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Ethical and Sustainable Quantum Computing: Conceptual Model and Implications

Kumar Saurabh, Research Scholar, Devi Ahilya University, Indore, India. Email- kumdoc03@gmail.com
Yashika, Assistant Professor, Deen Dayal Rustagi College of Management and Technology, Gurugram, India. Email- yashikadua15@gmail.com
Varsha Rustagi, Assistant Professor, Deen Dayal Rustagi College of Management and Technology, Gurugram, India.Email- rustagi.varsha@gmail.com

Abstract
Today, computing power is advancing with significant transformation in quantum technologies and provides state-of-the-art functionalities for next-generation digital solutions. At the same time, computing capabilities are influencing the various spheres of humanity while touching the operating models and end-user experiences. The advent of quantum computing raised many questions about the system design, development, implementation, and associated risks for human beings and species. The questions raised the call for a conceptual model to study ethics and quantum computing as a whole. The primary objective of the research is to develop a conceptual ethical and sustainable quantum computing model to investigate the ethics standards, trust levels, social aspects, access rights, privacy, moral and good-duties issues based on the current situations. The paper adopts the literature survey approach based on existing business ethics models to evaluate the model's human, organisation (society) and opportunity factors. The research has investigated the ethical constitutes of quantum computing led digital transformation. The research findings provide the substantial foundations for the research and managerial applicability to integrate the social, human, technology-based inclusive, ethical issues.
Keywords : Quantum computing, business ethics, ethical model, digital transformation, sustainability.

1. Introduction

Among Gartner 2021 Hype cycle marketing technologies, data and computing ethics is in the top 5 areas of technologies (Chohan and Paschen, 2021). Most of the time, organisations start with the compliance exercise, progress to risk management, and later the words like accountability, utilitarian strategy, fairness & inclusiveness, privacy, security, integrity, perceived value, reliability & safety, etc. become the advertising slogan of ethical organisation design, governance and justice. Recently there was extensive hue and cry in the USA because of facial recognition technology-led racism cases. All tech biggies came forward and announced publicly that the law agencies would not possess any data owned by

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enterprises.The concern was, technology can become susceptible to errors, not sustainable; ultimately, it is not ethical.

The thought of developing acomputing machine/system which can think like humans can raise many sustainable and ethical issues. Sometimes these machines and systems harm human rights and things relevant to being moral (Siau and Weiyu, 2020). Today, we live in the digital age where things are digitally connected and powered by quantum computing. Data is the new fuel to run this digital economy. Digital innovations have touched the very corner of life, goods to services, environment to law, society to individuals, primarily all industries like healthcare, logistics, government, BFSI, manufacturing, energy, utilities, law, public services, agriculture etc (Salah et al., 2019; Corea, 2019; Smith and Bean, 2019; Wirtz et al., 2019; Shortliffe and Sepúlveda, 2018; Krausová, 2017). Like other technologies,quantum computing based machines/systems faces some challenges leading to open social risks. There are chances of errors, prejudicedprocedures and inaccuracies for unexpected and destructiveinfluencesoncivilisation (Winfield and Jirotka, 2018; Yuste et al., 2017).

Quantum computing solutions are impacting public services. Therefore, quantum systems should be responsible, answerable, sustainable, andmoral over all the benefits. Quantum engineering paradigms need a shift from traditional models to social engineering paradigms considering integrating social and ethical inferences (Harris et al., 2013). This requires a holistic approach of collaborative efforts with different personas like data scientists, domain experts, social activists, philanthropists, entrepreneurs, general public to develop, accept and support the quantum technologies aligned with ethical and sustainable values that protect and encourage community well-being affected by quantum solutions (Sharkey, 2008; Burton and Goldsby, 2005; Gunkel, 2012; Dignum, 2018; Boddington, 2017).

Recent ethical and sustainability issues with respect to quantum computing in the last 4-5 years and World Economic Forum (WEF) 2021 theme on Digital ethics and sustainability motivated us to pursue this research in the area of Quantum ethical and sustainability implications and morality discussions (Bughin et al., 2018; Awad et al., 2018). Ethics and sustainability are the fundamental constituent of Quantumtransformation journey.

We believe that this research is one of the first attempts to target ethical and sustainability issues of quantum computing. The research attempts to study ethical and sustainableinnovation, adoption, intention and behaviour as a research topic and develop the constructs for exploratory findings and evidence. The research takes the literature survey route as the sample of ethical and sustainable quantum computing solutions intention, how they adapt and use the platforms, their substitutes, adoptions, philosophy and its influence on humanity. The intention is to comprehend a conceptual model and platform that is ethical and sustainable- practices utilitarian/ deontological ethics, provides sustainable ecosystem, believes in fairness & inclusiveness, safeguards privacy, security & integrity, accountable and ultimately reliable.

2. Quantum computing

There is a misconception that quantum computing extends classical computing and servers available for faster processing. In the real sense, quantum computing is designed for

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aparticular purpose with unique features for specific workloads (Preskill, 2018). Quantum computing harnesses quantum physics suitable for computing involving exponential scaling-based computations. The quantum solutions are based on two characteristics, i.e., superposition and entanglement, while classical computing devices are based on binary (Hirvensalo, 2003). While classical computing is limited to one of the two states of information, quantum computing information can be superpositioned to zero and one state (Li et al., 2005). Like bit is the unit of classical computing, the qubit is the unit of quantum information. A qubit can superposition zero and one (even the points between) at the same state and time stamp. Quantum entanglement is a state when subatomic constituents enmesh together to perform any activity. Two qubits are entangled in a pair where one qubit can provide the information of another qubit to quickly move the information from one state to another in the quantum system. The entanglement attribute is not common with the binary system of classical computing models (Kaye et al., 2006)

Based on the current development and designs, it can be comprehended that quantum computing systems will not replace classical systems because of their power and faster computations(Hey, 1999). There are specific use cases where quantum benefits can be harnessed better to be used as a surrogate of the extensive natural systems as simulators of variational quantum eigen (VQE)values, climate change, chemical simulation for nuclear energy, complex global supply chain systems and blockchain opportunities(Shor, 1998).

Cryptography and random number generations are also viable and approachable use cases for computing requirements. Quantum randomness for keys and certificates based on the optical quantum process provides the true random number generations for security solutions(Stefanov, 2000). Quantum key distribution (QKD) refers to distributing and sharing the security keys for cryptographic protocols. The mechanism is simple where the light particles are transmitted over fibre optic cables between source and destination using qubits with the random quantum state privately (Scarani et al., 2009).

3. Methodology

The paper adopted preferred reporting items for systematic reviews and meta-analyses (PRISMA) framework to a certain extent to synthesise and filter the literature **(**Moher et al., 2009).Figure 1a represents the four-step identification, screening, eligibility and inclusion. Figure 1b shows a more detailed explanation of the literature review process. We started with 109 papers explored with prestigious databases like Scopus, Web of Science, Science Direct, Google Scholar and Wiley. 14 articles and reports were added from the sources like search engines and company websites. We finally landed with 26 papers for our review based on inclusion, exclusion, and quality assessment criteria. The paper searched with the keywords related to ethical theories, sustainability, governance targeted towards quantum computing concepts and business ethics. Ultimately, we filtered the papers based on the themes of quantum computing, business ethics, governance, sustainability, ledger, business model, customer experiences, utilitarianism, deontology, equity & human rights, corporate social responsibility, fairness and inclusiveness, non-maleficence.

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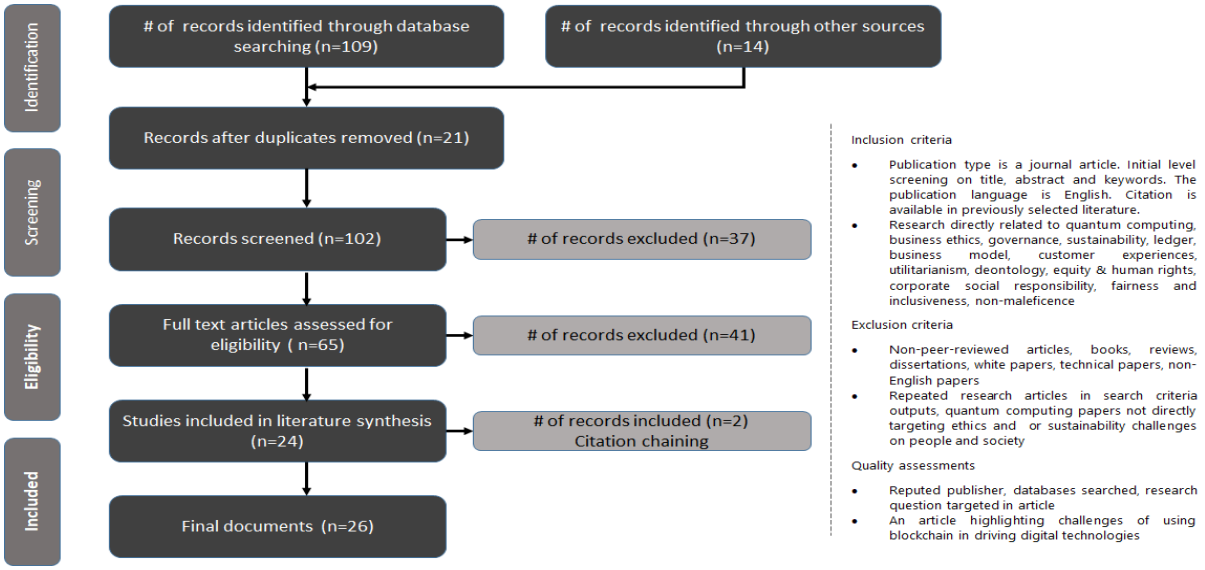

Figure 1a. PRISMA literature survey workflow, Moher et al., (2009)

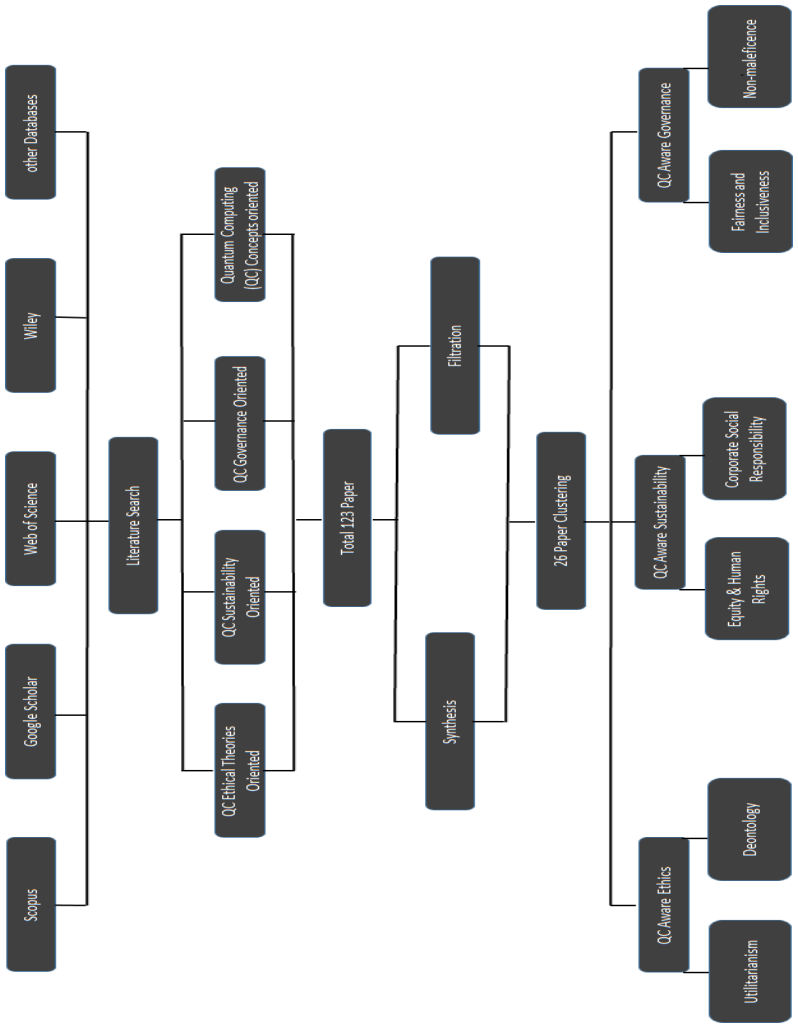

Figure 1b.
Preparatory Research
workflow

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4. Quantum computing- ethics and sustainability

The best time to consider the ethical and substantial implications of the technology is when it is in the early design and development phase. Quantum computing is also evolving with the early phases of its design and development phase.The technical, social and economic impact needs to be considered with the lens of ethics and sustainability. It provides the greater opportunity to mitigate the issues and risks to humans, society, values, morals, goods and duties to change the design choices to meet the more significant societal causes (De Wolf, 2017).

There are several examples from AI, robotics and blockchain where it cannot fulfil the promises of inclusive technology. There are several examples where digital technologies failure raised the issues of ethics and morality (Dignum, 2018; Baura, 2006; Boddington, 2017). Chinese traffic police display a giant public screen showing the jaywalkers using AI-based face recognition techniques. It displayed the wrongly recognised billionaire and faced much criticism. Another incident Uber's self-driving autonomous vehicle killed a pedestrian as the self-driving algorithm failed to take necessary action once the sensor detected an object ahead of the car (Greenblatt, 2016). Amazon's AI-powered recruitment tool recommended more male candidates as the initial training dataset was based on male candidates (West et al., 2019). One popular portal featured many real- alike porn videos using many female celebrities using digital face swap techniques. Google photo based on AI failed to recognise skier and mountaineer and could not merge backgrounds with the image. LG robot failed on the first day of it unveil because of the stage fear. Football world cup 2018 predictions went wrong as most digital machine learning algorithms failed because they worked on historical training data sets. Facebook chatbots developed their secret language to communicate, the chat was harmless, but it was shutdown. I-phone X face recognition system failed using a mask by a security firm and unlocked the phone (Davenport and Kirby, 2016; Allen, 2001). There are many incidents when Alexa and google Minis spied conversations, home locks problems and absurd responses to queries (Malkin et al., 2019). Last year at World Economic Forum (WEF) 2020 digital ethics and sustainability was one of the essential themes of discussion and provided a platform to discuss digital ethics and sustainability (Webster and Ivanov, 2021).

There are various ethical technology frameworks available by many agencies and the federal government. Commission on the Ethics of Scientific Knowledge and Technology (COMEST) by the United Nations forms the basis of the ethical responsibility of the newly developing technology. The framework covers the unacceptable ills to human life, society, rights, environment and future generations. However,a specific ethical and sustainable framework for quantum computing is not available as per the literature survey conducted in the paper with the timeframes of this article publication. Next section, we will discuss the proposed conceptual, ethical and sustainable framework for quantum computing.

5. Conceptual ethical and sustainable quantum computing model

Quantum computing as a technology is at a nascent stage, and on top of that, quantum ethics is a much young discipline to understand with very few standards-based ethical dilemma control methods and mostly no authoritative point of view (Züfle, 2019). We need to

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understand quantum computing as technology in various contexts, outline community or systems-level responses to handle legal, regulatory and compliance requirements. We need to evaluate and comprehend what is not 'ethical' and what is promoted as more like an image and promotional exercise. Quantum technologies are now penetrating our daily lives. Its degree to impact and interfere with our social life, moral and human rights are drastically changing. Some issues can be old, carried by other technologies, but quantum computing might have intensified by scale and proliferation (Möller and Vuik, 2017). Quantum computing ethics can be viewed from various lenses (like human rights agencies, standards, legal and regulatory requirements, power differentials, corporate houses, economic exchanges, data protection) through which AI can be evaluated in the context of ethics (Penney et al., 2018). Figure 2presents the conceptual ethical and sustainable quantum computing model covering the aspects of ethics, sustainability and governance with the intention and factors influencing the individual, organisation and opportunity.

Quantum Computing Aware Ethics

Utilitarianism

Utilitarian quantum ethics refers to the moral reasoning system based on the consequences. The primary objective is to look for ultimate happiness and near-zero ailments. One side quantumsystemissuitable for mundane complex, tedious, unsafe work (assembly line), increasing worker safety. These quantum systems savemuch money for corporate houses. On one side, there are benefits. Another side takes away many jobs and isolates humans from the overall understanding of the work, input data process, and outputs (Knill, 2005). It is so dangerous that now it is threatening even the existence of humans, their lives and relationships. There were various examples of how quantum systems with AI abused humanity using patterns (photos, media content, purchase history), giving power rights to agencies inconsistently. This requires studying the utility of the quantum systems rather than just joining the bandwagon.

Deontology

Another way to adhere to quantum ethics is to cater toequality and generality that says every individual ought to receive his/her due entitlements. It can be a reward and punishment and should be fair and transparent(Wolf et al., 2012). For example, quantum systems can help to achieve this by supporting a better standard for physically and mentally challenged individuals. Quantum systems can also be used for the common good approach of the communities. Industrial automation is an excellent example of both the positive and negative sides(Ten Holter, 2021). Many accidents happen because of driver carelessness, but if we get efficient reliable and safe vehicles without any human drivers, the individual commute will be significantly easier. On the other side, it will hit one community of drivers as it will snatch all the driver jobs (Greenblatt, 2016). Quantum System should demonstrate good characters by practising algorithmic tuned virtues. It is not easy to achieve for quantum systems but under experimentation of AI-led quantum systems can include virtue characteristics like compassion, fairness, humbleness, conscientiousness, morality, truthfulness, kindness, appreciation, and perception (Goertzel, 2007, 2014; Pei et al., 2019).

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Quantum Computing Aware Sustainability

Equity & human rights

Quantum systems with AI is impacting human rights in a societal ecosystem. It influencesan individual's belief & emotional state at the community level affecting political, legal and religious beliefs. There are various examples, at least now, where it even influenced the democratic system of the nation. Quantum solutions are now deployed using the face recognitions method to know mood and state of mind (Walther et al., 2005). So even the human mind is not in our control. Law and judicial agencies have started using and accepting quantum solutions using face recognition, home devices (Alexa, Smart TVs, pacemakers, GIS positions, surveillance cameras, drones) as evidence. This violates many human rights, and even agencies fail to safeguard societal interests at large (Hleg,2019). Mass communication and social media channels are also manipulated for various reasons, maybe to favour a belief or intention. For a democratic society, freedom of speech is the foundation of human rights. Quantum coupled with AI is hitting democracy also where the sentiments are analysed, and AI solutions help remove the content based on desired outcomes. It can work both positively and vice versa. However, one thing is clear: too much surveillance is digitally powered by quantum solutions expression hit rights being a human (Risse, 2019).

Quantum solutions are impacting user privacy and security. Data rights and integrity is also now questionable. Design considerations and architectural principles should safeguard the dignity of user privacy and security concerns while designing solutions, implementing any quantum service, product or robots under acceptable limits of human rights(Sajwan and Jayapandian, 2019). Quantum devices learn user interests by listening, using patterns hence not respecting privacy (Wachter and Mittelstadt, 2019). Quantum data bundled with AI can provide the details and identification of the individual and its interests from the archived data while being anonymous. Data available from the social platforms can be used for content analysis to know his choices, mental and emotional status that results in privacy, security, and data integrity issues using the power of quantum solutions. Some laws and compliances are now available, like General Data Protection Regulations (GDPR) for personal data privacy and protection (Malina et al., 2021). Agencies are also getting loopholes in this process as it is not applicable for large volume anonymous data where the quantum system can be trained and learn to predict the desired outcome. An ethical issue exists for data control, ownership, training and use, identity theft, archival, destroy and personal data secrecy, etc. (Aradau and Blanke, 2018).

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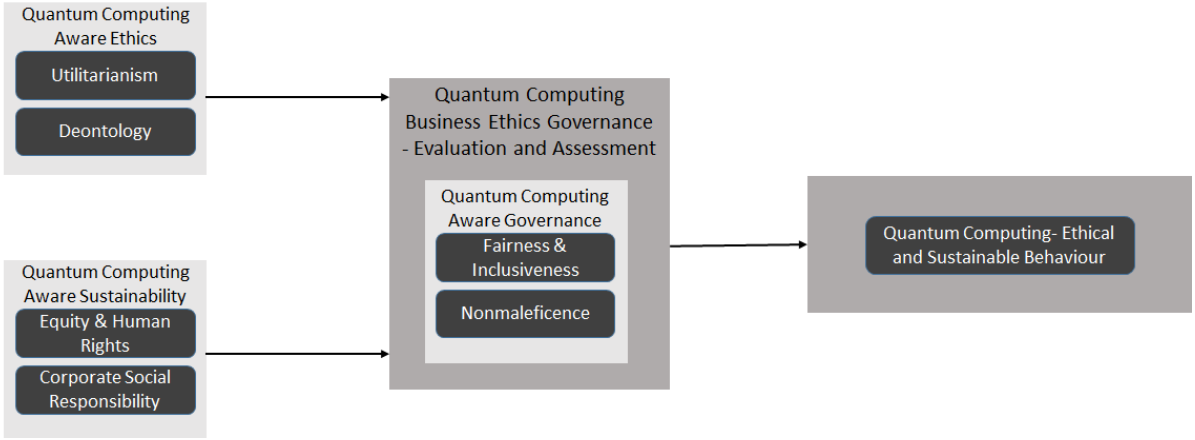

Figure 2. Conceptual ethical and sustainable quantum computing model

Corporate social responsibility

Quantum technology solutions work on computing resources thatrun-in datacentres with massive growth in energy, adding the issues of climate change. Devices are needed to run quantum use case applications like intelligent devices, computing items, electronic cars made of lithium batteries, graphite, and silicon chips, damaging the ecosystem. The growth will translate to mining, extraction, deforestation, manufacturing etc. that will further increase the pollution levels as it emits toxins (Casati, 2020). Electronic waste is also aggravated because of AI automation, robotics in action. Combating this requires mature manufacturers and consumer quantum ethics to promote and accept eco-friendly, sustainable quantum products and services (Heinen, 2020).

Quantum computing aware governance

Fairness and Inclusiveness

Fairness and inclusiveness are the most talked about ethical issues when discussing quantum or technology-led ethics. In most of the use cases, it is influencing humanity. Implementing quantum systems can lead to very different human existence based ethical issues. At the same time, when quantum practitioners choose the alternatives of algorithms, parameters, data fields and analytics based on preconceived notions potentially leads towards the 'biased' intention of quantum ethics issues (Rocha et al., 2005). Quantum systems are fed with data initially to train the system and learn gradually. If the dataset does not represent a sufficient population sample, the implications will have discriminatory results. This has triggered many biased ethical issues where racism cases are reported because the quantum systems with AI were fed with flawed, insufficient data representing the limited demographic population samples, encouraging inadvertent social bias (Fjeld et al., 2020).

Non-maleficence

As per quantum ethics,the system becomes transparent and trustworthy once it is obligated to take the right decision for governance. It means the envisaged quantum system can be interpreted clearly to a context, and there exists a justification for developing intent to its behaviour (Visvizi, 2021). It is not like the black box and is considered intelligent enough to clarify and prove its rationality (Winfield and Jirotka, 2018). Governance wise Quantum system should be sensible to justify its design, deployment and results as a processor meaningfully executed as a workflow. Processes must be justified and interpreted for their

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actions and consequence handling for behaviour pattern of permission ethics, fairness and inclusion, well-being, reliability and safety. Governance intelligentquantum systems should be transparently aligned to process, ensuring that all the fair and permission techniques are followed for the desired outcome appreciating public interest at large (Clarke, 2019). Governance is achieved by design level accountability that is auditable for regulatory and compliance requirements. The models and algorithms can be explained in simple business language for the user content and how the results are achieved. Specialists are not required to comprehend the model behaviour; it can be visualised using business modelling language (Blanco and Piattini, 2020).The logic used in the model is meaningful and does not harm humanity, and is socially viable. Results compiled by AI systems should match the expectancy levels. The model should work as intended or based on the specified decision. If it is not performing in the desired ethical way, a feedback loop can be introduced to the back process level or to starting point to adhere to the guidelines (Aradau and Blanke, 2018). Autonomous automation agents perform tasks based on rational thinking and possible outcomes(Back et al., 2012). These agents sometimes behave in an undesired fashion when it meets an unusual situation, or developers might not have thought of that situation, resulting in malicious output not fulfilling the ethical and sustainable quantum systems requirements (Gonçalves, 2014).

6. Implications

Quantum solutions work on data; if the same system uses volumes of data that is not managed correctly, designed poorly, immature process execution and inefficient deployment may result in the quantum ethics and sustainability issues of safety and reliability. It damages technology acceptance facilitating conditions, individuals'well-being, and the public trust of using quantum as a responsible technology (Chen and Bastani, 1991; Howe, 1995). Quantum systems reliability is concerned with the intended behaviour of the system for which it is designed. Quantum systems should adhere to the software and functional specifications. Therefore, a measured way of consistent design and specification is a way to have reliable quantum systems. The more the reliability,the more the safety, helps launchassurance in the arrangement. Quantum systems should adapt to the envisioned well investigated, verified and recognisedoutcomes (Baum,2017; Guzman, 2016). However, current systems are like beta systems, creating havoc in society withminimal reliability and safety. Software/hardware architecting skills are the most important thing while working for reliability and safety. Which algorithm to use, data source, its protection, interfaces, how it is deployed is million-dollar questions to avoid ethical issues of the poorly designed, unreliable and unsafe ecosystem. Software engineering paradigms need to understand the social engineering factors, and ultimately the lifecycle of development, testing, quality assurance, staging and production should be transformed as per envisaged quantum safety standards.

To eradicate such algorithmic bias and discrimination because of unusual training data sets requires good assessments at design, solution, and implementation level to have a fair and inclusive nature. The operational process should use workflow at each level and evaluate the required dataset reliability to provide unbiased results. We should achieve fairness and inclusion in our dataset. The model should predict fairness in the case of individuals, or

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fairness can be equitable among groups. We should work in the way that quantum systems and datasets should behave like the system's product.It is cognizant that the wrong dataset to quantum algorithms result unfair and can risk the community and society. The Quantum learning fairness module should be robust to avoid such unwanted situations. There should be options to zoom in and out the datasets to simulate the inclusion braces. It will give us the option to see the big picture and look for objectionable biases that unreasonably disturb model performance to be fair and inclusive.

7. Conclusion

Societal ethics looks for human values and the well-being of all creatures and the entire planet. Therefore, trust-based relationships and respect towards humanity and all living beings require an ethical way to implement technology like quantum,which touches every walk of life. It needs to be thought, how much autonomy can be granted to machines as control that it is not violating the ecosystem's trust-based balanced relationship. The proposed conceptual ethical and sustainable quantum computing model provides an excellent opportunity to address the question raised by quantum computing ethical and sustainable design, development and deployment. Ethical and sustainable quantum computing starts with the corporate and end-user (both practitioners/researchers) to support proper funding, adopt and encourage all-inclusive quantum solutions. The proposed model can create a community of relevant stakeholders responsible for driving ethical and sustainable quantum computing programs and initiatives. The proposed model helps to envisage inherent risks, ethical consequences, design principles and test the framework in different settings empirically or qualitatively for specific industries.

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