Telecommunications Policy xxx (xxxx) xxx

Contents lists available at ScienceDirect

Telecommunications Policy

journal homepage: www.elsevier.com/locate/telpol

Key value indicators: A framework for values-driven next-generation ICT solutions

Gustav Wikström [a], Nona Bledow [b], Marja Matinmikko-Blue [c,*], Henning Breuer [d], Cristina Costa [e], George Darzanos [f], Anastasius Gavras [g], Tobias Hossfeld [h], Ioanna Mesogiti [i], Katrina Petersen [j], Pawani Porambage [k], Razvan-Andrei Stoica [l], Stefan Wunderer [m]

[a] *Ericsson Research, Sweden*
[b] *Innovationszentrum für Telekommunikationstechnik (IZT), Germany*
[c] *University of Oulu, Finland*
[d] *UXBerlin - Innovation Consulting & Hochschule für Medien, Kommunikation und Wirtschaft (HMKW), Germany*
[e] *Consorzio Nazionale Interuniversitario per le Telecomunicazioni (CNIT), Italy*
[f] *Athens University of Economics and Business (AUEB), Greece*
[g] *Eurescom GmbH, Germany*
[h] *University of Würzburg, Germany*
[i] *OTE - Hellenic Telecommunications Organization S.A., Greece*
[j] *Public Safety Communication Europe (PSCE), Belgium*
[k] *VTT Technical Research Centre of Finland, Finland*
[l] *Lenovo Research, Germany*
[m] *Nokia Solutions and Networks GmbH & Co. KG, Germany*

ABSTRACT

Technology design, development and evaluation has long been driven by functional performance optimization and estimated market opportunities. Today, societal challenges and sustainable development goals are calling for a paradigm shift towards aligning technology development with a values-based consideration and re-prioritization of different ecological, social and economic outcomes. Values have been identified as key drivers of Information and Communication Technology (ICT) research. They are taken into account in the development of 6G networks, e.g. in the context of EU research funding frameworks, but a clear conceptual framework for values-driven development is still missing. This paper deals with the concept of Key Value Indicators (KVIs) as a method for analyzing the values-related outcomes stemming from ICT developments. Leveraging established definitions, frameworks and value identification methods, the paper proposes a structured KVI framework tailored to the ICT research and development (R&D) sector. The proposed framework comprises five steps, starting from the use case-related identification of values to the assessment of value outcomes. ICT-enabled smart cities are analyzed as an example use case to illustrate how this framework can be applied. The KVI framework is aimed to be a useful tool for the ICT research sector (to be used - primarily but not exclusively - by ICT research projects and programs) to address social challenges in technology design and development phases and to identify and estimate value outcomes from technology use. In addition, the proposed framework aims to assist policy makers to establish value-related targets and set requirements and conditions for ICT developments.

* Corresponding author.
E-mail address: marja.matinmikko@oulu.fi (M. Matinmikko-Blue).

https://doi.org/10.1016/j.telpol.2024.102778
Received 24 October 2023; Received in revised form 15 April 2024; Accepted 16 April 2024

1. Introduction

Facing a multitude of threats and a global poly-crisis (World Economic Forum (2023). et al., 2023), research and technology development have a central role to play in addressing global and local societal challenges. Technology for the future is expected not only to meet technical and user requirements, but also to proactively address these challenges and their underlying societal values. Developers should not only focus on delivering economically feasible technological services but also prioritize the end goals and outcomes that these services will achieve. This is especially the case for ICT, as researchers and developers encounter new innovation opportunities with unique social, environmental and economic concerns. It is particularly pertinent for ICT driven by 5G and 6G technologies with the aim to ensure beneficial access to everyone everywhere. Such *values-driven technology development* constitutes a paradigm shift for industries and academia with a high potential for creating a positive impact on society, and it is nowadays in the focus of European Research Funding activities. However, how to systematically integrate societal challenges and values into technology and ICT development, is an open topic. In order to address this research and policy question, this paper defines a conceptual framework for values-driven development that combines concepts and frameworks from social sciences with concepts and process models from ICT development. The intention with the framework is for stakeholders to understand the impact from technology on general values of importance.

It is useful here to distinguish between two ways ICT can impact values: a *direct* impact where ICT operations can be studied in terms of direct resources required, e.g. through material and energy consumption; and an *indirect* impact where induced positive and adverse effects in other sectors stemming from ICT usage can be studied. The study of the direct impact is often done under the aim for "Sustainable ICT", whereas the indirect impact is often referred to as "ICT for Sustainability" or the "enabling effect" (HEXA-X Deliverable D1.2, 2021).

Most recently, 6G development has taken a values-based approach where like-minded countries agree on, for example, promoting shared values in 6G including EU and US Trade and Technology Council (EU-US Beyond 5G). Prior work (Matinmikko-Blue et al., 2020) has also linked 6G with the United Nations (UN) Sustainable Development Goals (SDGs), emphasizing the role of new technology in (1) providing services to help steer communities and countries towards reaching the SDGs, (2) enabling measurements and data collection to help with reporting of indicators, or (3) reinforcing a new technological ecosystem to be developed in line with the UN SDGs. However, this work has been mainly vision-driven, rather than based on applying analytical foresight methodologies to impact assessment of ICT technologies. Moreover, while policymakers set the operational conditions for the development and use of technologies, existing political and regulatory frameworks only provide high-level guidance for international, national and regional actors and need to be translated into local contexts and specified for individuals, organizations and communities.

While regulatory frameworks set the objectives and legal requirements, standards provide the technical specification and best practices to meet them. Standards related to sustainable development goals provide insight, such as recommendation Y.4903 of the International Telecommunications Union Telecommunication Standardization sector (ITU-T) on Key Performance Indicators (KPIs) for smart sustainable cities (Recommendation ITU-T Y.4903, 2022), by listing KPIs regarding different pillars of sustainability: social (e.g., higher education degrees), economic (e.g., unemployment rate) and environmental (e.g., Green House Gas (GHG) emissions). Additionally, theoretical frameworks and empirically grounded approaches to values-driven innovation and design exist to guide activities, such as responsible research and innovation (Stilgoe et al., 2013), values-based innovation (Breuer et al., 2022) and value-sensitive design (Friedman & Hendry, 2019a). But they do not provide sufficient detail on how benefits are realized, and how risks are identified. Nor do they provide a coherent and clear methodology, how to make informed system design decisions, or how to assess their effectiveness in ICT development. This gap is exacerbated by a lack of common language to mediate between engineering disciplines, sustainable business design practices, and societal impact assessments.

Nevertheless, the identification and evaluation of the impact of technology research and development on societal values is in the focus of EU funded research activities (as set in the establishment of Joint Undertakings under Horizon Europe (European Commissiona) and as implemented through EU funded R&D projects), and is explicitly required as part of the R&D projects' activities. To this end, the Societal Needs and Value Creation (SNVC) subgroup of the Vision work group of the 6G Industry Association (6G-IA) (6G-IA Vision and Societal Challenges) has been formed. The aim of this group is to fuse knowledge and experience from EU funded R&D projects (public sector), from external experts (especially representing the social sciences domains) and from the ICT industry (private sector), towards providing guidelines for the project's relevant activities, and towards aligning the relevant activities at EU funded research level. SNVC's method of work is to conduct long-lasting multilateral conversations between the participants which represent a wide number of ICT industry stakeholders (from vendors, operators, IT developers, vertical industries, end users, etc.) and to develop methodologies and frameworks jointly with the participation of its members. Although simple conversational methods are used, the value of the outcomes (i.e. methodologies and frameworks) lies in their resulting from close, long-term interaction of the conversing members and with highly versatile background in terms of fields of expertise and of representation of stakeholders.

This paper seeks to respond the following research question: How to systematically integrate societal challenges and values into technology and ICT development? This paper presents a structured methodology to fill the gap in values identification and evaluation, stemming from the work of SNVC (Wikström et al., 2022), following aforementioned conversational methods. It describes a framework of identifying *Key Values* (KVs) and developing *Key Value Indicators* (KVIs) for R&D in the ICT sector. This proposed KVI framework builds upon the familiar engineering approach of using KPIs to find a process that systematically integrates considerations of economic, social and ecological impact into technological development projects. A key improvement with the framework is that instead of starting from available metrics, i.e. KPIs, and assuming this is relevant for KVs, the analysis starts from what is relevant, i.e. the KVs. Starting from the definition of scenarios and use cases, KVs as criteria and desired outcomes are identified, i.e. in a bottom-up process. The analysis of those KVs results in the formulation and selection of KVI metrics, reflecting a top-down approach in the value selection.

Understanding that such an integrated methodology requires multi-disciplinary and expert interaction, KVIs offer a way of engaging stakeholders and innovators to collaboratively agree upon shared values and formulate concrete targets on dimensions of societal benefits, to translate the targets into design and development requirements, and to evaluate the targets (and innovation itself) relative to the societal values. They aim to serve as a facilitator for widespread adoption of resulting solutions. This method has previously been discussed in (HEXA-X Deliverable D1.2, 2021) and (Wikström et al., 2022) but is here expanded, thoroughly explained and illustrated, driven by formulating future scenarios depicting a context in which intended technology usage is introduced.

A mid-term aim is to transition from a one-dimensional, financially-oriented notion of value to a multi-dimensional consideration encompassing economic, social, and environmental value creation that guides both technical and business development. A long-term aim is to ensure that all 5G and 6G technologies, and ICT in general, are developed in ways that are conscious of and transparent towards their impact on the world in which they are adopted and used.

The paper is organized as follows: Section 2 summarizes the related literature and frameworks on values-based innovation and societal impact. Section 3 reframes ICT development based on values and provides the terminology used across this paper. It further details the KVI framework as incorporated through ICT technology development processes from initial R&D stages to commercial products, aiming at capturing both the measurement of societal value impact and the influence of these measures on technology. Section 4 further elaborates on the application of the KVI framework on a scenario and use cases serving as an illustrative example. In Section 4.1 (Step I) the indicative scenario and use cases are outlined. In Section 4.2 (Step II), societal key values are identified as being relevant for the intended technology usage in question. In Section 4.3 (Step III), the methodology is used in the formulation of the KVIs for use cases. With the set of KVIs at hand, Section 4.4 (Step IV) presents how to analyze the outcome of technical solutions and system design on enabler KVIs, to provide in turn a handle on steering technology development in a certain direction. Closing the process, Section 4.5 (Step V) presents aspects of evaluating the KVIs in light of a certain technology usage. Section 5 provides a discussion on the use of the KVI framework. Finally, conclusions are drawn in Section 6.

2. Related literature on values, value creation and societal impact

The importance of ensuring various societal benefits is underlined by a broad set of commitments from organizations, such as the UN SDGs (United Nations, 2020), the European Green Deal (European Commissionb) and technological sovereignty reflecting European values (European Commissionc). These frameworks, in turn, are implemented in funding programs, regulation, as well as market and public expectation. Engaging in technology research and innovation for the 2030's therefore entails not only aiming at enhancing performance with respect to technical and user requirements but also committing to enhancing societal values including economic prosperity. The need for a multidimensional understanding of value creation to assess the outcomes and impact of technological development, thus, starts from a synthesis of previous work and ongoing discussions on societal impact of technological development. This includes a disambiguation of essential notions of values and value-add (see sub-section 2.1), an understanding of overarching normative frameworks (2.2) and conceptual frameworks (2.3) to facilitation and assessment methods (2.4), highlighting specifically work on KVIs and the ICT context (2.5, 2.6). These existing frameworks and previous contributions that form the basis from which a value-centric framework could be developed for ICT are presented next.

2.1. Disambiguation: values as criteria and goals versus values as outcomes

In order to create a KVI framework, and to avoid confusion through different understandings of the term 'value(s)', at least two existing discourses and notions need to be distinguished. The first is a notion of human values, which understands *values as criteria and goals* that drive how a given society defines progress and public goods. The second is a notion of key values in terms of benefits induced by the creation or use of an artifact or system, referring to *value as an outcome*.

Values as criteria and goals refer to notions of the desirable and ordered systems of priorities of an individual (Schwartz, 2012) or an organization (Breuer et al., 2022; Lü et al., 2022). In psychology, for example, values have been defined as concepts or beliefs about desirable end states or behaviors that guide the selection or evaluation of behavior or events, which are structurally ordered according to their relative importance (Frey, 2016). Values act as such strong drivers for how society evaluates any given contribution that some scholars in information science consider moral commitments to universal values of human well-being, justice and dignity as indispensable (e.g. recent works on value-sensitive design (Friedman & Hendry, 2019a)). Examples are social inclusion, enabling participation or access, ecological reduction of emissions or positive contributions to the strengthening of ecosystems.

Values, in this sense, provide a guide for a person's or an organization's activity and decisions and serve as criteria and guidelines in collaborative action. Within this perspective, different institutions are adopting sustainability and related core values following the values codified in global normative frameworks on the UN or regionally binding frameworks of the European Union. In business organizations, such values guide the formulation of normative (purpose, mission, vision) statements that permeate decision-making and collaborative action and to establish a values-based innovation culture. Innovation-specific value indicators are used for a comparative assessment of innovation projects within an organization. How these values matter is context and user dependent. Thus, identifying and articulating the values, in use case context, as criteria and goals that drive activity and decision-making is a necessary starting point for any innovation process.

This broad notion of human values as criteria is sometimes conflated with a narrower sense of *values as outcomes* of economic activity or "value creation", what is often referred to as value-add. In the context of technological innovation and economic activity, value-add refers to the benefits that a technology, or a product or service offers. Traditional economic and management theory focuses on value creation in three dimensions: in terms of customer benefits, profit to investors through company revenues, and (indirectly) benefits to society through taxes and employment. This conception of value as a result of economic activities can and has been recently expanded to encompass the generation of social and environmental benefits. Such additional value can be tangible, such as additional features, or intangible, such as convenience or customer service. The outcome of an activity can generate gain or loss of such value-add. What the outcomes are and which value domains are impacted depend, among other things, on the business model and the scale of adoption or proliferation of the use case.

In this way, the two notions of values meet: one type of value as an outcome or achievement regarding those things that are held to be important as values in the human values sense, whereas conversely human values motivate and direct the striving for specific outcomes. Any value framework for ICT innovation has to consider both in order to sustainably create, deliver, and capture value.

Moreover, it is important to note that considering value is not a process of creating a hard and defined line between good and bad use of ICT. It is not about designing a value "into" a tool that ensures that the value is met by all users. Rather, grounding innovation in the values of society and use contexts will overall increase the potential for a given technology to create beneficial impacts. In addition, stakeholder and use case value considerations would support R&D in due diligence, increasing reflection on their own ethics and values in order to proactively address the risks of dual or misuse of the results of their activities, including harms that could result, unfair outcomes, or violations of human rights.

These two notions of value, namely values as criteria and goals and values as an outcome, thus, contribute to addressing sustainability challenges and can create economic, social and environmental benefits (Lü et al., 2022). But there is no conclusive list of such benefits in the scientific literature. Which particular environmental, social and economic value outcomes innovation can and should provide is an open issue for innovation practices, business development and economic research. Normative frameworks are often, then, a place to start.

2.2. *Normative frameworks*

While values as criteria and goals can be formulated on the individual, organizational, and business level as presented in Section 2.1, at the overarching societal level, they constitute normative frameworks. These are meant to provide goals that actors in society do their best to strive towards and realize, e.g. the UN SDGs (United Nations, 2020) and the European Green Deal (European Commissionb). These existing frameworks provide high-level objectives and broad dimensions from which indicators can be derived to measure and evaluate values as outcomes.

Striving towards these normative goals is often obligatory. In particular, since 2023, the Corporate Sustainability Reporting Directive (EU, 2022) and compliance with the EU taxonomy (EU, 2020) require business activities to substantially contribute to at least one of the six EU environmental goals (climate protection, adaptation to climate change, water/marine protection, circular economy, environmental pollution and biodiversity/ecosystems), to do no significant harm with regards to the other goals, and to fulfill social minimal standards. Engaging such normative frameworks warrants a transition from a traditional, economically focused, to an extended, multidimensional understanding of value creation, accounting for social and ecological concerns (Lü et al., 2022). It also requires business actors to reconsider values and interests of different stakeholders and to re-prioritize business goals to come up with more sustainable business models. Indeed, taking these normative frameworks as a starting point for business models ties business reputation and access to capital to aspects of sustainability in formulation of business goals and business decisions.

While they guide much activity in society, these overarching normative frameworks addressing nations or businesses, provide only global anchor points for the specification of organizational or even project specific values. Innovation management frameworks have recently explored the role and potential utilization of values held by different stakeholder in contexts of innovation. Articulating normative values as goals and outcomes requires an understanding of how these normative values are applied in context of use.

2.3. *Values in innovation: conceptual frameworks and facilitation methodologies*

Values as criteria for research and development have been extensively discussed in theoretically grounded approaches to innovation and design, namely within the frameworks of value-sensitive design, responsible research and innovation as well as values-based innovation. Each approach provides methodologies to build from that facilitate values-driven technology research and development. These methods all consider user or societal context, where stakeholders drive the evaluation and validation of a value-centered innovation.

Value-sensitive design (Friedman & Hendry, 2019a) proposes a set of methods to be used in an iterative design process that involves conceptual investigation of stakeholder values, empirical design research and technical inquiry of technology use and system design. Its methods generally combine empirical, value, and technological elements to build a process of assessing how values impact design. These range from analysis of context and choices being made, elicitation and representation of stakeholder values at stake, to co-design and envisioning innovation pathways with those whose values are affected.

Responsible research and innovation was developed by policy makers and researchers to account for ethical and societal concerns in science and technology development (Burget et al., 2017). Anticipation, reflexivity, inclusion, deliberation, responsiveness are proposed as responsible innovation practices to govern the innovation process (Burget et al., 2017; Owen et al., 2012; Stilgoe et al., 2013). These practices are intended to support innovators to step back and consider how their decisions affect others. While several issues around values remain unresolved, such as the values work to elicit stakeholder values (Boenink & Kudina, 2020) or resolution of conflicts (Lubberink et al., 2017), this framework offers an approach to eliciting values as criteria and goals that should drive a given innovation and their relationship to values as outcomes from that innovation. Still, discrepancies have been observed between concepts and policies of responsible innovation and their operationalization and implementation (Rommetveit et al., 2019), which require new methods of bridging them.

Values-based innovation management framework (Breuer et al., 2017a, 2017b, 2022) focuses on the potential of values to integrate diverse stakeholders into innovation processes, to direct collaborative efforts, and to generate innovations that matter. The framework was developed based on case studies and literature review and collaboration in European projects (Breuer et al., 2022). A range of good practices and methods facilitates the values-based approach. Values-based innovation research and management methods range from a review of organizational policy, elaboration of exploratory and normative future scenarios, to different business modeling and workshop formats, and evaluation of intermediary results across the stage-gate process (Cooper, 2008). A values-based open innovation funnel (Breuer et al., 2017a) with iterative phases (of futures search, exploration, prototyping and evaluation) and exemplary methods provide a useful foundation for the design of a stepwise ICT development process working with value indicators.

Together these approaches provide valuable empirical insights and suggest a range of useful practices, methods and principles for action. However, until now we are missing a coherent and clear methodology to drive values-based and sustainable technology development projects in the context of 5G and 6G.

2.4. Values in assessment: terminology and methodological approaches

Another broad branch of literature that considers values as both criteria and outcomes is the literature on sustainability assessment, which captures social, environmental and economic aspects. It encompasses a multitude of approaches. Some focus on environmental impacts, such as Life Cycle Assessment (LCA), Environmental Impact Assessment (EIA) and comprehensive Cost-Benefit Analysis, while others focus on social impacts, such as Social Impact Assessment (SIA), Social Life Cycle Assessment (SLCA) (Sala et al., 2015) and Social Footprint. Most (but not all) of these approaches stem primarily from development research as well as research regarding infrastructure and other public projects and interventions (Esteves et al., 2012; International Association for Impact Assessment; Kosow et al., 2008), but each has a somewhat different point of focus. For example, while SIA focuses on the assessment of the social impacts of specific projects, policies, or actions, SLCA examines specific products or services; and Social Footprint focuses on quantifying and tracking the social sustainability performance of organizations, products, or services. They demonstrate that there is no single dominant starting point to assessing how normative values become actionable leading to impacts.

These approaches draw from a broad toolbox of methods. They often combine qualitative and quantitative methods, involve different stakeholder groups and employ participatory techniques. While these approaches mostly adopt the perspective of policy makers and actors in development rather than R&D in technology companies, often they face similar questions, such as which values are relevant in a specific case and what indicators could be used.

A further approach, namely the scenario methodology, allows to assess sustainability in R&D projects to help consider potential impacts before they happen. To realize sustainability goals, it is important to assess whether developments are on track in early development stages. However, impacts relevant for, e.g, social sustainability, often only emerge once a technology is brought to the market and adopted at scale and such factors are difficult to model. It is therefore helpful to study sustainability potentials via the scenario method, widespreadly used in future studies (Kosow et al., 2008; Breuer, 2023). Constructing and comparing future scenarios on the basis of identified key factors and their interrelation can provide insights on courses of action needed to achieve values-related goals.

In order to assess and anticipate the relations between use cases and societal impact we can build on a widely established distinction used in development cooperation, which was introduced by the Organization for Economic Cooperation and Development (OECD) Development Assistance Committee (DAC) (OECD, 2010). It understands results as the "output, outcome or impact (intended or unintended, positive and/or negative) of a development intervention", and uses this distinction to describe envisioned changes and achievements. Accordingly, result chains lead from inputs and activities (e.g., use cases in a scenario) to immediate outputs such as products or services, outcomes as short-to mid-term effects of the output and long-term direct or indirect societal impact. These distinctions have proven helpful to specify and validate result chains and to ensure that interventions in technological developments achieve the desired effects. Mapping values to indicators can follow similar result chains, moving from the objectives in a use case, to endeavored outputs sought in a design, to the desired outcomes that should emerge as a result of the designs in use.

2.5. Published work on values in ICT

Previous research establishes the potential for the elicitation and application of values in design, development, and use of ICT. Much of this work demonstrates how it is possible to identify which values are relevant for an ICT in a given situation of use, and to use that understanding to affect the design of a given ICT. This research has explored how the values and associated concepts can be identified and mapped through the study of normative statements in the domain literature from representative organizations in ways that can inform design (Brahimi et al., 2023). Further, they present a series of methods for value elicitation from stakeholders, building specific interpretations and contextual understanding of priorities for ICT design and impact from the ground-up (Van der Velden & Mortberg, 2015). In parallel, research has explored how design affordances (as well as the politics and beliefs of the designers) influence how an ICT can be used and the impacts it can materialize (Shilton, 2013a) (Friedman & Hendry, 2019b) (Powell et al., 2022) (Kernaghan, 2014). In addition, standards have been developed to support designers to begin their considerations of values (see, for example (Recommendation ITU-T Y.4903, 2022)). In all cases, this work relies on interactions with stakeholders.

Articulating values offers opportunities to engage, for example, with marginalized communities, to consider ICT's ability to make concrete acts of inclusion by anticipating possible outcomes and contingencies and fold those into innovation planning processes. Similarly, researchers have worked with stakeholders to reveal general societal concerns for environmental impact, economic progress, or geopolitical tensions that inform the context of ICT application and thus sustainability (Boshuijzen-van Burken et al., 2023, pp. 1–5). Further lines of research have considered how it is possible to not only raise awareness with ICT developers of the existence of values, but also realize their importance to design criteria and decisions to improve the likelihood of value incorporation in the technologies themselves (Shilton, 2013b).

One major challenge of value identification is conflicting or different values between stakeholders, including between technology developers and end-users, often making it hard to know how to concretely consider a value (Kozlovski, 2022). Another challenge is that these methods assume that the act of identifying values in itself supports designers to act on those values, but existing literature does not explore in great depth when designers have such agency to do so or when organizational cultures do not support such ethics of responsibility (Donia & Shaw, 2021). Challenges have also been identified around how the flexibility in interpretations of values makes it possible to employ them to make specific marketing points or mask risks to vulnerable communities, often termed ethics- or green-washing (Magalhã et al., 2021). To address this, emerging research argues for ICT innovation practices to move away from engaging abstract values or principles to instead focus on the complexities of everyday practices with technology (by developers, users, and stakeholders more broadly) to assess and understand the how values are at play, for who, and their real-world implications (Powell et al., 2022) (Møller et al., 2020). KVIs add this to line of research, offering a method for both eliciting and grounding values in agreed upon definitions and indicators.

There are examples of specific values being designed into and through technology. For instance, research has explored how democratic and civic duties, thus citizen well-being, become tied to network platforms (van Dijck et al., 2019), how networked ICT and platforms can become both enablers of access to information, to services, to being heard, as well as drivers for inequality (in labor markets, in democracy, in autonomy) (Lawrence & Laybourn-Langton, 2018). However, this work generally acknowledges that while there are rich assessments of which values matter to all phases of innovation, there is little guidance as to how to consistently and comparatively apply them in practice (Brahimi et al., 2023). Some of these argue the responsibility for change lies within individual agency (Goldberg et al., 2021) while others suggest this attribution of responsibility to act on the values needs to consider the social constraints on ethical action, and how ideal intentions and practical outcomes are not always aligned (Powell et al., 2022). KVIs, as presented here, aim to bridge this gap, offering a method to translate a value and desired impact into a measurable indicator that helps all involved assess the potential of a tool to meet that intended outcome.

2.6. Published work on KVIs in 6G

Recently many European research projects for 6G have promised to consolidate societal and technical requirements of 6G in the form of KVIs and KPIs. For instance, the European Union's Horizon Europe research and innovation program Smart Network and Services Joint Undertaking (SNS JU) was launched to support Research and Innovation (R&I) as a widely validated approach that should be developed to transform key SDG requirements into technological solutions and performance objectives (Smart Networks and Services Joint). They are encouraged to establish a commonly used list of KPIs and KVIs for 6G as federating SNS targets for European R&I actions in the field. Some SNS JU projects (e.g., TARGET-X (SNS JU Project TARGET-X), IMAGINE-B5G (SNS JU Project IMAGINE-B5G), 6G-SANDBOX (SNS JU Project 6G-SANDBOX)) are aiming to identify and validate KVIs verified as relevant to the use cases supported, through demonstration of their importance to end-to-end (E2E) large-scale trials and pilots. The 6G Flagship project of the SNS JU program - Hexa-X-II (SNS JU Project HEXA-X-II) - has also identified the importance of incorporating key values with 6G research. As a continuation of the concept initiated in Hexa-X (5G PPP Project HEXA-X), Hexa-X-II envisions an E2E system blueprint for 6G platform with the goals of achieving sustainability, inclusiveness, and trustworthiness. According to the concept of Corporate Social Responsibility (CSR) as highlighted in (HEXA-X-II Deliverable D1a), the inclusion of sustainability of social (i.e., including inclusiveness and trustworthiness), economic, and environmental is a key element of the 6G value proposition. 6G values may also influence drivers, use cases, requirements as well as technology solutions.

Moreover, the design process of E2E systematization in Hexa-X-II considers the development of 6G technologies with the benefits of technology usage through KVIs and the related performance requirements through KPIs (HEXA-X-II Deliverable D2a). However, it is still too early to identify a more concrete roadmap of setting KVIs in these projects and their process towards validating and quantifying with the 6G technologies. Moreover, sometimes in academic literature as well as in project descriptions, the term "KVI" has been used side by side with "KPI", with an absence of disclosure regarding its proper usage, thereby contributing to a state of heightened uncertainty. The working groups of the 6G Smart Networks and Services Industry Association (6G-IA) are also actively contributing to 6G research related to values from the European perspective (G Infrastructure Association). The aforementioned white paper (Wikström et al., 2022) was published as one initiative from 6G-IA activities from the Societal Needs and Value Creation Sub-Group. This white paper (Matinmikko-Blue et al., 2020) introduces initial concepts towards the development of 6G technological enablers from both perspectives, namely societal values as well as performance matrices.

3. Key value indicators framework

Since the need for *values-driven technology development* is increasingly acknowledged, the question raised in the previous literature about how to do this gains urgency: How to systematically integrate societal challenges and values into technology and ICT development? In order to address this research question, we define a framework for values-driven development that combines concepts and methodologies from social sciences with concepts and process models from ICT development. While value-related terms and definitions are well-established in the social and some of the innovation management sciences, they are subject to ongoing debate in different traditions of ethics and philosophy. As previous research shows, they can be mapped at the high level from the literature, their meanings in application can be contested depending on context and user. Terms related to technology research and development processes are typically settled in the context of ICT domains. However, bridging the two worlds is only recently addressed - in the context of innovation management and design frameworks, and for assessing outcomes from ICT-related activities. This is important, considering the potential shown in section 2 for ICT design to impact societal outcomes. The approach presented below does not resolve these issues, but acknowledges them as it draws together the lessons from these disciplines and methods to integrate values and technology in professional practice.

The proposed KVI framework builds on existing normative and conceptual frameworks outlined in section 2 and relates their central concepts in such a way that become useful for ICT research and development. This section introduces terminology, central concepts and their relations, explains how they build on existing frameworks and methods, and justifies conceptual decisions taken in the development of the framework. It also explores when context, via use cases, and stakeholder engagement should be considered in the process to both understand how the values should be defined but also how they matter in that context. The final arrangement and overview of central terms has been iteratively discussed and refined through multilateral conversations between a wide number of ICT industry stakeholders (from vendors, operators, IT developers, vertical industries-end users, academia etc.) and European ICT research projects. Two workshops were held collecting feedback from European 5G-PPP research projects on the initial KVI framework (Wikström et al., 2022), leading to a clarification of terminology and a separation of KVIs into enabler-related and use case-related (see 3.2). Co-authors from the social sciences domains have fused their knowledge on existing work and frameworks; co-authoring technology experts have provided their experience on future ICT technologies, capabilities and applicability in use cases; and co-authoring industry representatives have provided insights on restrictions, limitations, and needs enabling the adoption of research outcomes. In addition, participants in ongoing research projects within Horizon Europe have been interviewed and have been given opportunity to review the framework, leading to an improved work process (described in Section 3.3).

3.1. *A values-based framework for ICT development*

As noted above, while the SDGs and European directives (including the EU taxonomy) provide general normative frameworks, they are only global anchors for the definition of organizational or project-specific values as criteria for ICT research and development. Conceptual frameworks and related methods are required that consider the complexity of stakeholder practices with the technology to support embedding these overarching directives into organization- and project-specific contexts. The KVI framework takes a values-based approach to re-frame the established process for ICT development following existing frameworks of values-based (Breuer et al., 2022) and responsible innovation (Owen et al., 2012) following their distinction between values as criteria and as outcomes. The values-based innovation management framework (Breuer et al., 2017a) describes how a re-consideration of different stakeholder values can fulfill heuristic, integrative and directive functions for technology development, and exemplifies different methods to facilitate the process across different stages of a values-based innovation funnel. Responsible innovation practices and methods from value-sensitive design facilitate the translation of values as criteria to desirable outcomes in term of economic, social and/or ecological benefits.

The ongoing debates about values-based and responsible innovation (and substantive, procedural or practice-based approaches to work with values (Boenink & Kudina, 2020) have additional implications for KVIs: First, values cannot be assumed as just being given by normative treaties or individual stakeholders, but their initial elicitation and analysis require dedicated attention and methodological facilitation (through workshops or even ethnographic inquiry with stakeholder representatives). Second, since values are not ready-made entities, their interpretation, formulation and relative importance may change over context, use, and time - an iterative process allowing for reformulation and re-specification is not just required for technological development but also for the KVIs themselves. Following the practice-based approach (Boenink & Kudina, 2020) the elicitation of values as criteria and outcomes with stakeholders is therefore conceptualized as a dedicated step preceding an in-depth analysis and specification of indicators.

Previous methods, mentioned in Section 2.5 and 2.6, have demonstrated that while it is possible to map concepts from literature, there is great potential in engaging use cases, user context, stakeholders, and future scenarios as a way to ground principles in value objectives, defining contextual objectives and scopes to work within. These methods also support elicit key factors to achieve these values and the objectives within, particularly as a way to address the flexibility in interpretation of the values. They also describe how to enrich innovation with values to define the project's frame, goals and broader objectives and to evaluate intermediary results of iterative phases, from use cases to outputs to outcomes. In addition, previous work also points to the need for a framework that helps designers and users both clearly articulate their own politics and responsibility in working towards a value.

The steps in the framework follow the typical flow of technology development in the ICT domain, from research collaborations (step I-II), over regulatory activities and pre-standardization (step III) to standardization and deployment (step IV-V). With this setup, the output created at each step of the framework is adapted to the relevant stakeholders active at the time and the type of activity, such that the KVIs are formulated well in time before they are needed. But, each is also mapped with a value-based practice, building from the research described above.

3.2. *Terminology*

When working with values, many terms in this field are overloaded with versatile meanings, reflecting the background versatility of stakeholders, domains and contexts in which they are used. This is a fact usually experienced in the context of R&D projects run by consortia comprising versatile academic and industry partners. It is therefore necessary to first introduce the key terminology in order to ensure sufficient precision for comparison, and to enable common understanding between stakeholders and experts of diverse scientific domains. Fig. 1 gives an overview of the essential terms and their relations, where the separate roles of KVIs and KPIs are clarified as gauges of societal value and technology performance, respectively.

The definitions of the key concepts in this paper, building on definitions in e.g.(HEXA-X Deliverable D1.2, 2021; Wikström et al., 2022; Schwartz, 2012), (, are as follows (see overview in Fig. 1).

- *Normative frameworks* are important as anchor points for deriving more specific values to pursue and to demonstrate positive outcomes and impact in a wider context, for instance to inform sustainability reporting in line with the European corporate sustainability reporting directives.
- *Values as criteria*: Human values providing motivating goals for technological development and criteria for evaluating intermediary results.
- *Values as outcomes*: the enabled benefits or detriments. As an outcome of "value creation" economic, social and/or ecological benefits stem from a technology, service or business model, but also detriments or risks can result. Outcomes can be connected to the technical enablers, meaning directly stemming from the technology itself, or connected to use cases, meaning emerging from the usage of the technology.
- *(Key) Value*: A selection of values agreed among stakeholders. This selection of values determines the set "values as criteria" and "values as outcomes" to be considered in a value analysis.
- *KVIs:* quantitative or qualitative indicators for gauging effects on values as outcomes. The purpose of KVIs is to gauge the impact from the execution of a use case in terms of economic, social and/or ecological benefits (gain) or detriments (loss). KVIs are here defined as metrics, either on a qualitative scale (good-bad, etc.), or when possible on a quantitative scale (high-low, etc.), and are defined within the scope of a specific use case and scenario (*use case KVIs*), e.g. related to the ICT for Sustainability ambition; or in relation to a use case enabler (*enabler KVIs*), e.g. related to the Sustainable ICT ambition.
- *Scenario:* the context of stakeholders and their interactions, the physical environment and a high-level objective to be achieved.
- *Use cases:* a technology usage aimed at getting a certain result in the scenario fulfilling requirements. Use cases define interactions between activities of applied technology and an end-user or stakeholder. Use cases aim at achieving a certain result in a certain scenario context fulfilling a set of performance requirements and supported by a set of technical enablers. Executing use cases affects value domains in terms of benefits (gains) or detriments (losses). Using the concept of use cases is well established in the planning phase of future mobile communication systems.
- *Performance:* the technical capabilities needed to deliver a use case.
- *KPIs:* Key performance indicators as quantitative results of gauging performance.
- *Requirements:* needed performance (measured against KPIs) or functionalities to deliver a use case, to define a service.
- *Technical enablers:* the realization of technical capabilities, i.e. ICT solutions.

As illustrated in Fig. 1, to enable a certain use case and achieve the targeted *direct* value impact, certain technical enablers should be developed. Concurrently, these technical enablers also *indirectly* impact certain values in terms societal, economic and environmental aspects of ICT technology. This indirect impact is captured by the enabler KVIs. It is crucial to emphasize that the selection of the most appropriate technical enablers requires comprehensive consideration of both UC and enabler KVIs.

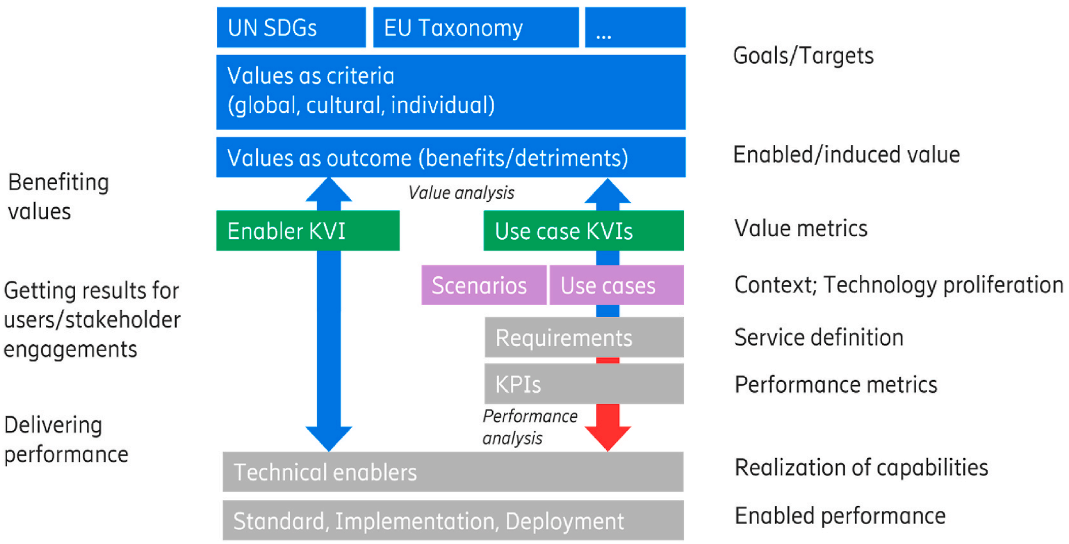

Fig. 1. Overview of terminology.

3.3. A conceptual framework for ICT research and development

In order to steer ICT R&D activities to effectively address the problems under research and at the same time maximize their societal impact, it is necessary to incorporate value-creation visions and impact assessment methodologies through the various technology development stages from initial concept to prototype and to commercial product. The KVI framework presented in this paper involves a series of steps starting from research at low Technology Readiness Level (TRL) and Societal Readiness Level (SRL), up to deployment at high TRL, as outlined in Table 1.

An important preparatory step before a use case analysis, is to align the involved stakeholders' views on a baseline set of KVs to refer to. The set of KVs should be agreed among the involved stakeholders as the relevant ones to refer to. An approach to find this set is to start from the intersection of prioritized values on the one hand, and on the other hand values that ICT operations may impact. As one example, the UN SDGs can provide the basis for a KV set.

With a KV set, agreed the steps in the KVI framework are then the following:

Step I) Definition of scenario and use cases: In this step the global scenario that is addressed by the technological solution is outlined and instantiated to specific use cases.
Step II) Elicitation: Identification of KVs as criteria and KVs as outcome to be associated with the use case.
Step IIIa) Analysis of outcome on value domains, leading to formulation of KVIs as metrics associated with the KVs for the use case. In this step, KVIs are formulated as absolute or relative measures of the impact of technology solution on the identified KVs. Use case KVIs will need to capture KVs that are both benefited as well as those that are determined. This gives a possibility for formulating targets based on societal impact, and get a first-guess view of the expected outcome.
Step IIIb) Analysis of value proposition and estimation of use case proliferation, leading to an established view on the KVI outcome.
Step IIIc) Analysis involving prioritization and balance between KVIs and KPIs, leading to target formulations based in policy.
Step IV) Technical realization, involving identification and specification of enablers (i.e. ICT solutions), identification of KVs and formulation of KVIs associated to those, and a design iteration with respect to the KPIs and KVIs. In a more mature phase of development, the technology and system effects of providing a use case is better understood in terms of enablers.
Step V) Assessments, where KVIs can subsequently be gauged through a progression of evaluations, notably Va) expert assessments, Vb) simulations, and Vc) twinned systems. Assessment should be done with defined methodologies and can lead to a reformulation of KVIs and associated targets based on an increased understanding. Mitigating actions, related to the technical enablers and service solution of the use case, can also be launched as an outcome of these assessments to avoid negative impacts and regain positive impacts.

Table 1
Overview of the KVI framework in 5 major steps.

Step #	Phase	Knowledge level	Action	Outcome	Technical aspects	Actors/Stakeholders/Fora
I	TRL 1–3: Research	Vision	Definition of use case Definition of scenario	Precondition	Identification of capabilities/ performance	UN, governments, industry, enterprises, NGOs, industry associations, interest groups, academia
II	SRL 1–3: Stakeholder		Elicitation of values as criteria and as outcome	Identification of KVs		
IIIa	context	Initial view	Identification of relevant metrics for values outcome	Formulation of use case KVIs	Identification of use case requirements	Researchers in industry and academia
IIIb			Value proposition, deployment and proliferation aspects, mitigation	First-guess KVI ranges, identified risks	KPI target formulation for use case	Regulators, SDOs, industry, reference groups
IIIc			Prioritization, trade-off, mitigation	Target formulation on KVIs		Policy makers, Regulators, SDOs, industry, reference groups
IV	TRL 4–6: Validation of technology SRL 4–6: Validation of	Technical realization	Analysis of technology, system and ecosystem enablers, mitigation	Identification and specification of enablers; Formulation of enabler KVIs	Standardization study item, PoCs, KPI checkpoint	Regulators, SDOs, reference groups
Va	expected impact	Expert assessment	Reformulation of KVI, mitigation	Assessed KVI outcome	Standardization work item stage 2	SDOs, reference groups
Vb		Simulations	Reformulation of KVI, mitigation	Expected KVI outcome	Standardization work item stage 3	SDOs, stakeholders
Vc	TRL 7–9: Deployment	Digital twinning	Reformulation of KVI, mitigation	Predicted KVI outcome	Trials	Stakeholders
Vd	SRL 7–9: Operation	Actual system	Measurement, conclusion, mitigation	Measured KVI outcome	Market introduction, standardization maintenance	Stakeholders

In a final step Vd), after deployment of the use case, the outcome on KVIs can be gauged with defined methodologies adapted to the specific use case (to be developed), and subsequently compared with formulated targets, after which the value impact can be concluded.

The work process of defining, eliciting, analyzing, and assessing KVIs is illustrated schematically in Fig. 2. The figure illustrates the central role of KVs in the process, which are associated to use cases and successively to KVIs. It also shows two main iterations; one where both KVIs and KPIs are considered in the design of enablers and technical solutions (step IV), representing a combination of values-driven and performance-driven development; and one where the outcome on values is studied (step V), leading to mitigation activities and prioritization of values based on the increased knowledge.

The KVI framework presented in this paper has already been piloted in evaluations by e.g. the Hexa-X-II and FIDAL projects, which have led to modifications in the steps described above, notably agreeing on a KV set and the inclusion of enabler-KVIs. For instance, as the first steps towards this process, in (HEXA-X-II Deliverable D1b) a qualitative sustainability analysis for six selected 6G use cases is provided by outlining the KVs and the potential effects on those relevant use cases. This analysis is leading towards the development of the novel concept of KVIs as a complement to KPIs and guiding the design of 6G end-to-end system (HEXA-X-II Deliverable D2b).

4. Application

This section elaborates on how to convert the methodology steps of the KVI framework into tasks -from the scenario and relevant use cases definition, to the identification of the relevant KVs, KVIs and specific targets. The description can serve as a blueprint for how the framework can be used. Fig. 3 outlines these main steps, along with the key characteristics and parameters to be defined in each step. As noted in Section 3.3, an important preparatory action is to agree on a set of KVs to refer to in the process.

4.1. Step I: definition of use case and scenario - smart city

The determination of value-adding scenarios and use cases should be rooted in a vision of a future evolution of the status quo in a given field, area, domain, or alternatively, for a given prototype, group, community of users and stakeholders. Such a vision can be drawn from industry vision documents (such as (NGMN, 2021)) or normative guidelines such as ecosystem vision and mission statements (e.g. Breuer, 2023; IMT). The envisioned future outcomes should generally and qualitatively bring a net effect of improving the status quo and benefiting values while taking into account potential downsides that the proliferation of the vision may bring to the environment, society, individual, and economy. To this extent, it is already possible at conceptual level that use cases are discarded or promoted due to the expected detriments or benefits on values, respectively.

In this sense, a scenario represents a greater context taking into account the physical reality (e.g., the boundaries of a typical EU city), external factors, constraints of the status quo (e.g., average air pollution levels and trends in major EU cities registered in last 3 years), and stakeholders' involvement while projecting the final high-level goal to achieve by the targeted future vision (e.g., healthier urban environments with a lower environmental footprint by 2030). The use case should further enunciate the scenario context and add specific details related to the context, deployment, user journey (e.g., typical user behavior in the scenario context), user actions, inputs and outputs leading to the associated scenario and main goal(s). Often, scenarios and use cases are co-created by many interest groups and stakeholders with contribution from domain specific expertise. The outcome of the scenario and use case definition should be the determination of the preconditions that needs to be satisfied technically, and in other respects related to its feasible and sustainable realization.

For instance, the next-generation mobile communications systems, i.e., 6G, is expected to technically, economically and sustainably enable future smart urban environments among other use cases (HEXA-X Deliverable D1, 2021). To this end, 6G will create and provide ICT infrastructure, networking and intelligence enablers necessary to deploy, empower and thus meet smart sustainable cities KPIs and KVIs related to the outcome on various KVs as detailed next.

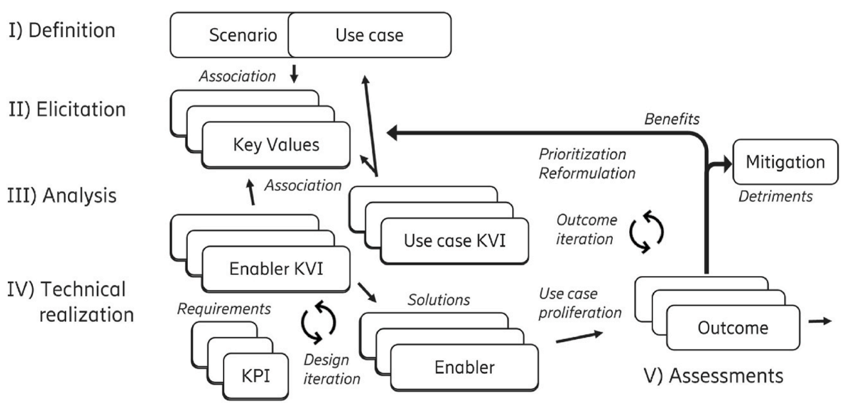

Fig. 2. Work process of the KVI framework.

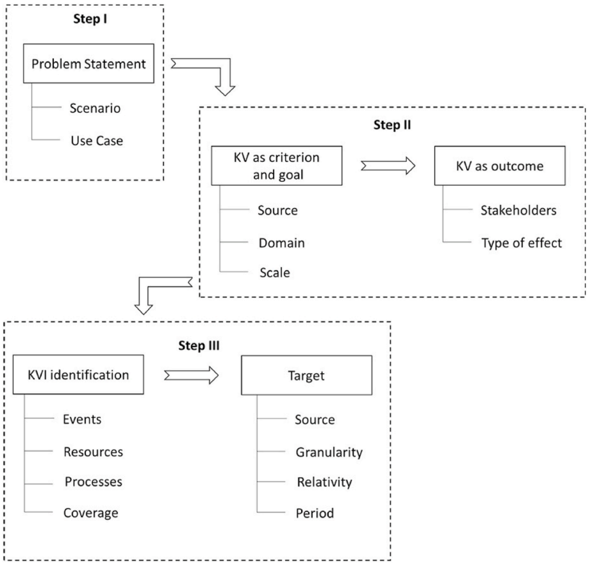

Fig. 3. Key tasks of Steps I to III, leading to the definition of KVIs and their target values.

The following subsections exemplify the co-creation of a scenario and use case with expected benefited values and positive outcomes on the environment, society, economy and individual. In particular, the smart mobility management in urban environments is discussed as an exemplary use case.

4.1.1. Global scenario

The most ambitious global goal of our generation is to achieve carbon neutrality. The European Commission has committed towards a sustainable European future by the 2050 net-zero greenhouse gas emissions and climate-neutrality act (European Commission, 2018). In cities the challenge of decarbonization must be achieved while still maintaining a high-quality fabric of public transportation, mobility of goods, and activity of people and businesses.

In Europe, 75% of the population lives in an urban environment and this figure is expected to grow to 85% by 2050 (European Commission, 2022). Thus, cities contribute significantly to local climate and climate changes, and this motivates the digital transformation of future urban centers to smart cities. At the same time, life in cityscapes is a comparatively efficient way of using and sharing resources, which offers many possibilities for optimizations.

4.1.2. (European) smart cities scenario

Smart cities are expected to become entities using technology and digitalization for common good and sustainable benefits. Towards the 2050 net-zero European mission, some of these benefits are mainly represented by *increasing the quality of inclusive and safe mobility services* and by *improving citizens' health* urban environments (by optimizing traffic flow, providing enablers for car-free cities, reducing congestion and waiting times, dynamically adapting street and traffic lighting as well as reducing accidents and emission gasses).

The technical enablers to achieve these value outcomes towards the European smart cities of 2050 reside on the ability to acquire data from a plethora of distributed sensors (e.g., cameras, air quality sensors, environmental sensors, speed sensors, on-vehicle telematics, network nodes and mobile devices etc.), transport the data to a processing unit (e.g., a distributed network of edge compute capacity and/or a cloud) and perform computations on the acquired data based on different optimization goals. The results of the computation may actuate other deployed devices and infrastructure (e.g., traffic and navigation signs, dynamic traffic policies, navigation instructions and routing) or equip city governance with analytics necessary to derive effective policies (e.g., new urban development such as bike lanes, new urban mobility 3D modes, i.e., drone hopping, e-scooter/e-boat riding, etc., public transportation express lanes, anti-congestion policies, smart logistics etc.). Additionally, smart cities may further provide a data-centric platform for the development of over-the-top services meant to improve quality of life in cities.

4.1.3. Use case: mobility management and autonomy support

One of the major contributors to city pollution is urban mobility. The local city-wide transportation contribution to the greenhouse gas and particulate matter emissions has evolved to a combination of personal transportation (i.e., personal vehicles), public transportation (i.e., buses, trams, subways), and freight and goods transportation (i.e., delivery vans/trucks etc.). The transportation of goods, people and services is vital in an urban environment for the maintenance and improvement of the quality of life, economy and society as a whole as demonstrated over the past century. However, this progress comes at a cost that has increasingly unacceptable due to the negative impacts fossil fuel vehicles on the environment. Despite the current electrification trends in mobility, experts widely agree that in urban environments transitioning from fossil-fueled vehicles to electrical vehicles is not a one-size-fit-all solution in the global fight against climate change (MIT Energy Initiative, 2019). The reality is that people and goods urban mobility needs to go hand-in-hand with societal change promoting increased usage of flexible, on-demand public transportation, and alternative modes of travel, including bicycles and walking. Regarding goods and services, alternative means exploring the 3D urban landscape (e.g., drones) may become feasible with evolving legislature and social acceptance, but the outlook is still uncertain.

Complementary to the pollution monitoring in the context of smart cities is therefore the people, goods and service mobility planning, management and support. To lower the greenhouse gas emissions, access to well-developed public transportation catering to on-demand needs as well as smart traffic management are necessary. This can in effect further reduce congestion and cope with the increase in number of vehicles on the streets. Furthermore, it enables public administration and local transportation companies with better planning of routes, including goods and freight.

The requirements are therefore aimed not only on the monitoring as in the first case, but also in the sensing of live traffic events (e.g., intersection crossings, turns, give ways and ramps). These can be sensed by means of deployed infrastructure, including cameras, lidars, and radio-based sensing. The events need to be acquired and communicated in real-time locally by means of traffic-awareness messages (e.g., like the ones standardized in Intelligent Transportation Systems), but also globally for ingestion into the city Digital Twin apparatus for active planning, traffic management and on-demand route optimization at a city-wide level. All in all, such aspects can be intertwined with policies for an improved mobility management in smart urban environments. Furthermore, such infrastructure would provide additional support and enable better sensing, monitoring and integration of autonomous mobility (e.g., autonomous buses, autonomous delivery vans, autonomous taxis etc.) in the context of an urban canyon with heterogeneous means of transportation and vulnerable road users (e.g., pedestrians, bicyclists).

4.2. Step II: elicitation of values as criteria and as outcomes

The second step provides an example of how an R&D activity can enable the previously defined scenario and use case. It begins by identifying Key Values (KVs) as criteria and then elicits KVs as outcomes. This process links the identification of KVs, both as criteria and outcomes, to the R&D activity's vision and objectives.

KVs as criteria could include a range of values, often framed at a high level within Environmental Sustainability, Economical Sustainability and Societal Sustainability. These can be further specified as, for example but not limited to: Democracy, Cultural Connection, Knowledge Building, Privacy, Quality of Living, Inclusion, Personal Health, and Safety (Wikström et al., 2022). As mentioned above, an alignment on a baseline set of KVs to study is an important preparatory step.

A baseline set for KVs as criteria can be derived from relevant directions from UN SDGs adopted by policy or funding agencies of international, EU, national or community level. However, as already discussed in section 2, UN SDGs are formulated for states to address the impact of their policies, thus they need to be interpreted and further expressed as KVs for the ICT industry to study their impact. At the same time ICT can affect positively or negatively KVs not addressed by the limited set of UN SDGs. Thus, KVs as criteria can also reflect the values defined explicitly by the mandate of R&D program (e.g. program mission or policy frame) and the R&D project definition itself (e.g. project brief, project proposal, etc.). Finally, KVs as criteria can come from stakeholders involved in the R&D project, as those who define and evaluate the broader needs for the ICT innovation. KVs as criteria can be further nailed down to specific goals, thus to the KVs as outcomes.

However, identified KVs should not be limited to normative frameworks or defined from policy makers and funding agencies alone, as this may raise a risk of overlooking direct, indirect or adverse effects on various other impacted domains. For cases in which the KVs as criteria are not clearly visible from these existing frameworks and visions a more thorough study of the impacted domains and values is needed. Further foresight scenario and use case analysis, ideally with stakeholder input, can reveal potential side-impacts or rebound effects on other KVs at initial TRL and SRL. Such value elicitation should be complemented by KVs defined by KV-related and impact-related research studies, in various domains of social sciences. Stakeholders directly involved in or impacted by R&D activities should also provide their insights, observations and target KVs based on their experience, needs, and contexts.

In this analysis, it is useful to distinguish between two forms of impact that can inform KVs: a *direct* impact where deploying and operating networks could be studied in terms of direct resources required, e.g. through material and energy consumption; and an *indirect* impact where positive and adverse induced effects caused by the usage of networks could be studied. The study of the direct impact is often done under the aim for "Sustainable ICT", whereas the indirect impact is often referred to as "ICT for sustainability" or the "enabling/induced effect" (HEXA-X Deliverable D1, 2021). The latter is studied in relation to use cases, whereas the former is studied in relation to enablers and technical solutions.

In addition, it can be helpful to assess scale of effect by distinguishing, categorizing and elaborating on societal, organizational, and personal values. Similarly, the impacted domain can be expanded to include environmental or ecological, social, economic, and personal values (i.e. KVs as goals or as outcome).

Once KVs as criteria are defined, they need to be further analyzed to KVs as outcome, prior to being quantified or qualified into KVIs. This part of step II includes analyzing the use case proliferation and obtaining a contextual understanding of the impact on KVs. More specifically, it includes identifying the KV as outcome in terms of whom will the impact concern (i.e. who is the impacted stakeholder), which aspects of life will be impacted (i.e. which is the type of effect, e.g. an activity or a state of being). These can be complemented by a cost-benefit analysis to assess whether the outcome is beneficial and value-adding against the target goals. A range of methodological approaches can be used here, such as scenario analysis, participatory techniques, or foresight analyses, as presented in more detail in sections 2.4 and 2.5. The flow of Step II is also illustrated in Fig. 3.

4.2.1. KVs for smart cities scenario and use case

Adhering to the proposed methodology and the aforementioned guidelines in eliciting values as criteria and as outcomes, and taking as an example the Smart Cities scenario and use case, a set of KVs as criteria and KVs as outcomes will be derived in Step II. This set of KVs will be the result of a conversational analysis task (corresponding to Step II) performed by the stakeholders involved in the R&D activity. The outcome of such analysis is presented in Table 2. This table is non-exhaustive and focuses on the main expected values. Other impacts and value domains could also be identified with further engagements of stakeholders or as use cases are tested and evaluated. To illustrate, in the studied use case, depending on the area in which the use case is deployed and its specificities, minimization of sound pollution may also impact positively the animal life in the area (value addressed: animal life, domain: environmental), or high drinkable water quality may positively impact the households' expenditure on bottled water (value addressed: economic sustainability, domain: economic, scale: individual or organizational). On the other hand, adverse impact on other KVs as criteria and as goals can be also identified. Indicatively, privacy related challenges may emerge, and personal health can be negatively impacted in cases of low service performance or availability.

4.3. Step III: KVI formulation for use case

KVIs are meant to be metrics that can quantitatively (preferably) or qualitatively assess the potential impact of new under-development or existing ICT solutions on society. In other words, KVIs can be used for assessing whether a technology has the potential to add value once integrated into society. Therefore, appropriately selected use case KVIs can be either utilized to demonstrate or validate that a developed technology usage is in the right direction to contribute to benefiting certain KVs, but more ambitiously such KVIs can be used to drive technology development towards a path that generates greater value in terms of KVs. This can be done in two main ways: by identifying use cases with a positive value outcome and ensuring they are supported and proliferated, and by analyzing the solution enablers and making sure their negative value outcome is minimized. The latter is covered in terms of enabler KVIs in Section 4.4.

For each of the KVs identified as relevant for a specific use case, certain use-case specific KVIs should be formulated to serve as measures of impact for the KVs. While the use case relevant "KVs as a criterion and goal" define the categories of KVs that are affected in a more high-level view, the "KVs as outcome" define the specific impact on the KV when considering the use case, and the KVIs aim to define quantifiable or qualitative metrics that assess progress towards such impact.

4.3.1. KVI identification

For identifying the necessary KVIs for a specific use case of a certain scenario, the output of Step II should be considered. In particular, the use case KVIs should be metrics that assess the extent of impact of a solution on the use-case specific KVs as outcome that

Table 2
KVs for Smart Cities scenario and use case.

Source/Process	Segment	KV as criterion and goal	KV as outcome
Activity (Program Project) Mandate or Normative Framework *(Reduce the greenhouse gas emissions by 2050)* UN SDGs & Health Sciences	Scale: Individual Domain: Personal	Personal health	*Stakeholder:* Humans – Citizens Effect on: State of being KV1: Maintain air quality to levels at which human life is not endangered Effect on: State of being KV2: Improve personal health factors related to air quality Effect on: State of being KV3: Longer life expectancy
Stakeholders	Scale: Organizational Domain: socio-economic	Economical Sustainability	*Stakeholder 1:* Smart Cities, Policy makers etc., citizens Effect on: Process KV1: Provide economically sustainable solution to stakeholders (Smart Cities, Policy makers etc.) KV2: Make logistics more economically efficient KV3: More efficient lead-times for delivering goods/services
Problem Statement & Environment Sciences	Scale: Individual Domain: socio-economic	Quality of Living and Personal Health	*Stakeholder:* Citizens Effect on: State of Being KV1: Maintain and improve air quality Effect on: Process KV2: More efficient urban mobility KV3: Less stressful mobility for citizens
Problem Statement & Environment Sciences	Scale: Individual Domain: socio-economic	Personal health and protection from harm	*Stakeholder:* Smart Cities, PPDR stakeholders, citizens Effect on: Process KV: More efficient mobility for emergency cases
Stakeholders	Scale: Individual Domain: Personal	Privacy	*Stakeholder:* Citizens Effect on: Process KV: Possible privacy leaks of moving individuals
Stakeholders	Scale: Individual Domain: Personal	Quality of Living and Personal Health	*Stakeholder:* Citizens Effect on: State of Being KV: Possible injuries caused by low mobility service performance, service outages etc (e.g. caused by autonomous vehicles problems, conflicting mobility management processes etc.)

has been defined. Considering a certain KV as outcome, different dimensions of quantification should be taken into account for identifying relevant KVIs. In particular, KVIs may address one or more of the following aspects.

- *Events:* A KVI may capture scale of impact of a solution on a KV in terms of number of certain events related to the use case. Depending on the case, the aim may be to reduce the *number* or *volume* of adverse events or/and increase the number and volume of positive events. For instance, in the scenario of the smart city, and mobility management and autonomy support use case, this can be "number or severity of accidents in the city" or "number or volume of incidents of health problems caused by air pollution in the city".
- *Resources:* A KVI may assess the impact of a solution on a KV through the number or quality of certain type of resources relevant to the use case. For instance, in the scenario of the smart city, and mobility management and autonomy support use case, this can be the "city air quality levels" or "Life expectancy for city population".
- *Processes:* A KVI may assess the efficiency of a process related to a use case that affects the realization of a KV. The difference between events and processes is that processes are controlled and initiated by the use case, while events may occur at times (potentially random) that are not controlled by stakeholders involved in the use case. The efficiency of such processes may be assessed in terms of accuracy, response time or cost. For instance, in the scenario of the smart city, and mobility management and autonomy support use case, this can be the "efficiency in the detection of dangerous areas for vulnerable groups" or "response time in emergency events".
- *Coverage*: A KVI may assess the impact of a solution on a KV with respect to geographic or population coverage. For instance, in the scenario of the smart city, and pollution monitoring use case, this can be the "city area in km^2 that offer adequate air quality for human beings."

Table 3
KVIs for Smart Cities scenario and use case.

KV as criterion and goal	KV as outcome	Use case KVIs	Target
Personal Health	KV1: Maintain air quality to levels at which human life is not endangered KV2: Improve personal health factors related to air quality KV3: Longer life expectancy *Stakeholder:* Human - Citizens *Effect on:* State of Being	Number of incidents of health problems caused by air pollution in the city - Event Severity of incidents of health problems caused by air pollution in the city - Event Efficiency in the detection of dangerous areas for vulnerable groups - Process Life expectancy for city population - Resource	% decrease compared to current % decrease compared to current % increase compared to current % Increase compared to current
Economical Sustainability	KV1: Provide economically sustainable solution for city stakeholders KV2: Make logistics more economically efficient KV3: More efficient lead-times for delivering goods/services *Stakeholder:* Smart Cities, Policy makers etc., citizens *Effect on*: Process	Cost of city mobility management solution - Process Total cost of city-level logistics and transportation (after adoption and Intelligent Transportation System based on the Mobility management solution) - Event	Affordable % decrease compared to current
Quality of Living	KV1: Maintain and improve air quality KV2: More efficient urban mobility KV3: Less stressful mobility for citizens *Stakeholder:* Citizens *Effect on*: State of Being	City air quality level - Resource City area with adequate air quality level for human beings - Coverage Transportation and logistic efficiency - Event Accuracy of public transportation schedule - Process	% increase compared to current 100% coverage % increase compared to current % increase compared to current
Personal health and protection from harm	KV: More efficient mobility for emergency cases *Stakeholder:* Smart Cities, PPDR stakeholders, citizens *Effect on*: Process	Emergency response time - Process	% decrease compared to current
Privacy	KV: Possible privacy leaks of moving individuals *Stakeholder:* Citizens *Effect on*: Process	Number privacy leak events - Event	zero privacy leaks
Quality of Living and Personal Health	KV: Possible injuries caused by low mobility service performance, service outages etc (e.g. caused by autonomous vehicles problems, conflicting mobility management processes etc.) *Stakeholder:* Citizens *Effect on*: State of Being	Number of accidents - Event Number of mobility service outages - Event	% decrease compared to current

4.3.2. KVI target value definition

Similar to the KVs, the target values of the KVIs can be influenced by various *sources*. These sources can include external (to the use case) entities like policy makers, governments, and normative frameworks, as well as internal stakeholders who have an interest in or are affected by the specific use case. Depending on the use case, the target value of KVI for the under-development solution may be set in relation with the performance of current solution, e.g., increase by 5% the KVI compared to the current solution, or set as a standalone value, e.g., certain number of daily CO_2 emission for a city. We use the term *relativity* to capture the characteristic of a KVI target value. In addition, the target values of different KVIs may have different levels of *granularity*. For instance, a use case may require a certain percentage of improvement for a KVI (compared to the current solution), while for other KVIs the target may be any level of improvement within a range of values, or even any level of improvement possible. Finally, a target value may also have the dimension of time, i.e., the *period*/time frame in which the target value should be achieved. For some KVIs this target value may need to be achieved from day 1 while for some of them some period of the solution application may be required to reap the targeted benefits.

The flow of step III -i.e. the identification of the relevant use case KVIs and their target values - is also illustrated in Fig. 3. For each task within the step, the key characteristics and parameters that drive the process are also highlighted.

4.3.3. KVIs for smart cities scenario and use case

For the use case example a set of KVI examples starting from the KV as outcome are listed in Table 3. This table is non-exhaustive and focus on the main KVIs that can be foreseen at initial use cases and technical solution definition stages. Additional KVIs can be defined at more mature stages of use case development and deployment, following also the identification of other possible impacts and value domains as mentioned in 4.2.1.

4.4. Step IV: technology and system enablers

Once the potential outcome benefits of proliferating a use case has been studied, the natural subsequent ambition is to understand what outcome detriments are connected to the solution behind and realization of the use case. This task can be structured into an analysis of 1) technical enablers and 2) system (usage) design and ecosystem aspects. The outcome of this step can be used as input targets in research activities and as arguments in standardization and regulation discussions.

Studying the technical enablers naturally involves a performance-driven analysis, i.e. to ensure that the solution meets the KPI requirements. This step will not be further discussed here, but it's worth highlighting the parallel processes of analyzing KPIs and KVIs in association to technical enablers. In both processes, a similar approach of developing technology towards a target can be taken, with a difference between how the targets relate to a wanted performance or a wanted value outcome, respectively. A design iteration (indicated in Fig. 2) will lead to a convergence of targets and design of enablers, which also can lead to a reformulation of the use case, including their goals and objectives.

Similar to the KVIs formulated for the use case proliferation, KVIs can also be formulated for the use case enablement. As it is with KPIs, this kind of KVI can be expected to have a direct impact on the design of the enabler. This includes elements about how systems can be used in practice, governance or standards that support desired outcomes, and broader features within an ecosystem (e.g., ability to gather data about socio-economic impacts, data about current devices and infrastructures, access to repair training or recycling facilities). When enablers are relevant for multiple use cases these KVIs can be applied on a general level for the technology development, supporting impacts upon higher-level values. This would be the case, for instance, for KVIs related to resource usage or digital inequalities.

The technical enablers concern the feasibility of the use case, which can be broken down into a list of features that the network needs to contain in order to support the relevant service. Listing features necessary to deliver a use case can further be used to create a mapping table between features and enabled services. From these features it is often possible to derive the kinds of measures that can be taken in a lab to conduct early assessments of if a technology has the potential to support the objectives of a KV. For the enablers it is therefore critical to understand both the outcome benefits as well as the outcome detriments and to encourage or mitigate them by modifying the technical design, if possible. This outcome iteration, which can also involve reformulating and prioritizing between KVIs to better capture the outcome, is indicated in Fig. 2.

Being aware that a technology alone does not create benefit, technical KVIs need to be balanced with system (usage) design and ecosystem aspects. These relate to other enablers that are needed in order to proliferate a use case. This can be about how services are offered; how technologies can be used in practice by stakeholders; what deployment of hardware and software is needed, in terms of network nodes and devices; data about stakeholders and contexts that support necessary awareness and analysis; trainings or service access that make technology design function as intended; and what business and governance relations are needed.

In the long run, the results of such analysis can be used as arguments for or against a certain feature in standardization. Open standardization or pre-standards is an established model of capturing the different views of various stakeholders. But relevant stakeholders are not likely to engage in standardization before the use case is established (indeed, users of smart city technology might not even have ability to participate in standardization activities), and additional ways to capture their views are needed; such as joint or multidisciplinary research projects that also include early and ongoing engagement of stakeholders throughout.

4.4.1. Example use case and scenario

4.4.1.1. Technical enablers. The sixth generation (6G) network of mobile communications is expected to provide the connected platform towards many of the key technology enablers listed in the prequel. 6G is expected to provide an integrated sensing, connectivity and computing fabric providing a platform for development and deployment of energy-efficient new devices and infrastructure (i.e., sensors, actuators, road infrastructure etc.) needed for the realization of the smart city 2050 net-zero vision (Matinmikko-Blue et al., 2020).

The use case described in this chapter would rely on network delivering connectivity solutions as well as related support services in form of computing and software. In this paper we will not go into any detail of technical solutions, but only illustrate by examples how the KVI framework can be applied also for enablers, to formulate technology-related *enabler KVIs*. One important aspect to note is that use cases build on a common and specific set of enablers, where the first is the basic network functionality required by all services, and the second is the additional functionality required for the specific services, respectively. Studying the outcome detriments of a use case should involve sharing the burden of the common set, however a useful starting point to consider a use case is the specific set.

Specifically, the studied use case is based on sensing and positioning from the network infrastructure. Therefore it is relevant to study the value outcome of these technical enablers, as it is done on a high level in Table 4. The analysis is here simply done based on the performed actions: measurements to localize objects and devices, which will involve energy consumption and identities. It should be noted that a more detailed analysis of the value outcomes needs to be done, and the KVIs formulation should be clarified in relation to how they should be evaluated.

4.4.1.2. System (usage) design and ecosystem aspects. Similarly, the value from the use case relies not just on what a technology or network can do, but how its context of use enables the activities and objectives. Many of the KVIs require baseline data about the people the infrastructure effects (e.g. quality of living, personal health) and thus require that the data gathering, practice, and governance systems for these elements can be aligned with the delivery of e.g. 6G technology. In other words, even if a technology is recyclable or repairable, if the systems are not in place to support recycling or skills for repairability, then in practice, they are neither. While technologically a KPI can be met, in system usage, the KVI is not. It is expected that in many cases, the use of KVIs can instigate not only improved ICT innovation but also improved practices by stakeholders in support of shared value-based goals. An example is given in Table 5.

4.5. Step V: assessment or KVI evaluation

In Step V, we provide a guidance for assessing how the use of ICT network and use case solutions impact Key Values Indicators (KVI) formulated for the specific use cases/socio-technical systems. The outcome of the assessment of a KVI can reflect the enhancement of a KV due to the introduction of the ICT solution, or avoidance/mitigation action on a negative trend on a KV due to some external factor, and addresses both positive and negative effects on the KV measure.

Besides gauging the level of the KVIs, the drivers, i.e. the metrics that have the most impact — both negative and positive— on the KVI need to be identified. In the subsequent step it is determined whether the KVI can be expressed as a formula of the drivers: ideally, we should be able to express the KVI as a function of all or some of the drivers — but this may not always be achievable.

KVI evaluations should generally support knowledge creation, as needed for discussions with societal stakeholders and regulators, identify mitigation actions and help reformulate metrics and targets to impact the direction of technical development. It should be noted that the latter outcomes can be achieved without a detailed numerical understanding. With a gradual and iterative assessment methodology, improving from best-guess over expert analysis to simulations and actual measurements, the benefits of a KVI-based analysis can be achieved at an early stage when actually needed, i.e. during the actual technology development.

In the following we consider the assessment of the use of an 6G-based solution in a (present or potential) usage scenario. The metrics related to the impact of an 6G-based solution are derived based on a case study, i.e., the effect of the solution is calculated for a specific setting and the results can be used to model its effects in a different situation. When considering the impact of 6G solutions on KVs, we consider effects of multiple orders. First order effects, are the ones that come from the direct deployment of the technology (from the deployment and operation of the 6G solution itself), e.g., creation of jobs or facilities or infrastructure energy requirements. Second order effects reflect the enabling of new services, the modification of old ones or substitution – where the new service substitute an existing one. This can mean optimization of processes leading to a change in KVIs or the introduction of new functionalities and usage possibilities impacting the KVIs. Higher order effects describe rebound effects, reflected in behavior changes of the broader society. Enablement of new usages would e.g. trigger a behavior change, optimizations would lead to more efficient operations. Rebound effects describe situations in which enhanced efficiency of processes/resource usage does not lead to an overall decrease in resource usage, but instead to a higher consumption of resources in absolute terms. This occurs if a service is delivered more efficiently, but in consequence is used to a substantially higher degree thus leading to a rise in required resources overall. Considering more

Table 4
Enabler examples and enabler KVI examples for use case.

Technical enabler	KV as criterion and goal	KV as outcome	Enabler KVI
High coverage of network sensing and positioning	Environmental Sustainability -Climate action	Minimal emission of GHG	Additional energy consumption in the network per monitored vehicle
	Personal integrity	Maintained privacy in public spaces	Degree of anonymity of identities

Table 5
Enabler examples and related enabler KVIs for the studied use case.

System enabler	KV as criterion and goal	KV as outcome	Enabler KVI
Socio-economic and geographic demographic data gathering by local governments	Digital Inclusivity	Minimize people without access to benefits from services	Degree to which different demographic groups and regions have access
	Personal Health	Efficiency in the detection of dangerous areas for vulnerable groups	Decrease in (disadvantaged) regions negatively impacted by poor air quality

general values, such as decarbonization goals, it can also refer to efficiency gains in one sector, e.g. less kilometers traveled to work due to home office possibilities, which lead to more resource consumption through the use of saved resources (time, money) for a different activity, e.g. more kilometers traveled for leisure purposes. While rebound effects are difficult to estimate, they are very important to consider in order to get an idea of the actual overall impact of 6G solutions on key values (ITU-T Recommendation L).

- Relevance: Selected data and methods shall be appropriate to the assessment.
- Completeness: All outcome that have an effect on the KVI and contribute to the overall result shall be included and assessed.
- Consistency: Meaningful analysis regarding the development of results over time shall be enabled by using the same methodological approaches for compared results.
- Accuracy: Biases and uncertainties shall be reduced as far as practicable.
- Transparency: When communicating the results, sufficient information shall be given to support the interpretation of the results. This means that data sources, data collection processes as well as the modeling and the assumptions made shall be clearly stated and motivated in the documentation, as well as all the assessment boundaries and cut-offs.
- Conservativeness: Conservative assumptions and values shall be used when there are uncertainties. Conservative quantification results are underestimated rather than overestimated.

One other aspect often required in proving the impact of the enabler KVs is their inherent causality relative to the assessed KVIs. This helps on one hand determine the relevance and to some degree the accuracy of the KVIs determined for enabler KVs. On the other hand, it provides an insight into the impact scale of the enabler KVs based on their assessed KVIs. The determination of causal relations is difficult to realize a priori, and requires a posteriori assessment which may be coupled with the KVIs assessment. This may be thus performed during the assessment stage whereby the temporal enabler KVs states and their causal relation to the assessed KVIs are evaluated. To this end, different methodologies, such as Granger Causality, or more generally, Directed Information Theory (Massey, 1990) alongside Universal Directed Information Estimation (Jiao et al., 2013), may be utilized to determine causation and causal relation between enabler KVs and KVIs. Multi-dimensional causality in complex cyber-physical systems may however be difficult to determine even in controlled measurement environments. In such cases utilizing proxy statistical hypothesis testing relying on typical correlation metrics may determine sufficient evidence of the impact scale of enabler KVs based on the KVI assessment.

The KVIs assessment can go through various steps of progressing complexity and realism, for each of which specific methodologies should be defined, as outlined in the following.

4.5.1. (Va) expert assessments

Expert Assessment, in response to the question of evaluating a KVI (or a collection of KVIs), provides an interpretation, opinion or recommendation, as much as possible based on objective criteria, and devised from available data, knowledge and observations. The assessment requires independence, neutrality and impartiality. Requirements on referred data quality should be defined.

In order to properly assess the KVI, it is necessary to define the specific context (use case or scenario); the implementation scale (organization, city, region, worldwide); which group of stakeholders is it affecting (e.g. all users/citizens, some users/citizens, specific targeted users/citizens).

Assessments can be made from three different time perspectives (ITU-T Recommendation L).

- Ex-ante, i.e., the assessment is taking place before the deployment and operation of the use case;
- Mid-way, i.e the assessment is taking during the operational life of the use case and reflects a present situation.
- Ex-post, i.e., assessment is taking place retrospectively, and takes place after the assessed operation period of the use case.

Also the type of the assessment should be defined. It must be specified whether the assessment is referring to the specific implementation of one or several use cases, or to a general usage.

4.5.2. (Vb) simulations

Socio-technical systems represent a conceptual framework enabling the simulation of how these systems respond to the integration of new ICT solutions. This process involves modeling the socio-technical system, conducting simulations, and gathering data to quantify the impact of each evaluated ICT.

4.5.3. (Vc) twinned systems

Digital twins, as simulation, rely on model-based simulations, but they are not the same. The digital twin of a system allows, through (near) real time collection of data (e.g. gathering input from connected sensors, machinery, and people) to see how it is operating in (near) real time. Unlike simulation, it is Ex-ante and Mid-way assessments, since it is not limited to looking back at a scenario, but also can be used for in advance what-if analysis before introducing an ICT solution.

A digital twin integrates simulations of the use case it represents, which can operate at different levels of specificity (e.g. device, process, or even plant level) and combines real-time data and system-level behavior modeling.

4.5.4. (Vd) actual system

Once the use case is deployed, either with general availability or in a more limited test scenario, the outcome on KVIs can be directly measured. Specific methodologies are defined, and subsequently compared with formulated targets or baseline scenarios, after which the value impact can be concluded. The steps from Va) to Vc) assessments can lead to a reformulation of KVIs and associated targets based on an increased understanding. Mitigating actions on the development can also be launched as an outcome of these assessments to avoid negative impacts and regain positive impacts.

4.5.5. Example use case and scenario

For the example use case, the KVIs and their means of measure have been identified in Table 2. Each of these KVIs can be evaluated through methods that must be identified in each of the aforementioned steps. Hereby we define evaluation as the process of computing quantitative information of some characteristics of a certain solution. Not all evaluation steps (expert assessment, simulation, twinned system, actual system) are suitable for all identified KVIs and a choice has to be made as to which steps and methods are most suitable. In Table 6 an initial assessment about the suitability of evaluation methods to evaluate KVIs is shown.

5. Discussion

KVI discussions are a new dimension in the ICT and mobile communications development. The global framework recommendation for IMT-2030 (i.e., 6G) that was approved and published in November 2023 by the International Telecommunication Union Radiocommunication sector (ITU-R) discussed KVIs in the preparatory phase but the concept was not yet included there (Recommendation ITU-R M.2160, 2023). However, new capabilities beyond traditional KPIs were identified including e.g., sustainability and interoperability.

To address the research question about how to systematically integrate societal challenges and values into technology and ICT development, this paper has taken a multi-disciplinary approach and developed a new structured KVI framework.

Still, the exemplary scenarios described above are only presented for demonstration purposes. While applying the KVI framework in the real world context, it should be applied not only with the involvement of ICT experts but also with other relevant stakeholders such as domain experts, social scientists, and representatives of civil society. This has been already highlighted in the first steps of formulating use cases and KVs that require the involvement of the relevant expertise and different viewpoints. Already the first steps of

Table 6
Evaluation methods for a selection of KVIs.

KVI	Evaluation step
Number of incidents of health problems caused by air pollution in the city - measured in % decrease compared to current baseline	*Simulation* based on suitable models can provide a theoretical estimate of the expected reduction in health incidents. In complement, the *actual system* can provide data that can be compared to agreed baselines, *expert assessment* can provide professional judgment on the potential impact of the proposed solution, and a *twinned system* can be used to relate real-time data for judging the effectiveness of the solution.
Severity of incidents of health problems caused by air pollution in the city - measured in % decrease compared to current	Due to the nature of the indicator, *expert assessment* is the best evaluation method that can consider factors like complexity of severity measurement, severity and context sensitivity as well as multi-dimensional factors like hospitalization rates, disease progression and long-term effects. While *simulation*, *twinned system*, and *actual system* evaluations are valuable for assessing various aspects, they may not capture the full complexity of severity assessments as effectively as expert judgment.
Efficiency in the detection of dangerous areas for vulnerable groups - measured in % increase compared to current	A *twinned system* through real-time data integration, proactive monitoring and scenario-based *simulation* appear to be the best way to evaluate this KVI, in particular because it could be constructed with a feedback loop for incorporating improvements. *Expert assessment* and *actual system* may not be able to respond properly to the dynamic nature of the KVI and the need for fast adaptation.
Life expectancy for city population - measured in % increase compared to current	Being a long-term metric this KVI should be evaluated through *actual system* measurements, since the evaluation depends on reliability of data, historical data and trends and is strongly influenced by secondary parameters like lifestyle choices and public health programs. While *expert assessment*, *simulation*, and *twinned system* evaluations could be used in certain contexts, life expectancy is a fundamental health indicator that is best assessed through the collection and analysis of real-world data.

formulating use cases and KVs need to involve the relevant competence and viewpoints. Without this multi-disciplinary voice, it becomes difficult to both assess which key values should be in focus and whether the indicator link to value is acceptable.

This framework clarifies the separate roles of KVIs and KPIs, and derives KVIs from a top-down analysis of KVs which need to be agreed on collaboratively among stakeholders. This guarantees a strong connection to ethical and normative frameworks that drive stakeholder activities and also benefits alignment of views during the subsequent analysis. Further, the method of stepwise grounding from *KV as criterion and goal* to KV *as outcome* constitutes a practical way of identifying useful metrics through KVIs. Finally, engaging the framework as an iterative and gradually improving approach to evaluations can help overcome the obvious challenges of measurability and causality. Mitigations and formulation of metrics are here established as important, actionable, components of R&D beyond mere knowledge creation.

KVIs following the framework are not restricted to assess beneficial outcomes. In contrast, the KVIs associated to enablers (*enabler KVIs*) would typically estimate detrimental effects, so-called "footprints", which are to be mitigated by development. Also the KVIs associated to use cases (*use case KVIs*) can be used to estimate detrimental as well as beneficial outcomes, relative to a baseline. Further, they can be used to design scenarios and evaluation practices, to understand the distance between current innovation and broader aims of societal values or to consider gaps in the reach of innovation benefits (e.g. segments of society or domains that are not able to access benefits).

The KVI framework contributes to the normative and conceptual frameworks it builds on, and to the related body of literature. In addition, its application to Smart City scenarios and use cases exemplifies, how to address social challenges in technology design and development phases and to identify and estimate value outcome from technology use. Integrating societal challenges and values into technology and ICT development, the framework provides the terminology for interdisciplinary and stakeholder-inclusive collaboration, outlines a stepwise approach to steer values-based ICT research and development, and allows to specify its economic, social and ecological benefits.

While a value framework for ICT innovation has to consider both values as criteria and as outcomes, it is an open issue which environmental, social and economic benefits can be provided through ICT development. The KVI framework and its 5 steps describe a viable approach to specify these benefits in ICT research and development projects, and each application of the framework adds to the long list of potential benefits that then can be distinguished from or merged with already proven ones. The application to the smart city scenario and use case provides some examples of such desirable outcomes.

While normative frameworks of the UN and EU provide global starting points for ICT research and development, there remains quite a distance to bridge when trying to apply or even understand how these normative values are applied in context of ICT development and usage. In particular, the global frameworks cannot fulfill the heuristic, integrative and directive functions values-based innovation management (Breuer et al., 2022). However, whereas the conceptual frameworks value-sensitive design, responsible innovation and values-based innovation only provide rather general guidelines, practices and methods, the KVI framework adds specification through measurable indicators and operationalization through its five steps bridging the gap of missing alignment with professional engineering practices (Gerdes & Frandsen, 2023). Developed through interdisciplinary research across institutions, it bridges discrepancies that have been observed between conceptual frameworks (e.g. of responsible innovation) and efforts trying to implement and operationalize according practices (Van der Velden & Mortberg, 2015). Again, the smart city scenario provided exemplifies the approach and serves as a reference to establish a coherent and clear methodology for values-based and sustainable ICT and next generation telecommunication development projects.

The KVI framework proposed and demonstrated above gives a framework for how KVIs can be created. This framework puts forth a way to start with literature and policy assessments of principled-based values, but then pushes to ground these assessments in contexts of practice, via use cases and stakeholder engagement. Doing so, the framework offers a route to build shared understanding between designer and stakeholders of the values, the validity of the indicators, and the potential for impact they intend to demonstrate. This transparent and step-wise process provides clear documentation of the definitions being used making it easier to know how to consider the value. It also creates one step, however incomplete, towards supporting those involved in the process to improve awareness of their own values that inform this process and affect the ICT design and use decisions they make. Compared to previously published frameworks, notably (HEXA-X Deliverable D1, 2021) and (Wikström et al., 2022) a considerable clarification has been made considering the terminology and the concretization from values to indicators, offering a better grounded and more useful method for value-based technology development.

6. Conclusion

This paper proposes a paradigm shift for defining an evaluation scheme and setting targets for next-generation ICT solutions right from the beginning of the relevant R&D activities. In previous eras, research on ICT was driven by technology-specific targets and performance KPIs. The assessment of ICT solutions' impact on societal values through the enablement of use cases typically occurred after deployment and proliferation. In the 6G era, technology R&D is directed and driven by the expected impact on properly defined targets and values for society. However, setting such targets and bridging societal and technology domains at this early stage is a huge challenge. This paper aims to bridge this gap, by establishing a common language for R&D activities, and proposing a conceptual framework for ICT researchers to identify the impact of technology advancements relevant to 6G, on key values. The goal is to define specific, measurable, attainable and realistic Key Value Indicators (KVIs), which are suitable in steering R&D activities towards maximizing environmental, social and economic value creation. This can be done in two main ways: by identifying use cases with a positive value outcome and ensuring they are supported and proliferated, and by analyzing the solution enablers and making sure their negative value outcome is minimized. This approach enables a deeper understanding and familiarization with the yet-to-be-determined local and global outcomes and impact of 6G networks, for steering 6G R&D efforts to address global sustainable development goals.

The proposed KVI framework comprises five main steps, corresponding to and evolving together with the solution development and use case proliferation life-cycle from initial to final technology or societal readiness levels. The process encompasses the identification of key values, the conception and elaboration of KVIs for the use case and its enablers, as well as evaluation of KVIs. The process described by the framework begins with the definition of scenarios and use cases for which key values are identified in a bottom-up manner. These values can be thought of as important criteria and objectives to be considered, as well as concrete outcomes, derived from the particular needs that arise from the scenarios and use cases. From the analysis of the key values, the KVIs are formulated and selected. The process of formulating and selecting KVIs represents a top-down approach. This phase involves a strategic, high-level view, focusing on prioritizing the most critical metrics. This integrated approach ensures that both overarching objectives and specific details are considered in the value assessment process.

Utilizing the framework described above, and within the context of smart cities, particularly focusing on a Mobility Management and Autonomy Support use case, initial insights have been gained regarding the potential impact of 6G technologies on relevant key values. This foundation provides a basis for the evaluation of these impacts through KVIs.

Moreover, the KVI framework has already received significant attention from the scientific community. It was briefly presented at European Conference on Networks and Communications (EUCNC) June 2023 and received attention from other organizations and standardization entities to consider the concept particular for 6G development. Notably, working group 1 for Service and System Aspects (SA1) from 3rd Generation Partnership Project (3GPP) has initiated discussions on how to use KVIs in 6G standardization. This demonstrates that KVIs are gaining traction as a valuable part of the innovation toolkit, and this framework can provide key stakeholders relevant concepts and components to work with.

With each usage of KVIs, the understanding of catering to values expands, creating a wealth of experience. Over time, pathways of proven results chains emerge, spanning from use cases to services, outcomes, and impact. These established pathways become resources for other developers to draw upon, especially when prioritizing values like energy efficiency or privacy protection for a new project. Consequently, the targets of optimization are no longer limited to performance parameters, financial revenues, and costs of a service, but also encompass societal and ecological outcomes. Shared values and intended outcomes can additionally foster the formation of new business ecosystems that collectively serve these common values.

Concerning the next steps we formulate the following recommendations to advance the application of the KVI framework in R&D for values-driven next-generation ICT solutions:

- Create awareness of the linkage of the KVI framework to the UN SDGs.
- Incorporate the KVI framework in ICT R&D and integrate it within the definition of use cases and scenarios that drive technology development, thereby ensuring that key values are formulated and measurable indicators are identified.
- Introduce continuous assessment and evaluation to track the effect of technology on key values in order to maximize impact on key values and minimize undesirable side-effects.
- Establish a priority classification, and possibly weighting criteria, for formulated key values from societal, environmental and economic perspectives.
- Engage with multi-disciplinary stakeholders, experts and users, to collect feedback on key values, the indicators thereof, as well as during assessment.
- Establish and document proven results chains, and explore opportunities to generalize process steps for easier applicability to several different vertical use cases and scenarios.
- Use the pathways of proven results chains to share knowledge with the broader technology R&D community
- Emphasize importance of key values and the KVI process for the sustainable ICT system design.

CRediT authorship contribution statement

Gustav Wikström: Writing – original draft, Methodology, Conceptualization. **Nona Bledow:** Writing – review & editing, Conceptualization. **Marja Matinmikko-Blue:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Henning Breuer's:** Writing – original draft, Writing – review & editing, Methodology, Conceptualization. **Cristina Costa:** Writing – review & editing, Methodology. **George Darzanos:** Writing – review & editing, Methodology. **Anastasius Gavras:** Writing – review & editing, Writing – original draft, Methodology. **Tobias Hossfeld:** Writing – review & editing, Investigation. **Ioanna Mesogiti:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Katrina Petersen:** Writing – review & editing, Methodology, Conceptualization. **Pawani Porambage:** Writing – review & editing. **Razvan-Andrei Stoica:** Writing – review & editing, Investigation. **Stefan Wunderer:** Writing – review & editing, Writing – original draft, Methodology, Investigation.

Acknowledgments

This work has been performed within the scope of the Societal Needs and Value Creation subgroup of the Vision work group of the 6G Industry Association (6G-IA), which has an eclectic expertise provided by experts and stakeholders from telecommunications, information technology, operational technology and social sciences sectors. The 6G-IA represents the private side in the Smart Networks and Services Joint Undertaking (SNS JU) and works closely with members of ongoing research projects that receive funding from the Smart Networks and Services Joint Undertaking (SNS JU) of the Horizon Europe program. The authors would like to thank the members of the Hexa-X-II project for valuable discussions and feedback on the KVI framework.

References

5G PPP Project HEXA-X: A flagship for 6G vision and intelligent fabric of technology enablers connecting human, physical, and digital worlds, online: https://hexa-x.eu/accessed October 2023.

6G Infrastructure Association (6G-IA) working groups, online: https://6g-ia.eu/6g-ia-working-groups/accessed October 2023.

6G-IA Vision and Societal Challenges WG: https://6g-ia.eu/6g-ia-working-groups/#vision.

Boenink, M., & Kudina, O. (2020). Values in responsible research and innovation: From entities to practices. *Journal of Responsible Innovation, 7*(3), 450–470.

Boshuijzen-van Burken, C., Spruit, S., Fillerup, L., & Mouter, N. (2023). Value sensitive design meets participatory value evaluation for autonomous systems in defence. *2023 IEEE international symposium on ethics in engineering, science, and technology (ETHICS), west Lafayette, IN, USA*. https://doi.org/10.1109/ETHICS57328.2023.10155025

Brahimi, L., Krishnaraj, G., Pringle, J., Schwartz, L., O'Mathúna, D., & Hunt, M. (2023). The ethics of humanitarian innovation: Mapping values statements and engaging with value-sensitive design. *Canadian Journal of Bioethics/Revue canadienne de bioéthique, 6*(2), 1–10. https://doi.org/10.7202/1101123ar

Breuer, H. (2023). Sustainability foresight – practices and methods for future-oriented innovation management. *Proceedings of ISPIM innovation conference 2023*. Ljubljana, online https://www.uxberlin.com/wp-content/uploads/2024/04/2023_Sustainability_Foresight_ISPIM.pdf.

Breuer, H., & Lüdeke-Freund, F. (2017a). *Values-based innovation management. Innovating by what we care about.* London: Palgrave Macmillan.

Breuer, H., & Lüdeke-Freund, F. (2017b). Values-based network and business model innovation. *International Journal of Innovation Management, 21*(3), Article 1750028.

Breuer, H., Lüdeke-Freund, F., & Bessant, J. (2022). Managing values for innovation. *Editorial paper to the IJIM Special Issue on Managing Values for Innovation*, Article 2201001, 31 page(s).

Burget, M., Bardone, E., & Pedaste, M. (2017). Definitions and conceptual dimensions of responsible research and innovation: A literature review. *Science and Engineering Ethics, 23*, 1–19.

Cooper, R. G. (2008). The stage-Gate® idea-to-launch process - update, what's new and NexGen systems. *Journal of Product Innovation Management, 25*(3), 213–232.

Donia, J., & Shaw, J. A. (2021). Ethics and values in design: A structured review and theoretical critique. *Science and Engineering Ethics, 27*, 57. https://doi.org/10.1007/s11948-021-00329-2

Esteves, A. M., Franks, D., & Vanclay, F. (2012). Social impact assessment: The state of the art. *Impact Assessment and Project Appraisal, 30*(1), 34–42. https://doi.org/10.1080/14615517.2012.660356

EU. (2020). *Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088 (Text with EEA relevance)*.

EU. (2022). *Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending regulation (EU) No 537/2014, directive 2004/109/EC, directive 2006/43/EC and directive 2013/34/EU, as regards corporate sustainability reporting* (Text with EEA relevance).

EU-US Beyond 5G/6G Roadmap: https://6g-ia.eu/wp-content/uploads/2024/01/eu-us-aligned-6g-roadmap-joint-paper.pdf?x44222.

European Commission, Joint Undertakings: https://eur-lex.europa.eu/eli/reg/2021/2085.

European Commission, The European Green Deal, online: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en accessed October 2023.

European Commission, The European Commission's priorities, online: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024_en accessed October 2023.

European Commission. (2018). *2050 long-term strategy*. https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategy_en. (Accessed 20 November 2022).

European Commission. (2022). Focus – energy and smart cities. https://ec.europa.eu/info/news/focus-energy-and-smart-cities-2022-jul-04_en. (Accessed 20 November 2022).

Frey, D. (2016). Einführung und konzeptionelle Klärung [Introduction and concpetual foundation]. In *Psychologie der Werte [Psychology of Values]: Von Achtsamkeit bis Zivilcourage – Basiswissen aus Psychologie und Philosophie, S. Vols. 1–12*. Springer-Verlag.

Friedman, B., & Hendry, D. G. (2019a). *Value sensitive design: Shaping technology with moral imagination*. Cambridge, MA: MIT Press.

Friedman, B., & Hendry, D. G. (2019b). *Value sensitive design: Shaping technology with moral imagination*. Cambridge, MA: MIT Press.

Gerdes, A., & Frandsen, T. F. (2023). A systematic review of almost three decades of value sensitive design (VSD): What happened to the technical investigations? *Ethics and Information Technology, 25*, 26.

Goldberg, Z. J. (2021). Translating ethical theory into ethical action: An ethic of responsibility approach to value-oriented design. In S. Yildirim Yayilgan, I. S. Bajwa, & F. Sanfilippo (Eds.), *Communications in computer and information science: Vol. 1382. Intelligent technologies and applications. INTAP 2020*. Cham: Springer. https://doi.org/10.1007/978-3-030-71711-7_28.

HEXA-X Deliverable D1.2, Expanded 6G vision, use cases and societal values. https://hexa-x.eu/wp-content/uploads/2021/05/Hexa-X_D1.2.pdf, (2021) accessed October 2023.

HEXA-X-II Deliverable D1.1, Environmental, social, and economic drivers and goals for 6G, online: https://hexa-x-ii.eu/wp-content/uploads/2023/07/Hexa-X-II_D1.1_final-website.pdf accessed October 2023.

HEXA-X-II Deliverable D1.2, 6G Use Cases and Requirements, online: https://hexa-x-ii.eu/wp-content/uploads/2024/01/Hexa-X-II_D1.2.pdf accessed January 2024..

HEXA-X-II Deliverable D2.1, Draft foundation for 6G system design, online: https://hexa-x-ii.eu/wp-content/uploads/2023/07/Hexa-X-II_D2.1_web.pdf accessed October 2023.

HEXA-X-II Deliverable D2.2, Foundation of overall 6G system design and preliminary evaluation results, online: https://hexa-x-ii.eu/wp-content/uploads/2024/01/Hexa-X-II_D2.2_FINAL.pdf accessed January 2024.

International Association for Impact Assessment, Social Impact Assessment, online https://www.iaia.org/wiki-details.php?ID=23, accessed October 2023.

Recommendation ITU-R M.2160. Framework and overall objectives of the future development of IMT for 2030 and beyond. 2023. Recommendation ITU-R M.2160-0 (11/2023) - Framework and overall objectives of the future development of IMT for 2030 and beyond.

ITU-T Recommendation L.1480, https://www.itu.int/rec/T-REC-L.1480-202212-I..

Jiao, J., Permuter, H. H., Zhao, L., Kim, Y. H., & Weissman, T. (2013). Universal estimation of directed information. *IEEE Transactions on Information Theory, 59*(10), 6220–6242.

Kernaghan, K. (2014). Values, ethics and information technology. *Canadian Public Administration, 57*, 295–317. https://doi.org/10.1111/capa.12069

Kosow, H., & Gaßner, R. (2008). *Methods of future and scenario analysis overview, assessment, and selection criteria, DIE Studies No. 39*. German Development Institute.

Kozlovski, A. (2022). Parity and the resolution of value conflicts in design. *Science and Engineering Ethics, 28*, 22. https://doi.org/10.1007/s11948-022-00375-4

Lüdeke-Freund, F., Breuer, H., & Massa, L. (2022). *Sustainable business model design – 45 patterns*. Berlin: Self-Published.

Lawrence, M., & Laybourn-Langton, L. (2018). *The Digital Commonwealth: From private enclosure to collective benefit*. IPPR. http://www.ippr.org/research/publications/the-digital-commonwealth.

Lubberink, R., Blok, V., van Ophem, J., & Omta, O. (2017). Lessons for responsible innovation in the business context: A systematic literature review of responsible, social and sustainable innovation practices. *Sustainability, 9*. https://doi.org/10.3390/su9050721

Møller, H. N., Shklovski, I., & Hildebrandt, T. (2020). Shifting concepts of value: Designing algorithmic decision-support systems for public services. In *Proceedings of the 11th Nordic conference on human-computer interaction: Shaping experiences* (pp. 1–12). Shaping Society (Tallinn, Estonia: ACM).

Magalhães, J. C., & Couldry, N. (2021). Giving by taking away: Big tech, data colonialism and the reconfiguration of social good. *International Journal of Communication, 15*, 343–362.

Massey, J. (1990). Causality, feedback and directed information. In *Proc. Int. Symp. Inf. Theory Applic.(ISITA-90)* (pp. 303–305).
Matinmikko-Blue, M., Aalto, S., Asghar, M. I., Berndt, H., Chen, Y., Dixit, S., Jurva, R., Karppinen, P., Kekkonen, M., Kinnula, M., Kostakos, P., Lindberg, J., Mutafungwa, E., Ojutkangas, K., Rossi, E., Yrjölä, S., & Öörni, A. (Eds.). (2020), *6G research visions, No. 2White paper on 6G drivers and the UN SDGs*. University of Oulu.
MIT Energy Initiative. (2019). Insights into future mobility. https://energy.mit.edu/wp-content/uploads/2019/11/Insights-into-Future-Mobility.pdf.
NGMN. (2021). 6G drivers and vision. v1.0 https://www.ngmn.org/wpcontent/uploads/NGMN-6G-Drivers-and-Vision-V1.0_final.pdf.
OECD. (2010). *Glossary of key terms in evaluations and results based management*. OECD, 2002, re-printed in 2010.
Owen, R., Macnaghten, P., & Stilgoe, J. (2012). Responsible research and innovation: From science in society to science for society, with society. *Science and Public Policy, 39*, 751–760.
Powell, A. B., Ustek-Spilda, F., Lehuedé, S., & Shklovski, I. (2022). Addressing ethical gaps in 'Technology for Good': Foregrounding care and capabilities. *Big Data & Society, 9*(2). https://doi.org/10.1177/20539517221113774
Recommendation ITU-TY.4903. (2022). *Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals*.
World Economic Forum (2023). The Global Risks Report 2023. 18th Edition. Geneva, Rockström, J., Gupta, J., Qin, D., et al. (2023). Safe and just earth system boundaries. Available online: https://www.weforum.org/reports/global-risks-report-2023 *Nature, 619*, 102–111. https://doi.org/10.1038/s41586-023-06083-8.
Rommetveit, K., Van Dijk, N., Gunnarsdóttir, K., O'Riordan, K., Gutwirth, S., Strand, R., & Wynne, B. (2019). Working responsibly across boundaries? Some practical and theoretical lessons. In *International handbook on responsible innovation* (pp. 83–100). Edward Elgar Publishing.
Sala, S., Vasta, A., Mancini, L., Dewulf, J., & Rosenbaum, E. (2015). Social Life Cycle Assessment: State of the art and challenges for supporting product policies. *Eur 27624*. Luxembourg (Luxembourg): Publications Office of the European Union, Article JRC99101.
Schwartz, S. H. (2012). An overview of the Schwartz theory of basic values. *Readings in Psychology and Culture, 2*(1). https://doi.org/10.9707/2307-0919.1116
Shilton, K. (2013a). Values levers: Building ethics into design. *Science, Technology & Human Values, 38*(3), 374–397. https://doi.org/10.1177/0162243912436985
Shilton, K. (2013b). Values levers: Building ethics into design. *Science, Technology & Human Values, 38*(3), 374–397. https://doi.org/10.1177/0162243912436985
Smart Networks and Services Joint Undertaking, online https://smart-networks.europa.eu, accessed October 2023.
SNS JU Project 6G-SANDBOX: Supporting Architectural And Technological Network Evolutions Through An Intelligent, SecureD And Twinning EnaBled Open EXperimentation Facility, online: https://6g-sandbox.eu/accessed October 2023.
SNS JU Project HEXA-X-II: Hexa-X II: A Holistic Flagship Towards The 6G Network Platform And System, To Inspire Digital Transformation, For The World To Act Together In Meeting Needs In Society And Ecosystems With Novel 6G Services, online: https://hexa-x-ii.eu/accessed October 2023.
SNS JU Project IMAGINE-B5G: Advanced 5G Open Platform For Large Scale Trials And Pilots Across Europe, online: https://imagineb5g.eu/accessed October 2023.
SNS JU Project TARGET-X: Trial PlAtform FoR 5G EvoluTion – Cross-Industry On Large Scale, online: https://target-x.eu/accessed October 2023.
Stilgoe, J., et al. (2013). Developing a framework for responsible innovation. *Research Policy, 42*(2), 1568–1580.
United Nations. (2020). *Department of economic and social affairs, sustainable development, the 17 goals*. https://sdgs.un.org/goals accessed October 2023.
Van der Velden, M., & Mortberg, C. (2015). Participatory design design participatory and design for values. In *Handbook of ethics values and technological design: Sources theory values and application domains* (pp. 41–66). Dordrecht: Springer Netherlands.
van Dijck, J., Nieborg, D., & Poell, T. (2019). Reframing platform power. *Internet Policy Review, 8*(2). https://doi.org/10.14763/2019.2.1414
Wikström, G., Schuler, S., Arianna, M., Ioanna, S., Razvan, A., Georgiev, G., Barmpounakis, S., Gavras, A., Demestichas, P., Hamon, M.-H., Hallingby, H.-S., & Lund, D. (2022). What societal values will 6G address? *Zenodo*. https://doi.org/10.5281/zenodo.6557534