes to the rapid development of artificial intelligence (AI): while some "post-humanists" are optimists and greet with enthusiasm the emergence of a new hybrid man-machine species, some pessimists see such inevitable "singularity" as the final catastrophe in the history of humankind.

Besides technological voluntarism and determinism, the third main alternative is to claim that technological change is indeterministic, chaotic, and unpredictable. An expression of the "contingent" and "heterogeneous" nature of technology is the *constructivist* approach in the STS studies. Wiebe Bijker and John Law (1992) suggest that "sociotechnology" constitutes a "seamless web," where society and technology cannot (or should not) initially be distinguished so that one of them does not dominate the other. This means that there are no predetermined trajectories for the evolution of technological projects (Bijker, 1995).

All three approaches have their insights and merits, but limitations as well. Naive voluntarism is certainly an illusion. Technology is a powerful social system which, in Émile Durkheim's sense, has coercive power over us. Yet determinism is not warranted: technological development does indeed present its "imperatives" to us, but they are always conditional on some value premises (about what should be desired or avoided), and therefore we always have the option to disobey them (Niiniluoto, 1990). The relevant value premise is usually hidden, which gives the misguided impression that such commands are unconditional imperatives (Niiniluoto, 2017).

Voluntarism should steer between two extremes. One is *value objectivism*, where the philosophical, religious, or technocratic elite can settle the permitted valued to all others. This is typical of totalitarian or authoritative political systems. In a liberal state, the citizens enjoy personal freedom and rights, and they are allowed to have different perspectives which also influence decision-making about social welfare and technology policy (Niiniluoto, 1997a). *Decisionism* is another extreme version of voluntarism, which takes value choices to be purely arbitrary, subjective, and situational so that technology decisions are accomplished by pure political power. Jürgen Habermas (1970) criticizes decisionism by defending the possibility of rational discourse on values. Even though progress in technology may to some extent influence our goals and values, our choices need not be random, non-purposive, or externally determined, but also the social needs and reasonable ends must be publicly and freely discussed in a democratic community.

So instead of *allowing* technology to develop in a deterministic or chaotic manner, we ought to find democratic ways of assessing and controlling it.

## Values in Science and Technology

*Science* is the systematic pursuit of knowledge (Gr. *episteme*) about nature, human beings, and society. Scientific research always takes place in a social context which influences its organization, orientation, and sometimes even the content of knowledge. The results of research are fallible and revisable, but—as long as the methods of scientific inquiry are employed—they are constrained by what is *true* and what kind of *evidence* is available. The basic *epistemic utilities* are standards for assessing the quality of success in knowledge-seeking: truth, information, truthlikeness, confirmation, understanding, explanatory power, predictive power, and simplicity. The tentative acceptance of scientific hypotheses can be based upon their epistemic utilities—without appealing to other value judgments. Thus, science adheres to the principle of *objective value neutrality*: the arguments for the acceptance or rejection of hypotheses are not allowed to appeal to such (assumed) facts that the truth or falsity of the hypothesis would benefit or harm us for political, religious, ethical, or economic reasons. If this norm is violated, as some sociologists of science have tried to illustrate by historical case studies, the conclusions or reasons must be revised or corrected.

Applied science seeks instrumental knowledge that has practically significant applications. An important form of applied science is *design science*, whose results are what G. H. von Wright calls *technical norms*: "If you want A and believe that you are in situation B, then you ought to do X." Here A may be any practical value such as health (clinical medicine and nursing science), welfare (social policy studies), peace (peace research), productivity (agricultural and forestry sciences), efficiency of machines (engineering sciences), and economic profit (economics) (Niiniluoto, 2022a, pp. 181–196). The recommended action X is a means to the end A in situation B. Epistemic utilities are relevant also in design sciences since the truth claims about instrumental means—end relations must be justified by objective evidence about causal regularities. Design science is thus value-intensive but, at the same time, value-neutral since the acceptability of technical norms should not depend on the question of whether the investigator is personally committed to the conditional value A.

*Technology* (Gr. *techne* = skill, art) is much older than science (Mitcham, 1994). It does not produce knowledge like science but rather designs new artefacts, tools, and machines (Niiniluoto, 1997b, 2016). While earlier stages of technology were independent of science, in the modern age the development of technical products and systems is based on innovation chains and cycles from fundamental research via applied design sciences. These technological products are not constrained by truth in the same way as knowledge claims, but by what is physically and economically *possible* (Skolimowski, 1966). This makes technology *value-laden* in a way which differs from science (Niiniluoto, 2020). Therefore, the criteria for the acceptance of technological products are different from the epistemic utilities in science. Commercial value in the market is one of such factors, in our Western societies even the primary criterion for the innovation and diffusion stages in the life cycle of artefacts. But it need not be the only relevant factor. This is a basic issue of technology assessment.

## Technology Assessment: TA = 6E + S

Philosophers have disagreed about the role of facts in the evaluation of technology. Alex Michalos (1983) has argued that it is useless and even dangerous to appeal to the

 https://doi.org/10.21500/22563202.6983

fact-value distinction in technology assessment. A deconstruction of such a distinction is also given by the constructivist approach. It denies the use of facts about artefacts as explanations of how they work: machines are claimed to work because they have been chosen by relevant social groups, not vice versa (Bijker, 1995; Latour, 1987).

Against such claims, it is of utmost importance to make a clear distinction between the objective properties of an artefact and the value criteria of its assessment (Niiniluoto, 2022a, pp. 337–354). For example, a car has a shape and colour, and its engine has a measurable efficiency in horsepower. The behaviour of the car (e.g., its ability to carry passengers, and its maximum speed) is a function of these facts (Sahal, 1987). To be sure, these properties are results of human design, and in this sense depend on us or our decisions, but, when the car has been produced, they are as objective facts as the colour of a bird and the material constitution of a tree. In the same way, the technical norms sought in applied research have factual content about the relations between means and ends. The task of establishing such facts about artefacts belongs to the scientific and technological experts.

An exception to the fact-based evaluation of artefacts is provided by *fetishes*, used in magical and religious practices since their assumed properties are only imagined or believed. Thus, the mistake of social constructivists is the failure to distinguish fetishes from real technological tools (Niiniluoto, 2020).

The properties of artefacts make them *tools* which may have *instrumental valu*e relative to human purposes. Each technological artefact has an intended function, or “final cause” in Aristotle’s sense, and its *effectiveness* or “instrumental goodness” depends on its ability to serve or fulfil this function (von Wright, 1963). Intended functions are sometimes specific (e.g., spade, medical drug), sometimes multiple and open-ended (e.g., computer). They may be culturally and historically relative: a tool may change when it is transferred to another social context or when it is placed into an exhibition in a museum.

By their effectiveness, technological tools open up new resources and possibilities for human action. Thereby they increase the domain of human *positive freedom*. Such an increase of freedom may be a good or bad thing relative to human values. Such possibilities are created by utilizing some resources, and the use of tools has also often unintended and unwanted by-products and side effects. Besides the misuse of tools and their harmful effects on nature and society, such by-products include increased risks (Shrader-Frechette, 1991). This suggests a straightforward utilitarian calculus of evaluating technological projects by their costs and benefits, or risks and utilities. In the 1970s, several Western industrial countries developed systems of *technology assessment* (TA) for the evaluation of large-scale technological projects (Durbin & Rapp, 1983). This approach can be compared to “social indicators” which were developed since the 1970s in many countries as a supplement to economic criteria of progress like GNP per capita.

In the United States, the Office of Technology Assessment (OTA) was established in 1974—and closed in 1995—, but similar institutions have operated in many European countries, Japan, and India. Together they form the network EPTA (European Parliamentary Technology Assessment). Another network ECAST (Expert and Citizen Assessment of Science and Technology) aims to bring public perspectives and values to technology decisions.

Each tool and the related novel possibility can be evaluated by several criteria, and there is no consensus about the best framework. Niiniluoto (1997a, 1997c, 2020) suggests that the basic method of technology assessment can be expressed by the formula

T = 6E + S,

Where the six Es are:

– effectiveness (ability to achieve the intended use or function),
– economy (economic profit),
– esthetics (beauty),
– ergonomy (health of the user or worker),
– ecology (health of the natural environment),
– ethics (good or bad by moral standards).

Finally, S refers to the social impact and consequences of technology.

*Effectiveness* is a basic requirement of individual technical tools and large technological systems. As argued by Skolimowski (1966), each branch of technology has its functions and associated utilities: knives cut, lamps spread light, cars drive, planes fly, and houses are habitable. Engineers and other technological experts are responsible for the instrumental value of the designed and produced artefact.

As commodities and innovations in the economic market, technological products have monetary exchange value, which guarantees their potential to sustain *economic* growth and bring about economic profit. This has been the domain of economic theories since Adam Smith in the late 18th century (Elster, 1983). As the production of artefacts uses natural and human resources, the net profit depends on the relation between costs and benefits. This combination of high effectiveness and low expenditure is called *efficiency*. John Dewey's instrumentalism and Tadeusz Kotarbiński's (1965) praxiology are systematic general theories of efficient problem-solving and human action.

Effectiveness and efficiency are the typical criteria which are standardly applied in the evaluation of "good" technology. The fact that this discourse is dominated by engineers and economists has made technology a target of criticism by philosophers (e.g., Martin Heidegger) and critical social scientists (e.g., the Frankfurt School), who think that instrumental rationality is a misuse of human reason (Mitcham, 1994). But instrumental rationality as such should not be rejected, but rather supplemented by cognitive rationality (i.e., science) and value rationality (i.e., reasonable goals): we should expect that planes fly with tested security systems and medical drugs heal diseases without harmful side effects (Niiniluoto, 2022a, pp. 137–150). In the same vein, productivity and economy are not the only dimensions of technology assessment, but additional criteria should be supplemented to TA.

The concept of *beauty* has been traditionally associated with works of art, human faces, and natural landscapes. Perception of beautiful objects generates a pleasant "esthetic" experience in us. *Esthetics* was born as a discipline in the late 18th century when the mechanical arts and the fine arts were distinguished and thereby esthetic qualities were separated from useful ones—as Immanuel Kant stated, they do not involve "interest and concept." But in the late 19th program of "applied arts," these two aspects were again joined. The task of an artisan or a designer is to create artefacts or prototypes which have a beautiful shape, Aristotle's "formal cause," so that they can be used in daily life as tools of consumption. The systematic teaching of such industrial designers was developed in Bauhaus in the 1920s and Ulm in the 1960s. The prominent fashion in industrial arts and architecture was functionalism with the slogan "form follows function." Today engineers work together with industrial designers: the former makes an invention, and the latter

 https://doi.org/10.21500/22563202.6983

gives an attractive shape to its implementation as a commodity in the economic market. Therefore, the assessment of technological products should include their esthetic qualities.

*Ergonomy* is a branch of work psychology which studies the relation of tools and machines to the health and well-being of their users. It was anticipated by Karl Marx who argued in his early writings that work should not be hard drudgery (Aristotle's *poiesis*) but rather creative self-realization (Aristotle's *praxis*), but not understood by F. W. Taylor's program of scientific management in the early 20th century. Fritz Lang's film *Metropolis* (1926) and Charles Chaplin's *Modern Times* (1936) gave artistic critique of the work lines in Ford's car factories. The inhuman conditions of factory labour were gradually improved, and the first professors of ergonomics were established in technical universities in the mid-20th century. Today routine labour is largely given to industrial robots, but there is still a challenge to design user-friendly chairs, cars, interfaces, and phones. It is thus natural to include ergonomy as a factor in technology assessment.

Technology was originally developed to mediate and improve the relation of human beings to their natural environment (Ihde, 1979). The adaptation of species to their environment is studied in *ecology*. The idea of protection of nature was initiated in the late 19th century, but it was not until the 1960s that serious awareness of an "ecological crisis" emerged as the consequence of the pollution of air and water. Green political movements and NGOs (like Greenpeace and WWF) started their campaigns for conserving nature and protecting life. Environmental "eco-philosophy," supporting the intrinsic value of nature, gained popularity in the academia. Gro Harlem Brundtland's UN commission introduced the concept of *sustainable development* in 1987, and "sustainability science" is now seeking ways of preventing climate change and the loss of biodiversity (Niiniluoto, 2022a, pp. 277–298). A key to these solutions is to reduce carbon dioxide emissions by getting rid of fossil energy in agriculture, industry, and everyday consumption. A tool for this task is the notion of the "carbon footprint" of individuals and institutions. For large-scale constructions (e.g., mines, dams, bridges, power plants, gas pipes) there are standards for measuring their potential risk to nature. Ecological factors indicating the health of the environment are thus indispensable in the assessment of technological projects.

Of the six Es in the equation TA = 6E + S, *ethics* is the oldest one. With politics, it was the main ingredient of Aristotle's "practical science." Aristotle's ethics was based on virtues, which can be applied to the professional ethical codes of engineers. But later systems of ethics were formulated in terms of deontological duties and rights (Kant) and utilitarian consequences of actions (John Stuart Mill). Ethical issues have been traditionally raised in connection with arms and other military technologies used in warfare. But, more generally, we may always ask whether the new possibilities opened by technical tools and systems are worthy or evil by moral standards. Such judgments are highly sensitively related to the moral doctrines in different cultures, as one can see in the debates about contraceptives or genetically modified foods. A special difficulty is faced with so-called dual-use goods (e.g., facial recognition, drones) which can be applied for peaceful purposes in the civil sector and military purposes in the defence sector.

Finally, technology has also an impact which is *social* in the broad sense including professional, legal, institutional, and political changes. In the long history, technical inventions have generated new occupations, means of living, social class structures, political systems, systems of economy, education, medicine, and media. Axes, ploughs, guns, writing, printing machines, steam engines, cars, trains, computers, mobile phones, and the internet have been driving forces of social change. Today we live in a post-industrial information society, which will be transformed in unpredictable ways by new kinds of "experts" created by the AI methods of deep learning and advanced language models

(Niiniluoto, 2022b). The impact of technology on society is studied in the sociology of technology. Many of these issues have an ethical dimension since it is important to assess whether the societal changes and transitions are implemented by respecting the principles of social justice (Niiniluoto, 2022a, pp. 319–336).

The formula TA = 6E + S can be applied to individual technical tools and wholesale technological systems (Niiniluoto, 2020). This can be illustrated by examples.

Social media companies have been the most successful technological enterprises in the early 21st century, but they are also criticized for human and political reasons. The TA scheme for Mark Zuckerberg's Facebook (2004, later Meta) could look as follows:

Effectiveness: connected three billion monthly active users in 2023.

Economy: revenue 34 billion dollars, net income 11,6 billion dollars in 2023.

Ergonomics: addiction, stress, lack of concentration, jealousy, narcissism.

Esthetics: visual appearance and photos of Instagram and virtual reality.

Ecology: waste of resources, attempted to reduce its carbon footprint.

Ethics: negligence of responsibility, tricks and algorithms to hook and control users, platform for fake news and hate messages, tax avoidance, collection and illegitimate distribution of user data, failures of privacy.

Social: monopoly position as a technology giant, creates closed "bubbles" of likeminded people, influenced the Brexit referendum and Trump's election in 2016 by trolls, and thereby started the "post-truth era" (Niiniluoto, 2022a, pp. 251–274).

A similar exercise could be given to the potential dangers and risks of global warming, or the promises and threats of the car industry and new AI inventions like Chat GPT.

The formula 6E + S also allows us to give transparency to our judgments about how new technologies may promote good human life. *The Millennium Technology Prize* (one million euros) is awarded by the Technology Academy of Finland for a groundbreaking innovation which enhances people's *quality of life* both now and in the future. This demanding criterion is philosophically highly interesting, as it appeals to the value-laden concept of "quality of life" (Niiniluoto, 2022a, pp. 319–336). Quality of life is a many-dimensional notion which can be assessed both by subjective experiences (what feels good to some or most of us) and objective standards (like health, wealth, and education). There is no simple definition in terms of human needs since technological progress has always influenced and escalated the expectations and aspirations which we require as necessary conditions for a happy life.

The first Millennium Prizes, in fact, provide test examples of these criteria. The World Wide Web (2004) and open-source operating systems (2012) are inventions with a significant social impact. Blue and white led as new sources of light (2006) and dye-sensitized solar cells (2010) have profitable economic and ecological consequences through global energy savings. Biomaterials as drug-delivery techniques (2008) and ethical stem cell research (2012) effectively assist the fight against many diseases. Pioneering directed evolution (2016) and next-generation DNA sequencing (2020) enhance the potential of synthetic biology and genetic technology. Increased data storage density (2014) and enabling smart technology (2018) have advanced the development of mobile phones. Passivated emitter and rear cell (2022) have made solar cell energy more affordable than fossil-based alternatives. So far, the prizes have been given to advances in information technology, material technology, and medical technology. Connection to sustainable development is more evident than to the quality of life.

Some TA systems have the ambition to use only indicators that have clear operational definitions. However, some technologists have misunderstood the nature of TA by believing that numerical indicators are always "objective" and "value-neutral." As noted by Shrader-Frechette (1983), they have also tended to ignore those dimensions that cannot be neatly quantified. The same problems are common in the use of numerical performance indicators of scientific progress: the numbers of exams and publications are easy to calculate, and quality questions are easy to forget. It is better to see such indicators as attempts to express and articulate values. There are specific issues in the "measurement" of each dimension of assessment (such as esthetic or ethical value), but at least in the case of esthetic value, there are attempts to develop numerical approaches using information theory (Niiniluoto, 2022a, pp. 29–46).

To prefer or choose one technology over another, it may be sufficient to apply comparative notions. However, a difficulty for such choices is that the dimensions of TA may conflict with each other. While esthetic and ergonomic aspects of a commodity may enhance its value in the economic market, sometimes effectiveness and economy are achieved only at the expense of ecology. For example, in debates about the conservation of natural forests, the economic interest of landowners may conflict with the demands of ecological sustainability. Ultimately it is a value question to balance or weigh the dimensions relative to each other. The situation is the same in science and technology, even though the relevant epistemic and technological utilities differ from each other.

## Toward Democratic Technology Policy

The conception of *technology policy* is often restricted to the role of the state (or more generally the public sector) to support and subsidize research and development (R&D) in the firms (or the private sector). For example, in Finland, a new funding agency for technology, Tekes, was established in 1983, and after 2018 it has continued with the title Business Finland. The EU allocates funding to agriculture and industrial projects in the "green transition" and attempts to find legal ways of regulating social media companies and AI. In the heavy competition between the USA, China, and the EU, this *state-centred* approach has recently gained even more impetus. But this narrow conception overlooks the fact that political decisions about the development of technology are made also by private companies (in its heydays the R&D investments of Nokia were larger than the budget of all Finnish universities together), NGOs, foundations, and individual citizens as consumers. Indeed, some companies apply expert methods of TA to forecast the relative success of their new products, so that they can decide about their technological investments, avoid costly mistakes, and save time and money in the long run. The models of *participatory* TA allow citizens to influence the development of technologies.

The evaluation of the Finnish system by the Ministry of Education and the Ministry of Employment and the Economy (2009) maintained the view that technology policy aims to generate better innovations in the private sector. But it also advertised the *user-driven* technology policy, where the joint activity of technological designers and potential users is called "co-design" or "co-creation." Its counterpart in science policy is the "mode 2 research," where researchers, engineers, designers, and potential customers work together to create "innovation cycles" (Gibbons *et al.*, 1994).

A different emphasis is represented by the "resolution on technology," approved by Prime Minister Sanna Marin's government in Finland in 2022: technology policy aims to improve the construction and utilization of technologies and the operating environment that supports these for companies and civil society. It is also significant that new technologies are used in different sectors of public administration so that technology assessment covers also social innovations (Teknologianeuvottelukunta, 2021).

The value-ladenness of technology means that the legitimate domain of technology policy is quite different from that of science policy (Niiniluoto, 2022a, pp. 337–354). In a democratic state, the citizens (or their representatives in the government) should have the right to decide how large per cent of the GNP is spent on research and education, and whether public funds are allocated to military research or AI. However, in matters concerning evidence-based truth-claims, scientific quality, and the scholarly significance of research, the scientific community should have autonomy in society at large, and it should function as an expert system rather than a democracy. When a scientific project or publication is evaluated, the members of the scientific community do not vote about the issue, but the best expert in the field is asked to do the assessment. This is the basic idea of *peer review* in science (Merton, 1973, pp. 460–496).

Technological experts have a special role in evaluating facts about technological constructs and rules, but their task is not to decide alone the value questions about the development of technological innovations. The decisionist strategy would lead to the libertarian market model of delegating all decisions about the use of technological products to individual consumers (Buchanan, 1986). This populist idea, in fact, easily gives the power back to the technocrats, since human needs and hopes are constantly influenced and manipulated by marketing and advertising. Still, it may work well for some "innocent" artefacts: when a rational person chooses his or her toothbrush, we have no reason to exercise paternalism over such a decision. And in some cases, market rationality may lead to socially desirable results, if the individuals have enlightened preferences (e.g., using electric cars and "eco-products)."

But most commodities are not private affairs, as they may have harmful environmental and social effects. When it turns out that a deodorant affects the ozone layer, or a weedkiller starts to kill insects, it becomes a dangerous tool. As Liisa Uusitalo (1986) has shown by applying game-theoretical models of "free riding" to consumer behaviour, what seems individually rational may lead to collectively irrational consequences—unless some moral or legal constraints on our actions are accepted. Most of us approve some restrictions on the selling of drugs and guns. Some decisions about large-scale technological developments are socially so important and difficult that they are handled in democratically elected boards. For example, in Finland, the Parliament has the right to make decisions about the building of nuclear power plants.

Technologists should feel responsible for the uses and effects of their inventions. On the level of business firms and companies, this demand is expressed by the notion of *corporate responsibility*, which is normally taken to consist of the impact of a technological organization on society, the environment, and the economy, but it may also involve the relations to its employees and customers. Progressive firms see adherence to such responsibility as a competitive asset, since it may be parallel in a win-win way to the enlightened values of their clients. It is also important that the engineers have agreed on codes of *professional ethics*. They should be ready to cooperate with other professions who have expertise in the different domains of valuations: medical doctors and psychologists in ergonomics, industrial designers and architects in esthetics, applied philosophers in ethics, sociologists and lawyers in the social studies, etc. These other professions should play an key role when technology assessment is organized and administrated systemati-


https://doi.org/10.21500/22563202.6983

cally. But they in turn should be ready to work in cooperation with laymen, who are potential *consumers* of technological tools and methods.

In Finland about two third of carbon emissions result from households (energy, traffic, food, wastes). Therefore, individual citizens have responsibilities for their participation in a luxury form of life which brings about emissions and thereby global warming as a collectively produced harm (Kutz, 2000). Moreover, consumer panels can be used in the evaluation of technologies, e.g., surgeons and women have joined activities in the development of methods of treating breast cancer. In many issues about the quality of life, ordinary citizens are the best experts on their attitudes and feelings (Shrader-Frechette, 1985), which supports the user-driven model of technology policy. Hennen (2012) finds support for "participatory TA" from Habermas' critique of decisionism and technocratic approaches, while Durán and Pirtle (2020) argue that Kitcher's (2001) model of "well-ordered science" advises on how to tutor active citizens in consumer panels.

Stanley Carpenter (1983) has argued that technology assessment as a program is not sufficiently radical, since its own cost-benefit methods rely on technological and utilitarian ideas. He suggests that TA should be replaced by AT, i.e., *Alternative Technology*, advocated by "green" environmentalist movements and proponents of "appropriate," "soft," and "participatory" technology. But there need not be a real contradiction between TA and AT. To promote democratic procedures in technology policy, we need the participation of many interest and stakeholder groups on several different levels. We need state and city councils, political organizations, international cooperation, legislation on the treatment of wastes in industrial production, bureaus protecting consumers from unfair commerce, self-reflection by technological professions, teaching of engineering ethics, multidisciplinary research on sustainability, public debate on environmental issues, measurement of carbon footprints, value discussion about good life, NGOs, and active citizens working in free groups and societies. And for all these responsible actors in technology policy, the formula TA = 6E + S serves as a reminder of the relevant value criteria of their choices.

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