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The Impact of Innovative Financing Models on Economic Sustainability in Fluoride Management: The Mediating Role of Cost Efficiency, Technological Innovation, and Public Awareness

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ABSTRACT

Purpose: In this study, the advent of Innovative Financing Models (IFMs) in improving fluoride management at an economic sustainability level is studied with respect to cost efficiency, technological innovation and public awareness. The research examines how IFMs balance financial returns and environmental and social responsibility.

Design/Methodology/Approach: This study grounds economic, environmental and the social dimensions of sustainability, based on the Theory of the Triple Bottom Line (TBL). Data was gathered through a survey of 459 professionals from the sector of water management in order to understand their thinking on IFM applications. The direct and mediated effects of IFMs were analyzed using the Structural Equation Modeling (SEM) approach to discover resulting key pathways and interactions.

Findings: The results suggest that IFMs can provide a large benefit for economic sustainability by making costs more efficient and supporting diffusion of advanced technologies. The positive impact of IFMs on sustainable fluoride management practices was mediated by public awareness as a critical mediator. It implies that to increase acceptance of new financial strategies and technological methods, some level of community engagement is necessary. The findings also point to the need for an integrated solution, where financial instruments are complemented by social and environmental objectives to foster longer term sustainability.

Originality/Value: This research adds to the knowledge of sustainable financing by showing how IFMs can bridge the gap between economic goals and sustainable water management. It develops a strategic framework for how financing models can serve as tools to achieve comprehensive sustainability in fluoride management practices.

Keywords: Innovative Financing Models, Economic Sustainability, Fluoride Management, Technological Innovation, Public Awareness, Triple Bottom Line Theory, Cost Efficiency, SEM, Sustainable Water Management

1. INTRODUCTION

The Innovative Financing Models (IFMs) have subsequently assumed important roles in the management of pressing environmental and public health issues, especially fluoride contamination [1]. This issue is common in many areas of the world creates risks to both the health of the population and financial stability. Health effect which arise from the presence of fluoride is dental, and skeletal fluorosis, which has long term impacts on the health of the people. Inadequate financing has however been realised despite the various risks associated with the traditional methods of funding fluoride management. These methods in most cases offer short term solutions, which are constrained by limited resources, misuse of available resources and lack of technology. Consequently, the current approaches are incapable of delivering long-term sustainable solutions of addressing the problem of fluoride in water.

To overcome these drawbacks IFMs propose more flexible and innovative principles for financing that support more cost efficient and technologically advanced supply. IFMs are unlike traditional financing as they draw to mobilise funds in a manner compatible with the objectives of sustainability that goes beyond the economic to offer environmental and social benefits [2]. Such models are directly applicable for fluoride management as resource constraints play a dominant role in terms of technological advances and public health spending. Innovation in financing methods (IFMs) offer a way around the weaknesses of conventional approaches to managing fluoride contamination.

In order to advance the options for fluoride management, this study applies the Triple Bottom Line (TBL) theory, a theory developed by Elkington [3] to examine how IFMs could be a contribution to the enhancement of sustainability of fluoride management efforts. The TBL framework emphasizes that organizations must balance three interconnected pillars of sustainability: economic, environmental and social outcomes. In this study IFMs are regarded as a strategic tool for achieving financial sustainability of organisation and minimising environmental damage and improving social outcome through the increase of public health awareness. The financial resources provided by IFMs are enough to fund technological innovations that cut down fluoride contamination and effective resource management. Moreover, through raising public awareness of the health risks of fluoride, IFMs can encourage greater support from more spirited community and government, and result in more sustainable fluoride management practises.

IFMs have the potential to be sustainable solutions to fluoride contamination; however, fundamental obstacles remain in many regions' ability to effectively manage fluoride contamination. The success of sustainable practises is impeded by lack of resources, lack of technology, and low public awareness. Many fluoride management programmes do not have the financial backing to put advanced technologies in place that would help reduce contamination levels [4, 5]. Meanwhile, in addition to the endeavour of raising the public and government awareness of the risks of fluoride contamination and the advantage of sustainable management, there is the failure of the communities to remain exposed to long run of health and economic impacts [6, 7].

In light of these challenges, this study seeks to answer the following research question: "What does Innovative Financing Models do (IFMs) via cost efficiency, technological innovation, and public health and economic awareness to drive economic sustainability in fluoride management?" This question is critical to understanding how the alignment of finance resources, technological progress, and public engagement can enhance more effective and sustainable fluoride management practises.

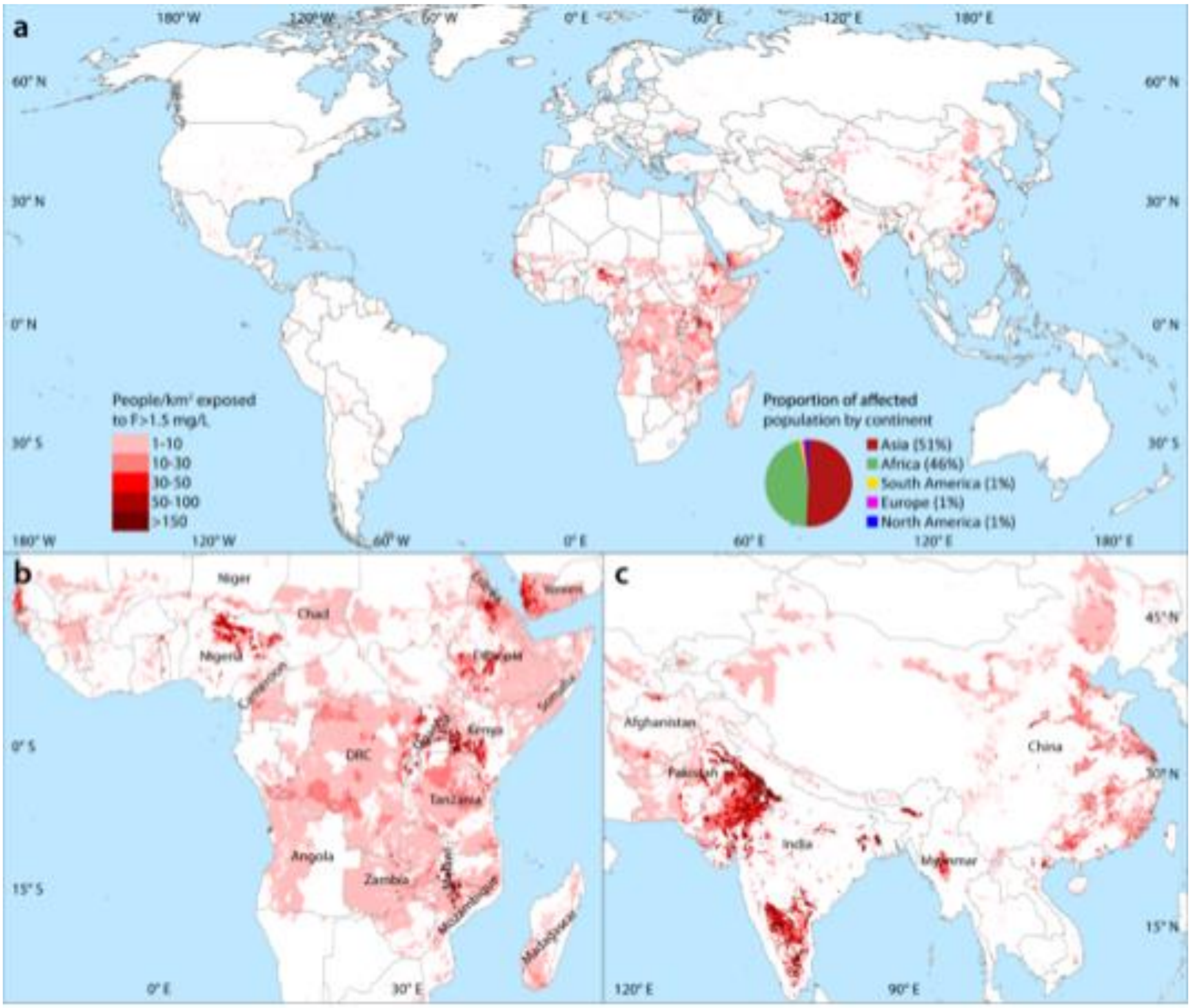

Figure 1: Ground water contaminated regions

The purpose of this research is to answer the question how does the hyperrealist interval evolve from the hyperrealist space on the complex plane through the construction of a multivalued function, the hyperrealist log, from the complex logarithm that generalises the multivalued logarithms often encountered in elementary textbooks? The first objective is to assess the effect of IFMs on economic sustainability of fluoride management initiatives, in particular, assessing how IFMs make fluoride management activities more long run efficient and resource allocation. Second, I aim to examine how technological innovation serves as a mediator, specifically how IFMs promote the use of advanced technologies that optimise the treatment of fluoride contamination in an operational context. Additionally, the study intends to investigate whether public health and economic awareness can help with stronger public and governmental support for sustainable fluoride management practises that will ultimately strengthen the sustainability of these endeavours.

Through this exploration, the study shows how these aspects can be utilised to develop more sustainable solutions to fluoride contamination with regard to public health and long term economic stability through innovative financing.

2. THEORETICAL BACKGROUND

2.1. Triple Bottom Line (TBL) Theory

The Triple Bottom Line (TBL) theory, introduced by Elkington [3], posits that for organizations to achieve true sustainability, they must balance three key pillars: outcomes that are economic, environmental, and social. This theory also suggests that economic only success is an inappropriate goal for an organisation, particularly for public health or environmental problems. However, organisational operations need also to factor in the environmental impact of their functions and their serving of social welfare. Studies on sustainable development, environmental management, and corporate social responsibility have been extensively applied of the TBL theory. As a framework, it has been useful for assessing what businesses, governments, and nonfor-profits can do to create value for the environment and society in addition to the shareholders [8, 9].

For several reasons, the TBL framework is particularly suitable for this study. First, fluoride contamination is itself a complex challenge to solve, but doing so depends on more than a single dimension. Contamination of public water supplies with fluoride is a public health and economic issue that requires solutions that address the water, environmental, and social dimensions of sustainability. As this study has shown, IFMs are not only intended to fund the required financial resources as well as to integrate environmentally debatable and socially responsible fluoride management methods. This study applies the TBL framework to analyse how IFMs lead long term sustainability by inducing cost efficiency, technological innovation, and public health awareness.

Second, the TBL theory facilitates the comprehensive investigation of the extremely important impact of IFMs on fluoride management. It (efficient allocation of financial resources and promotion of cost effective solutions) does mean that the economic sustainability can be achieved[10]. Tapping into this technology is an important move towards environmental sustainability, because it will help future generations be able to access safe water supplies. Finally, promotion of social sustainability involves increasing public health and economic awareness resulting in building community and governmental support of initiatives that handle fluoride management for the good of the public, as has been described by [11].

Within the context of this study we can consider IFMs to be mechanisms to tackle the pillars of sustainability. The financial resources provided for cost efficient management of fluoride contamination result in economic sustainability. Technological innovations that reduce the negative environment impact to fluoride are incorporated in this, tackle environmental sustainability. Third, public health and economic awareness initiatives designed to educate communities and policymakers about the necessity of sustaining fluoride management and social sustainability are at the last. For this study, we employ the TBL theory to demonstrate how the application in this study offers a structured and inclusive approach to evaluate the effect of IFMs on fluoride management within the three dimensions of sustainability.

3. MODEL AND HYPOTHESES DEVELOPMENT

The theoretical background provided in the previous sections help explain the impact of Innovative Financing Models (IFMs), mediated by their role in Cost Efficiency (CEFM), Public Health and Economic Awareness (PHEA) and Technological Innovation (TIFM), on economic sustainability of Fluoride Management Projects (ESFCP). The relationships between these variables and the research model is presented below.

3.1. Cost Efficiency and Technological Innovation

The technological innovation of fluoride management is supported by its cost efficiency. Utilising efficient organisations which invest a small amount of financial waste to acquire innovative technologies to enhance the effectiveness of overall fluoride management processes are more likely. The idea of allocating resources economically reduces the financial strain found on organisations which can instead redirect the savings towards vital research, development and the implementation of technologically advanced tools [12, 13]. However, technological innovation is also essential to further environmental and economic sustainability of fluoride management. Because of this we hypothesise that cost efficiency has a positive relationship with technological innovation adoption in fluoride management. Thus, we present the following hypothesis:

H1: Technological innovation (TIFM) is positively associated with CEFM.

3.2. Innovative Financing Models and Cost Efficiency

Innovative Financing Models (IFMs) generate the financial mechanisms that can make the cost efficiency challenge of organisations managing fluoride contamination possible. IFMs allow organisations to better allocate their resources by offering flexible funding solutions, such as public-private partnerships as well as blended funding. IFMs have been found in studies to help reduce operational costs, by spreading the financial risk and improving resource allocation

[14]. The improvement of the cost efficiency is critical to sustaining the long term viability of the fluoride management initiatives. If this is the case, IFMs are very important to improving cost efficiency, resulting in better management practise. Based on this, we propose the following hypothesis:

H2: Cost efficiencv (CEFM) is positively associated with innovative financing models (IFM).

3.3. Financing Models and Public Awareness

Raising fluoride management awareness and securing public and governmental support for fluoride management projects is supported by Public Health and Economic Awareness (PHEA). The IFMs provide the financial means to allow public health campaigns and educational programmes that are educating communities and legislative bodies on the health risks of sources containing fluoride. The literature suggests that IFMs have been proven to help increasing public awareness through their financial support of educational initiatives for the public related to the environment health matters[15]. Building momentum around sustainable management practises follows from this, further helping to form social and political cohesion that can influence management processes in more collaborative ways. We hypothesise therefore that IFMs will be positively related to public health and economic awareness. Thus, we formulate the following hypothesis:

H3: Positive association is found between Public Health and Economic Awareness (PHEA) and Innovative Financing Models (IFM).

3.4. Public Awareness and Technological Innovation

Fluoride management technology innovation is driven by Public Health and Economic Awareness (PHEA). The development of such advanced technologies will receive greater demand for public awareness of the health risks associated with fluoride contamination. Experiments have demonstrated that raised public awareness increases capitalization in technological innovations improving water quality and decreasing environmental contamination [16]. The more communities and policymakers learn about these new technologies, the more pressure will be put on organisations to embrace cutting edge technology. Therefore, we propose the following hypothesis:

H4: Technological Innovation (TIFM) is positively related to Public Health and Economic Awareness (PHEA).

3.5. Technological Innovation and Economic Sustainability

Improving economic sustainability of fluoride contamination projects (ESFCP) requires technological innovation. The use of advanced technologies for handling fluoride reduces such costs and minimises an environmental impact. Past research has shown that technological innovation results in better environmental outcomes and longer lasting project viability [17]. New technologies are implemented to help organisations overcome fluoride contamination issues much better and in a way that facilitates long term sustainability of these efforts. We therefore hypothesise that entries with technological innovation have a positive effect on the economic sustainability of fluoride management projects. Based on this, we propose the following hypothesis:

H5: The Economic Sustainability of Fluoride Contamination Projects (ESFCP) is positively related to Technological Innovation (TIFM).

3.6. Financing Models, Awareness, and Innovation

IFMs raise public health and economic awareness and promote technological innovation. These IFMs make available financial resources that will allow educational programmes to increase awareness of fluoride contamination and its associated risks [18]. Greater demand is put on the utilisation of new innovative technologies that would address these problems better . As a result, we hypothesise that IFMs mediate the relationship between technological innovation and public health and economic awareness. The following hypothesis is proposed:

H6: The relationship of Innovative Financing Models (IFM) and Technological Innovation (TIFM) is mediated by Public Health and Economic Awareness (PHEA).

3.7. Financing Models, Cost Efficiency, and Innovation

The relationship between Innovative Financing Models (IFMs), technological innovation is mediated by cost efficiency. IFMs improve cost efficiency and allow investing in technological innovations that would otherwise become financially unfeasible to the organisation. According to prior research, organisations that allocate concern resources more efficiently implement new technologies for which the organisation performs better overall [14]. We therefore theorise that cost efficiency is a mediator between IFMs and technological innovation. Based on this, we present the following hypothesis:

H7: The Innovative Financing Model (IFM) depends on the Technological Innovation through the mediation of Cost Efficiency (CEFM).

3.8. Cost Efficiency, Innovation, and Sustainability

Technical innovation moderates the relationship between cost efficiency and economic sustainability of fluoride contamination projects. Organisations are thus able to get better cost efficiency enabling them to authorise use of innovative technologies when needed. On the other hand, these technologies make fluoride management projects more sustainable as they enable to improve operational efficiency and reduce the cost [19]. Therefore, we propose the following hypothesis:

H8: The relationship between Cost Efficiency (CEFM) and the Economic Sustainability of Fluoride Contamination Projects (ESFCP) is mediated through Technological Innovation (TIFM).

3.9. Public Awareness, Innovation, and Sustainability

Technological innovations that are more sustainable in public health and economic awareness (PHEA) project fluoride contamination projects. The more people learn about fluoride contamination, the more organisations are being urged to mitigate the risks with new technologies [20]. The technological innovations for fluoride management initiatives have made the management economic sustainable by lowering costs and increasing operational efficiency. Therefore, we hypothesize the following:

H9: The relationship between Public Health and Economic Awareness (PHEA) and the Economic Sustainability of Fluoride Contamination Projects (ESFCP) is mediated by Technological Innovation (TIFM).

3.10. Financing Models, Awareness, Innovation, and Sustainability

Technological Innovation (TIFM) and Public Health and Economic Awareness (PHEA) apply mutual mediating weights to the relationship between the economic sustainability of fluoride contamination projects and Innovative Financing Models (IFM). IFMs are the financial means to trigger the raising of public awareness, and the adoption of innovative technologies. In turn, these technologies also enhance the sustainability of project management of fluoride by reducing costs and increasing operational efficiency [21]. Thus, we propose the following hypothesis:

H10: The relationship between Innovative Financing Models (IFM) with the Economic Sustainability of Fluoride Contamination Projects (ESFCP) is mediated by Public Health and Economic Awareness (PHEA) and Technological Innovation (TIFM).

3.11.Financing Models, Cost Efficiency, Innovation, and Sustainability

Innovative Financing Models (IFMs) and the economic sustainability of fluoride contamination projects are are mediated by cost efficiency and technological innovation. IFMs improve the cost efficiency that organisations can invest in technological innovations in order to increase the sustainability of their projects. They result in improved operational efficiency and lower costs behind long term success in fluoride management initiatives [22]. Therefore, we hypothesize the following:

H11: Innovative Financing Models (IFM) are influenced by Economic Sustainability of Fluoride Contamination Projects (ESFCP), and mediating roles of two REWS components: Technological Innovation (TIFM) and Cost Efficiency (CEFM).

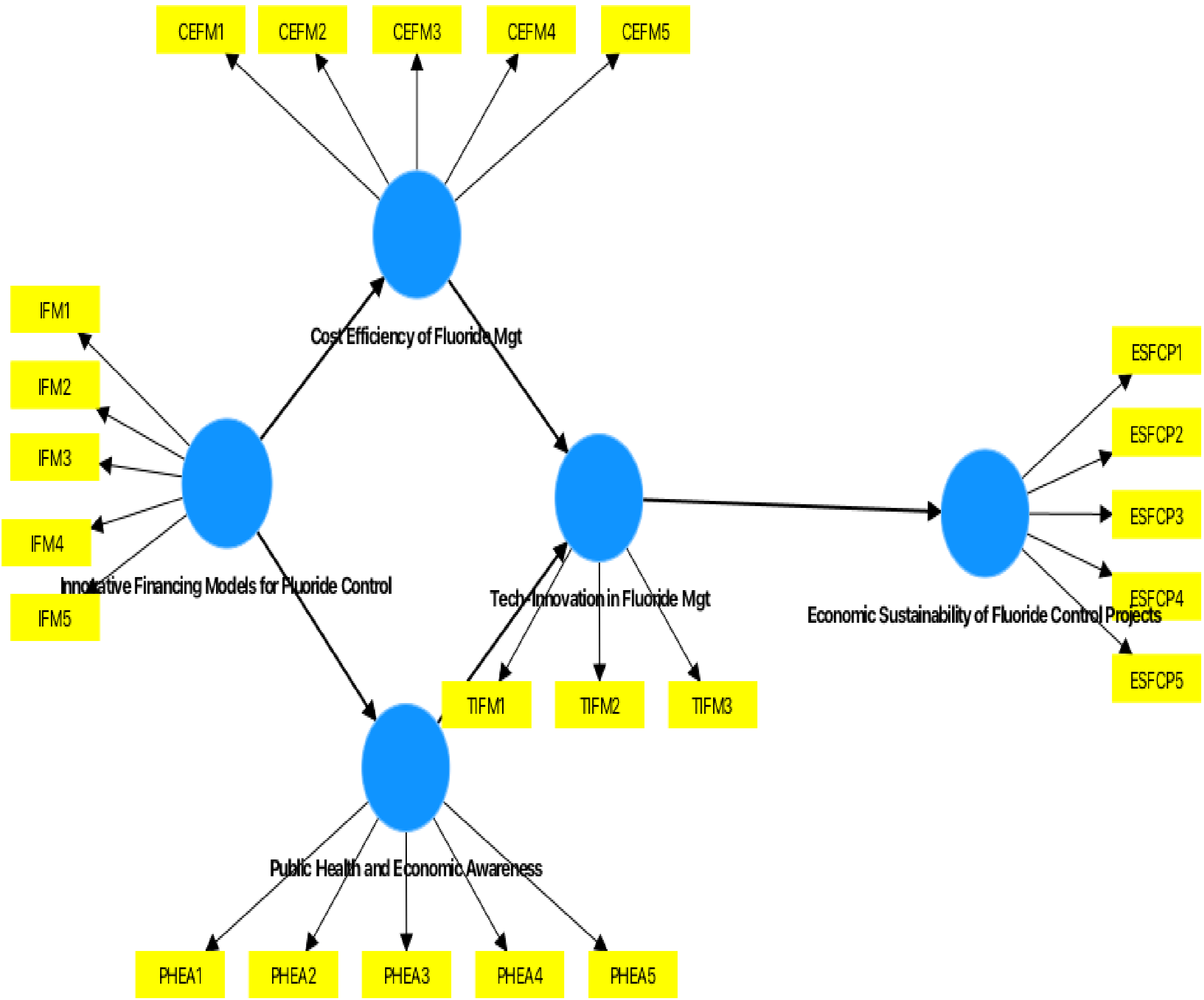

Figure 4: Path model

4. METHODOLOGY

We conducted a survey based study to test the proposed research model for the impact of Innovative Financing Models (IFM) on economic sustainability in fluoride management. Structured questionnaires were distributed online and data were collected. The population under study included the professionals and public sector officials involved in water management and environmental sustainability initiatives in China. They chose these people because they knew how to fund this and have tracks of having done successful fluoride contamination projects. There were 600 distributed questionnaires of which 459 were valid.

4.1. Measurement Instruments

All measurement items were adapted from previous validated research in order to achieve content validity. All items were answered on a 7 point Likert scale: 'strongly disagree' (1) to 'strongly agree' (7). Key variables measured include: Innovative Financing Models (IFM): Based on previously developed research on financing mechanisms in public health and environmental sustainability All the detailed measures with item and adopted scales are presented in the table 1.

Table 1: Constructs

Variable	Question	Source
Innovative Financing Models (IFM)	1. Our organization has used innovative financial models to support fluoride management projects. 2. Public-private partnerships have enhanced funding for sustainable fluoride management initiatives. 3. Blended financing models have provided better access to resources for fluoride management. 4. Impact investing has allowed us to implement more cost-effective fluoride mitigation methods. 5. We have adopted flexible financing methods to achieve long-term sustainability in fluoride contamination projects.	[23]
Cost Efficiency (CEFM)	1.Our organization's fluoride management practices ensure efficient use of financial resources. 2.We have reduced operational costs through efficient resource allocation in our fluoride mitigation projects. 3. The costs associated with our fluoride management projects are manageable and well-optimized. 4. Innovative financing has improved our cost-efficiency in managing fluoride contamination. 5. Our organization regularly evaluates project costs to ensure long-term sustainability.	[24]
Technological Innovation (TIFM)	1.We have invested in new technologies to improve fluoride contamination detection and mitigation. 2. Technological innovation in our organization has reduced the environmental impact of fluoride management. 3. We use advanced technological methods that have improved the overall effectiveness of fluoride management.	[25]
Public Health and Economic Awareness (PHEA)	1. Our organization regularly conducts public health awareness campaigns on the risks of fluoride contamination. 2. The public is well informed about the health and economic implications of fluoride contamination. 3. Our organization collaborates with policymakers to raise awareness about sustainable fluoride management. 4. Public health awareness has led to greater community involvement in fluoride management initiatives. 5. Economic awareness campaigns have contributed to increased support for our fluoride management projects.	[26]
Economic Sustainability of Fluoride Contamination Projects (ESFCP)	1.Our fluoride management projects are financially sustainable over the long term. 2. The economic outcomes of our fluoride contamination projects meet both short- and long-term goals. 3. We ensure that our fluoride management practices contribute to the economic stability of the region. 4. Our projects optimize both financial and environmental sustainability. 5. The innovative financing models we use ensure that our fluoride management initiatives remain economically viable in the future.	[27]

4.2 Sample and Data Collection

Data were collected employing an online survey method and the questionnaire was provided in English. A pilot study was conducted with 15 professionals in the water management and public health sectors, and then a consumer study was completed involving participants who were neither professionals, nor members of the relevant target group. To make the measurement items clearer and more relevant, their feedback was utilised to refine the wording of the measurement items. Finally, in 2024, over a two month period, the revised questionnaire was distributed. The final version of the questionnaire was translated into

Chinese and administered online using the survey platform (https://www.wjx.cn/). For two weeks in June 2024, data collection took place. This study targeted professionals and officials in the environmental management who have roles in fluoride contamination in China. To distribute the survey link, we worked with public health departments and water management agencies to give the link to the most relevant participants. Surveys were used to find out what respondents' views on innovative financing models were and how they see them contributing to economic sustainability.

Follow ups were made through professional networks and agencies to boost the response rate. A total of 600 questionnaires were distributed and 459 returned questionnaires. Of theses, 41 were discarded because of missing data, 459 remaining valid responses were used for analysis. To control for non response bias, we compared early and late respondents and found no significant difference. Non response bias was not a concern for this study, as a result.

Table 2 summarises the demographic characteristics of the sample. Almost two-thirds of the respondents were in the age group of 25 to 45 years, and the gender wise distribution was 59.9% male and 40.1% female. Furthermore, a majority of the sample had a bachelor's degree, as education for 43.6% of participants. For combinations regarding professional experience in Fluoride management, the most represented category in the sample was having 2–5 years of work experience (37%). Understanding the characteristics of a target population as well as the relevance of these to the study are what these key demographic groups reveal about the study population. Table 2 presents demographic Characteristics below.

Table 2: Demographic Characteristics of Respondents

Demographic Variables	**Frequency**	**Percentage**
Gender		
Male	275	59.90%
Female	184	40.10%
Age		
18–25 years	98	21.30%
26–35 years	154	33.60%
36–45 years	117	25.50%
46+ years	90	19.60%
Education		
Bachelor's degree	200	43.60%
Master's degree	172	37.50%
Doctoral degree	87	18.90%
Experience in fluoride management		
Less than 2 years	85	18.50%
2–5 years	170	37.00%
6–10 years	120	26.10%
More than 10 years	84	18.30%

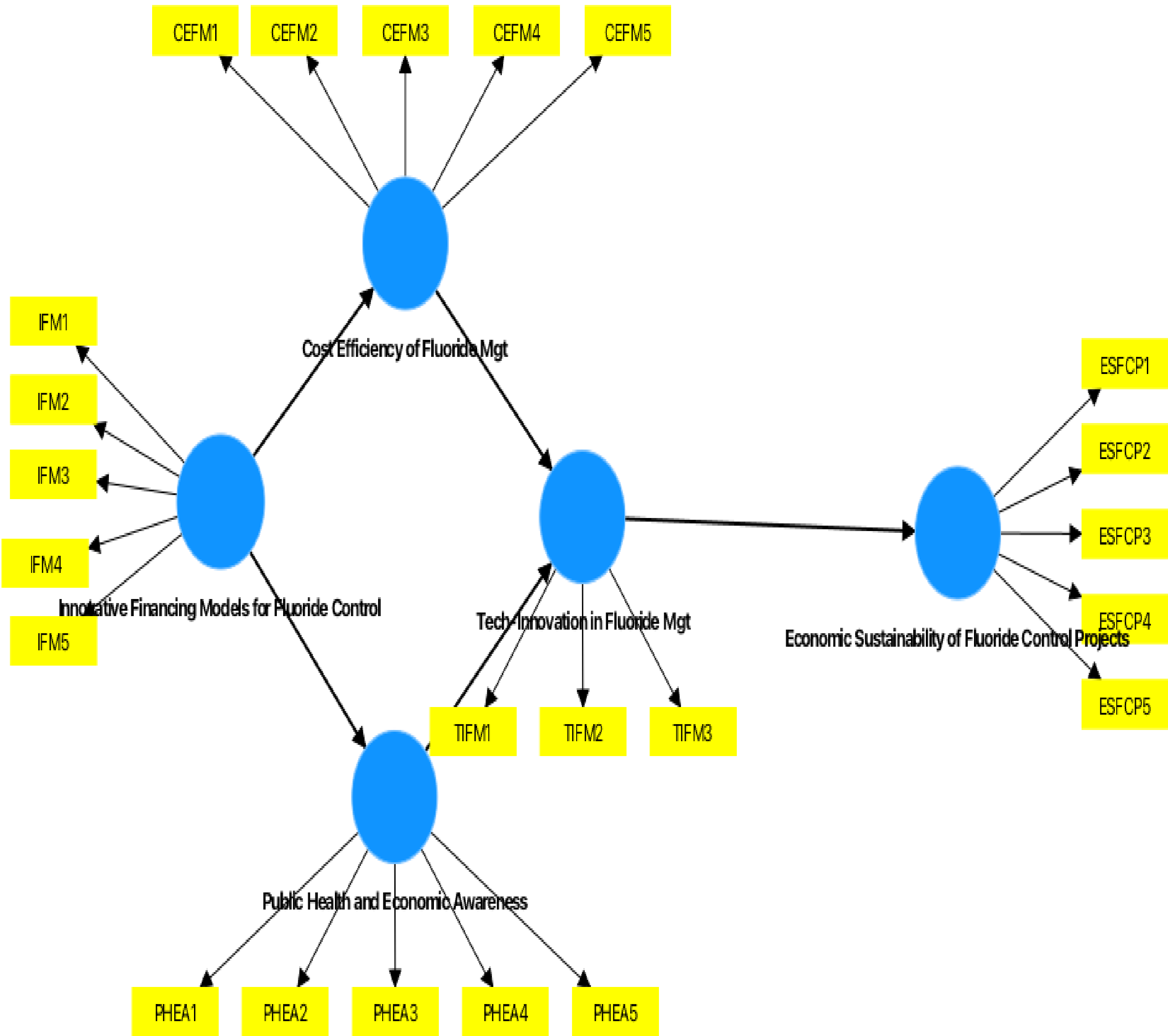

Figure 2: Path model

5. DATA ANALYSIS AND RESULTS

Structural equation modelling (SEM) was used with SmartPLS 3.0 for structural equation modelling (SEM) to test the proposed measurement and structural model. This choice of software was made because of SmartPLS's ability to handle complex models, small to medium size sample sizes and it can account for formative and reflective constructs. Variance based SEM is also supported by the software especially in exploratory study and moderating and mediating effects are supported (Hair et al., 2011). This methods is adapted to the testing of the hypothesised relationships between the variables in our model.

5.1 Measurement Model. Reliability and Validity

Confirmatory Factor Analysis (CFA) was used to verify the reliability and validity of the constructs, and this measurement model was assessed. All factor loadings were assessed, however all loadings were above the suggested cut-off of 0.7 indicating item reliability (Hair, Black, Babin, Anderson, & Tatham, 2010). Secondly, the construct reliability were also further evaluated by Cronbach’s alpha and composite reliability (CR), and the values were all higher than 0.7 (Table 3). Convergent validity (Fornell & Larcker, 1981) was shown for each construct by applying Average Variance Extracted (AVE) greater than 0.5[28]. Achievement of the CR values exceeded the 0.70 benchmark, reflecting a good reliability across the constructs. The Average Variance Extracted (AVE) was evaluated to assess convergent validity, with all values above the minimum requirement of 0.50, meaning that convergent validity was satisfactory. Besides, the factor loadings for all items were examined, and every loading exceeded the sufficient threshold of 0.70, which shows that each item represents its associated construct well. The findings together suggest that the measurement model reveals a high degree of both reliability and validity. A summary of the results is provided in Table 3.

Table 3: Construct Reliability and Validity

Constructs	Items	Loading	Cronbach alpha	CR	AVE
Cost Efficiency of Fluoride Mgt (CEFM)	CEFM1	0.912	0.861	0.901	0.648
	CEFM2	0.856			
	CEFM3	0.921			
	CEFM4	0.927			
	CEFM5	0.865			
Economic Sustainability of Fluoride Control Projects (ESFCP)	ESFCP1	0.739	0.839	0.884	0.605
	ESFCP2	0.794			
	ESFCP3	0.783			
	ESFCP4	0.829			
	ESFCP5	0.739			
Innovative Financing Models for Fluoride Control (IFM)	IFM1	0.815	0.854	0.894	0.629
	IFM2	0.870			
	IFM3	0.847			
	IFM4	0.607			
	IFM5	0.850			
Public Health and Economic Awareness (PHEA)	PHEA1	0.808	0.846	0.891	0.621
	PHEA2	0.845			
	PHEA3	0.673			
	PHEA4	0.835			
	PHEA5	0.765			
Tech-Innovation in Fluoride Mgt (TIFM)	TIFM1	0.803	0.789	0.876	0.703
	TIFM2	0.812			
	TIFM3	0.789			

5.2 Common Method Bias (CMB)

One factor test was performed by Harman given that a considerable portion of the data came from self reports, and assessed the potential for common method bias. The results showed that the most influential factor was responsible for 28.7 % of the total variance, well below 50 % threshold, greatly allaying concerns regarding the common method bias. Furthermore, in the correlation matrix, the constructs were not significantly correlated (r > 0.90), indicating that there was no common method bias influence on this analysis, and supporting the conclusions of the study. Together, these results confirm the reliability and validity of this measurement model employed in this research.

5.3 Discriminant Validity

We tested discriminant validity by the Fornell and Larcker criterion and the Heterotrait-Monotrait Ratio (HTMT) metric and examined a comprehensive assessment of each construct's individuality. Heterotrait-Monotrait Ratio (HTMT): The HTMT criterion also assessed the correlation levels among constructs in the Discriminant Validity section. To confirm that each construct measures only a unique aspect of the model, the Heterotrait-Monotrait Ratio (HTMT) is used to assess the discriminant validity between constructs in a structural model. In the results shown in Table 4, the HTMT values highlight the relationships between the key constructs: Innovation in Fluoride Management through Fluoride Management Economics (IFE) cost efficiency of fluoride management (CEFM), economic sustainability of fluoride control projects (ESFCP), innovative financing models (IFM), public health and economic awareness (PHEA), technological innovation in fluoride management (TIFM). The value of HTMT between CEFM and ESFCP is 0.733 implying a moderate relationship. As this value is less than the threshold of 0.85, we see that the discriminant validity between these two constructs is then sufficient. The value of 0.828 for IFM and ESFCP is relatively strong, but not out of the range of acceptability of discriminant validity. PHEA and TIFM have an HTMT value of 0.882, approaching the upper acceptable value (usually between 0.85 and 0.90). Although close to the threshold, discriminant validity is still supported. Overall, the constructs are indeed distinct from each other since all HTMT values are below the strict threshold of 0.90. This validates the model, as all measured constructs are sufficiently unique, even when some of them, say PHEA and TIFM, show high correlation.[29].

Table 4 :HTMT mattrix

	CEFM	ESFCP	IFM	PHEA	TIFM
CEFM					
ESFCP	0.733				
IFM	0.640	0.828			
PHEA	0.831	0.732	0.653		
TIFM	0.926	0.771	0.739	0.882	

Fornell and Larcker Criterion

As a criteria for verifying discriminant validity in the structural equation model, the Fornell-Larcker criterion is used. The square root of the Average Variance Extracted (AVE) for each construct is compared to correlations in the constructs. The square root of AVE for a construct is greater than its correlations with other constructs, therefore creating discriminant validity because the construct is unique. The off diagonal values in Table 5 are the correlations between the constructs and the diagonal values are the square roots of the AVE for each construct. In particular, square root of the AVE for CEFM (0.805) is greater than the correlation between CEFM and ESFCP (0.663), IFM (0.575), PHEA (0.705), and TIFM (0.771). That is, it supports the claim that CEFM has discriminant validity vis a vis the other constructs. Just as it is with ESFCP, the square root of the AVE for ESFCP (0.778) is higher than its correlations with other constructs, and thus, this variable too discriminately validates. AFE and IFM square root of 0.793 is greater than correlations with CEFM (0.575), ESFCP (0.707), PHEA (0.574) and TIFM (0.615). Similarly PHEA and TIFM have the same pattern of correlation (AVE vs other constructs) AVE square root for PHEA and TIFM 0.788 and 0.838 respectively which are greater than their respective relations with other constructs. Discriminant validity of the constructs has been established according to the Fornell–Larcker criterion, because these results confirm that the constructs are unique to each Other [30].

Table 5:Fornell and Larker criterian

	CEFM	ESFCP	IFM	PHEA	TIFM
CEFM	0.805				
ESFCP	0.663	0.778			
IFM	0.575	0.707	0.793		
PHEA	0.705	0.645	0.574	0.788	
TIFM	0.771	0.650	0.615	0.728	0.838

The model was also measured by R-squared for predicting the dependent constructs. The R squared value of 0. 77 is high: it indicates that 77 percent of the variation of TIFM can be explained by independent variables. The R squared value was 0.65 (% = 65) which related to the variance in the value explained to be 65% in the case of Economic Sustainability of Fluoride Control Projects (ESFCP). Moreover, we checked multicollinearity and VIF scores ranged from 1.28 to 1.59 indicating no multicollinearity concerns.

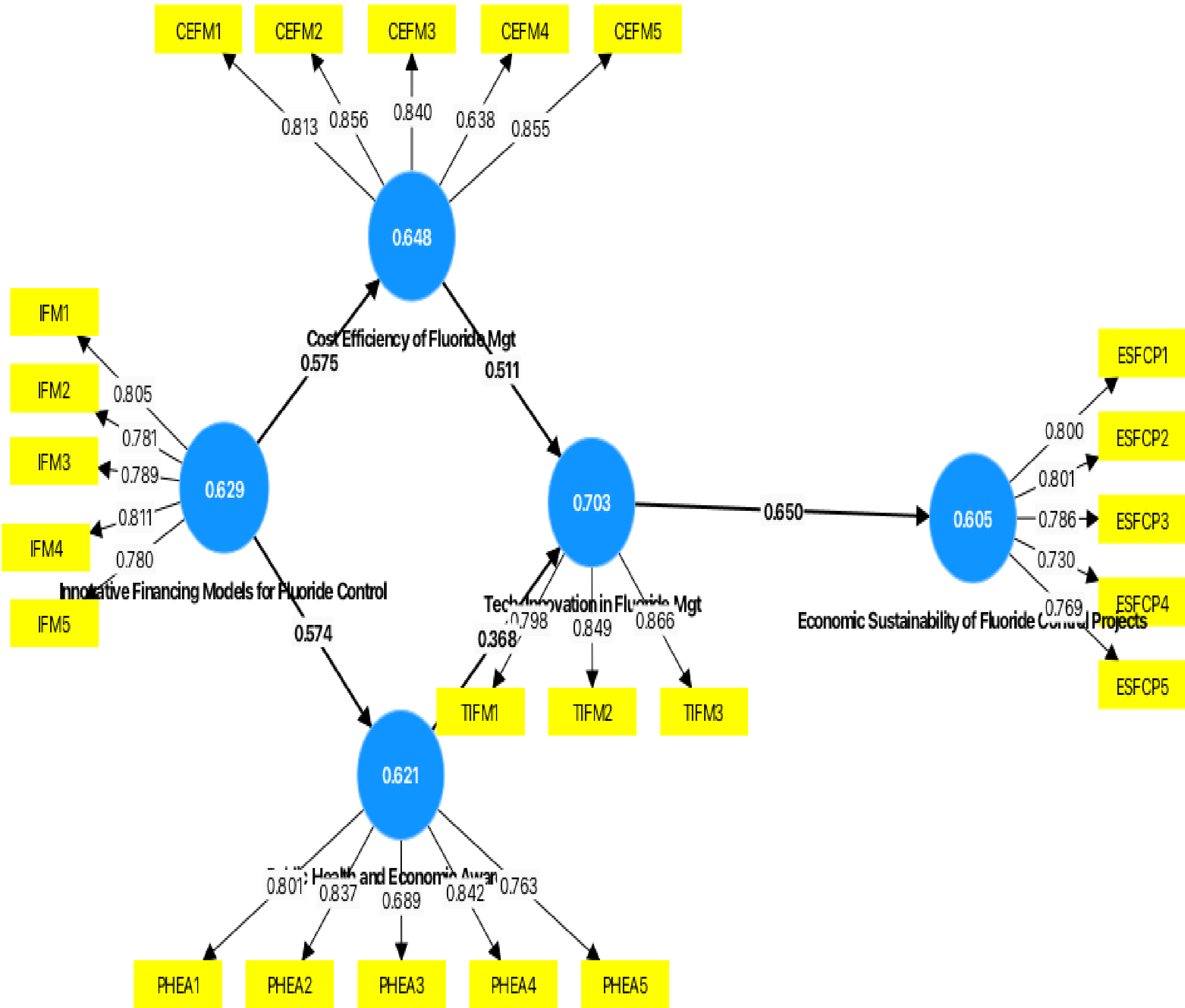

Figure3: Measurement Model. Structural Equation Model (SEM) Showing Factor Loadings and Path Coefficients Among Latent Variables and Observed Indicators.

5.4. Structural model

5.4.1 Model Fit Assessment

The data collected for the validated measures were used to test the structural model and both the model's fit indices were within acceptable ranges. Of the overall fit indices, a strong model fit is evident. Using the Standardised Root Mean Square Residual (SRMR) of 0.057, which is less than the cut off at 0.08, the fit was good (Hu & Bentler, 1999). Furthermore, the Chi-square/df (CMIN/DF) was 2.770 bu the CMIN/DF is acceptable 1 to 3 (Kline, 2015) indicating that the model was valid. RMSEA of 0.057, which is close to the allowable threshold of 0.10 (Browne & Cudeck 1993) fell within the threshold. The CFI of 0.926 and the TLI of 0.914 both exceeded the recommended cut off of 0.90, which permitted me to know that the model fits the data sufficiently (Bentler, 1990). Next, the Incremental Fit Index (IFI) also revealed acceptable value of 0.926, which confirmed good model fit.

The path coefficients were analysed with the model fit confirmed.

5.4.2 Hypotheses Testing Results

The relationship between Cost Efficiency of Fluoride Management (CEFM) and Technological Innovation in Fluoride Management (TIFM) was found to be significant (H1: There was statistical support for H1 (β = 0.511, t = 8.973, p < 0.001). Similarly, the path between Innovative Financing Models (IFM)and Cost Efficiency (CEFM) was significant (H2: H2 was supported by the finding that β = 0.575, t = 11.846, p < 0.001. The association between IFM and Public Health and Economic Awareness (PHEA) was also confirmed to be significant (H3: H3 is supported by the result that innovative financing models tend to positively affect public and economic awareness (β = 0.574, t = 14.230, p < 0.001). Additionally, the relationship between PHEA and TIFM was significant (H4: Finally, H4 is further supported (p < 0.001, β = 0.368, t = 7.067). Finally, TIFM was found to have a significant positive impact on Economic Sustainability of Fluoride Control Projects (ESFCP) (H5: H5 is confirmed (β = 0.650, t = 19.891, p < 0.001), and the importance of technological innovation is emphasised for the long term sustainability of fluoride management projects. Given, the model explains 77% of variance in TIFM and 65% variance in ESFCP, which indicate the model has strong explanatory power and the hypothesised relationships are valid. The results highlight critical roles of innovative financing models, cost efficiency and public awareness in supporting technological innovation and in fostering economic sustainability of fluoride management projects.Table 6 presented below.

Table 6: Path coefficient

	Original sample (O)	**T statistics (|O/STDEV|)**	**P values**
H1:CFEM -> TIFM	**0.511**	**8.973**	**0.000**
H2: IFM -> CFEM	**0.575**	**11.846**	**0.000**
H3:IFM -> PHEA	**0.574**	**14.230**	**0.000**
H4:PHEA -> TIFM	**0.368**	**7.067**	**0.000**
H5:TIFM ->ESFCP	**0.650**	**19.891**	**0.000**

5.4.3 Results from Mediation and Serial Mediation Analysis

Results from the mediation analysis, reported in Table7, shed light on the indirect effects between the study constructs. In this model all of hypothesised indirect relationships were found to be significant which implies that there are mediating effects in the model. The mediation effect of Public Health and Economic Awareness (PHEA) between Innovative Financing Models (IFM) and Technological Innovation in Fluoride Management (TIFM) is significant (H6: Results indicate that PHEA acts as a partial mediator in this relationship (β = 0.211, t = 6.114, p < 0.001). The fact that the positive effect of IFM on TIFM is channelled to some extent through increased awareness and understanding of economic issues further supports this hypothesis. Similarly, the mediation effect of Cost Efficiency of Fluoride Management (CEFM) between IFM and TIFM is also significant (H7: To confirm that cost efficiency significantly mediates the relationship between innovative financing models and technological innovation, β = 0.294, t = 6.745, p < 0.001). This highlights the importance of efficient resource allocation to spur technological developments of fluoride management. The analysis also reveals that TIFM mediates the relationship between CEFM and Economic Sustainability of Fluoride Control Projects (ESFCP) (H8: These results yield β = 0.332, t = 7.536, p < 0.001), which supports the intuition that technological innovation reinforces a positive relationship between cost efficiency and economic sustainability. Finally, the indirect effect of PHEA on ESFCP through TIFM is significant (H9: Results show that public awareness, coupled with technological innovation, increases fluoride control project economic sustainability (β = 0.239, t = 6.775, p < 0.001). Taken together, these results suggest the importance of mediation effects in explaining the economic sustainability of fluoride management initiatives and that cost efficiency, public awareness, and technological innovation are important mechanisms through which innovative financing models contribute to the realisation of economic sustainability of fluoride management initiatives.

Table 7:Specific Indirect Effect

	Original sample (O)	T statistics (|O/STDEV|)	P values
H6:IFM -> PHEA-> TIFM	0.211	6.114	0.000
H7:IFM -> CEFM-> TIFM	0.294	6.745	0.000
H8:CEFM -> TIFM -> ESFCP	0.332	7.536	0.000
H9:PHEA -> TIFM -> ESFCP	0.239	6.775	0.000

5.4.4. Serial Mediation Analysis

Results from the serial mediation presented in Table 8 demonstrate significant mediation effects in the model. Discussion of these results underscores the chain of mediators that together explain the relationship between Innovative Financing Models (IFM) and Economic Sustainability of Fluoride Control Projects (ESFCP). The first serial mediation result (H10) shows the path from IFM through Public Health and Economic Awareness (PHEA) and Technological Innovation in Fluoride Management (TIFM) to ESFCP (H10: $t = 5.706$, $p < 0.001$, $\beta = 0.137$}. This means that IFM's positive impact on economic sustainability is mediated through public health awareness and technological innovation, so IFM first raises public awareness that brings about technological innovation, and so increases economic sustainability. The second serial mediation (H10) examines the path from IFM through Cost Efficiency of Fluoride Management (CEFM) and TIFM to ESFCP (H10: The results; $\beta = 0.191$, $t = 5.721$, $p < 0.001$). Such finding further confirms cost efficiency and technological innovation serve to mediate the relationship between IFM and economic sustainability. IFM allows for better cost efficiency, which translates into more technological innovation, ultimately and crucially results in improved economic sustainability for fluoride control projects.

The results suggest both serial mediation effects for IFM to influence ESFCP through public health awareness and cost efficiency, with technological innovation to mediate both pathways. The results point out the multi step process by which innovative financing models help economic sustainability of fluoride management projects.

Table 8:Serial Mediation

	Original sample (O)	T statistics (|O/STDEV|)	P values
H10:IFM -> PHEA -> TIFMt -> ESFCP	0.137	5.706	0.000
H10:IFM-> CEFM -> TIFM -> ESFCP	0.191	5.721	0.000

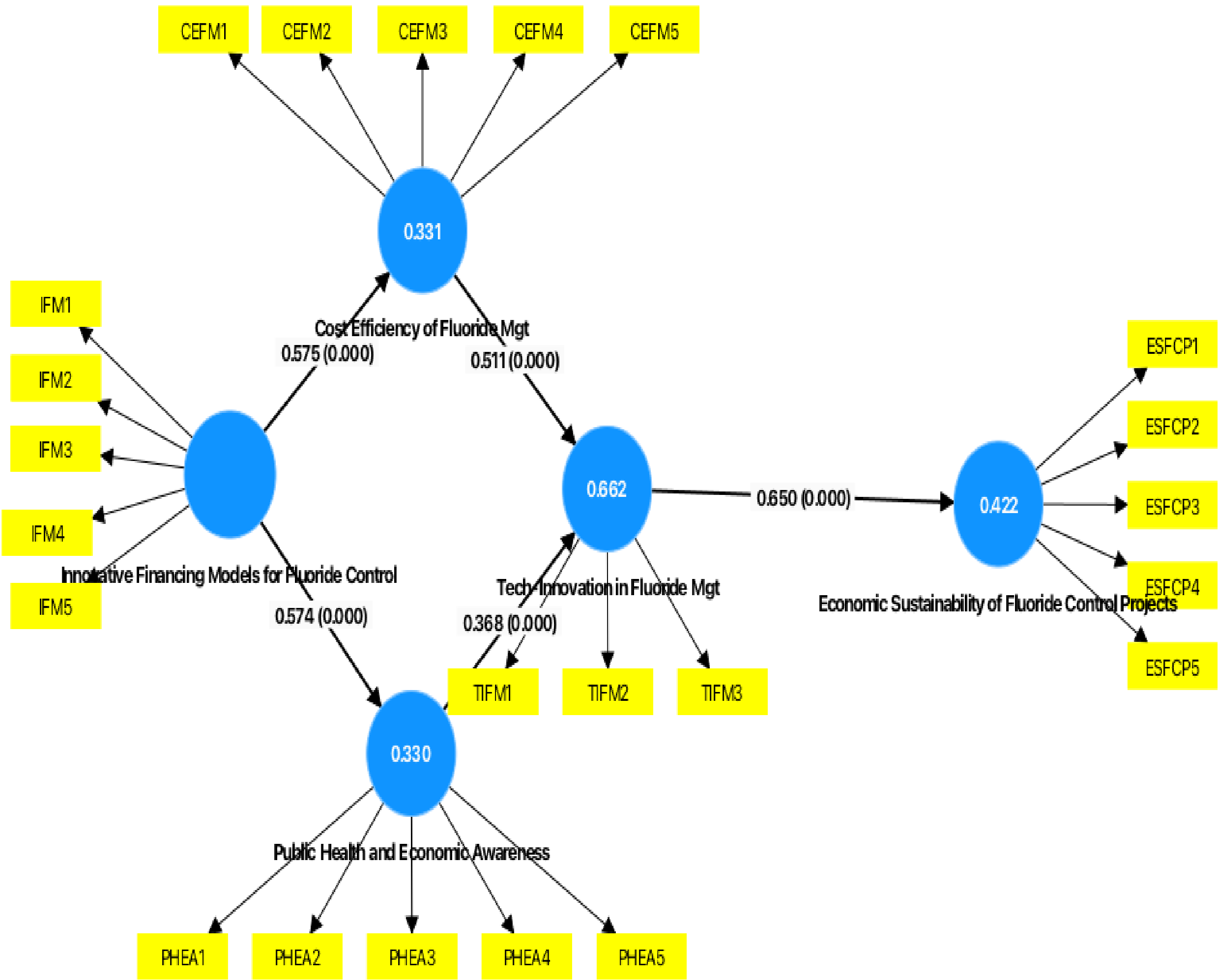

Figure 4: Structural model

6. DISCUSSION AND CONCLUSIONS

The results of this study have important implications for understanding how Innovative Financing Models (IFMs) influence Economic Sustainability of Fluoride Control Projects (ESFCPs) through the mediating effects of Cost Efficiency of Fluoride Control Projects (CEFP), Technological Innovation in Fluoride Management (TIFM), and Public Health and Economic Awareness (PHEA). Results confirm hypothesised relationships in the context of fluoride management, and confirm the roles of these variables in delivering economic sustainability.

The strong connexion between IFM and CEFM is consistent with the idea that innovative financing instruments play an indispensable role in maximising resource allocation and minimising the cost efficiency of environment project [31]. IFMs help support efficient use of financial resources to manage the costs for fluoride mitigation projects through flexible and sustainable funding approaches. This result corresponds to studies aiming to point out that financial innovation involves in reaching the goals of both the economic and environmental domains [32].

Additionally, the mediation of CEFM and TIFM between IFM and ESFCP highlights the gaining significance of the role of cost efficiency and technological improvements in making economies financially sustainable. Significant indirect effects underscore that efficient financing and cost control enabled by technological innovation can contribute to better project results. As Musara and Fatoki [33] writes technological innovation is a major accelerator of sustainable economic development in sectors characterised by resource constraints and environmental problems.

Results present strong mediation effects of PHEA regarding the association between IFM and TIFM, indicating that increased public awareness regarding fluoride contamination risks and the promotions of sustainable practises to benefit technological innovation. The results demonstrate that increased community and stakeholder understanding of public health and economic issues surrounding fluoride contamination result in increased support for the adoption of innovative fluoride reduction methods. This supports previous research [34] that stakeholder engagement and public awareness is a key factor in the successful implementation of environmental and technological programmes.

In addition, the results support the serial mediation hypotheses of PHEA and TIFM on the linkage between IFM and ESFCP. The finding implies that public awareness and technological development can be used concurrently to improve the economic sustainability of fluoride control projects. In line with previous research [35], successful novel financial models are those that go hand in hand with improved environmental and economic performance as a result of technology advances and raised public involvement.

The strong mediation of the relationship between CEFM and ESFCP by TIFM further underscores the critical importance of technological innovation in facilitating the transition of more cost-efficient practises to long term economic sustainability. This also aligns with the resource based view, which maintains that firms and projects can gain sustainable competitive advantage by utilising rare, undiminishing resources that are valuable, non-substitutable such as innovative technologies.

Overall, results from this study show that IFMs foster economic sustainability in fluoride management through providing cost efficiency, promoting technological innovation and raising public awareness. As this adds empirical evidence to the increasing recognition of financial innovation and stakeholder involvement as core enabling factors for the implementation of sustainability in environmental management [36], they are therefore relevant beyond cost accounting. However, application of this study’s findings could provide policymakers and practitioners with especially useful ideas for tackling the problem through the fusion of cutting edge technological, awareness raising, and cost effective strategies, with equally appealing financial models.

In sum, this study makes a major theoretical contribution to how innovative financing models affect the economic sustainability of environmental projects. The study demonstrates how identifying the mediating roles of cost efficiency, technological innovation and public awareness can present a comprehensive framework for achieving sustainable outcomes in fluoride management with practical implications for policy and project development.

6.1. Theoretical Implications

The theoretical contributions of this study expand understanding regarding innovative financing models and their effects on economic sustainability in fluoride management. First, the research emphasises the important role of innovative financing models (IFMs) as the driving force of economic sustainability in resource constrained environmental management projects. This complements the existing literature by incorporating the Triple Bottom Line (TBL) context to capture how the financing models affect environmental and public health outcomes (Elkington, 1997) besides the financial bottom line. Building upon the TBL perspective, the paper extends the literature by empirically showing that cost efficiency, technological innovation, and public awareness mediate the relationship between IFMs and sustainable outcomes of a public health interventions, to provide a more comprehensive view of sustainability in public health interventions.
Second, the study further clarifies how public health and economic awareness mediate between project outcome and the identified financing models. Third, the study contributes to this understanding of public health as it is mediated between project outcome and financing models. In this aspect, it contributes to existing public health literature, showing how raising awareness can create an opportunity for the adoption of sustainable practises in fluoride management where public engagement is critical (Freeman & Cavusgil, 2007). Overall, this research contributes to an ongoing theoretical discussion on how integration of financing, technological, and social factors has been successful or unsuccessful in driving sustainable outcomes in environmental management.

6.2. Practical Implications

The findings are based on which several recommendations are made for practise. The first is that governments and environmental organisations must design and implement IFMs that are flexible and can address both short and long term environmental challenges. If projects are economically viable and also address public health and environmental concerns, organisation can align these models’ with sustainability goals.

Second, stakeholders should contribute in public awareness campaigns not only promoting the risks of fluoride contamination but also the benefits of cost efficient and innovative solutions. This campaigns can provide a foundation for building stronger community support to technological innovations in environmental projects and is important for public engagement is a successful case.

Third, project managers should constantly observe and enhance cost efficiency of their initiatives. Environmental projects can have better outcomes at the same, or even reduced, financial input if we work to improve resource allocation efficiency. Through this approach projects remain economically sustainable while benefitting public health and the environment

6.3. Limitation and Future studies

This study has several limitations despite its contributions. However, the generalizability of the findings was restricted by data collection from a single geographical area, China. Going forward, the study should be duplicated in other countries and other regions to better understand how IFMs influence fluoride management worldwide. Self reporting data is also used, thereby adding potential bias. IFMs provide a richer picture of project outcome with longitudinal studies.

Secondly, this study concentrates on the Triple Bottom Line framework without taking into account other theoretical perspectives that can be able to explain the complexities of financing and sustainability in environmental projects. Future research may extend the analysis beyond the concepts discussed in this work into other theories, such as Stakeholder Theory or Institutional Theory, to gain a more comprehensive understanding of the factors that drive economic sustainability in environmental health projects.

Finally, while this study focuses on fluoride management, there are plenty of other areas of environmental health (e.g., water management, waste treatment, climate change mitigation) where the findings can be expanded. Investigation of the mediating role of technological innovation and public awareness in these fields may offer useful insights into broader utilisation of IFMs to support sustainable development.

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