

IEEE Recommended Practice for Assessing the Impact of Autonomous and Intelligent Systems on Human Well-Being

IEEE Systems, Man, and Cybernetics Society

Developed by the
Standards Committee

IEEE Std 7010™-2020

STANDARDS

IEEE Recommended Practice for Assessing the Impact of Autonomous and Intelligent Systems on Human Well-Being

Developed by the

Standards Committee
of the
IEEE Systems, Man, and Cybernetics Society

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IEEE SA Standards Board

Abstract: The impact of artificial intelligence or autonomous and intelligent systems (A/IS) on humans is measured by this standard. The positive outcome of A/IS on human well-being is the overall intent of this standard. Scientifically valid well-being indices currently in use and based on a stakeholder engagement process ground this standard. Product development guidance, identification of areas for improvement, risk management, performance assessment, and the identification of intended and unintended users, uses and impacts on human well-being of A/IS are the intents of this standard.

Keywords: artificial intelligence, autonomous and intelligent system, IEEE 7010™, well-being indicators, well-being metrics

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Introduction

This introduction is not part of IEEE Std 7010-2020, IEEE Recommended Practice for Assessing the Impact of Autonomous and Intelligent Systems on Human Well-Being

This is a recommended practice for the assessment of the impact of autonomous and intelligent systems on human well-being. It was prepared by Working Group IEEE 7010 (SMC/SC/Well-being for Ethical AI) for the IEEE Systems, Man, and Cybernetics Society/Standards Committee (SMC/SC).

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IEEE Recommended Practice for Assessing the Impact of Autonomous and Intelligent Systems on Human Well-Being

1. Overview

1.1 Scope

This recommended practice provides specific and contextual well-being metrics that facilitate the use of a Well-Being Impact Assessment (WIA) process in order to proactively increase and help safeguard human well-being throughout the lifecycle of autonomous and intelligent systems (A/IS).

1.2 Purpose

This recommended practice provides A/IS creators (designers, developers, engineers, programmers, and others) with impact-related insights that should be taken into account throughout the lifecycle of any A/IS to increase and help safeguard human well-being at the individual, population, and societal levels.

1.3 About IEEE Std 7010

IEEE Std 7010 is intended for use by A/IS creators in order to help in the following:

- a) Establishing a concept of human well-being in relation to A/IS
- b) Establishing a means to assess the impacts of A/IS on human well-being from conception to end of A/IS life
- c) Guiding A/IS development
- d) Identifying areas for improvement
- e) Informing risk mitigation strategies
- f) Assessing performance
- g) Identifying intended and unintended users, uses, and impacts on human well-being of A/IS

This recommended practice is intended for use in all sectors where A/IS are developed to guide the conception, design, development, assessment, monitoring, management, and improvement of A/IS impacts on human well-being. This includes business, academic, government, and nongovernmental organizations.

A/IS creators who do not have a methodology or means to understand or evaluate the intended and unintended impacts on human well-being by A/IS on users and other stakeholders are directly provided such a means with this recommended practice. It is grounded in the principle that businesses, governments, and individuals should aim to promote human well-being. While profit, economic growth, and personal wealth are instrumental to this goal, they should be placed inside a broader conception of well-being. Additionally, this recommended practice incorporates the notion of sustainability such that the well-being of future generations is considered. The overall intent is that IEEE Std 7010 supports the outcome of A/IS having positive impacts on human well-being.

A/IS creators should recognize that well-being measurement is a developing area of research, and that attributing impacts to specific A/IS is a complex effort. A/IS creators should be aware that there are likely to be many factors impacting the well-being of users or stakeholders when using A/IS (see 1.9). Nevertheless, this recommended practice should be used by A/IS creators to understand how to engage and work with users and stakeholders to assess, forecast, manage, and prepare for mitigation of the impacts on human well-being of A/IS.

A successful application of IEEE Std 7010 will have the following effects on A/IS creators:

- An increased awareness about well-being concepts and indicators for A/IS
- An increased capacity to monitor, evaluate, and address the well-being impacts from A/IS
- The ability to evaluate the ongoing well-being impacts of A/IS on users and stakeholders
- The ability to evaluate the ongoing well-being impacts of A/IS for continual improvement of the A/IS in helping to safeguard and improve human well-being
- Greater ability to avoid unintentionally harming the well-being of users and stakeholders

IEEE Std 7010 is composed of a WIA that results in a well-being indicators dashboard for use by A/IS creators in designing, developing, deploying, monitoring, and iteratively improving A/IS that help safeguard or improve human well-being. Core to IEEE Std 7010 is an iterative process that encompasses adaptation and continual improvement. When it is adopted, the IEEE 7010 WIA shall be conducted as an iterative process at every phase from conception, design, and development, to the ongoing assessment and management of A/IS.

This recommended practice is applicable to any stage of the lifecycle of an A/IS. Before an A/IS is deployed, IEEE Std 7010 helps shape ideation and guide development. After deployment, it helps the assessment of well-being impacts and guide improvement of an A/IS. IEEE Std 7010 is provided for use alone or in tandem with or as part of a life cycle processes or other processes already in place. It is possible to implement IEEE Std 7010 through integration of holistic engineering practices already in place, such as human-centered design, computational sustainability, and systems-thinking, or as a new practice undertaken by A/IS creators using routine engineering practices. It is possible to use IEEE Std 7010 in conjunction with other standards, such as ISO's quality management standards. It is also possible to use it as part of a quality circle/plan/do/check/act standard or other process or standard. See [Annex C](#) for ideas and examples for using IEEE Std 7010 as part of another process, system, framework, or other effort. Use of IEEE Std 7010 as part of another process does not preclude the use of best practices, guidelines, standards, regulations, or other guidance regarding data privacy, bias, nudging, transparency, etc.

NOTE 1—One use of IEEE Std 7010 is as part of existing processes, such as with the system life cycle processes of ISO/IEC/IEEE 15288 [B42]¹ and documentation within gate life cycle information item contents of ISO/IEC/IEEE 12207:2017 [B41]. For example, the use of IEEE Std 7010 to supplement the requirements definition process by explicitly addressing well-being indicators in the process of requirements capturing and analysis. Another use of indicators is to assess the impact of the developed product on well-being as part of the validation process. See [Annex D](#) for some notional examples for integrating IEEE Std 7010 into existing processes.²

¹The numbers in brackets correspond to those of the bibliography in [Annex G](#).

²Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

This recommended practice is intended for use by A/IS creators, however, in some cases, A/IS creators do not have the authority to adopt IEEE Std 7010. Decision makers include managers, organizational executives, acquirers, clients, or customers. To encourage the adoption and acceptance of IEEE Std 7010 within an organization, raising awareness about the recommended practice and the relevance of well-being indicators to A/IS is often beneficial. See [Annex C](#) for values statements for the use of IEEE Std 7010 as suggestions and starting places for raising awareness. Other resources for raising awareness include, IEEE Global Initiative on Ethics of Autonomous and Intelligent System's *Ethically Aligned Design* [B36] and the Organization for Economic and Co-operation's (OECD) Going Digital website [B60]. It is recommended that IEEE Std 7010 is integrated into the organizational and institutional process of the business, agency, organization, etc., including (but not limited to) the design, assessment, and marketing of AI/S. [Annex F](#) contains information for managerial adoption of IEEE Std 7010 also as suggestions and starting places for integrating it into organizational and institutional processes.

NOTE 2—IEEE Std 7010 presents a new concept and process, and as such there are not existing case studies, example well-being dashboards in use, or other evidence of its use. As it is used, it is expected that case studies will emerge, as well as examples and lessons to improve future iterations of this standard. To this end, it is expected that the user will adapt it to their circumstances and needs when they use it.

1.4 Iterative approach

This recommended practice is based on an iterative approach to measuring, improving, or helping to safeguard human well-being. It is important to emphasize that an iterative WIA process should facilitate continual feedback from AI/S implementations, resulting in a continuous cycle of assessment and improvement that is responsive to well-being impacts.

Use of this recommended practice does not imply that A/IS creators will have full knowledge of the well-being impacts on users. Moreover, it is assumed that the full range of well-being impacts on humans will not be known during any phase of the lifespan of an A/IS. Iterations of the WIA should help identify unknown impacts throughout the lifecycle of an A/IS project, with the well-being indicators dashboard being used as a guide for positively increasing human well-being from A/IS. See [A.1](#) for dashboard resources.

Most of the time, A/IS creators do not fully know how users will use a technology before the technology is in use, nor do they know the full range of impacts on human well-being by the A/IS. It is expected that the first iteration of the WIA will be rudimentary, and that repeated iterations allow for feedback loops and continual improvement. [A.1](#) lists resources describing iterative approaches.

1.5 Stakeholder engagement

Use of this recommended practice does not imply that A/IS creators are expected to solve all well-being problems related to A/IS in isolation. Integral to the recommended practice is a stakeholder engagement process in which A/IS creators engage stakeholders. See [A.1](#) for stakeholder engagement resources. IEEE Std 7010 is not intended to be a product used only for or with ISO products, so references added are not normative references.

1.6 Outside the scope of IEEE Std 7010 but important to its use

IEEE Std 7010 is limited to well-being impacts on humans as defined and delineated by subjective and objective well-being indicators. It encompasses consideration of individual and collective well-being, as well as the linkages and connections between individual and collective well-being including but not limited to human rights, economic fairness and equality, social equality, ecological health, stable and full employment, honest and trustworthy governments, and other interlinked and connected dimensions of individual and collective well-being. There are many aspects of collecting and using data that are related to well-being, but are not the subject of this standard, some of which are identified in this clause. It should be noted with particular emphasis

that measures should be taken to address these issues in order to help safeguard human well-being in the course of data collection for IEEE Std 7010.

Moreover, it is conceivable that the collection and management of data for the use of this recommended practice itself has an impact on the well-being of A/IS users and stakeholders. For this reason, the European Parliament Regulation 2016/679 General Data Protection Regulation (GDPR) [B17] is recommended as an informative reference when using IEEE Std 7010. However, there are other aspects of data collection and use not addressed by GDPR. In [Annex A](#), [A.2](#) provides some resources (e.g., codes, guidelines, standards) that relate to data use, but are outside the scope of IEEE Std 7010.

In addition, there are many aspects of the use of A/IS that might negatively impact human well-being. A non-exclusive list of potential negative impacts is described in the well-being section of the IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems document, *Ethically Aligned Design* [B36] as:

“...economic and labor impacts, including labor displacement, unemployment, and inequality; accountability, transparency, and explainability; surveillance, privacy, and civil liberties; fairness, ethics, and human rights; political manipulation, deception, nudging, and propaganda; human physical and psychological health; environmental impacts; human dignity, autonomy, and human vs. A/IS roles; and security, cybersecurity, and autonomous weapons.” (page 85)

Other emerging standards in the IEEE 70xx series may address some of these negative impacts and matters related to data use/collection and A/IS that fall outside the scope of IEEE Std 7010. The issues the IEEE 70xx series may address are: algorithmic bias considerations; child and student data governance; data privacy processes; employer data governance; ethical concerns during system design; ethically driven nudging for robotic A/IS; fail-safe design of autonomous and semi-autonomous systems; inclusion and application standards for automated facial analysis technology; machine readable personal privacy terms; ontological standard for ethically driven robotics and automation systems; personal data AI agents; processes of identifying and rating the trustworthiness of news sources; and transparency of autonomous systems (see [A.3](#)).

The scope of A/IS is vast, the stakeholders are diverse, and only recently have governments, NGOs, and businesses begun to study the impact of these technologies on human well-being. As of the publication of IEEE Std 7010-2020, there is no widely accepted set of recommendations, standards, best practices, guidelines, or regulations for contributing to or helping safeguard or improve human well-being. Therefore, in addition to using IEEE Std 7010, users should periodically do the following:

- a) Assess the applicability of the IEEE Std 7010
- b) Gather and employ new best practices and standards as they become available and as are applicable
- c) Formulate codes or procedures for their entities in an effort to prevent potential harms to human well-being
- d) Implement and monitor compliance with codes or procedures

This process should include assessing new data collection technologies and procedures. See [A.2](#) for resources.

1.7 Measuring well-being

Well-being can be reliably measured (IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems [B36]; Diener (2009) [B12]; Helliwell, Layard, and Sachs [B31]). Well-being indicators measure both what is good for well-being and what is detrimental to well-being as well as that for which the impact on well-being is not necessarily clear. The current way of measuring success for A/IS endeavors is predominantly economic value, sometimes without consideration of or at the expense of human well-being. Measuring what is good and bad for well-being allows A/IS creators to manage positive and negative impacts on well-being. Measuring the

impact on well-being when one does not know if the impact will be good or bad allows A/IS creators to know what the impact is and manage it as well.

Subjective indicators are used to gather data for how people perceive their state of well-being. Subjective indicators include measurement for satisfaction with life, affect, psychological well-being, satisfaction with earnings, sense of safety, sense of loneliness, satisfaction with the domains of well-being, etc. Research supports the use of subjective indicators, such as those based on questionnaires, surveys, polls or other means of gathering data from subjective experience. Subjective indicators that meet rigorous scientific standards are considered valid and reliable measures within the scientific community (OECD [B64]; Pavot and Diener, 1993 [B69]; Frey and Luechinger, [B25]; Ovaska and Takashima, [B67]). Subjective indicators are being used by national and international institutions and governments to better understand well-being within countries and country sub-populations and to understand people's satisfaction in specific domains of life. Examples of surveys that include subjective well-being indicators include the European Social Survey [B18], Eurostat's statistics on income, social inclusion and living conditions (Eurostat Income and Living standards [B21]) and the UK Office for National Statistics' well-being program [B87].

Objective indicators are used to gather data for observable phenomena. Objective indicators include measurement for income, productivity, employment status, education, life expectancy, hours per week worked, etc. Well-being is measured using objective indicators such as income, consumption, health, education, crime, housing, etc. These indicators have been used to understand conditions enabling well-being of countries' populations. Objective well-being indicators are also used by some companies to measure their performance. Examples of objective indicators in use are the OECD's Better Life Index [B58], the World Happiness Reports [B106] (both of which also include subjective indicators), and United Nations Sustainable Development Goals (SDG) indicators [B91], as well as, for business, the Global Reporting Initiative [B28], and B-Laboratory's Certified B-Corporations [B9].

Multiple indicators can be combined or aggregated into a single index. An index often uses a combination of subjective and objective measures. While aggregation sometimes helps to provide an overall snapshot of a person's or population's well-being, there are also downsides. High scores in one aspect of well-being sometimes hide low scores in another, and averages sometimes hide low scores for the majority of a population. Examples of aggregate or composite indices are the United Nations Development Programme's Human Development Index [B95], the Social Progress Index [B82] and the UK's Office of National Statistics Measures of National Well-being [B87]. (The OECD Better Life Index [B58] and the World Happiness Reports [B106] also use composite metrics).

Certain social mediums can be other potential tools to understand the well-being of a geographic region or demographic group, based on analysis of publicly available data. Examples include the Hedonometer [B54] and the World Well-being Project [B112].

Well-being should not be reduced to a single dimension. IEEE Std 7010 considers both direct indicators of well-being, such as an indicator for satisfaction with life or indicators for psychological well-being, and indirect indicators of well-being, such as indicators for poverty levels, commute time, sense of belonging to community, good governance, etc.

IEEE Std 7010 comprises well-being indicators from a variety of sources that capture impacts in a wide variety of domains (e.g., health, environment, community, etc.). Which indicators an A/IS creator should use depends on the nature of the A/IS in question and the circumstances of persons or populations potentially impacted.

Well-being refers to what is directly or ultimately good for a person or population and depends on what is indirectly good for a person or population as well. Direct indicators for well-being capture people's reflection of how satisfied they are with their lives, their perceptions of their well-being, etc. While indirect indicators capture many important contributors and circumstances that lead to well-being, a direct indicator of well-being helps to understand overall well-being. Direct indicators of well-being are used to understand relationships between other well-being indicators, and, hence, to explore and understand impacts on well-being.

What is directly or indirectly good for a person or population depends on context. However, this context is bound by indispensable principles such as human rights and ecological harmony. IEEE Std 7010 should not be used to justify harming human well-being, abusing human rights, mistreating non-human animal life and ecosystems, or perpetuating systems of inequality and exploitation.

Indicators that have been tested to help ensure they measure what they intend to measure are scientifically validated. The indicators in [Clause 6](#) are drawn from publicly available indices that are composed of scientifically validated indicators. Scientifically validated indicators are used to gather reliable data, subject to the means by which the data is gathered. When indicators are adapted or changed, they should be tested to help ensure they measure what is intended to be measured. For subjective indicators, the *OECD Guidelines for Measuring Subjective Well-being* [\[B64\]](#) is a useful guide. For objective indicators, von Shirndling's chapter "Construction of Indicators" in *Health in Sustainable Development Planning: The role of indicators* [\[B102\]](#) is a useful guide. The OECD report *How's Life in the Digital Age? Opportunities and Risks of the Digital Transformation for People's Well-being* [\[B62\]](#), issued in 2019, contains a set of 33 indicators across the domains of education and skills, ICT access and use, health, environmental quality, governance and civic engagement, income and wealth, jobs and earnings, personal security, social connections, subjective well-being, and work-life balance that should be useful to users of IEEE Std 7010 in selecting indicators.

While the fulfillment of strategies with respect to particular indicators may lead to goal tension at times, IEEE Std 7010 should not be used to justify harming the well-being of any one person, group of people, or the environment for the well-being of others. The various indicators should be understood to exist within a larger effort to help safeguard and improve well-being. As such, the protection of human rights, avoidance of exploitation and abuse, and environmental harmony should be used to guide the selection and application of indicators.

NOTE—IEEE Std 7010 does not include a scoring or evaluation tool that would allow users to definitively gauge whether the A/IS had a positive impact on human well-being. IEEE Std 7010-2020 Working Group members encourage exploring the feasibility and utility of such a tool. Suggested frameworks for such a tool include the triple bottom line, a well-being domain assessment, the IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems' Happiness Screening Tool for Business Product Decisions (in *Ethically Applied Design* [\[B36\]](#)), or a scoring system based on changes over time for indicators used within a well-being indicators dashboard. Prior to the deployment of an evaluation tool, trade-offs, no-go indicators, and potential misuse of a scoring or evaluation tool should be thoroughly considered and addressed in any development of a scoring or evaluation system or tool. The use of a scoring or evaluation tool should include processes and instructions that do not allow it to be used to justify harm to human well-being or for greenwashing.

[Annex B](#) contains indicators for various A/ISs for use as examples and starting places, but that should not be used to replace the WIA process.

1.8 Relationship of well-being and sustainability

For the purposes of IEEE Std 7010, it should be understood that an important factor in helping safeguard and improve human well-being is ecological health, access to nature, safe climate and natural environment, biosystem diversity and other aspects of a healthy sustainable natural environment. Not only is a healthy and sustainable natural environment instrumentally important to the well-being of the current generation, but integral to the well-being of future generations. This understanding of well-being for the purposes of IEEE Std 7010 also encompasses sustainable development or "meeting the needs of the present without compromising the ability of future generations to meet their needs" (World Commission on Environment and Government [\[B105\]](#)).

1.9 Data considerations

IEEE Std 7010 entails the analysis of data. A/IS creators who are not familiar or comfortable with data analysis are encouraged to learn about data analysis or otherwise develop the capacity for data analysis. A few resources and examples of analyzing well-being data are in [Annex A](#).

Data gathered for an individual reflects that individual's well-being. For example, data for an individual's, income, sense of safety, or average time spent in commute reflects that individual person's well-being for those areas of well-being measured by those indicators.

Data gathered for a population generally reflect that population's well-being. When data is gathered for a population, such as a geographic area or region, it is possible to use it to reflect the well-being for that population, albeit care should be taken to help ensure averages or aggregation does not hide high or low scores for segments of a population or other anomalies. For example, average satisfaction with life for a population, average gross domestic product (GDP), average sense of safety for a population, or average commute time for a population reflects the well-being of a population for those areas of well-being measured by those indicators. Data gathered through random sampling to reflect a population is often relied upon to reflect the well-being of the entire population. Data gathered through convenience samplings whereby people opt-in to provide data sometimes reflects a population, and should be analyzed and compared to similar data collected through random samples before assumptions are made about its reliability for a population.

Collecting data for satisfaction with life or any other subjective indicator should be done independently from any A/IS to help ensure the data collected is not biased. For example, a satisfaction with life indicator should not be phrased as: "How does this A/IS impact your satisfaction with life?" as phrasing a question like this or in any similar way could bias the data. Instead, data should be gathered for all subjective indicators independently. For example, the indicator should be phrased as: "Overall, how satisfied are you with your life?"

Many of the well-being indicators in [Clause 6](#) indirectly rather than directly measure the well-being of an individual, community, or population. Most of the indicators are useful for gathering data to determine whether impacts on well-being are positive, negative, or neutral impacts. All of the indicators, by themselves, capture only a dimension of the well-being of an individual, community, or population. The indicators in [Clause 6](#) are intended to be used in conjunction with each other as part of a well-being indicators dashboard (see [Clause 4](#) and [Clause 5](#)) to capture a holistic picture of well-being.

NOTE—Changes in data collected for indicators measuring the impact on human well-being are likely not to be exclusively the result of A/IS use. Other life events and influences, in part or in whole, also explain changes in data. A dramatic example is the death of a loved one or getting a new job between times data is collected. These and less dramatic events are likely to impact the data collected.

Difficulty in measuring the impact of the A/IS does not mean that the data should not be gathered or used. It is suggested that A/IS creators or others investigate reasons outside the use of the A/IS for changes in data and use this information for more advanced statistical analysis of data to better understand the links and other relationships between use of their A/IS and the well-being impacts measured. While clear demonstration of causal effects is not a requirement of this recommended practice, it is recommended that efforts are made to improve the well-being of human lives when possible through learning from iterations and analysis.

2. Definitions, acronyms, and abbreviations

2.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.³

affect: Feelings felt by humans. Positive affect comprises positive feelings such as feeling calm, contented, happy, joyful, pleasant, etc. and negative affect comprises negative feelings such as feeling afraid, angry, bad, unpleasant, stressed, etc.

NOTE—The term **affect** is similar but not the same as the use of the term affect in Affective Computing or A/IS that can recognize, interpret, and simulate human emotions and related affective phenomena. Affective Computing is computing that relates to, arises from, or deliberately influences emotion or other affective phenomena (Picard [B75]).

A/IS creator: Person or entity that designs, develops, engineers, programs or similarly creates an A/IS.

artificial intelligence (AI): The capacity of computers or other machines to exhibit or simulate intelligent behavior.

autonomous/intelligent system (A/IS): A semi-autonomous or autonomous computer-controlled system programmed to carry out some task with or without limited human intervention capable of decision making by independent inference and successfully adapting to its context. An example is an A/IS that refers to a computer system instantiated in a product or service.

NOTE—For the purposes of IEEE Std 7010, A/IS encompasses AI and information systems (IS).

baseline data: Data collected at the beginning of a process and used for comparison to subsequently collected data.

domain: An aspect or area of knowledge or activity characterized by a set of concepts and terminology understood by practitioners in that area.

NOTE—The Organization for Economic Cooperation and Development (OECD) Better Life Index [B58] uses the term “conditions of life,” which include jobs and earnings, environmental quality, social connects, and many others.

index: A composite set of measures that reflect a concept such as well-being. An example of an index is the OECD Better Life Index [59]. Some use the term indicator and index synonymously.

NOTE—For the purposes of IEEE Std 7010, the terms should not be used synonymously.

indicator: A measure of a discrete element of a domain. One domain can have one or more indicators.

intended user: A person by whom an A/IS creator intends an A/IS to be used.

life cycle: Evolution of a system, product, service, project, or other human-made entity from conception through retirement.

NOTE—See IEEE 1517-2010 [B37].

primary data: Data that is collected directly from a subject.

³IEEE Standards Dictionary Online is available at: <http://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

secondary data: Data that has already been collected from various sources, such as governmental census or statistical bureaus, nonprofits, academic institutions and consultancies.

stakeholder: Anyone or any organization that is a) meaningfully or potentially meaningfully be impacted by the A/IS and/or b) meaningfully or potentially meaningfully impacts the A/IS.

unintended user: A person who an A/IS creator does not intend an A/IS to be used by, but who nonetheless interacts with the A/IS.

user: A person who interacts with an A/IS. A user is a type of stakeholder.

well-being: The continuous and sustainable physical, mental, and social flourishing of individuals, communities and populations where their economic needs are cared for within a thriving ecological environment.

well-being metrics: Subjective and objective indicators—indicators measuring both internal phenomena and external factors—encompassing the capabilities and subjective well-being approaches, and including but not limited to the domains of a) affect, b) community, c) culture, d) education, e) economy, f) environment, g) human settlements, h) health, i) government, j) psychological well-being/mental well-being, k) satisfaction with life, and l) work.

2.2 Acronyms and abbreviations

AI	artificial intelligence
A/IS	autonomous/intelligent systems
AV	autonomous vehicles
WIA	Well-Being Impact Assessment

3. Roadmap and process checklist for IEEE Std 7010

[Clause 4](#) introduces the WIA and the well-being indicators dashboard, while [Clause 5](#) provides more detailed guidance on implementation of the WIA and the well-being indicators dashboard. The WIA is the process by which one identifies potential well-being impacts through stakeholder engagement, measures said impacts through data collection and analysis, and modifies an A/IS based on the insights derived from stakeholder engagement and data analysis. This process is an iterative process that should be repeated throughout the A/IS's lifecycle. The WIA is composed of five activities, as follows:

- a) Internal analysis and stakeholder/user engagement
- b) The creation of the well-being indicators dashboard
- c) The creation of a data collection process and the collection of data
- d) Data analysis and the use of said data to improve the A/IS in question
- e) Iteration

The well-being indicators dashboard is a proposed tool for organizing information related to the WIA. This dashboard may take many different forms depending on the needs and resources of the user of IEEE Std 7010. In some cases, the dashboard may be an interactive application that collects, analyzes, and surfaces data related to the well-being indicators; while in other cases it may simply be a collection of documents and spreadsheets used to organize information related to the WIA.

Table 1 is the IEEE Std 7010 process checklist. When all activities are completed, the process for implementing the recommended practice is complete.

Table 1—IEEE Std 7010 general checklist

		Yes/No
1	Completed internal analysis for WIA	
2	Engaged users for WIA	
3	Engaged stakeholders for WIA	
4	Developed well-being indicators dashboard	
5	Gathered baseline data	
6	Gathered post-baseline data	
7	Engaged in A/IS improvement	
8	Engaged in well-being indicators dashboard improvement	

4. Well-Being Impact Assessment (WIA) and Well-Being Indicators Dashboard Activities and Steps

This clause lists the activities and tasks of the WIA process. Figure 1 provides a visualization of the WIA process and creation the well-being indicators dashboard.

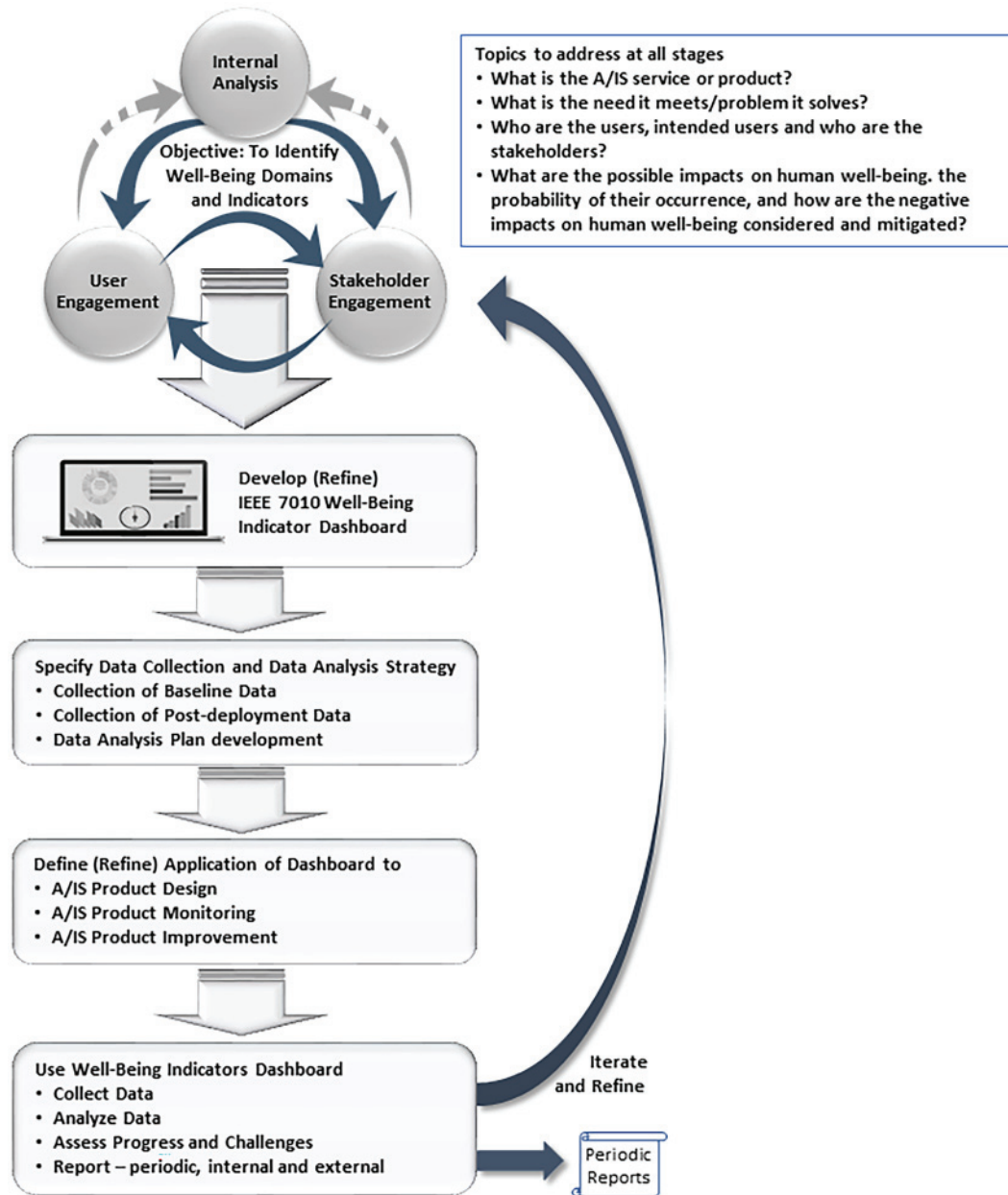


Figure 1—Flowchart of the iterative and adaptive nature of the WIA

4.1 WIA Activity 1: Internal, User, and Stakeholder Impact Assessment

4.1.1 Activity 1 Task 1: Internal Analysis

In Task 1, the following four questions should be asked:

- What is the A/IS?
- What are the needs it meets/problems it solves?
- Who are the intended users, unintended users, and who are the stakeholders?
- What are the possible impacts on human well-being, the probability of their occurrence, and how are negative impacts on human well-being considered and mitigated?

The impact assessment should begin with consideration for all of the domains in [Clause 6](#). These domains of well-being are the following: satisfaction with life, affect, psychological well-being, community, culture, education, economy, environment, government, health, human settlements, and work. [Clause 6](#) contains indicators that may be selected to reflect the well-being impacts on humans. Indicators should first be selected from [Clause 6](#), and they may be adapted. When there are no indicators in [Clause 6](#) that reflect the impacts on human well-being, additional indicators can be found in [A.4](#) and [A.5](#).

Internal analysis should be a continual process.

4.1.2 Activity 1 Task 2: User Engagement

In Task 2 the following four questions should be asked:

- a) What are the benefits to the well-being of users?
- b) What are the harms to the well-being of users?
- c) What are the possible impacts on human well-being, the probability of their occurrence, and how are negative impacts on human well-being considered and mitigated?
- d) What are the unintended uses and impacts, the probability of their occurrence, and how are risks and negative impacts on human well-being considered and mitigated?

Indicators are refined to reflect the impacts on human well-being.

Additional indicators are first selected from [Clause 6](#). Other sources for indicators are in [A.4](#) and [A.5](#).

4.1.3 Activity 1 Task 3: Stakeholder Engagement

In Task 3 the following four questions should be asked:

- a) What are the benefits to the well-being of stakeholders?
- b) What are the harms to the well-being of stakeholders?
- c) What are the possible impacts on human well-being, the probability of their occurrence, and how are negative impacts on human well-being considered and mitigated?
- d) What are the unintended uses and impacts, the probability of their occurrence, and how are risks and negative impacts on human well-being considered and mitigated?

Indicators are refined to reflect the impacts on human well-being.

Additional indicators are first selected from [Clause 6](#). Other sources for indicators are in [A.4](#) and [A.5](#).

4.2 WIA Activity 2: Well-Being Indicators Dashboard

A dashboard based on the domains and indicators identified in Activity 1 should be created. The dashboard should include a way for current and future A/IS creators to easily access the following:

- a) The definition of each domain used
- b) The source of each indicator (where the indicator came from)
- c) An explanation of how each indicator was selected
- d) If appropriate, how each indicator was adapted
- e) How the data was collected

4.3 WIA Activity 3: Data Collection Plan and Data Collection

A plan for collecting data from users and stakeholders should be formed. Baseline data and data over time should be collected. The well-being indicators dashboard should be populated with data.

4.3.1 Activity 3 Task 1: Establishing a Data Collection Plan

The data collection plan should include the following descriptions:

- a) What data is to be collected
- b) How the data will be collected
- c) The frequency with which the data is collected
- d) How data will be time stamped and other means of identification when it is collected
- e) How baseline data is collected
- f) When baseline data is collected

It should include specific activities and details or be more general, as fits the circumstances. Secondary data for populations is available from the sources for indicators listed in [Clause 6](#), from [A.4](#) and [A.5](#) or from other sources for data, such as governments, nongovernmental organizations, education, and research organizations or businesses.

4.3.2 Activity 3 Task 2: Collect Data and Populate the Well-Being Indicators Dashboard

The activities for data collection and population of the well-being indicators dashboard should include the following:

- a) Collect baseline data for the users
- b) Collect baseline data for the stakeholders
- c) Collect baseline data for the population that reflects users and stakeholders (i.e., data for populations that are similar to users and stakeholders)
- d) Collect data for users over time
- e) Collect data for stakeholders over time
- f) Collect data for the population that reflects users and stakeholders over time
- g) Populate the well-being indicators dashboard with the data sets

Where there is not data for an indicator or indicators, it should be noted.

4.4 WIA Activity 4: Well-Being Data Analysis and Use of Well-Being Data

Activity 4 involves two tasks that are action based. The well-being data should be analyzed and used for design, development, deployment, monitoring, and iterative improvement of an A/IS to help safeguard and improve human well-being.

4.4.1 WIA Activity 4 Task 1: Well-Being Data Analysis

Well-being data analysis should include the following activities:

- a) Identify trends over time
- b) Use the data to understand the impacts the A/IS has on the well-being of users and stakeholders

- c) Use the data to illuminate unexpected uses, behaviors, outcomes, and impacts
- d) Document the implementation

4.4.2 Guidance for WIA Activity 4 Task 2: Use of Well-Being Data

WIA Activity 4 Task 2 use of well-being data should include the following activities:

- a) Improve the design, development, assessment, monitoring, management of A/IS to positively impact user and stakeholder well-being
- b) Improvement to well-being indicators dashboard
- c) Documentation of implementation as fits the A/IS creators process and organization

4.5 WIA Activity 5: Iterate

Iterative use of the well-being indicators dashboard and WIA process for continual improvement to the A/IS should be conducted through the following:

- a) Assess the of the WIA process and well-being indicators dashboard
- b) Improve the data collection and analysis strategy
- c) Improve the well-being indicators dashboard
- d) Report as helpful to users and stakeholders

5. Guidance for WIA and Well-Being Indicators Dashboard Activities and Steps

This clause provides guidance for implementing [Clause 4](#). The WIA is an iterative process that entails producing a well-being indicators dashboard and using it for the design, development, deployment, monitoring, and continual improvement of an A/IS in order to help safeguard and improve human well-being. The WIA is designed to be an iterative process whereby there is continual engagement, adaptation, and improvement. As noted in [1.7](#), [Annex B](#) provides notational examples of indicators for various A/IS as starting places, but notational examples should not be used to replace the WIA process.

NOTE—[Annex E](#) contains notional examples intended to help in understanding the application of IEEE Std 7010. They are for illustrative purposes only.

5.1 Guidance for WIA Activity 1: Internal, User, and Stakeholder Impact Assessment

Activity 1 of the WIA involves first identifying and later refining (through an iterative process) well-being domains and indicators to employ in a well-being indicators dashboard. This activity involves the following three tasks:

- Initial analysis
- User engagement
- Stakeholder engagement

The latter two tasks, user engagement and stakeholder engagement, should be conducted in parallel when it is effective to do so, and should inform iterative revisiting of internal analyses. All three tasks should be revisited as appropriate with each major iteration of the overall WIA process.

At the first iteration of the WIA, A/IS creators should begin with the assumption that human well-being in every domain is impacted. When going through WIA Activity 1 Task 1, Internal Analysis, A/IS creators should seek to understand what the impacts are in each domain and identify the indicators for each impact. In Task 2 and Task 3, User Engagement and Stakeholder Engagement, A/IS creators should seek to test their assumptions and identify other impacts for all the domains. If at the end of the tasks, no impacts are identified for a domain, that domain should be excluded from the well-being indicators dashboard for that iteration. Future iterations should include consideration of the domains that are not included in a well-being indicators dashboard if any domains are excluded.

A definition for each domain is in [Clause 6](#). The initial set of domains and indicators should be selected from [Clause 6](#) and adapted as needed to reflect the well-being impacts arrived at from the tasks in this activity. Additional indicators are in [A.5](#), and from other sources.

5.1.1 Guidance on WIA Activity 1 Task 1: Internal Analysis

Task 1 is an internal analysis conducted by A/IS creators and, when appropriate, others within the organization. Internal analysis should involve forecasting, hypothesizing, projecting, utilizing scenarios, or other means of internal analysis.

This task should be conducted in stages.

In this task, A/IS creators answer the following four questions to guide the indicator selection process:

- a) What is the A/IS?
- b) What is the need it meets/problem it solves?
- c) Who are the intended users, unintended users, and who are the stakeholders?
- d) What are the possible impacts on human well-being, the probability of their occurrence, and how are negative impacts on human well-being considered and mitigated?

The initial analysis should be conducted by A/IS creators alone then with involvement from other departments or functions of an organization for part or all of this task.

The first question entails describing the A/IS. Answering this question is prerequisite for assessing its impacts.

The second question involves specifying the purpose of the A/IS and the problems it is intended to address. This question is addressed in terms of specifying the goals and utility of a project. This question is designed to help understand the scope of the well-being impacts for users and stakeholders. A/IS creators should use the well-being domains in [Clause 6](#) as a starting point for brainstorming and articulating the need the A/IS meets or problems it solves.

The third question involves understanding the intended users, the unintended users and stakeholders. It is important to capture unintended users and stakeholders because they are positively or negatively impacted and it is possible that they suffer negative unintended harm. (See [A.1](#), for information about stakeholder engagement.) Impacts on users and stakeholders are direct or indirect, and actual or potential. When answering this question, it is necessary to determine which users and stakeholders to include in tasks 2 and 3 and which not to include.

When identifying users and stakeholders, special consideration should be given to children, vulnerable populations, and populations needing assistive technologies. With each iteration, the identification of users and stakeholders should be revised as users and stakeholders often change with new understanding from data or with changes in uses of an A/IS.

The fourth question involves understanding the possible impacts on human well-being. A/IS creators should be attentive to both positive and negative impacts. A/IS creators should acquaint themselves with [Clause 6](#) to understand the scope of well-being and possible well-being impacts. A/IS creators should keep in mind the Confucius saying, “Real knowledge is to know the extent of one’s ignorance,” in a continual effort to improve their understanding of well-being impact and indicators. For example, it is expected that autonomous vehicles would impact users’ and other stakeholders’ access to transportation, commute times, and household costs in terms of transportation, but using the domains and indicators in [Clause 6](#) suggests unintended impacts for positive or negative impacts, including getting less physical exercise or increasing resting or sleep time.

After answering these four questions, the A/IS creators and others engaged in this task should have both an understanding of well-being impacts and a grasp of the limits of their understanding. A/IS creators should select indicators to measure the impact identified if they have not already from [Clause 6](#), [A.5](#), or other sources. This task results in an initial set of domains and indicators.

NOTE—See [Annex E](#) for a notional example of this task.

[Table 2](#) is a checklist for Activity 1 Task 1.

Table 2—WIA Activity 1 Task 1 internal analysis checklist

	Yes/No
1 Has the A/IS been identified?	
2 Have the needs it meets, and/or problems it solves been identified and defined?	
3 Have users, unintended users, and stakeholders been identified?	
4 Have possible impacts on human well-being been identified?	
5 Did the impact on human well-being assessment begin with considering impact on all domains?	
6 Did the assessment include brainstorming potential impacts within each domain?	
7 Were indicators that measure the identified areas of impact selected from Clause 6 and if there were none, A.5 or other sources?	
8 If there were no impacts identified within a domain(s), was it noted for Task 2 and Task 3?	
9 Were unintended and unexpected issues considered, such as potential biases, negative impacts, and other unknowns considered, including how risks and negative impacts to human well-being can be mitigated?	

5.1.2 Guidance on WIA Activity 1 Task 2: User Engagement

In this task, A/IS intended and unintended users (“users”) identified in Task 1 are engaged in order to further understand the direct and indirect impacts A/IS have and the well-being domains and indicators that reflect and measure those impacts. Assumptions and conclusions arrived at from the Task 1 internal analysis are tested, and the domains and indicators collected from Task 1 are revised. By engaging with users, this process should uncover additional unintended users and stakeholders at which point a decision should be made about whether to include them in this task.

This task involves clearly explaining A/IS to users and exploring the intended and unintended uses, as well as benefits, harms, and risks to human well-being. At the end of this task the A/IS creator should be able to answer the following questions:

- What are the benefits to the well-being of users?
- What are the harms to the well-being of users?

- c) What are the possible impacts on human well-being, the probability of their occurrence, and how are negative impacts on human well-being considered and mitigated?
- d) What are the unintended uses and impacts, the probability of their occurrence, and how are risks and negative impacts on human well-being considered and mitigated?

Means for engaging users include focus groups, surveys, experts, crowdsourcing, and other means. User engagement should mirror the demographics of the future users. Caution should be taken to help ensure that the engaged users are representative of the entire breadth of the user population, and that the needs of underrepresented demographics are also sufficiently identified. For example, if users are children, teachers, and parents from public and private schools, then the users engaged should reflect these six kinds of users. It is possible that some users are children, populations requiring assistive technologies, members of vulnerable populations, or others who have impairments. See [Annex A](#) for definitions of and information about working with vulnerable populations.

The methods for user engagement should be determined as fits the circumstances of the WIA process. Although IEEE Std 7010 does not offer recommendations for managing issues of trust, transparency, privacy, and similar issues when personal data is collected or used, A/IS creators should pay special attention to issues related to the collection and use of personal data (see [1.6](#)). When engaging with users, A/IS creators should use the domains in [Clause 6](#) to frame discussions and help identify impacts. The indicators identified in Task 1 should not be included in discussions with users during the engagement process as this could lead to bias. It is recommended that A/IS creators learn about processes and models for user engagement before conducting this task if user engagement processes are novel to them. (See [Annex A](#) for resources for user engagement.)

NOTE—A/IS creators should be aware of the risk that an WIA does not fully represent users or is inaccurate or misleading if the entire spectrum of users is not engaged, and make reasonable efforts to engage every spectrum of user. However, the level and scope of user engagement will vary depending on the size and resources of an organization, and it is up to the judgement of the A/IS creator to determine reasonable efforts. The level of user engagement will vary based on the size and capacity of an organization, the stage of development or market readiness of an A/IS, and other factors. In a very small organization, it is conceivable that user engagement can be conducted with a handful of users. In medium and large enterprises, it is conceivable that it be large scale and incorporated into market studies, focus groups, research projects, pilot studies, etc.

This task results in a refinement of Task 1 well-being domains and indicators to reflect the well-being impacts as identified through engagement with the users. After conducting the user engagement, A/IS creators should have a better understanding of the well-being impacts of their A/IS.

This task is complete when a saturation point has been reached. A saturation point is arrived at when further engagement results in the identification of the same impacts, domains, and indicators already found in prior engagements. A/IS creators should note that when the same information is revealed repeatedly in such a process, it often reinforces the importance of that feedback. This is the saturation point for any one iteration. It should be considered that future iterations will reveal new impacts, domains, and indicators. This phase should inform an iterative revisiting of the WIA Activity 1 internal analysis. All three tasks of WIA Activity 1 are interdependent and should be performed in an iterative manner until a saturation point is reached.

[Table 3](#) is a checklist for Activity 1 Task 2.

Table 3—WIA Activity 1 Task 2 user engagement checklist

		Yes/No
1	Where methods of user engagement identified?	
2	Have intended and unintended users identified in Task 1 been engaged?	
3	Have additional (current and potential future) benefits to the well-being of users been identified?	
4	Have additional (current and potential future) harms to the well-being of users been identified?	
5	Have additional (current and potential future) risks to the well-being of users been identified?	
6	Have additional unintended (current and potential future) uses and impacts been identified?	
7	Were the assumptions about the indicators that were identified in Task 1 tested and, when relevant, revised?	
8	Were additional indicators reflecting the impacts identified for all the domains identified in Task 1? (From Clause 6, A.5 , and other sources?)	
9	Were indicators reflecting the impacts identified for any domains that were not identified in Task 1? (From Clause 6, A.5 , and other sources).	
10	Was a saturation point for domain and indicator identification reached?	
11	Were blind spots, potential biases, negative impacts, and other unknowns considered, including how risks and negative impacts to human well-being can be mitigated?	

5.1.3 Guidance of WIA Activity 1 Task 3: Stakeholder Engagement

Task 3 involves engaging stakeholders to expand the understanding of how the A/IS impacts the well-being of stakeholders. This process should mirror the process used in Task 2, for user engagement. At the end of this task the A/IS creator should be able to answer the following questions:

- What are the benefits to the well-being of stakeholders?
- What are the harms to the well-being of stakeholders?
- What are the possible impacts on human well-being, the probability of their occurrence, and how are negative impacts on human well-being considered and mitigated?
- What are the unintended uses and impacts, the probability of their occurrence, and how are risks and negative impacts on human well-being considered and mitigated?

Stakeholder engagement should be undertaken through focus groups, surveys, experts, crowdsourcing, or by other means. As with user engagement, the methods for stakeholder engagement should be determined as fits the circumstances of the A/IS creators' organizational setting, project scope, and other considerations. It is recommended that A/IS creators learn about processes and models for identifying and engaging stakeholders before conducting this task if stakeholder engagement processes are novel to them. (See [Annex A](#) for resources stakeholder engagement.)

Guidance for user and stakeholder selection

After identifying stakeholders, for practical reasons it is conceivable that it will be necessary to select which stakeholders to engage in the current iteration of the WIA, which to include in future iterations, which it is better not to engage, and how to consider the impacts for stakeholders who are not available for engagement. Some factors influencing these decisions are cost, feasibility, indicator or data overwhelm, degrees of control or influence, etc. The degree and nature of material impacts on stakeholders should be one basis for selecting stakeholders for engagement. Stakeholders who are particularly vulnerable or present a high degree of risk should be engaged. The rationale for selecting which stakeholders to engage should be documented for reference in future iterations of the WIA.

End of guidance