Journal of
Ethics and Emerging Technologies

IEET

Article

An Ethical Framework for Emerging Technologies: the TEAeM Approach

Nitika Bhalla [1,*], Laurence Brooks [2], Kathleen Richardson[3] and Sara Cannizzaro [4]

[1] De Montfort University; nitika.bhalla@dmu.ac.uk
[2] University of Sheffield; l.brooks@sheffield.ac.uk
[3] De Montfort University; kathleen.richardson@dmu.ac.uk
[4] De Montfort University; sara.cannizzaro@dmu.ac.uk
* Correspondence: nitika.bhalla@dmu.ac.uk

Abstract: The inherent nature of *uncertainty* and the indefinite *time* horizon of emerging technologies means that their effective ethical governance is not sufficiently addressed by industry and hence society. This paper explores an approach to enhance existing ethical frameworks that can be useful and relevant to new and emerging technologies. We begin with the analysis of literature exploring some of the technical features of each framework and its potential applicability to emerging technologies. Following this, a detailed outline of a broad ethical framework has been proposed using a combination of existing ethical frameworks, namely Anticipatory Technology Ethics plus (ATE+), Ethical Impact Assessment (EIA) and a Futures Studies approach, including empirical insights and stakeholder consultation from an EC funded project called TechEthos. The results of the synthesis of the existing ethical frameworks have led to the development of an enhanced framework called 'TEAeM' (TechEthos Anticipatory Ethics Model), which builds on existing tools (rather than replace them) to support the ethical considerations of new and emerging technologies. The usefulness of this framework extends across industry, researchers and policy makers.

Keywords: Ethics; technology, futures studies, emerging, framework

Citation: Bhalla, Nitika, Laurence Brooks, Sara Cannizzaro and Kathleen Richardson. 2025. Title. *Journal of Ethics and Emerging Technologies* 9: x. https://doi.org/10.3390/xxxxx

Received: 04/02/25
Accepted: 04/02/25
Published: date

1. Introduction:

Technologies (often computer-based) are advancing at what seems to be an ever-increasing pace, often referred to as the 4th industrial revolution (Melville et al., 2023). These technologies are touching all aspects of our lives, from the environment in which we live (i.e. helping to deal with climate change and all the issues that it brings (Papa et al., 2015)) to individual support (i.e. personal therapeutic use of technology, such as

deep brain stimulation to help combat the symptoms of Parkinson's disease (Bucur & Papagno, 2023)).

Due to the inherent uncertainty of these new and emerging technologies and the significant amount of tools that already exist there is a need to establish a coherent framework and build on its best elements. This paper explores the need and usefulness of an ethical framework that can be applicable to a broader range of new and emerging technologies, where an ethical framework can be defined as "a heuristic tool that can be used by individuals or organizations to make better-informed decisions that have moral implications. Tools of this kind can take many forms: decision-making models, codes of conduct, an established set of principles or guidelines, training programs, and more"[1].

Although there are existing frameworks present in the literature including, Anticipatory Technology Ethics (ATE) (Brey, 2012b), Ethical Matrix (Mepham et al., 2006), IS Ethics Assessment Techniques (ETICA) (Stahl et al., 2010), Ethical Impact Assessment (EIA) (Wright, 2011), SATORI CWA (SATORI CEN Workshop Agreement, 2017), Futures Studies (Bell, 1996), Ethical Technology Assessment (eTA) (Palm & Hansson, 2006), Ethical Scenario Method (Boenink et al., 2010) and Anticipatory Technology Ethics (ATE) Plus (Umbrello et al., 2023) and others. Most of these frameworks do have some gaps and limitations, for example they do not apply specifically to a broad range of technologies, in particular those that are new and emerging. Some of the frameworks were static in nature and only assessed the technology at a particular time point i.e. a futures element is not considered. Given that we are trying to assess the relevance for the broadest range of technologies, a forecasting approach, together with stakeholder engagement, would be useful to try and predict any long term ethical and social impacts. Within this paper we introduce and describe a new framework called 'TEAeM' (TechEthos Anticipatory Ethics Model), which will bridge the gap in current frameworks and build on their best elements rather than to replace them. Before going into the main paper we need to establish two key definitions:

Emerging Technology: These are technologies whose development and application are not completely realised or finished, and whose potential lies in the future. Emerging technologies are also considered to be radically new, fast growing and potentially impactful across different economic sectors. To realise them, oftentimes different research streams and professionals are expected to come together (Rotolo et al., 2015).

Within the TechEthos project, the three named emerging technology families explored were: Neurotechnologies, Climate Engineering and Digital Extended Reality.

[1] https://www.carnegiecouncil.org/explore-engage/key-terms/ethical-framework

Ethical Framework: A framework that outlines general or specific principles to which countries, organisations, or research communities hold themselves to account. They tend to be adopted in situations where no or limited regulations exist, and groups of people want to influence the direction of a field by acting responsibly in a more coordinated fashion. Compliance with frameworks is usually motivated by social pressure and rewards; formal sanctions are rarer (Cannizzaro et al., 2021).

Ethical frameworks can provide a base for the development of applications that are consistent with the current accepted social norms and moral principles and values in society. Agreeing on an ethical framework or a combination of frameworks can help guide the developers, industry, policy makers, researchers and the end-users of these technologies to be more responsible (Bhalla et al., 2023). However, it must be noted that nothing can possibly eliminate *all* of the potential ethical risks involved in emerging technologies. This is due to the inherent nature of uncertainty and the unknown when describing new and emerging technologies. Since these technologies have not yet either been developed or entrenched into society, and sometimes emergent properties might only occur in their use. Therefore, what might be possible is to develop ethical frameworks which better create awareness for certain implications and facilitate the development of potential strategies to deal with them.

Although there are frameworks in literature, there are notable other gaps and limitations (Bhalla et al., 2023) that need to be highlighted, for example most of them do not take into account a 'futures' element, which should be considered in order to ascertain the effects of ethical and social consequences. Most of the framework's asses the technology in question at that *present* moment in time. As humans, we cannot predict the future, and therefore do not know which ethical issues will play out once the technology is fully developed and entrenched in society (Brey, 2012b). As the emerging technology is still *evolving*, many questions can arise about its nature, its intended and unintended use, and its consequences on individuals, society and the environment. Therefore, it is important to consider that the presence of an ethical framework has the potential to reduce the likelihood and negative impacts of ethical issues on society, thus making developers, researchers and policy makers aware of these possible implications earlier on during the design process.

However, if an ethical framework is to be useful in a broad area of emerging technology, it needs to be accepted and utilised by researchers, academics, industry and policy makers *prior* to any activity that uses the technology or during the technology's research and development phase. Furthermore, the framework should be dynamic and adaptable in nature to encompass the uncertainty of the future, and used in consultation at

every stage of development, and not just considered as an afterthought (using an ethics by design approach remains useful).

New and emerging technologies such as; Neurotechnologies, Climate Engineering and Digital Extended Reality (the selection of these technologies originate from an established criteria and thorough selection process that identified new and emerging technologies with high socio-economic impact, and is detailed in the TechEthos deliverable D1.2[2]), as well as research from the TechEthos project have opened up the opportunity to stimulate questions and proposals to enhance existing ethical frameworks, which can help to mitigate some of these ethical challenges from the use of these technologies and the impact on society.

This paper first begins with a view of representative frameworks under consideration for the broader ethical framework, these are the ATE (Anticipatory Technology Ethics) plus, Ethical Impact Assessment and a Futures Studies approach. The combination of frameworks was further 'enhanced' by incorporating methodologies from the TechEthos project, as well as expert stakeholder review, engagement and feedback from scenarios, workshops and consultations. Following this, a detailed outline of a broad ethical framework was created called the 'TEAeM' (TechEthos Anticipatory Ethics Model), which builds on the best elements of other tools currently in industry to support the ethical and societal considerations of new and emerging technologies in a broader sense. The usefulness of this framework can extend across industry, researchers, academia` and policy makers.

2. Methodology

Following a literature review of selected existing ethical frameworks, a key criteria was developed and used in order to assess the usefulness of these frameworks with respect to new and emerging technologies.

The critical evaluation of frameworks was produced in consultation of the Techethos project team, and stakeholder experts from the project advisory board to gain insights and collaborative learning (Voinov & Bousquet, 2010). Following this approach a key criteria was developed to try and analyse and understand which ethical framework or combination of, can be potential used as a framework model for new and emerging technologies. (Bhalla et al., 2023): The evaluation was based on the following eight key criteria:

- Description and key features of the framework from literature
- What are the advantages of the framework i.e. does it have demonstrable benefits? Has it been implemented/adopted and used by industry/organisations?

[2] D1.2 TechEthos technology portfolio: Assessment and final selection of economically and ethically high impact technologies, available at https://zenodo.org/records/7590422

- What are the disadvantages of the framework (for example is there any such evidence of the framework being used or tested in industry or by researchers)
- Can the framework be applied to new and emerging technologies?
- Does the ethical framework have a futures element?
- Can the framework be enhanced or refined with respect to the methodologies used within the TechEthos project?
- Does the ethical framework have applicability to a broad range of technologies?
- How effective is the ethical framework and how can it be measured?

	Ethical Framework for Task 6.1			
	ATE	**ATE plus**	**Ethical matrix**	**Health technology assessment techniques (HTA)**
Description	ATE employs three levels of ethical analysis, the technology, artifact and application level, which each contain various objects of analysis. Knowledge of them is acquired through forecasting, including the use of existing forecasting studies, expert panels and surveys, and self performed futures studies. Ethical analysis, finally, is performed at two initial stages, the identification and evaluation stage. At the identification stage, moral values and principles are operationalized and cross-referenced with technology descriptions resulting from the forecasting stage. The values and issues are derived from an ethical checklist as well as from the technology ethics literature and bottom-up analyses. At the evaluation stage, the potential importance of identified ethical issues is evaluated and these issues are elaborated. Evaluations may subsequently be used for improving technology development, for better governance of technology, or for other purposes. ATE may be applied to particular emerging information technologies	Enhancement of ATE framework: 1. Describe objects of interest, procedures, techniques, approaches, applications, use cases of interest, etc. (e.g., natural language processing; virtual reality; digital twins in training or health); 2. Investigate core philosophical notions and dilemmas that serve as conceptual scaffolding for the ethical issues (e. g., is there an inherent preference for material reality over virtual reality?); 3. Identify values and principles (e.g., transparency, dignity) and return to step 2 for clarification if necessary; 4. Use narrative analysis to demarcate both transparent ethical considerations and morally opaque presuppositions in technological judgment concerning the values and principles identified in step 3 (e.g., "Be careful what you wish for", "The rich get richer, the poor get poorer"); 5. Ethnographically engage with critical stakeholders associated with technologies based on narratives instead of an addition to open-ended questions; 6. Formulate a set of operationalised design questions to be asked regarding the implementation of techniques (or applications and use cases) (e.g., does the XR system take stock of the potential changes of behaviour in its users? Who profits from the changes in behaviour and how are the changes incited?).	The ethical matrix starts with generally-accepted ethical principles and interprets these ethical concerns according to all affected parties' situations involved in agricultural biotechnology issues: The three principles, care for wellbeing, respect for dignity, and justice, are suggested as they seem to cover most of the ethical concerns in the field and correspond to major theoretical approaches in ethics. The aim of the ethical matrix is to help users identify ethical issues raised by the use food & agriculture technologies and to arrive at intellectually defensible decisions	A framework for systematic identification of ethical aspects of health technologies. The framework consist of twelve items with sub-questions, short explanations, and a concluding overall summary. The items are organized into four different themes: the effects of the intervention on health, its compatibility with ethical norms, structural factors with ethical implications, and long term ethical consequences of using the intervention.
Advantages - demonstrable benefits (eg, usability (claim thats its been done in industry), implementation/cost effectiveness of framework)	Advantages of ATE is that it is capable of detailed and comprehensive ethical analysis of emerging technologies	enhances the ATE framework to encompass the variety of human processes and material forms, functions, and applications that comprise the socio-technical systems in which these technologies are embedded.	Used in biotechnology in stem cell research https://www.eurostemcell.org/stem-cells-ethical-matrix and also used in food & agriculture	A framework for identifying ethical aspects of health technologies could be useful for NT but not CE or XR
Disadvantages (no evidence of framework used)	Limitation - uncertainity of future	proposed framework, manuscript in-press	Overall matrix applies to bio/agriculture based technologies, does not take into account emerging technologies. however the ethical principals such as wellbeing (XR), dignity(NT) and justice (CE) can apply to 3 tech families.	may not be useful to CE and XR
Applicable to emerging tech?	yes	yes	not specifically for emerging tech. Ethical Matrix offers a structured way of working through equine welfare concerns in light of competing interests and outcomes,	more so for NT
Futures element?	The forecasting approach has as an advantage over the generic approach that it is able to consider more ethical issues, by including not only those that are generic to the technology but also those that are specific to projected future devices and their uses.	focus on 'plausible futures' through techethos scenarios WP3	no	nothing in literature to suggest
Can be enhanced/refined? WRT tech families and techethos empirical findings?	yes	yes	no - but use of matrix can be adapted as it provides a structured way of working through ethical concerns in light of competing interests and outcomes,	The Socratic approach is the result of a joint effort of experts in the field of ethics and HTA. Consensus is reached in the expert panel on an approach that is considered to be more clear, comprehensive, and applicable for addressing ethical issues in HTA.
specific to a tech family	all 3 tech families	all 3 tech families	no	NT
more general to emerging tech (crossing boundaries & broad insights)	yes	yes	Overall matrix applies to bio/agriculture based technologies, does not take into account emerging technologies. however the ethical principals such as wellbeing (XR), dignity(NT) and justice (CE) can apply to 3 tech families.	socratic approach is useful and forms the basis of ADIM board meetings with experts - elements of this approach can be applied to all 3 tech families for example discussions with ADIM board/experts
How effective? can it be measured	NA	NA - manuscript in press	used in specific technologies in agriculture and bio tech	NA

Figure 1. A snapshot of the critical evaluation of some current ethical frameworks in literature

Based on these criteria and in consultation with experts to identify gaps in addressing the need for a suitable ethical framework, the following three approaches were selected for further review:

1. Anticipatory Technology Ethics plus (ATE+)
2. Ethical Impact Assessment (EIA)
3. Futures Studies

Anticipatory Technology Ethics plus: This approach is based on the original ATE framework (Brey, 2012a) which provides a strong foundation for evaluating potential issues with novel or developing technologies. The ATE approach includes an identification stage at which ethical impacts are identified and descriptions of a technology (at the three levels i.e. Technology, Artefact and Application) (Figure 2) are analysed by means of a list of ethical values and principles i.e. 'Brey's checklist' (Brey, 2012a).

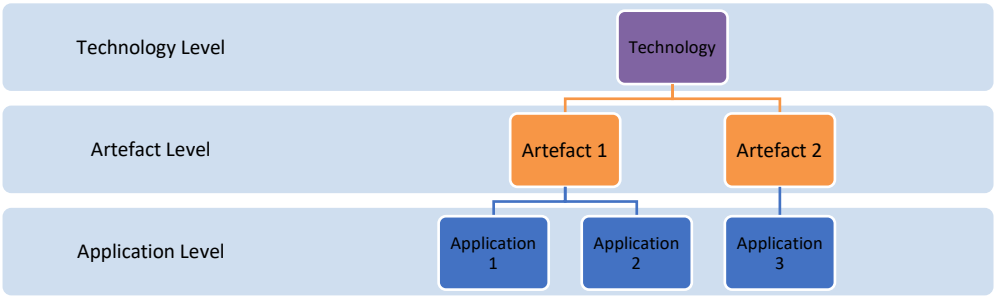

Figure 2: ATE three levels of analysis

In addition, the framework proposes an evaluation stage, during which the relative importance of ethical impacts is assessed along with their likelihood of occurring. However, during the lifetime of the TechEthos project, some gaps were identified that needed to be addressed before the ATE approach could be implemented, including the necessity to "bring values and principles into an *a priori* conversation with technology" (Umbrello et al., 2023). Furthermore, the need to address challenges such as uncertainty, inextricability of time horizons and the probability of consequences are required and this is the reason to explore the ATE+ approach. The ATE+ is a more comprehensive framework of the ATE approach that highlights further nuanced ways for distinguishing the levels and objects of analysis to better reflect the ontology of emerging technologies. ATE+ enhances the ATE framework to encompass the variety of human processes and material forms, functions, and applications that comprise the socio-technical systems in which these technologies are embedded, therefore providing some insights into the challenges of anticipating and responding to the potential impacts of emerging technologies (Umbrello et al., 2023). This is done by providing an analytical tool complementary to ethics-by-design approaches which consists of steps, investigating philosophical ideas, narrative analysis, identification of values and principles, engagement with expert stakeholders and creation of a list of design questions please see below, (Umbrello et al., 2023).

1. Describe objects of interest, procedures, techniques, approaches, applications, use cases of interest, etc. (e.g., natural language processing; virtual reality; digital twins in training or health);
2. Investigate core philosophical notions and dilemmas that serve as conceptual scaffolding for the ethical issues (e.g., Is there an inherent preference for material reality over virtual reality?);
3. Identify values and principles (e.g., transparency, dignity) and return to step 2 for clarification if necessary;
4. Use narrative analysis to demarcate both transparent ethical considerations and morally opaque presuppositions in technological

judgment concerning the values and principles identified in step 3 (e.g., "Be careful what you wish for", "The rich get richer, the poor get poorer");

5. Ethnographically engage with critical stakeholders associated with technologies based on narratives instead of an addition to open-ended questions.

6. Formulate a set of operationalised design questions to be asked regarding the implementation of techniques (or applications and use cases) (e.g., does the XR system take stock of the potential changes of behaviour in its users? Who profits from the changes in behaviour and how are the changes incited?).

The enhanced ethics assessment tool could potentially provide a more nuanced basis to develop ethics guidance in terms of informing ethics-by-design approaches where ATE is used early in the design process to bring to light important ethical issues.

Futures Studies: Futures Studies is not a singular methodology but an heterogeneous approach and Bell suggests it might be too fragmented to be called a 'field' at all (Bell 1996: 8). In drawing on Futures Studies we hope to show the various ways in which Futures are problematised, critically assessed and transformative. Brey (2012) describes it as a field that 'aims to study what possible or probabl[e] futures may look like' and 'technology forecasting' (3). One view is that the future does not merely come into being but is socially constructed by political agents (Inayatullah 2013) The future is not a clearly defined temporal point, but a series of unpredictable outcomes, or as Bell (1996) explains '[t]he future, of course, is still being made' (3). Futures are linked to socio-technical practices that inform and shape it, but as the present is the prioritising sphere of action, decisions and communication (Grunwald 2019: 18), particularly the role of 'socio-technical imaginaries' (Lösch 2019: 4). State and business have extensive resources to shape the narrative of the future, but citizens can also provide alternative perspectives. Futures Studies approaches examine the multiple layers of political engagement, recognising the social, economic, political, and legal shaping of the future (Paul 2019). Identifying assumptions is part of the process (Bell 1996: 11). Bell also identified other features of Futures Studies including: the process of time is irreversible - time passes; the future is novel, and may require responses that are not yet developed; the future may be influenced by individual or collective action; outcomes of the 'interdependence of the world' and some future are more desirable than others (ibid: 12). While non-state and non-corporate actors contribute significantly to influencing narratives, the resources at their disposal are severely limited compared to state and corporations. Inayatullah (2013) approaches regard 'the Future' as a fiction that can be indefinitely created by actors that inform it, while attempting, but not always succeeding, to balance out conflicting interests and priorities

mediated through power, resources, wealth, influence, physical, social or legal trajectories. Futures are "contested" (Brown, Rapport and Webster 2000, Bell 2004) and resources, imaginary and practical need to be leveraged in planning for it. As an eclectic approach, Futures Studies considers issues such as contingency, agency and imagination of actors and offers backcasting as means of identifying a desired future and working backwards. It is 'starting from a desirable (sustainable) future as a vision of success, then looking back to today to identify the most strategic steps or actions necessary for achieving that specified future' (Bibri 2018: 3). Höjer and Mattsson (2000) argue backcasting has benefits for situations of great change. But are desired futures even plausible? (Fischer and Dannenberg 2021). Moreover, with angst about global warming and species level extinction catastrophe predicted, social constructing desired socio-technical futures become ever more prescient (Gidley 2017). Futures studies approaches should not be solely about management of complex systems but about the managers and decision makers (Sardar 2010).

Futures studies provide a much-needed critical lens with which to approach the study of the ethical impact of emerging technologies. For these reasons, conceptual approaches from it were incorporated in several stages of the TechEthos project, namely digital ethnographies and ethical analysis of technologies through theoretical and empirical insights.

Ethical Impact Assessment: As the ATE Plus focuses on ethical values and principles, and Futures Studies focusses on problematising the future, the EIA framework emphasises stakeholder engagement. The EIA framework is specifically about people and public dialogue, to identify key social values and ethical issues, and therefore offers a different and complementary perspective. This framework raises questions aimed at the technology developer or policy maker to facilitate consideration of ethics, in consultation with a variety of stakeholders. Furthermore, this particular framework has previously been implemented and adopted into the SATORI CEN CWA 17145-2 ethics assessment, a pre-standard for research & innovation. This This CEN Workshop Agreement (CWA) sets requirements and provides guidelines for ethics assessment of research and innovation. It is a policy-oriented guide for researchers and ethics assessors on the different stages of the ethical impact assessment (EIA) process. This reinforces the effectiveness of the EIA framework and illustrates how it can be further enhanced when used in combination with ATE plus and Futures studies, to make this useful for new and emerging technologies.

However, some limitations of the EIA framework include the approach that this framework does not account for new and emerging technologies, but investigates continuously the ethical implications of what is known about the technology under development. Essentially, the framework is supported by ethical tools that aim to help the developer to get a better idea

of how the technology is perceived ethically by stakeholders and what measures could be adopted to ensure that the technology is ethically acceptable or what alternatives might be available (Wright, 2011).

Furthermore, a desktop literature review was carried out to explore the current ethical operational guidelines, codes and frameworks that are specific to the three technology families, (Cannizaro, 2021). The scan of ethical guidelines was based on (i) desk analysis, taking advantage of existing updated ethical guidelines, policy, industry and non-governmental organisations and governmental at international, EU and national levels (ii) a search for relevant codes related to the specific technology families using inclusionary/exclusionary criteria (iii) search documents with relevant keywords and (iv) an adapted mapping analysis approach.

Empirical findings:

This approach to the TEAeM model was further enhanced by a range of methodologies used in the TechEthos project, including expert interviews, scenarios and games workshops. The TEAeM model development specifically used findings from semi-structured interviews with experts from each of the technology family to gain insights into the ethical challenges and risks of new and emerging technologies. Questions included; (1) their opinion of future innovation within their research or technological area and the future global impact of their technology, (2) what are the benefits associated with their technology, (3) what would they envisage or anticipate the potential risks and harms of their technology in the future, (4) who will be the main beneficiaries of the technology (and who will be excluded from being able to use the particular emerging technology), (5) what potential new ethical issues could arise in the future, (6) what is their opinion on the concept of irreversibility in the context of technological innovation , (Adomaitis, 2022). The findings from the expert interviews were combined with the scan of ethical documents to identify key ethical challenges pertinent to the selected technologies.

Overall, the results found that the key ethical values and principles identified were: transparency, risk, fairness, safety, privacy, responsibility and bias amongst others. These findings were further enhanced by empirical results that were mainly composed of engagement and consultation with expert stakeholders through scenarios as well as participatory expert deliberation to explore these and other potential social and ethical issues. Each scenario was composed of different social, technical, economic, environmental, political and values (STEEPV) dimensions and designed to surface social and ethical issues. The creation of the scenarios followed a five-step process which was repeated for each technology family; (1) research about trends and drivers, (2) identification of key factors, (3) creation of future projections based on the results, (4) clustering of projections and validation of results to (5) writing up of three

narrative scenarios (Bernstein et al, 2022). Furthermore, public engagement exercises (Thornton, 2024) and consultations (including under-represented groups) were carried out to ensure that the voices of the public and marginalised communities were incorporated into the analysis (Umbrello et al, 2022). The main mechanism for feedback from the general public came from playing the TechEthos game (developed within the project) with citizens on three occasions on the premises of six science engagement organisations involved in the project, in Austria, Czech Republic, Romania, Serbia, Spain and Sweden. The findings from the empirical research helped to analyse and understand what the most important ethical principles are considered by a broad range of stakeholders and public in the context of new and emerging technologies.

The overall involvement and emphasis of diverse stakeholders supports the systematic reflection of ethical issues in decision-making through independent evaluation and supports the explicit communication about values (Wright, 2011).

3. Results and Discussion

A range of ethical frameworks from literature have been analysed to assess their usefulness in anticipating potential impacts with respect to new and emerging technologies (Bhalla et al., 2023). Each of these has some advantages and therefore, in order to achieve an outcome capable of being applied across a broad range of emerging technologies, we have chosen to take one approach using a combination of features, of three key existing ethical analysis frameworks to create the innovative TEAeM framework.

The TEAeM framework includes elements from ATE Plus (Umbrello et. al. 2023) which aims to assess technological innovations by providing an analytical tool which is complementary to an **ethics-by-design** approach to engineering novel technologies. Furthermore, in combination with the Ethical Impact Assessment (EIA) framework that emphasises **stakeholder engagement and consultation** (which was an integral part of the TechEthos project), and the Futures Studies as a field that provides much method-inspiration for anticipation and emergence is considered **forecasting and scenario development**. Therefore, this paper proposes an 'enhanced' ethical framework to support existing tools and has been further enhanced by empirical insights and findings of the TechEthos project. The 'TechEthos Anticipatory ethics Model/Method' (TEAeM) can be used by researchers, academics and policymakers wanting to assess the ethical issues of emerging technologies and provides some strategies for possible ways to mitigate these risks (Figure 3).

Note while there might be a natural flow to how the elements in TEAeM are used, in order to provide maximum flexibility, the TEAeM framework can also used such that the ordering of the various elements can be done in a range of ways, and do not need to be considered in a

specific linear way, depending on the specific emerging technology and context for application under scrutiny.

Figure 3. The TechEthos Anticipatory ethics Model (TEAeM), (please note *elements taken directly from ATE plus)

A further explanation of the various elements that comprise the TEAeM framework are presented below in Table 1. This provides the starting points or relevant questions that could be asked in each of the model elements. As has been noted above, although TEAeM is presented in a tabular format in Table 1, and could be carried out in this way, it is intended that this is a flexible approach, that is responsive to the needs for specific emerging technology under scrutiny, and so the steps can be returned to, or the order adjusted as and when needed. In this way, the steps shown below could be a useful order in which to proceed, but there is flexibility allowed for reordering, depending on the specific context.

Table 1. Explanation of TEAeM elements used in the framework

TEAeM element	**Explanation of the TEAeM elements**
Describe objects of interest, procedures, techniques, approaches, applications, use cases of interest, etc.	What are the main goals or features of the technology, application, use case, etc.?
Investigate core beliefs and dilemmas that serve as conceptual scaffolding, for the ethical issues.	Starting from societal, cultural, religious and legal issues in location of development, identify the relevant core beliefs and subsequent dilemmas that need to be dealt reviewed and possibly addressed.
Identify values and principles (e.g., transparency, dignity, social inequality, risk, responsibility, autonomy, power, justice, safety etc). Include consultation exercises such as the 'TechEthos Game' to consider key values important to citizens, public and under-represented groups	Identify values and principles relevant to each technology family (if appropriate include cross cutting ethical issues too), eg. TechEthos deliverable D2.2 identifying key values and principles, or TechEthos deliverable D3.1 report on the outcomes of using TechEthos game with underrepresented communities
Carry out impact assessment. Some of the principles and "issues" are also values, while other issues are related to tactics, policies or regulations adopted by decision-makers in pursuit of values (like data protection).	Use one of a range of impact assessment tools (accepted I.A. or company specific) to identify what are the potential impacts of the technology, as it currently stands. Use of academic and grey literature, as well as potentially relevant policy documents, to establish the set of values that have been linked to technology or application in question

TEAeM element	Explanation of the TEAeM elements
Potential use of Futures Studies view of alternative futures (including backcasting) to demarcate both transparent ethical considerations and morally opaque presuppositions in technological judgement concerning the values and principles identified.	For example, creation of scenarios and other stakeholder engagement activities around various emerging technologies in the near and middle future contexts to help developers, users and others to think about the range of issues, both transparent and opaque. Making explicit assumptions, exploring outcomes - what future is desired?
Ethnographically engage with critical stakeholders	One approach is to use LinkedIn to search for companies working in the particular technology area and then review websites/videos, etc., using a direct or digital ethnography approach.
Link to Future ethics. The possibility for a viable future depends on the imagination and on the imaginary as resources for (re-)shaping our world and imagining new relations.	Use of future oriented analysis in the direct or digital ethnography, to establish what kind of future is being envisioned by developers and application experts and organisations. Embed contingency into the analysis.
Link to empirical data. Aim to stay in contact with technology developers during the whole developmental process and discuss different approaches to problems that arise. … Continuous dialogue and repeated assessments are preferable to one single large-scale assessment.	Engage with developers and users in ongoing dialogue with them about problems that arise in the development and application processes. Use of databases, such as Cordis, to identify research projects in the appropriate field and contact them to establish a set of experts that can also be consulted with

TEAeM element	Explanation of the TEAeM elements
Formulate a set of operationalised design questions to be asked regarding the implementation of techniques (or applications and use cases).	Use the results from the various analysis carried out in the previous stages to create the set of relevant design questions, using an ethics-by-design approach
Carry out an efficacy study at specific timepoints to measure the effectiveness of the TEAeM intervention	Review and reflect on the TEAeM process, with measures to identify any changes seen, eg. whether developers incorporated any of these changes into their practices
Examine co-constructed counterfactual arguments for the use and non-use of an emerging technology	Reflect on the ethical conundrum of risks of omission or inappropriate prevention (non-use of a technology with desired outcomes), which stand in tension with risks of commission (e.g. undesired consequences from technology use), eg. CDR non-use results in greater harm to humans and environments compared to the world with CDR use. SRM non-use results in a possibility of more severe harm than with SRM use.

4. Conclusion and Potential next steps

New and emerging technologies such as Neurotechnologies, Climate Engineering and Digital Extended Reality have opened up the opportunity to stimulate questions and proposals to enhance existing ethical frameworks, which can help to mitigate some of the ethical challenges to technology and society. However, predicting the future is almost impossible, especially one where technology is involved. Equally, to create an ethics framework that works for one specific technology would have been relatively easier and perhaps more applicable or useful.

The enhanced ATE Plus, which builds on the original ATE approach, aims to assess technological innovations by providing an analytical tool complementary to ethics-by-design approaches to engineering novel

technologies. However, in combination with Ethical Impact Assessment (EIA) which emphasises stakeholder consultation and engagement, and Futures Studies for which the element of uncertainty will be considered through forecasting and scenario development.

In developing TEAeM for researchers, academics and policy makers, the aim was to enable future and emerging technologies to be able to be developed in a more ethically informed way (i.e. using an ethics-by-design approach) and as such we cannot yet know what those technologies might look like in the future. Hence, creating an ethical framework that considers the dynamic nature of emerging technologies, whilst retaining ethics at the forefront is a first of its kind. One of the key objectives of this research was to support the ethical governance of the broadest range of technologies and in doing so, support a more ethical and responsible society. We feel that the creation of the TEAeM model is a right step in this direction.

However, we would like to take this opportunity to consider some limitations of this research. Firstly, we do not know the 'effectiveness' of the TEAeM model, as it has not been tested, adopted or implemented in industry or organisations. For this framework to be deemed in any way operative, then it must be applied to a research and design process which develops new and emerging technologies and is evaluated. Secondly, this is a conceptual framework and has been designed using theoretical concepts and approaches, i.e. this can be seen as an applied ethical model which will most likely be open to interpretation by different stakeholders and public, depending on the context it is being used in. We therefore cannot quantify how realistic this framework would be and whether this is more of an ideal scenario model or something that can be operationalised for developers or researchers. However, given the frameworks on which it is based, the empirical research that underpins it and the flexibility built within it, we are confident that it can be used and make a contribution in practice. The next steps for this would be to test this framework with a range of emerging technologies to try and assess how effective this would be to create a more ethical and responsible technology.

Funding: This research was funded by the European Union's Horizon 2020 research and innovation programme, grant number 101006249.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

References

1. Adomaitis, L., Grinbaum A., Lenzi, D. (June 2022) TechEthos D2.2: Identification and specification of potential ethical issues and impacts and analysis of ethical issues of digital extended reality, neurotechnologies, and climate engineering. TechEthos Project Deliverable to the European Commission. Available at: www.techethos.eu.
2. Bell, W., (2009). Foundations of Futures Studies: History, Purposes, and Knowledge. Vol 1. New Brunswick and London: Transaction Publishers.
3. Bell, W., (2004). Foundations of Futures Studies: Values, Objectivity and the Good Society. Vol 2. New Brunswick and London: Transaction Publishers.

4. Bell, W., (1996). The Sociology of the Future and the Future of Sociology. *Sociological Perspectives*, 39(1), 39–57. https://doi.org/10.2307/1389342
5. Bernstein MJ and Mehnert EW (2022) Policy note: Analysis of expert scenarios addressing ethical implications of the selected technologies. TechEthos Project Deliverable to the European Commission. Available at: www.techethos.eu.
6. Bhalla, N., Cannizzaro, S., Richardson, K., & Brooks, L. (2023). TechEthos Project Deliverable: *Enhancement of Ethical Frameworks and Outline of Detailed Ethics Framework*. Available at: www.techethos.eu.
7. Bibri, S.E. (2018). Backcasting in futures studies: a synthesized scholarly and planning approach to strategic smart sustainable city development. *European Journal of Futures Research*, *6*(1), pp.1-27.
8. Boenink, M., Swierstra, T., & Stemerding, D. (2010). Anticipating the interaction between technology and morality: A scenario study of experimenting with humans in bionanotechnology. *Studies in Ethics, Law, and Technology*, 4(2).
9. Brey, P. A. E., (2012a). Anticipating ethical issues in emerging IT. *Ethics and Information Technology*, 14(4), 305–317. https://doi.org/10.1007/s10676-012-9293-y
10. Brey, P. A. E. (2012b). Anticipatory Ethics for Emerging Technologies. *NanoEthics*, 6(1), 1–13. https://doi.org/10.1007/s11569-012-0141-7
11. Brown, N. and Rappert, B., (2017). Introducing Contested Futures: From Looking into the Failure to Looking at the Future. In Brown, N. and Rappert, B. (eds). (2017). *Contested futures: A sociology of prospective techno-science*. London and New York: Routledge.
12. Bucur, M., & Papagno, C. (2023). Deep Brain Stimulation in Parkinson Disease: A Meta-analysis of the Long-term Neuropsychological Outcomes. *Neuropsychology Review*, 33(2), 307–346. https://doi.org/10.1007/s11065-022-09540-9
13. Cannizzaro, S., Brooks, L., Richardson, K., Umbrello, S., Bernstein, M., & Adomaitis, L. (2021). TechEthos D2.1 Methodology for ethical analysis, scan results of existing ethical codes and guidelines. TechEthos Project Deliverable to the European Commission. Available at: www.techethos.eu.
14. Gidley, J.M. (2017). *The future: A very short introduction*. Oxford: Oxford University Press.
15. Grunwald, A., (2019). Shaping the Present by Creating and Reflecting Futures in
16. Lösch, A., Grunwald, A. Meister, M. and Schulz-Schaeffer, I. (eds) (2019). Socio-technical futures shaping the present. *Socio-Technical Futures Shaping the Present: Empirical Examples and Analytical Challenges*. Wiesbaden: Springer VS
17. Höjer, M., Mattsson, L. (2000). Determinism and backcasting in future studies. *Futures*, 32(7), 613-634. https://doi.org/10.1016/S0016-3287(00)00012-4
18. Melville, N. P., Robert, L., & Xiao, X. (2023). Putting humans back in the loop: An affordance conceptualization of the 4th industrial revolution. *Information Systems Journal*, 33(4), 733–757. https://doi.org/10.1111/isj.12422
19. Mepham, B., Kaiser, M., Thorstensen, E., Tomkins, S., & Millar, K. (2006). Ethical Matrix Manual. Agricultural and Forest Meteorology - *AGR FOREST METEOROL*.
20. Palm, E., & Hansson, S. O. (2006). The case for ethical technology assessment (eTA). *Technological Forecasting and Social Change*, 73(5), 543–558. https://doi.org/10.1016/j.techfore.2005.06.002
21. Papa, R., Galderisi, A., Vigo Majello, M. C., & Saretta, E. (2015). Smart and Resilient Cities a Systemic Approach for Developing Cross-Sectoral Strategies in the Face of Climate Change. *Tema-Journal of Land Use Mobility and Environment*, 8, 19–49. https://doi.org/10.6092/1970-9870/2883
22. Rotolo, D., Hicks, D., & Martin, B. R. (2015). What is an emerging technology? *Research Policy*, 44(10), 1827–1843. https://doi.org/10.1016/j.respol.2015.06.006
23. Sardar, Z. (2010). The Namesake: Futures; futures studies; futurology; futuristic; foresight—What's in a name? *Futures*, 42(3), 177–184. https://doi.org/10.1016/j.futures.2009.11.001
24. SATORI CEN Workshop Agreement. (2017). Ethics assessment for research and innovation—Part 2: Ethical impact assessment framework (CEN CWA 17145-2 2017 Workshop Agreement). http://satoriproject.eu/media/CWA17145-23d2017.pdf
25. Stahl, B. C., Heersmink, R., Goujon, P., Flick, C., van den Hoven, J., Wakunuma, K., Ikonen, V., & Rader, M. (2010). Identifying the Ethics of Emerging Information and Communication Technologies: An Essay on Issues, Concepts and Method. International *Journal of Technoethics*, 1(4), 20–38. https://doi.org/10.4018/jte.2010100102
26. Thornton, A. (2024). Our Futures in Mind Uploading: Public Perceptions and Narratives. *Journal of Ethics and Emerging Technologies*, 34(1), 1–23. https://doi.org/10.55613/jeet.v34i1.140
27. Umbrello, S., Vermaas, P., Paca, C., Alliaj, G., Nishi, M., Whittington, A., Jouvenot, F., Bernstein, M.J., Mehnert, W., Buchinger, E., (2022). Tools to develop and advance scenarios dealing with the ethics of new technologies. TechEthos Project Deliverable to the European Commission. Available at: www.techethos.eu.
28. Umbrello, S., Bernstein, M. J., Vermaas, P. E., Resseguier, A., Gonzalez, G., Porcari, A., Grinbaum, A., & Adomaitis, L. (2023). From speculation to reality: Enhancing anticipatory ethics for emerging technologies (ATE) in practice. *Technology in Society*, 74, 102325. https://doi.org/10.1016/j.techsoc.2023.102325
29. Voinov, A., & Bousquet, F. (2010). Modelling with stakeholders. *Environmental Modelling & Software*, 25(11), 1268–1281. https://doi.org/10.1016/j.envsoft.2010.03.007
30. Wendell, B. (1996). What Do We Mean By Futures Studies? In Slaughter, R.A (ed). (1996). *New Thinking for a New Millennium*. London and New York: Routledge.

551 31. Wright, D. (2011). A framework for the ethical impact assessment of information technology. *Ethics and Information Technology*,
552 13(3), 199–226.
553