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Assessing the Impact of Nanotechnology on the Well-being of Human Life

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Abstract

Nanotechnology, at the intersection of science and engineering, holds immense promise for revolutionizing various aspects of our lives. This study employs the Partial Least Squares Structural Equation Modelling (SEM AMOS) algorithm to comprehensively analyze the effects of nanotechnology on the future living standards of society. We examine how nanotechnology innovations in fields such as medicine, energy, materials, and electronics are poised to reshape our quality of life. Through an extensive review of existing literature and empirical data, we provide insights into the potential benefits and challenges associated with the widespread adoption of nanotechnology. Our findings suggest that nanotechnology has the potential to significantly enhance future living standards by enabling advancements in healthcare, sustainable energy solutions, and cutting-edge materials. However, we also identify key considerations, including ethical and safety concerns that must be addressed to ensure the responsible development and utilization of nanotechnology. This research contributes to a better understanding of the multifaceted impacts of nanotechnology on society, offering valuable insights for policymakers, researchers, and stakeholders seeking to harness its transformative potential for the benefit of humanity.

Keywords: Nanotechnology, Artificial Intelligent (AI), Nanotechnology Development and Human Well-being

Introduction

A model of Nanotechnology offers the potential for new and faster kinds of computers, more efficient power sources, and life-saving medical treatments. Its potential disadvantages include economic disruption and possible threats to security, privacy, health, and the environment. Artificial Intelligence (AI) drives down the time taken to perform a task. It enables multi-tasking and eases the workload for existing resources. AI enables the execution of hitherto complex tasks without significant cost outlays (Arora et al., 2013).

There are many variables related to nanotechnology. The type and properties of the nanomaterials being used, such as their size, shape, composition, and surface chemistry, can significantly affect their behavior and performance. This comprehensive review delves into recent advancements in the realm of biomass-derived nanomaterials, with a primary focus on their surface interactions. Nanoparticles derived from plant biomass, such as nanocellulose and lignin sourced from industrial byproducts, exhibit substantial potential in fostering the development of lightweight, functional, biodegradable, and recyclable materials, thereby contributing to the realization of a sustainable circular bioeconomy. However, achieving optimal nanoparticle and material properties necessitates meticulous control of interactions throughout both particle fabrication and application phases.

According to the findings from Osterberg et al. (2023), the current state of knowledge surrounding these interactions includes solvent interactions during particle synthesis and production, as well as interactions with water, polymers, cells, and other components during various applications. Emphasis is placed on cellulose and lignin nanomaterials, both individually and in combination, elucidating how the surface chemistry of these nanomaterials profoundly influences these interactions. It becomes evident that exceptional performance is attainable only through meticulous control of these interactions.

Additionally, this review introduces a spectrum of effective methods for probing interactions with nanomaterials, providing insights into their respective advantages and challenges. Furthermore, less commonly employed techniques are introduced, with their potential applications discussed, and their utility in gaining a deeper understanding of the interfacial chemistry of biobased nanomaterials explored. Finally, the review identifies gaps in the current understanding of these interactions and highlights emerging research avenues that hold promise for further advancing our comprehension of the intricate world of biomass-based nanomaterials' interfacial chemistry.

Mei et al. (2023) showed that the methods and processes used to manufacture nanomaterials and nanodevices can affect their quality, consistency, and cost. Advances in nanomanufacturing techniques, such as 3D printing and self-assembly, are also enabling the creation of more complex and precise nanostructures. Carbon nanotubes (CNTs), especially those with junctions formed by covalent bonds, play a significant role in the realm of nanomaterials and nanodevices. However, the process of connecting individual single-walled carbon nanotubes (SWCNTs) on an atomic scale has proven elusive in experimental observations, and accurately quantifying the strength of these connections has posed challenges. Consequently, this study delves into the atomic-level reconstruction and structural evolution of SWCNTs at their junctions and investigates the connection strength through molecular dynamics (MD) simulations.

The study explores various connection effects between two distinct types of SWCNTs: metallic and semiconducting, aiming for a seamless covalent linkage with robust mechanical properties. The outcomes of the simulations reveal that both energy-related parameters (such as pulse widths, pulse number, and temperature) and structural factors (including relative rotation angles, end types, and chirality of SWCNTs) exert significant influence over the connection process. Remarkably, under specific conditions, the size of the energy zone and the diameter of the armchair and zigzag SWCNTs have minimal impact on the connection process and resulting strength.

This investigation highlights a pivotal insight: whether dealing with armchairs or zigzag SWCNTs, there exists an optimal combination of energy and structural parameters that can produce an ideal hexagonal junction boasting exceptional mechanical strength. By elucidating these critical technical parameters, this study contributes valuable guidance for manufacturing covalent junctions between SWCNTs, paving the way for their practical application in nanotechnology.

Association between Nanotechnology with Nanomaterial, Regulation, and Ethical

According to the findings of Peralta-Videa et al. (2011), nanotechnology has permeated virtually every facet of contemporary life, with engineered nanomaterials (ENMs) finding broad applications across consumer products, chemical and medical tools, information technology, and energy sectors, among others. The proliferation of ENMs has led to a surge in publications, both informative and scientific, dedicated to these materials. While the 1950s saw minimal attention given to nanomaterials (NMs), the landscape shifted dramatically by 2009, and witnessing over 80,000 journal articles incorporating the concept of nanotechnology.

This review aims to compile and analyze the body of publications concerning NMs within the biennium spanning 2008 to 2010. Encompassing the latest research, it delves into topics such as risk assessment and toxicity, characterization, and stability, as well as the fate and transport of NMs within terrestrial ecosystems, along with emerging ENMs. Noteworthy inclusions are carbon nanotubes, metallic and metal oxide/hydroxide nanoparticles, quantum dots, and polystyrene NPs.

The findings from Yeap et al. (2023) indicate that in recent years, there has been a growing interest in exploring novel applications of nanotechnology, particularly in sectors such as food, medicine, and chemistry. However, compared to these areas, the adoption of nanotechnology in agriculture remains relatively limited. Nanotechnology holds significant potential for introducing innovative applications in biotechnology and agricultural industries due to its unique physicochemical properties. Nanoparticles can be utilized in various agricultural aspects, including herbicides, nano-pesticides, nano-fertilizers, and targeted gene delivery systems that aim at specific cellular organelles within plants (Rajendran et al., 2023). This technology has the potential to reduce application losses of agrochemicals through enhanced stability in emulsions, increased coverage on leaf surfaces, and precise application methods. Recognizing that conventional agricultural technologies may not ensure sustainable food security and environmentally safe practices, researchers are increasingly turning toward more precise nanotechnology-based solutions.

Despite the potential benefits, there are significant concerns regarding the challenges associated with nanoparticles. Addressing these safety concerns requires the development of robust regulatory systems. Currently, only a few countries have begun to prioritize nano regulation. It is crucial, especially for agriculturally and biologically diverse countries like India, to establish norms for nano regulation and ensure the safe integration of nanotechnology into agricultural practices. Moreover, there remains vast untapped potential for the use of nanomaterials as a future technology in agriculture, which necessitates further exploration and research.

This study investigates the progress of nanotechnology within Kuala Lumpur, Malaysia, and the current and prospective ethical dilemmas arising from these advancements in the field. Additionally, it delves into proposed strategies to mitigate any adverse impacts resulting from this progression. While nanotechnology generally doesn't compromise human dignity and integrity, certain applications within this realm, as with any technology, may pose inherent risks. Therefore, heightened vigilance and regulation are imperative, particularly in domains where technology intersects with the natural environment.

This article explores this paradigm, starting with an examination of the parallels between nanotechnology and other disruptive technologies. To harness the full potential of nanotechnology, it's crucial to address its societal and ethical implications right from its inception, rather than addressing them later when problems have already become entrenched in society. Subsequently, it delves into various challenges that will need to be addressed as nanotechnology advances. Lastly, specific actions to address these issues are discussed (Mills & Fleddermann, 2005).

Figure 1 illustrates the conceptual framework of the research, drawing upon the Theory of Planned Behaviour (Ajzen, 1985). The independent variables include nanomaterials, regulations, and societal and ethical concerns. The dependent variables are formed as a construct comprising nanotechnology and human well-being. While these factors, including nanomaterials, nanotechnology, and human well-being, are linked to justify its mediating effect.

Conceptual Framework Based on the Theory of Planned Behaviour

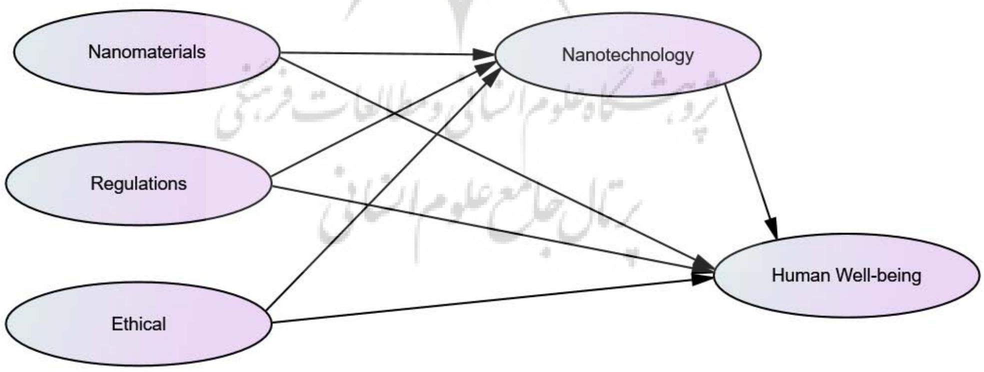

Figure 1. Conceptual Framework of the Study Based on the Theory of Planned Behavior (Ajzen 1985)

Problem Statement

The objective of this research is to conduct a thorough evaluation and examination of the diverse effects of nanotechnology on different facets of human welfare, encompassing nanomaterials, regulatory frameworks, and ethical dimensions. The aim is to provide insights for policymakers, industry participants, and the public regarding the possible advantages and obstacles linked to the incorporation of nanotechnology into daily routines. This endeavor seeks to close the gap between nanotechnology progress and human welfare, encompassing aspects such as quality of life and lifespan.

Research Questions

Based on the research problem, this study was guided by the following major research questions:

1. Are nanomaterials, regulation, and societal-ethical issues interconnected in the realm of nanotechnology?
2. To what extent do nanomaterials influence nanotechnology?
3. How significant is the influence of regulation on nanotechnology?
4. What level of impact do societal-ethical issues have on nanotechnology?
5. What is the extent of nanotechnology's impact on human well-being?
6. Are there mediating effects of Nanotechnology between nanomaterials and Well-being?

Research Objectives

The objectives of this research are:

1. Investigating the correlation between nanomaterials, regulation, and societal-ethical issues within the context of nanotechnology.
2. Assessing the extent of nanomaterials' impact on nanotechnology.
3. Examining the degree of influence that nanomaterials exert on nanotechnology.
4. Evaluating the level of impact of nanomaterials on nanotechnology.
5. Analysing the impact of nanotechnology on human well-being.
6. Examining the strength of mediation effectiveness of nanotechnology between nanomaterial and Well-being.

Table 1. Hypotheses of the Research

	HYPOTHESIS STATEMENT	STATISTICAL TEST
H_1	Nanomaterials, regulation, and societal-ethical issues interconnected in the realm of nanotechnology	Path Analysis in SEM
H_2	Nanomaterial has a positive and significant effect on Nanotechnology	Path Analysis in SEM
H_3	Regulation has a positive and significant effect on Nanotechnology.	Path Analysis in SEM
H_4	Societal-ethical issue has a positive and significant effect on Nanotechnology.	Path Analysis in SEM
H_5	Nanotechnology has a positive and significant effect on Human Well-being.	Path Analysis in SEM
H_6	Nanotechnology mediates the relationship between nanomaterial and well-being.	Path Analysis in SEM and MLE Bootstrapping

Based on the conceptual framework designed in Figure 1, six hypotheses are presented in Table 1 to verify and test the problem of the study. The research framework for this study is presented in Figure 1. In this study, the researcher intends to model and estimate the interrelationships among the variables in the model. The model consists of three independent variables, one mediator (nanotechnology), and one dependent variable (human well-being). Using IBM-SPSS-AMOS, the researcher only needs to convert the research framework into AMOS Graphic by inputting some syntax, as shown in Figure 2. The researcher needs to include residuals (e1, e2, e3, e4, and e5) for each regression equation. The research framework in Figure 1 has been converted into AMOS graphics, as shown in Figure 2 (Awang, 2012; Chua, 2021).

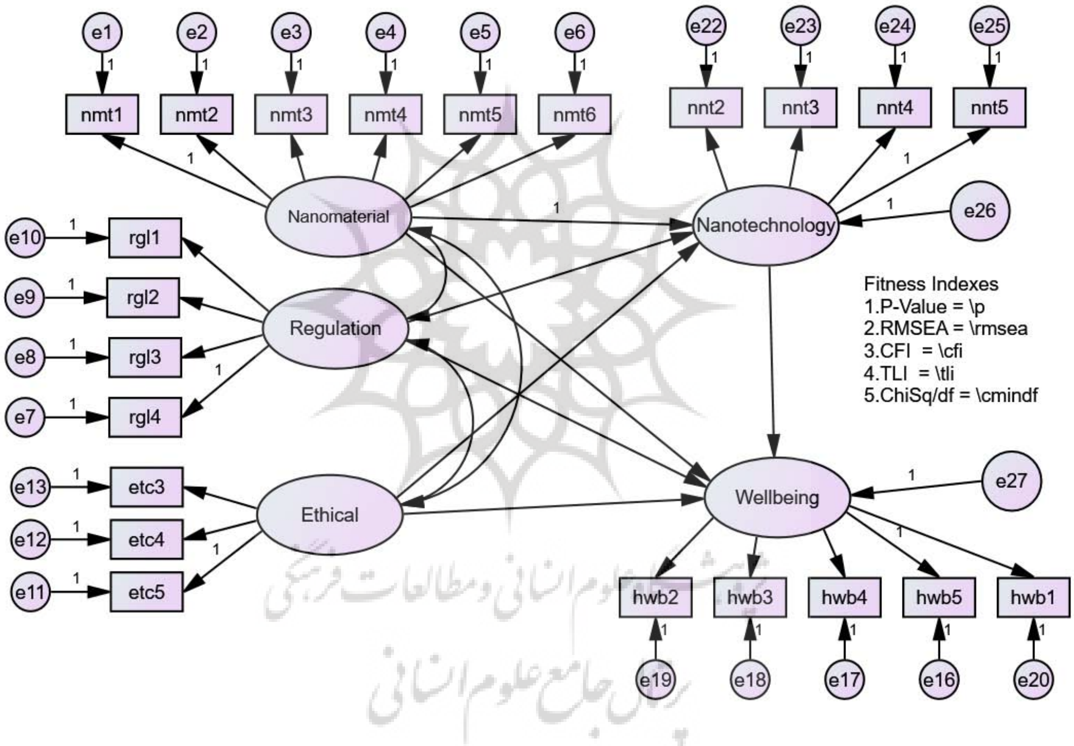

Figure 2. IBM SPSS AMOS Graphic

Methodology

Understanding the impact of Independent Variables (IV): Nanomaterial, Regulation, and Ethical on Nanotechnology towards Human Well-Bing (DV). It is a Quantitative Analysis. This study aims to investigate the relationship between IV and DV among a sample of 376 participants. The research seeks to contribute to the existing literature by providing empirical evidence on the impact of IV on DV, thereby enhancing our understanding of this relationship. Participants were recruited using a simple random sampling method from the population of Kuala Lumpur. Data was collected through a structured questionnaire consisting of various items shown in Table 2. Items are designed to measure IV and DV. The questionnaire was administered either online or in-person, ensuring consistency in data collection procedures. IV was measured using sematic inferential scale of 1 to 11 which has demonstrated reliability and validity in previous studies.

Data analysis will involve descriptive statistics to summarize the characteristics of the sample. In an SEM (Structural Equation Modeling) analysis using SPSS AMOS, there are typically four main outputs that can be tested. Model Fit Indices: These include various statistical indices such as chi-square, Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). These indices assess how well the proposed model fits the observed data.

Path Coefficients: Path coefficients indicate the strength and direction of the relationships between variables in the model. These coefficients are estimated for each hypothesized path in the model. Standardized Estimates: Standardized estimates (standardized coefficients) provide a standardized measure of the strength of the relationships between variables in the model. These estimates allow for comparisons of the relative importance of different paths within the model. Modification Indices: Modification indices suggest potential improvements to the model by indicating which parameters would lead to the largest reduction in model misfit if freely estimated. These indices can help identify areas where the model could be refined or modified to better fit the data. These outputs are essential for evaluating the overall fit of the SEM model, assessing the significance and direction of relationships between variables, and identifying potential areas for model improvement (Chua, 2012, 2013; Pang, 2019).

Table 2. Variables Count

Number of variables in the model:	51
Number of observed variables:	22
Number of unobserved variables:	29
Number of exogenous variables:	27
Number of endogenous variables:	24

Table 3. Three Categories of Model Fit and Their Level of Acceptance

Name of category	Name of index	Level of Acceptance***	Fitness Indexed	Results
Absolute Fit Index	RMSEA	RMSEA < 0.08	0.054	Achieved
	GFI	GFI > 0.90	Nil	N/A
Incremental Fit Index	AGFI	AGFI > 0.90	Nil	N/A
	CFI	CFI > 0.90	0.949	Achieved
	TLI	TLI > 0.90	0.939	Achieved
	NFI	NFI > 0.90	Nil	N/A
Absolute Fit Index	Chisq/df	Chi-Square/ df < 3.0	2.139	Achieved

***The indexes in bold are recommended since they are frequently reported in literature. Source: Awang (2015)

Results

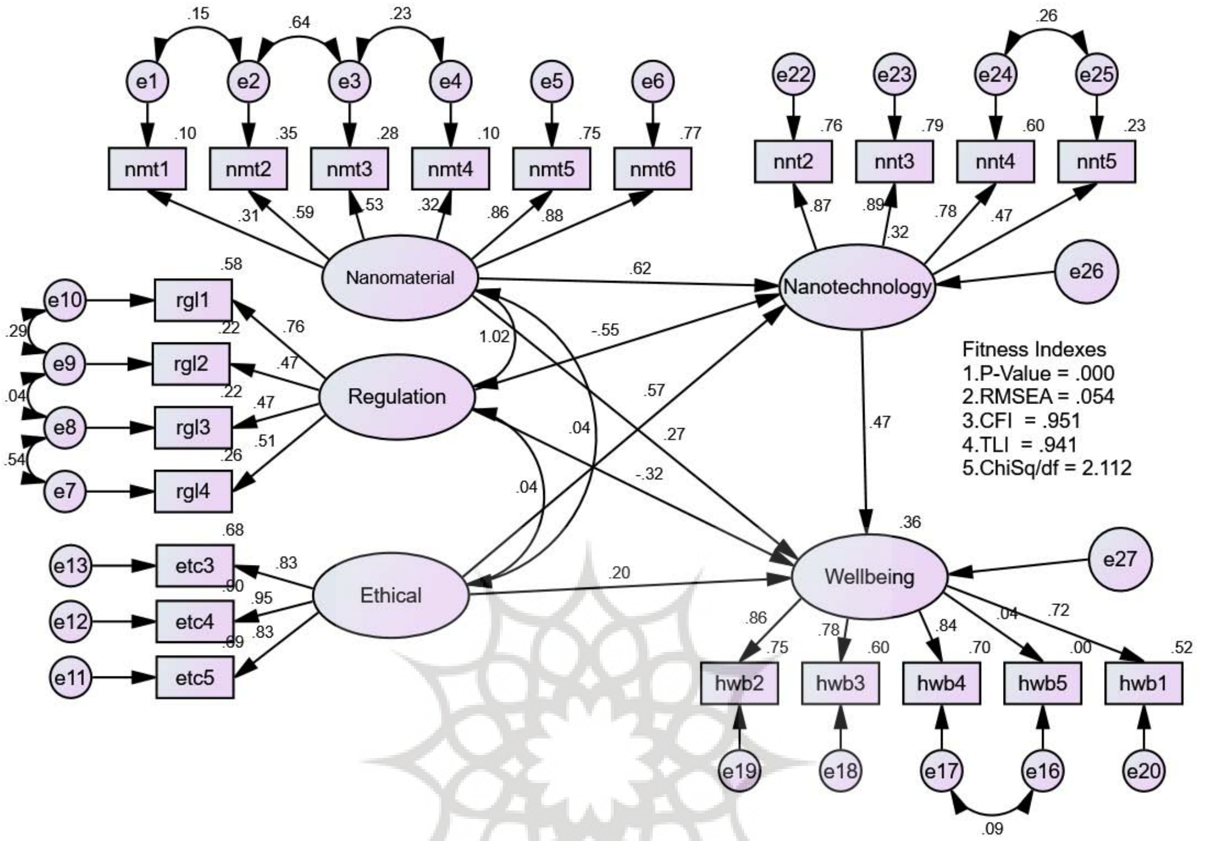

Figure 3. The Application of Sem in Amos Graphic Incorporating the second-order construct in the model

The explanation regarding the performance of R2 (coefficient of multiple determination) of the model (obtained from Figure 3) is explained in Table 4.

Table 4. The R2 and its Implication in This Study

Dependent Construct	R^2	Conclusion
Nanotechnology	0.32	The public's perception of Nanomaterials, Regulations, and Ethics in society accounts for 32 percent of the contribution to Nanotechnology understanding.
Human Well-being	0.36	The public's perception of Nanomaterials, Regulations, Ethics, and Nanotechnology in society accounts for 36 percent of the contribution to Human Well-being understanding.

Concerning Table 3, we conclude that based on the fit indexes, RMSEA = 0.54, CFI = 0.951, TLI = 0.941, and Chi-square/df = 2.11. Thus, the hypotheses H1, H2, H3, H4, and H5 are supported (Hair, Ringle, & Sarstedt, 2013).

In SEM, all important values in the model are estimated simultaneously. Among these values are the regression estimates, covariance, correlation, coefficient of multiple determination (R^2), item factor loadings, item R^2, variance of residuals, and more (Hair et al., 2023; Pang, 2019).

Hypothesis H6: Nanotechnology mediates the relationship between nanomaterial and well-being

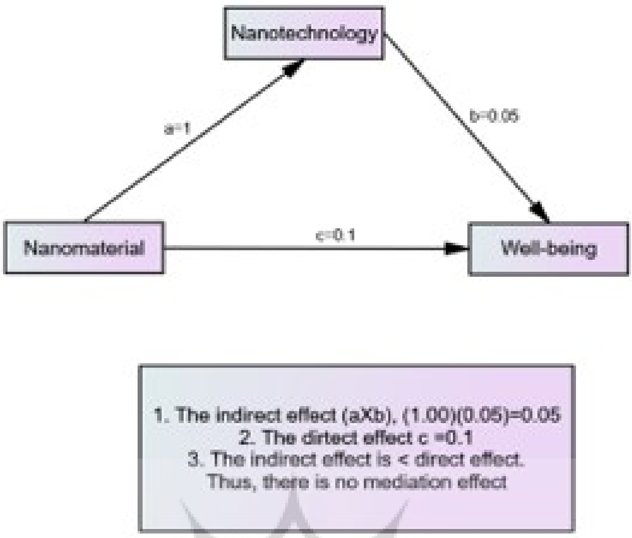

Figure 4. Mediating Effect of Nanotechnology between the relationship between nanomaterials and well-being.

Since there is no mediation effect as shown in Figure 4, H6 is not supported (Baron and Kenny 1986).

Discussion

Table 5. Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Age	.371	376	.000	.632	376	.000

a. Lilliefors Significance Correction

The examination of the data presented in Table 5 revealed that researchers utilized age group distribution data to assess sample normality. The Kolmogorov-Smirnov statistic, with a Lilliefors significance level for normality testing, yielded a significance level greater than 0.05, indicated by a Sig. value of 0.00, thereby assuming normality. Additionally, if the sample size was less than one hundred, Shapiro-Wilk statistics were computed (Razali & Wah, 2011).

In Figure 3, the analysis of the data indicated that constraining the redundant items as "free parameter estimates" resulted in improved fit indexes. Moreover, setting the redundant items as "free parameter estimates" was implemented, alongside the removal of the "lower factor loading item," which exhibited loading values below 0.7.

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Conclusion

The objective of this study is to conduct a thorough examination and evaluation of the diverse effects of nanotechnology on various dimensions of human well-being, encompassing physical health, environmental sustainability, socio-economic factors, and ethical considerations. The aim is to provide insights to policymakers, industry stakeholders, and the public regarding both the advantages and challenges associated with the integration of nanotechnology into daily life. Additionally, other factors such as global trends and policies, collaborative networks, technological aspects, and methods of nanoparticle synthesis are also considered. These independent variables can be employed to construct a comprehensive research framework for exploring different facets of nanotechnology and its ramifications across various domains. The selection and customization of these variables depend on the specific research objectives at hand.

Conflict of interest

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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