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Achieving sustainable development goals through adoption of hydrogen fuel cell vehicles in India: An empirical analysis

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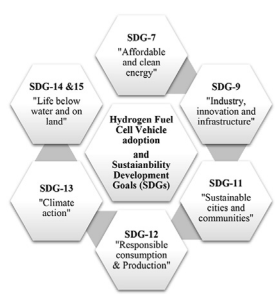
HIGHLIGHTS

- We examined public intention to adopt hydrogen fuel cell vehicles (HFCV).
- Adoption of HFCV significantly impacts ($t = 5.4$) Sustainable development goals (SDGs).
- Policy implications regarding HFCVs have a major impact ($t = 8.6$) on SDGs fulfilment.
- Risk perception and Safety concerns need to be addressed for better HFCV adoption.

GRAPHICAL ABSTRACT



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ABSTRACT

Hydrogen is a growing facilitator for a multisectoral transition to a renewable energy-based economy. Despite this, there is negligible scholarly literature examining the connections between the hydrogen economy and the Sustainable Development Goals (SDGs) established by the United Nations. In this empirical investigation, we demonstrate a correlation between adopting Hydrogen fuel cell vehicles (HFCVs) and their direct and indirect impact on SDGs (#7, 9, 11, 12, 13,14 and 15). This empirical investigation was performed based on 358 valid sample responses from the pan-India survey. Utilising structural equation modelling, the hypotheses were tested, and the research model was validated. The findings revealed that the adoption of HFCV has a positive impact on SDGs. The results confirm that policy implications significantly change public perception regarding high cost and infrastructure readiness. Keeping the finding in mind, we recommend that the fuel retailers create more hydrogen refuelling stations across the country to ease infrastructure bottlenecks. Further, governments at various levels should provide financial benefits to green hydrogen producers, fuel cell manufacturers, HFCV manufacturers, and early adopters of HFCVs in India.

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Abbreviations

ADP	Adoption
ATT	Attitude
AVE	Average variance extracted
COS	Cost perception
CR	Composite reliability
EV	Electric vehicles
HFCV	Hydrogen fuel cell vehicle
INDC	Intended nationally determined contributions
INF	Infrastructure requirements
MV	Motivation
PLS	Partial least square
POL	Policy
R2	Coefficient of determination
RSK	Risk perception
SDG	Sustainable Development Goal
SEM	Structural equation modelling
SFC	Safety concern
SSR	Sum of square due to regression
SST	Total sum of squares

Introduction

The primary allure of hydrogen and the impetus behind present research and development are its benefits over fossil fuels linked to climate change. However, the purity of hydrogen depends on the technology employed to manufacture and use it. Replacing fossil fuels with hydrogen in the provision of energy services might result in significant environmental gains if hydrogen is utilised in non-polluting fuel cells and that carbon dioxide and noxious gases released during the hydrogen-production process are minimised or eliminated [1]. At the time of use, hydrogen combustion in the presence of oxygen in a fuel cell generates just electricity and water. If the energy used to make hydrogen comes from nuclear power or renewable sources, there won't be any emissions [2]. If the energy comes from fossil fuels, the released carbon dioxide can be captured at the point of production and stored for good.

Both air pollutants and greenhouse gases that contribute to climate change are produced in significant quantities by the road transportation sector [3]. Exposure to contaminants generated by fossil fuel-driven vehicles has been hazardous to human health. Local air quality has thus emerged as a significant policy concern in nearly all nations [4]. Many large cities around the globe in the developing world now experience unprecedented levels of air pollution [5]. Through advancements in fuel efficiency, fuel quality, and the implementation of emissions reduction technology in vehicles, the majority of developed, industrialised nations have made significant progress in decreasing pollution generated by automobiles [6]. However, the increase in traffic has partially cancelled out the gains in emission levels performance [7]. To combat the growing problem of air pollution caused by vehicles on the road, researchers have been concentrating on developing fuel cells for use in automobiles.

Substituting hydrogen-powered fuel cells for gasoline or diesel-powered internal combustion engines would, in theory, eliminate automobile emissions [8]. In addition to replacing the direct usage of hydrocarbons, fuel cells may be utilised to produce electrical energy for industrial operations and structures [9]. Hydrogen could also help cut or stop the release of carbon dioxide and other gases that trap heat in the atmosphere [10]. For achieving this goal, hydrogen production methods will need to be either carbon-free or much less carbon-demanding than today's fossil fuel-based energy infrastructure [11]. Therefore, many nations like India, Australia, Japan, South Korea, China, the United Kingdom, and the United States emphasise green hydrogen adoption. Although switching to hydrogen might positively affect the environment locally and globally, the full extent of such effects is unclear. These are primarily concerned with the possible repercussions that may arise from the release of substantial quantities of hydrogen into the atmosphere.

The widespread use of hydrogen would make such releases inevitable, but the effects are very uncertain because scientists still have a limited understanding of the hydrogen cycle [12]. The most catastrophic consequences of any rise in hydrogen atmospheric concentrations would be a change in the volume of water vapour in the high atmosphere and, indirectly, the depletion of the ozone layer [13]. Additionally, increased hydrogen emissions may reduce the atmosphere's ability to oxidise, lengthening the life of air pollutants and greenhouse gases, including methane and hydrochlorofluorocarbons. More research is needed to learn more about where hydrogen comes from and where it goes. The question of safety is crucial.

Contrary to common belief, hydrogen is less flammable than most other fossil fuels, including light oil products like gasoline. However, additional risks are associated with transporting and storing it under high pressure or at shallow temperatures. There is enough proof that hydrogen can be handled and controlled safely enough to be as safe as the current fuels. There is a long history of safe industrial usage of hydrogen [14]. Thus, it will be more crucial than ever to create and practice globally approved laws, regulations, codes, and standards that govern the safe construction, upkeep, and operation of hydrogen facilities and equipment throughout the fuel supply chain. Establishing customer trust will depend on the uniformity of safety criteria and the robust implementation of those rules. Based on all these enablers and barriers to adopting hydrogen, this study attempts to analyse the individual response towards its adoption in the transport sector. Post-pandemic countries are battling hard to fulfil their Sustainable Development Goals (SDGs) commitments, and hydrogen undoubtedly adds significant value to it, making this study timely and relevant. Also, this is the first primary research-based study that attempts to find evidence of a link between the adoption of hydrogen in our daily life activities and its potential implications on SDGs.

HFCV and sustainability

A sustainable mobility system is accessible to everyone, efficient, environmentally friendly, and low in carbon emissions. Although transportation does not have its own sustainable development goals (SDGs), it is essential to achieve other SDGs to achieve the required advancement [15]. Fig. 1 displays the SDGs (SDGs-7, 9, 11, 12, 13,14 and 15) that may be directly or indirectly attained via HFCVs.

Multiple studies [14–16] have been conducted linking SDG directly and indirectly with the hydrogen economy. Chakraborty et al. [17], in their research, have suggested Goal-3 (good health and well-being), Goal-8 (decent work and economic growth), Goal-10 (reduced inequalities), Goal-11 (Sustainable cities and communities), Goal-13 (climate action), and Goal-15 (life on land) as critical aspects related directly or indirectly with sustainable mobility. Similarly, Falcone et al. [15] have interlinked Goal-7 (affordable and clean energy) with the hydrogen economy. Kar et al. [18] in their study have suggested that SDGs can be associated with HFCV for further research. In accordance with all these studies, we have adopted the SDGs for this research.

By 2030, the Indian government aims to boost its RE capacity to 500 GW and achieve 50% of the electricity generated from renewable sources, which aligns with SDG-7 [19]. The SDG-7 primarily focuses on making clean and modern energies available to each household at affordable prices by 2030 and doubling the global energy efficiency enhancement rate. Similarly, SDG-9 and 12 focus on sustainable practices in the industrial and transport sector. India's green hydrogen policy aims to improve infrastructure and fix up industries to make them more sustainable by using resources better and getting more companies to use clean technologies and processes [20]. Target-2 of SDG-11 emphasises providing safe and sustainable transport infrastructure for everyone, which is central to India's hydrogen economy ambitions. Such a target not only fulfils the efforts of inclusive and sustainable urbanisation but also promotes sustainable human settlement planning. EVs may not be a viable alternative to conventional cars from an environmental standpoint since their emission potential depends on how energy is generated [21]. HFCVs operated through green hydrogen can be the most effective eco-friendly alternative when taking urgent actions to combat climate change as a part of SDG-13 and fulfilling intended nationally determined contributions (INDCs) [22]. The oceans, which span about three-quarters of the Earth's surface, are the most conspicuous feature and are essential to the Earth's biodiversity. Every year thousands of marine birds and endangered species like bottleneck dolphins, spinner dolphins, melon-headed whales, sperm whales etc., are killed due to oil spills [23]. Adoption of green hydrogen for vehicles will not only decrease demand for oil production and oil imports made by multiple nations but also will pave way for introduction of green hydrogen into the shipping industry as well, thus fulfilling the needs of SDG-14 indirectly.

Following all these aspects, this paper attempts:

a) To fulfil the need for empirical research that considers the public opinions to measure their adoption intention towards HFCVs.
b) To create a bridge between the adoption of HFCVs and its impact on the fulfilment of SDGs, which previous research on HFCVs has always neglected.
c) To contribute policies that will help manufacturers and government bodies in successfully formulating consumer-friendly policies for better adoption of HFCVs and eventually fulfilling sustainable goals and targets, directly and indirectly, in the future.

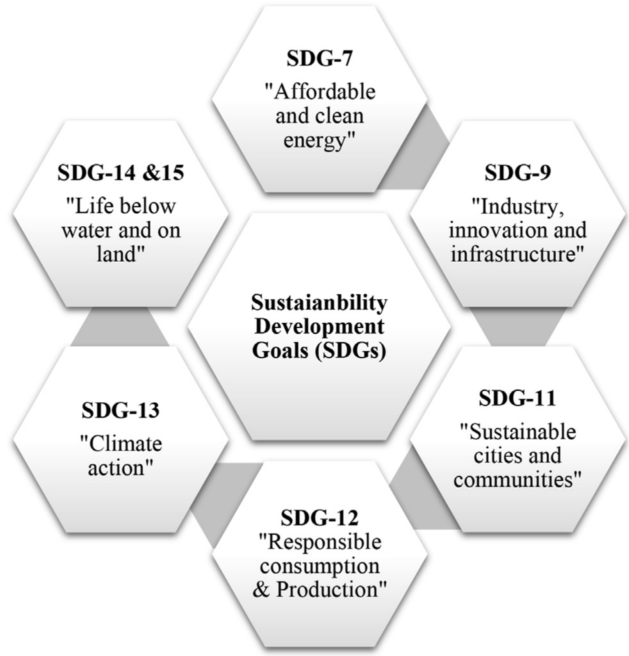

Fig. 1 – SDGs linked directly and indirectly to HFCVs.

Section Introduction introduces the study and establishes the relationship between the Hydrogen economy and SDGs. Section Literature review and hypothesis focuses on the existing literature and linkages between the variables under study, thus formulating hypotheses for this study. Section Research methodology presents the research methodology used in this research, while Section Findings presents the results and findings of this study. Section Discussion discusses the findings of this research, while Section Policy implications suggests policy implications which would help all the stakeholders involved in the HFCV ecosystem. Section Conclusion concludes this paper by highlighting the essential findings and recommendations for future research.

Literature review and hypotheses

The adoption decision of consumers is a complicated operation including multiple dimensions, including cognitive attributes like attitude, motivation etc. and environmental perception like ecological concern, infrastructural readiness etc. Jaykumar et al. [24] highlighted the techno-economic advantage from a sustainable perspective that hydrogen holds in their inclusion in the automobile industry. However, it was a review-based paper which lacks empirical evidence. Numerous pieces of consumer-centric research have been carried out in various Asian countries like Japan [8,25], South Korea [26,27], Malaysia [28], and China [11,29]. These studies have investigated the public's adoption intention of HFCVs through multiple methodologies including "self-efficacy theory, social cognitive theory, theory of reasoned action (TRA), and the theory of planned behaviour (TPB).

In contrast, this research which is the first to be carried out in the Indian scenario tries to interlink the TPB to SDGs. According to TPB, "an individual's behaviour is governed by their behavioural goal and their attitude is composed of their resonating beliefs and anticipated results for a particular goal" [30]. People examine the consequences of a specific behaviour before acting on it, resulting in a favourable outcome [31]. Thus, in this research, as evident in Fig. 2, we have tried to examine what Indians feel about their self-commitment towards the fulfilment of SDGs through their actions (in this case, through the adoption of HFCVs). In addition, this study also applies the adoption intention as a mediating factor to develop a linkage between the policy implications and SDGs.

To our knowledge, no attempt has been undertaken to systematically incorporate all these potential variables (SDGs and Policy) into a single empirical framework to assess each factor's relative significance. This strategy would aid academics and policymakers in understanding what motivates individuals to adopt HFCVs by identifying hidden linkages between variables that interact or replace one another. Understanding these conditional relationships is critical for policymakers seeking to promote HFCVs in the transportation sector to curb carbon emissions and the usage of conventional fossil fuels.

Factors influencing adoption of HFCVs

Motivation

Adopting HFCV is recognised as one of the most effective environmental solutions. However, previous studies [32,33] on the development of HFCVs have focused on expectations and perceptions toward HFCVs, ignoring the role of many human needs in the adoption intention process. According to Schutte et al. [34], a person's wishes (needs) are influenced by the person's values and impact on adoption. Motivation is the intrinsic factor of a human which drives them to achieve that need. This drive towards fulfilment can be classified into various aspects, social influence, environmental influence, or self-esteem influence. Previous studies [35,36] on electric vehicles (EV) have highlighted that motivation level plays a vital role in new technology adoption (especially in the transportation sector). Thus, the hypothesis suggests:

H1: Motivation level has a positive impact on HFCV adoption.

Risk perception

Risk perception is the consumer's impression of the uncertainty they may encounter when driving an HFCV. Because HFCV is still in its early stages, particularly in fuel cell technology, it is immature from the Indian perspective [20]. HFCV's restricted energy storage may provide a larger mobility danger (e.g., fire event) to customers as compared to gasoline vehicles. Higher risk perception would result in a lower level of buying intent [37,38]. Previous research has indicated that customer willingness to embrace innovations is negatively impacted by risk perception [39,40]. As a result, we assume.

H2: Risk perception has a significant influence on HFCV adoption.

Safety concerns

An essential worry with HFCV is safety. Hydrogen fuel is significantly more combustible than fossil fuels like gasoline and diesel [41]. Gaseous hydrogen may be produced in the car from various fuels, including methane, propane, alcohols, or even normal gasoline, therefore, providing multiple options to store hydrogen inside the vehicle [42]. However, each has its own flammability problems, and hydrogen is also quite flammable, which raises safety questions about using HFCV [43]. The hypothesis thus suggests:

H3: Safety concern has a significant impact on HFCV adoption.

Attitude

The "constructive idea of attitude formation" serves as the primary foundation for customers' attitudes about HFCV. Accordingly, it is said that buyers have an adoption intention towards HFCV when they exhibit favourable sentiments about interacting with vehicle manufacturers [44]. The term "purchase intention" refers to a customer's propensity to interact and converse with various HFCV stakeholders [45]. Adnan et al. [46] noted that attitude is a significant variable (anterior) of behavioural intention in numerous research. A comprehensive study by Schuitema et al. [47] discovered that customers with a good attitude toward ecological concerns are more likely to embrace green automobiles. According to Ajzen [30], customers with a more optimistic outlook will be more motivated to engage in a specific activity. Therefore, we assume that:

H4: Individuals' attitude toward HFCV positively impacts its adoption.

Factors influencing policy implications regarding HFCVs adoption

Cost perception

The financial cost is the monetary expenditure customers incur while purchasing or utilising a product [48]. When considering whether to embrace innovation, buyers may evaluate the cost of the innovation with that of the available alternatives, and they would base their impression of the cost of the innovation on this assessment [49]. Prior research corroborated that one of the key reasons why customers are resistant to innovations is the perceived cost [49,50]. In this study, cost perception is defined as how customers estimate the cost of adopting HFCVs, including the actual cost of the vehicles and the cost of charging. In this context, the total cost of owning and operating an HFCV is critical to adoption. According to prior studies [51], the high price of HFCVs is a significant barrier to their widespread adoption. Therefore, we propose that.

H5: Cost perception has a significant influence on policy related to HFCVs.

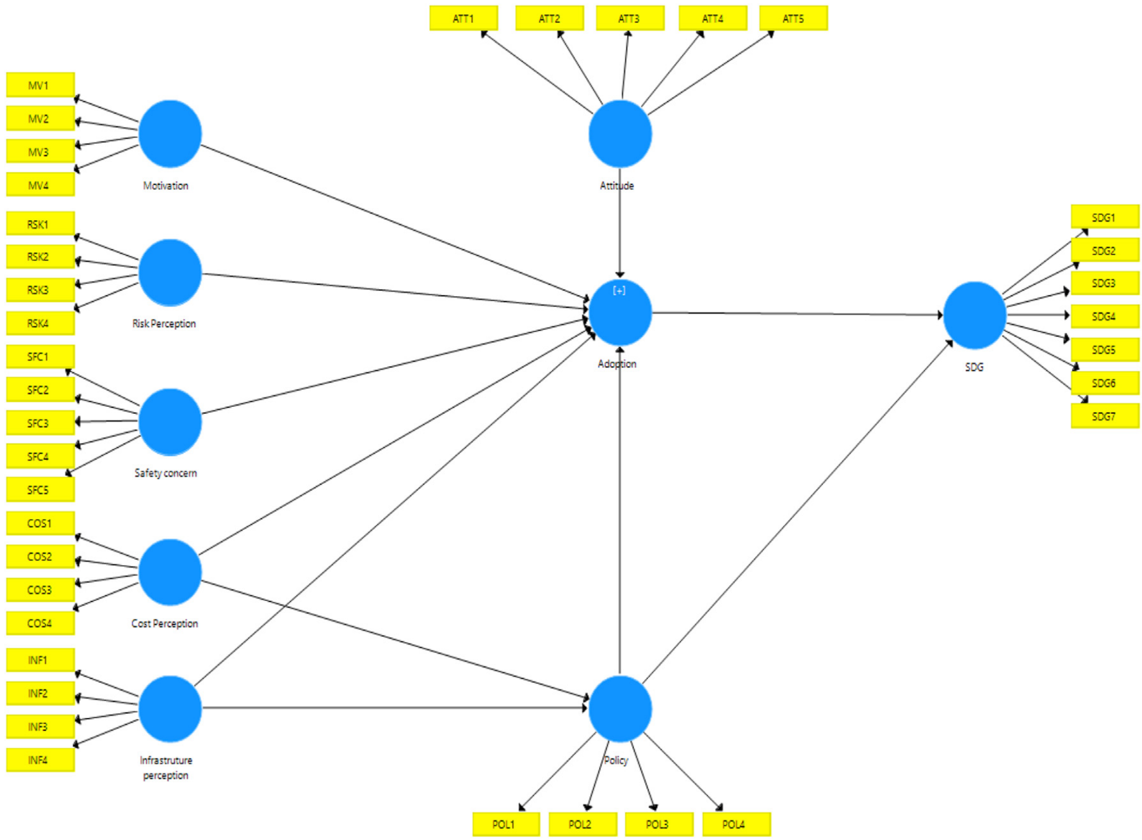

Fig. 2 – Proposed research model.

H7: Policy implications mediate between cost perception and adoption of HFCVs.

Infrastructure requirements

Vehicle manufacturers and other intermediaries supporting HFCV are hesitant to invest in new stations, given the uncertainty of consumer adoption [20]. While consumers' propensity to adopt HFCVs is unclear owing to the unavailability of hydrogen refuelling infrastructure and purchase price [52]. This results in prolonged uncertainty over the HFCV ecosystem. Schneider et al. [53], explored in a pilot-project study on hydrogen found that refuelling station infrastructures play a vital role in HFCV adoption in Germany. Policies associated with refuelling station safety, less refuelling time, and safe refuelling procedures significantly impacted consumer adoption intention. A similar kind of study carried out in England by Hardman et al. [54] found that respondents thought HFCVs were like conventional vehicles in terms of operational values. However, despite all the benefits associated with HFCV, their high price tag and scant refuelling stations are the spectrums where consumer-friendly policies must be formulated [55]. Thus, in our study, we assume.

H6: Infrastructure has a significant influence on policies related to HFCVs.

H8: Policy implications mediate between infrastructure readiness and adoption of HFCVs.

Factors influencing sustainable development goals

Despite the paucity of comprehensive research on the connections between a hydrogen economy and the SDGs, certain generalisations may be made [15]. Collaborations, trade-offs, and contradictions between the 17 SDGs were investigated in studies by Pradhan et al. [56] and Spaiser et al. [57], both analytically examining time series data and in research for the European Union (EU) by Weitz et al. [58] employing a cross-impact matrix. For instance, Spaiser et al. [57] not only pointed out a multitude of inconsistencies, such as those between certain environmental goals like low carbon footprint and goals associated to poverty and social involvement, but they could also point out elements like health programmes and renewable energy systems that significantly influenced both sides. Weitz et al. [58] argue that development in objective 13.2 (climate mainstreaming) boosts progress in SDG 7 and a variety of other SDGs, but also that, for instance, expanding bioenergy or hydroelectric power might have negative consequences for other ecological and sustainability goals. Von Stechow et al. [59] emphasise that achieving the SDGs requires reducing global warming to 2C, but that this is not a sufficient condition. This is a forward-looking viewpoint. In their assessment of the literature on climate co-benefits, Karlsson et al. [60] note that these advantages are often disregarded and, in part, understudied. However, implementing a hydrogen economy would lessen air emissions and the effects of air pollution on human health and the environment. It also intends to minimise greenhouse gas (GHG) emissions, given the creation of hydrogen is carried out through a renewable process. Because an emphasis on production is insufficient, urge for a larger concept that involves the (energy) resource, technology, and services, i.e., the implementation phase [61]. Several components of a hydrogen economy have undergone attributional (environmental) life cycle sustainability analyses (LCSAs) [15]. Up to 2022, Kar et al. [18] performed bibliometric analysis on Hydrogen economy (a lot of them focusing on production and mobility) and tried to interlink it with SDGs. Further research is required to support policy, including (i) an integrated assessment of SDGs related to HFCV adoption, (ii) prospective policies that consider improvements that can be anticipated within this emerging technology; and (iii) recognising the role of a HFCV adoption as an enabling factor for a high integration of renewable energy and reducing emissions. Thus, as shown in Fig. 2 and we develop the following hypotheses:

H9: Policies associated with HFCVs affect SDG significantly.

H10: Adoption of HFCVs mediates between Policy implications and SDGs.

H11: Adoption of HFCVs has a positive influence on SDGs.

Research methodology

Quantitative information was gathered using the survey research technique to test the proposed hypotheses. The structural equation modelling (SEM) technique was applied to analyse how different variables affect the Indian public's adoption of HFCVs. Research hypotheses were developed, data sources and sampling strategies were selected, and a questionnaire was designed (considering model fitness) to meet the research objectives. Online questionnaires were circulated through individual mail identities and social-networking platforms like LinkedIn, and WhatsApp. This was done to achieve the maximum number of possible respondents throughout the country and to improve inclusivity. The survey was carried out between the months of April–June 2022. After initial scrutiny, 358 valid responses were carried forward for further analysis. With six predictor variables, two mediating variables and one dependent variable, the 358 valid responses are sufficient than the minimum required sample size of 146 as suggested by the G-power software analysis (Fig. 3).

The structured questionnaire was divided into two sections. Section A inquiries about respondents' socioeconomic characteristics, including gender, age group, region of residency, educational level, and monthly income. The sociodemographic characteristics of the sample under study are summarised in Table 1. Section B seeks to evaluate (a) respondent's intrinsic psychological values like motivation, attitude (intention to interact and knowledge sharing) towards HFCVs, (b) perceptions like risk perception and cost perception regarding HFCVs, (c) concerns like safety and infrastructure readiness related to HFCVs. Section C of the questionnaire ultimately focuses on variables like consumer's adoption intention towards HFCVs, the role of policy interventions and the fulfilment of SDGs. Table 2 displays the survey items (questions) used to assess each construct, refined through pilot testing. A five-point Likert scale that ranges from (1) “Strongly disagree” to (5) “Strongly agree” was used to measure the items.

Attitude may be defined as the attributes that generate a favourable or unfavourable opinion towards an innovative product [34]. A set of five items was put in the attitude construct. The items shown in Table 2 were designed to reflect a person's interest and involvement not only in its better adoption but also in its future development over the course of time. An important factor influencing the acceptance of innovative products is motivation. The motivation to seek love, esteem, and self-actualisation through associating with the group by impersonating people who intend to adopt a commodity [30]. This can be being well viewed as different from those who cannot adopt the commodity or through treating oneself by purchasing something different and improved [47]. Thus, a person's motivation, which was one of the independent variables, was tested using the four items listed in Table 2.

In our questionnaire, we have added questions on the cost of HFCV, which are often neglected by other research [35]. Since HFCV need extremely sophisticated technology, they will be sold at a premium price. According to studies, alternative fuel cars' purchase price and operating cost are essential in determining whether or not they will reach the desired market penetration [22]. For the acceptability of HFCV, it is apparent that the cost of acquisition and operation will be the determining considerations [62]. Before its commercial release for consumers, other dominating latent factors, such as safety concerns and infrastructural readiness, must also be examined. Consequently, this empirical research evaluates all such essential aspects that impact the adoption of HFCVs, eventually contributing to achieving the SDGs.

Measuring a consumer's desire to purchase an HFCV is an effective technique to gauge their response to their commitment to achieving SDGs and promoting the notion of sustainability in their everyday activities [14]. As a result, the role of HFCV adoption and its impact on SDGs were analysed using seven items that directly and indirectly reflect seven different goals (#7,9,11,12,13,14,15).

A favourable or unfavourable perception, which is impacted by cognitive characteristics, such as personal interest and knowledge, and affective predictors, such as image, emotion, and affect related to one's perspective, is a crucial element in adopting new technologies and goods [63]. Consequently, the perception of HFCV as independent factors was examined using two variables, risk, and cost, with a total of four questions for each variable. These questions were created to assess the cognitive context of statements such as: “I trust HFCV because it can provide for my best interest in mind, HFCVs has high service charge as compared to conventional vehicles”.

Given the link between the cost-effectiveness of new technologies and the infrastructure readiness for their adoption, trust in government policies maintained by regulators is also expected to influence perceptions of emerging innovations. As a result, four questions were used to assess consumers' perceptions regarding government policies. It was created to

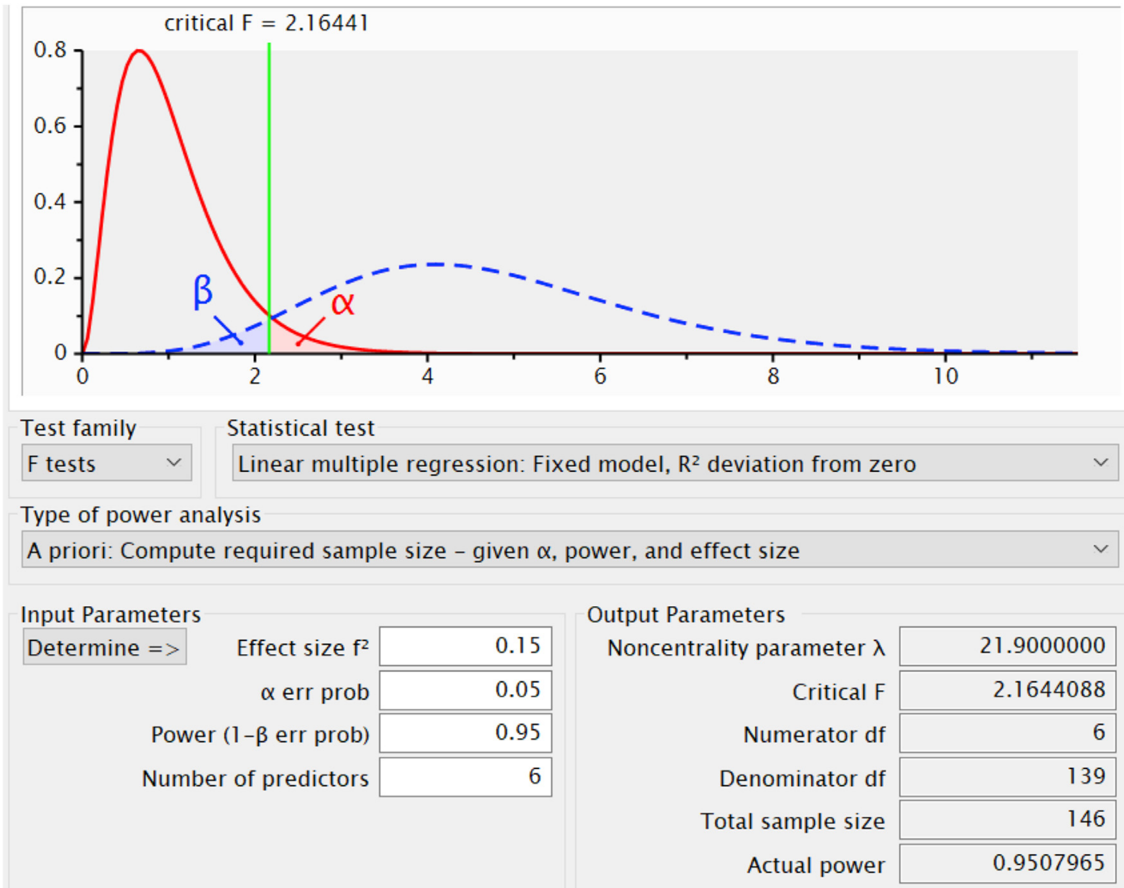

Fig. 3 – Estimation of minimum sample size by G-power test.

Table 1 – Profile of the sample respondents.

Variables	Description	N = 358	%
Gender	Male	247	69
	Female	111	31
Region	North-East	22	6.1
	Central	20	5.6
	South	44	12.3
	North	93	26
	West	19	5.3
	East	160	44.7
Age-group	18 to less than 28	239	66.8
	28 to less than 38	75	20.9
	38 to less than 48	21	5.9
	48 plus	23	6.4
Education level	Secondary school or lower	4	1.1
	Trade school certification/Diploma	2	0.6
	Graduate	237	66.2
	Postgraduate	69	19.3
	Doctorate degree/PhD	46	12.8
Occupation	Government Sector	55	15.4
	Private Sector	81	22.6
	Self-employed	9	2.5
	Student	202	56.4
	Other	11	3.1
Annual Income (in INR)	<500,000	223	62.3
	500,000–1000,000	71	19.8
	1000,000-1500,000	29	8.1
	>1,500,000	35	9.8

assess trust in the policymaking process and the policy's directionality and efficiency in reaching the SDGs timely.

Findings

Result analysis

Causal or structural equation modelling (SEM) facilitates the study of complex networks of variables and the evaluation of the consistency (reliability and validity) of the questionnaire item used to evaluate each model or construct. The structural equations that correspond to the SEM shown in Fig. 1 are as follows:

$$\begin{aligned}\text{Adoption of HFCV} = {} & \beta_{17}\ \text{Motivation} + \beta_{27}\ \text{Risk Perception} \\ & + \beta_{37}\ \text{Safety Concern} \\ & + \beta_{47}\ \text{Cost perception} \\ & + \beta_{57}\ \text{infrastructure readiness} \\ & + \beta_{67}\ \text{Attitude} + \beta_{87}\ \text{Policy implications} + \varepsilon_1\end{aligned}$$

$$\begin{aligned}\text{Policy Implications} = {} & \beta_{48}\ \text{Cost Perception} \\ & + \beta_{58}\ \text{Infrastructure Perception} + \varepsilon_2\end{aligned}$$

$$\begin{aligned}\text{Sustainable Development Goals} = {} & \beta_{79}\ \text{Policy Implications} \\ & + \beta_{89}\ \text{Adoption} + \varepsilon_3\end{aligned}$$

Table 2 – Summary of research constructs and items.

Constructs	Measures	Items
Attitude	ATT1	"I believe in interacting with the HFCV sellers about HFCVs."
	ATT2	"I prefer sharing knowledge about HFCVs among Indian consumers who have a friendly attitude."
	ATT3	"I feel more confident to involve in dialogue when HFCV sellers' employees take the initiative in dialogue."
	ATT4	"I will respond positively if HFCV sellers seek my suggestion to improve HFCVs."
	ATT5	"I will respond positively if HFCV sellers take the initiative to get my recommendations for innovation in its vehicles."
Risk perception	RSK1	"I am aware of the risk associated with HFCV"
	RSK2	"I believe that HFCV is a risk-free source of transportation"
	RSK3	"I trust HFCV because it can provide for my best interest in mind"
	RSK4	"I don't think I am at risk when using HFCV."
Motivation	MV1	"Neighbours' participation will motivate me to use HFCVs."
	MV2	"Important people to me feel that I should use HFCV soon."
	MV3	"People whom I adore think HFCV is desirable for me."
	MV4	"If I purchase HFCV, then people important to me would also buy it."
Safety concern	SFC1	"I feel worried while visiting hydrogen refuelling stations."
	SFC2	"Hydrogen fuel vehicles are prone to accidents."
	SFC3	"Hydrogen Fuel cell vehicles are unsafe."
	SFC4	"I will resist if a new hydrogen station is built near my house/office."
	SFC5	"There is an immediate need to establish codes, standards, and regulations concerning HFCV."
Cost perception	COS1	"HFCVs are expensive over conventional vehicles."
	COS2	"Hydrogen fuel has a high price as compared to conventional fuel."
	COS3	"HFCV has high service charges."
	COS4	"HFCV has a low maintenance cost per km travel."
Infrastructure readiness	INF1	"Inadequate hydrogen refuelling stations hinder the adoption of hydrogen fuel cell vehicles (HFCVs)."
	INF2	"The high cost of HFCV is a deterrent to their adoption."
	INF3	"Hydrogen refuelling station are insufficient."
	INF4	"The high price of hydrogen is a hurdle to HFCV adoption."
Policy	POL1	"Funding for hydrogen-related research and development should be increased."
	POL2	"Govt. should provide production-linked incentives to HFCV manufacturers."
	POL3	"Govt. should provide financial and tax incentives for HFCV buyers."
	POL4	"The hassle-free land allocation must be made available to set up refuelling stations at effective prices."
Adoption	ADP1	"I believe that innovation gives me more control over my daily life."
	ADP2	"I believe that the adoption of HFCV makes my life easier."
	ADP3	"I am enjoying figuring out how to use HFCV."
	ADP4	"I am willing to pay more to adopt an environmentally friendly HFCV."
SDG	SDG1	"HFCVs will support reliable and modern energy for all (SDG-7)."
	SDG2	"HFCVs will lead to sustainable industrialisation practices (SDG-9)."
	SDG3	"HFCVs will support access to sustainable transport for all (SDG-11).
	SDG4	"HFCV will promote the need for responsible consumption and production (SDG-12)."
	SDG5	"HFCVs are crucial for combating climate change and its impacts (SDG-13)."
	SDG6	"Using HFCV matches with the life below water goal requirement (SDG-14)."
	SDG7	"Using HFCV matches with life on land goal requirement (SDG-15)."

Here β_{ij} indicates "the path coefficients between the ith exogenous latent variable and the jth endogenous latent variable", and ε_3 signify "the error value associated with every endogenous latent variable".

After validating the research model, Partial Least Square (PLS) prediction using the software "Smart PLS 3.0" was used to test the null hypothesis. PLS prediction, a variance-based approach of SEM, helps explain variation in a statistical sense by calculating R^2 and the relevance of construct correlations as mentioned below:

$$\text{Coefficient of determination } (R^2) = \frac{\text{Sum of sqaure due to regression (SSR)}}{\text{Total Sum of sqaures (SST)}}$$

Here, SSR "measures how much the values of the estimated regression line deviate from the sample mean". SST is a "measure of the error involved in the estimation using the sample mean. For a perfect fit, the ratio must be equal to one".

PLS analysis is most suited for theory development in technological research, not as a confirming method but as a predictive method. Consequently, the PLS research is used to examine the "validity and reliability of the measurement scales" of the HFCV's intention to use and adopt models.

Research model validation

In the Smart-PLS analysis, the individual item dependability of the assessment model is determined by evaluating if the item loadings on their respective concept are more than 0.707%. Table 3 displays the item loadings on their respective structures. The highest loadings for each item are highlighted in bold font on their corresponding constructs. The majority of the survey questions reach the 0.707 acceptable reliability level, except the fourth item of the Cost perception COS 04, which displays a loading of 0.645. Namely, even though the level of item loading of COS 04 is lower than 0.707, the item loading of COS 04 is the largest one in the same column, obviously with an exception from COS 01,02 and 03. Consequently, item COS 04 is not highly suspected of being significantly unreliable; the question will be perpetuated in further analyses.

Fornell and Larcker [64] created a unique measure of internal consistency called composite reliability (CR) for PLS analysis that is comparable to Cronbach's alpha but is not affected by the number of indicators for a construct. Table 4 demonstrates CR and Cronbach's alpha. All the values of Cronbach's are above the acceptable limit of 0.70, which is recommended by Nunanally [65], their "corresponding CR is also higher than the acceptable level of 0.70". This suggests that each construct is sufficiently reliable and valid.

To assess the discriminant validity of a research model, the PLS analysis also calculates the average variance extracted (AVE), which reveals the average variance possessed by a construct and its variables. According to Fornell and Larcker [64], "a critical condition for the discriminant validity is that the AVE of a construct should be greater than the variance shared between the construct and other constructs in the model". Specifically, the diagonal components of the correlation matrix for the constructs listed in Table 4, which relate to the square root of the AVE, "should be considerably greater than the off-diagonal elements in the corresponding rows and columns" [66]. Table 4 displays a correlation matrix, the elements of which reveal that each item has sufficient discriminant validity.

Additionally, discriminant validity may be evaluated by studying any item with a greater loading on another construct than on its own construct. The component structure matrix given in Table 3, which excludes any item with larger cross-loadings on another construct than its loading on its corresponding construct, validates each variable's discriminant validity.

Research hypothesis validation

The model validation confirms that all the variables satisfy the reliability and discriminate validity test. A reliable and valid measurement model enables the effective assessment of complex networks of variables and the testing of hypotheses that establish relationships between the variables comprising the HFCV adoption model. Table 5 and Fig. 4 present the findings of the PLS analysis and the relationship based among the suggested hypotheses. The findings reveal that the paths are statistically significant, supporting the hypothesised relationships.

The R^2 value of each endogenous variable reflects the variance amount in the construct indicated by the research model, which can be inferred in a similar way as the R^2 found out from a multiple regression analysis. "In PLS path models, an R^2 value of 0.67 can be regarded as substantial; 0.33 and 0.19 can be interpreted as moderate and weak, respectively" [66]. While the values of R^2 as low as 0.25 are often regarded as useful in social sciences, all the R^2 values here are high above the acceptable criterion.

The PLS analysis was used to calculate the total effects, which consist of direct effects and indirect effects of antecedent constructs on consequent constructs; by these calculations, it can be supposed that, for SDG fulfilment, Policy implications (0.50) for promoting HFCV adoption is the stronger predictor, followed by the adoption of HFCV (0.36). Each direct path between the endogenous variable, in this case, policy implications, and intention to adopt HFCV towards the fulfilment of SDGs is statistically significant. The t-values for these are 8.66 ($p < 0.005$) and 6.70 ($p < 0.005$) respectively.

In the case of intention to adopt HFCV, motivation (0.29) is a stronger predictor variable, followed by attitude (combination of intention to interact and knowledge sharing) (0.36). The t-values for these are 5.6 and 4.9, respectively. Similarly, for Policy implication, infrastructure perception (0.53) is a stronger predictor with a t-value of 8.3 ($p < 0.005$).

Discussion

HFCVs are recognised as clean vehicles because they reduce emissions of dangerous particles and gases, such as carbon

Table 3 – Cross loading and VIF scores.

	ADP	ATT	COS	INF	MV	POL	RSK	SDG	SFC	VIF scores
ADP1	**0.792**	0.584	0.495	0.516	0.502	0.572	0.447	0.585	0.382	**1.698**
ADP2	**0.874**	0.572	0.414	0.352	0.600	0.440	0.612	0.563	0.346	**2.342**
ADP3	**0.858**	0.590	0.454	0.408	0.591	0.448	0.579	0.527	0.358	**2.207**
ADP4	**0.801**	0.546	0.327	0.347	0.589	0.414	0.523	0.488	0.316	**1.829**
ATT1	0.518	**0.732**	0.380	0.429	0.426	0.470	0.419	0.481	0.225	**1.625**
ATT2	0.557	**0.837**	0.489	0.497	0.452	0.536	0.452	0.525	0.317	**2.226**
ATT3	0.602	**0.843**	0.397	0.446	0.520	0.520	0.485	0.509	0.254	**2.314**
ATT4	0.594	**0.864**	0.387	0.460	0.456	0.564	0.399	0.507	0.243	**2.930**
ATT5	0.580	**0.864**	0.418	0.496	0.458	0.553	0.362	0.526	0.285	**2.756**
COS1	0.397	0.449	**0.839**	0.613	0.302	0.499	0.388	0.451	0.357	**1.911**
COS2	0.325	0.340	**0.818**	0.520	0.247	0.356	0.325	0.351	0.341	**2.085**
COS3	0.387	0.352	**0.830**	0.505	0.286	0.363	0.422	0.392	0.452	**2.044**
COS4	0.491	0.421	**0.688**	0.459	0.439	0.338	0.556	0.479	0.408	**1.243**
INF1	0.435	0.481	0.547	**0.855**	0.360	0.542	0.355	0.564	0.420	**2.207**
INF2	0.468	0.499	0.604	**0.875**	0.351	0.583	0.373	0.574	0.417	**2.348**
INF3	0.363	0.498	0.565	**0.868**	0.303	0.526	0.280	0.514	0.368	**2.490**
INF4	0.407	0.453	0.569	**0.845**	0.348	0.516	0.291	0.516	0.406	**2.205**
MV1	0.559	0.460	0.343	0.344	**0.820**	0.381	0.484	0.492	0.272	**1.897**
MV2	0.588	0.495	0.360	0.315	**0.866**	0.373	0.517	0.435	0.229	**2.438**
MV3	0.588	0.481	0.356	0.328	**0.873**	0.299	0.571	0.418	0.248	**2.521**
MV4	0.584	0.454	0.317	0.355	**0.824**	0.350	0.555	0.428	0.263	**1.899**
POL1	0.491	0.561	0.399	0.570	0.331	**0.899**	0.311	0.631	0.351	3.089
POL2	0.523	0.577	0.478	0.564	0.378	**0.915**	0.352	0.667	0.335	3.565
POL3	0.526	0.607	0.470	0.595	0.392	**0.918**	0.334	0.648	0.316	3.602
POL4	0.491	0.557	0.443	0.545	0.394	**0.874**	0.334	0.623	0.384	**2.573**
RSK1	0.473	0.387	0.475	0.329	0.373	0.271	**0.759**	0.350	0.325	**1.622**
RSK2	0.558	0.432	0.446	0.266	0.560	0.276	**0.881**	0.451	0.277	**2.597**
RSK3	0.640	0.530	0.478	0.405	0.600	0.402	**0.892**	0.550	0.317	**2.470**
RSK4	0.513	0.360	0.430	0.277	0.576	0.285	**0.849**	0.454	0.307	**2.311**
SDG1	0.539	0.565	0.485	0.562	0.465	0.612	0.523	**0.843**	0.398	**2.759**
SDG2	0.615	0.598	0.485	0.563	0.459	0.717	0.456	**0.875**	0.375	3.355
SDG3	0.587	0.563	0.425	0.512	0.459	0.632	0.460	**0.867**	0.381	3.170
SDG4	0.592	0.561	0.456	0.556	0.471	0.647	0.432	**0.890**	0.401	3.628
SDG5	0.519	0.468	0.446	0.569	0.408	0.583	0.435	**0.841**	0.390	**2.696**
SDG6	0.534	0.425	0.450	0.488	0.441	0.505	0.462	**0.835**	0.426	4.030
SDG7	0.503	0.480	0.455	0.532	0.433	0.545	0.480	**0.846**	0.412	4.032
SFC1	0.376	0.244	0.439	0.369	0.286	0.285	0.370	0.378	**0.843**	**2.169**
SFC2	0.293	0.172	0.367	0.337	0.148	0.226	0.292	0.346	**0.816**	**2.439**
SFC3	0.293	0.151	0.327	0.307	0.220	0.218	0.265	0.297	**0.846**	**2.727**
SFC4	0.295	0.212	0.323	0.228	0.235	0.210	0.263	0.268	**0.776**	**1.881**
SFC5	0.380	0.429	0.449	0.554	0.267	0.515	0.224	0.491	**0.682**	**1.284**

Table 4 – Internal consistencies and correlation of constructs.

	Internal Consistencies		AVE	Correlation of constructs (Fornell-Larcker Criterion)								
	Cronbach's Alpha	Composite Reliability		ADP	ATT	COS	INF	MV	POL	RSK	SDG	SFC
ADP	0.851	0.900	0.692	**0.832**								
ATT	0.931	0.916	0.688	0.689	**0.829**							
COS	0.805	0.873	0.635	0.510	0.499	**0.796**						
INF	0.884	0.920	0.742	0.488	0.561	0.664	**0.861**					
MV	0.867	0.910	0.716	0.686	0.559	0.407	0.396	**0.846**				
POL	0.923	0.946	0.814	0.564	0.638	0.497	0.630	0.414	**0.902**			
RSK	0.868	0.910	0.717	0.650	0.510	0.539	0.380	0.629	0.369	**0.847**		
SDG	0.940	0.951	0.735	0.651	0.615	0.533	0.631	0.523	0.712	0.540	**0.857**	
SFC	0.853	0.895	0.632	0.422	0.319	0.491	0.469	0.299	0.383	0.360	0.462	**0.795**

monoxide. Moreover, as India aims to fulfil its INDC obligations by 2030, the concept of emission reduction, climate change and greater renewable adoption are becoming familiar to Indians.

However, public distrust about HFCVs induced by a lack of adequate understanding and infrastructure regarding these vehicles might hinder their commercial success. To overcome these scepticisms, it is crucial to find other elements that

Table 5 – Test of hypothesis.

Hypothesis	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values	Supported
H1: Motivation -> Adoption	0.293	0.297	0.051	5.777	0.000	Yes
H2: Risk Perception -> Adoption	0.226	0.223	0.051	4.446	0.000	Yes
H3: Safety concern -> Adoption	0.111	0.113	0.039	2.868	0.004	Yes
H4: Attitude -> Adoption	0.293	0.294	0.056	5.220	0.000	Yes
H5: Cost Perception -> Adoption	0.019	0.017	0.053	0.361	0.719	No
H6: Infrastructure readiness -> Adoption	−0.030	−0.030	0.061	0.495	0.621	No
H7: Cost Perception -> Policy	0.139	0.142	0.060	2.308	0.021	Yes
H8: Infrastructure readiness -> Policy	0.538	0.534	0.061	8.816	0.000	Yes
H9: Policy -> SDG	0.506	0.500	0.059	8.637	0.000	Yes
H10: Policy -> Adoption	0.139	0.137	0.058	2.404	0.017	Yes
H11: Adoption -> SDG	0.366	0.369	0.056	6.474	0.000	Yes

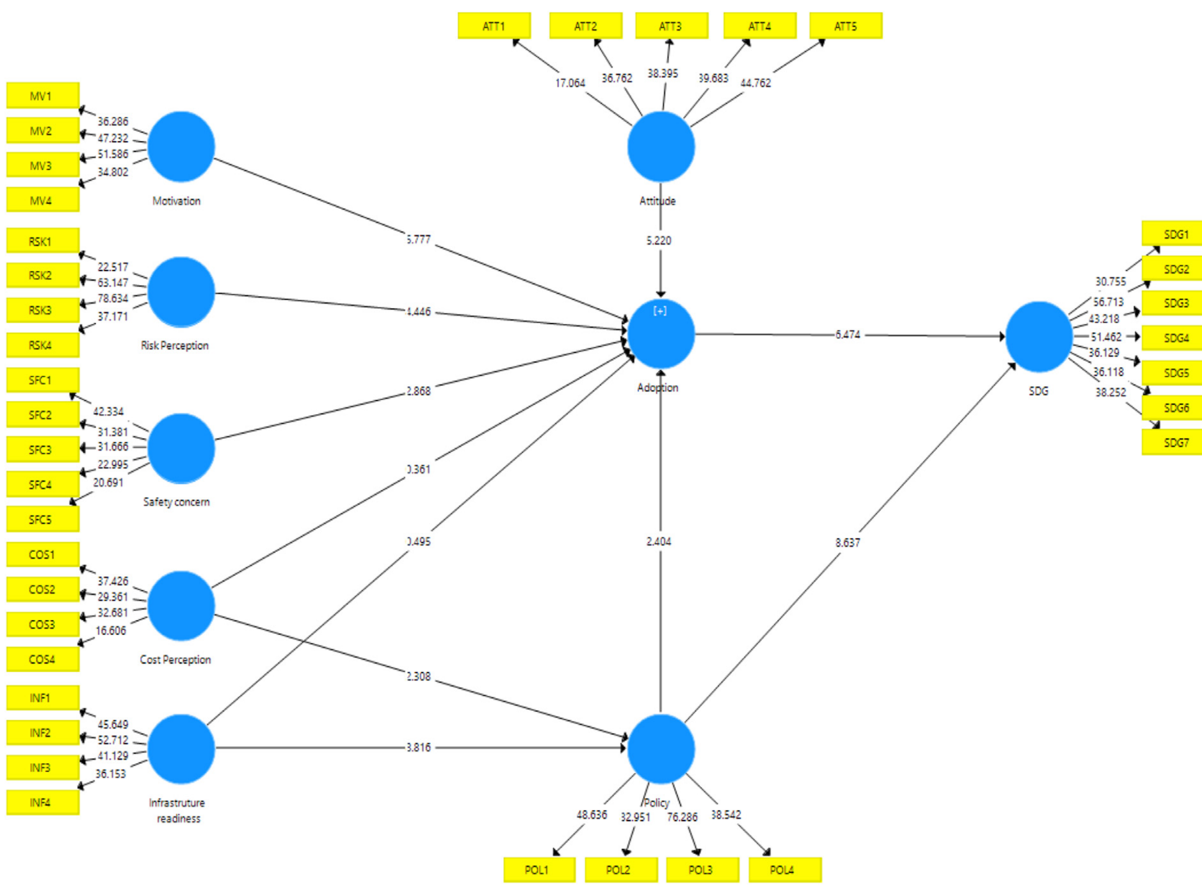

Fig. 4 – Research model analysis results from PLS analysis.

influence the public's adoption of HFCVs. According to the findings of this empirical investigation, consumer motivation is a significant element influencing their willingness to adopt. A customer's desire to be seen as someone who cares about the environment may prompt them to try an HFCV. This result is similar to that of prior research [35], which demonstrated that the desire to attain social status by emulating others' behaviour is more significant for early adopters and less significant for late adopters. Thus, fostering the desire to be perceived as an environmentally conscious person may be an effective strategy for driving the spread of HFCV in future markets.

The notion of an HFCV's safety and dependability might influence its adoption intent. This study is consistent with past studies [5,7,10], indicating that substantial potential demand for low-emission cars may be attained when they compete with conventional automobiles in terms of perceived safety. Although increasing an individual's psychological drive to be acknowledged as an ecologically concerned individual is a crucial marketing approach, it would not attract someone who is not concerned about environmental issues. Delivering safety justifications would be effective for reaching individuals who passively disregard or oppose environmentalism.

In addition, the cost of acquisition and operating expenses substantially influence the consumer adoption of HFCVs. Consequently, to increase consumer adoption of HFCV, it is possible to simultaneously stimulate the client's psychological drive and impression of performance parameters and manage its cost. Similarly, for the cost reduction of hydrogen fuel cells and the high price of the vehicles powered by them, the Indian government need to plan aggressive research, development and demonstration projects and execute them in a timely and efficient manner. Recently the Indian government has put forward its "Green Hydrogen Policy" with an aim to reduce the production and storage cost of green hydrogen [67]. Some of the key measures in this policy are "(a) waiving of inter-state transmission charges for green hydrogen producers, (b) facilitating land allotment process for setting up hydrogen production and storage plants, (c) allowing to set up bunkers near seaports for storing of green ammonia meant for export and usage in the shipping industry, (d) establishing a single portal for permission and statutory clearances related to green hydrogen applications". Similar cost-friendly schemes need to be rolled out for vehicle manufacturers and hydrogen refuelling station establisher/operators to benefit the overall HFCV-related ecosystem.

In addition, the MNRE must establish a hydrogen subsidising plan to assist up to 80% of the cost of purchasing and installing hydrogen fuel cells to power and heat residential properties. Such initiatives have been effective in Asian nations such as South Korea and Japan. Expanding the subsidy programme to include hydrogen fuel cells placed in automobiles will help increase their market penetration. Meanwhile, global automobile manufacturers like Toyota and Hyundai have rolled out their HFCV models like Toyota Mirai and Hyundai Nexo, respectively, in India. Indian manufacturers like TATA motors are cooperating with the Indian government as the main contractor in public-oriented projects like developing Hydrogen fuel cell buses.

Rapid dissemination of the SDG agenda necessitates a comprehensive evaluation of the impact of the policy on individual adoption intent. The findings of this empirical research illustrate that the direct path between policy implications and SDGs is statistically significant, with a t value of 8.63 (Table 5). As the statistical outcome of the PLS analysis enables the assessment of the cause-and-effect link between these two variables, it is feasible to draw judgments about the impact of policy implications on SDG achievement. The more consumers believe that public opinion was appropriately considered while formulating the policy, the more they learn about the policy in detail and see the change in general life that the policy wants to impose. Also, they assume that a fair assessment of the policy has been made, and they have faith that the policy will be implemented efficiently and effectively until the SDGs are achieved. Thus, it inculcates a feeling of self-belongingness in their environment and makes them more involved in fulfilling the SDGs. In the long run, such behaviour makes them adopt HFCV as a part of the environmentally sensible consumer and promotes good word of mouth in their social circles.

For manufacturers, it might be crucial for the government to provide positive market signals indicating that HFCVs would be pushed. It may assist businesses in assuming the risk associated with participating in this uncertain industry. When evaluating if a social marketing strategy can be employed to signalling the advertising of HFCVs, further study is required to produce more effective messaging and engagement among the stakeholders. This empirical study's findings may be utilised to create messages that increase consumer adoption of HFCVs.

Policy implications

A concerted effort toward clean transportation is essential to assist India in achieving its SDG targets, and HFCVs provide a glimmering glimpse of hope in this regard. They cut tailpipe pollution, minimise reliance on fossil fuels, promote community well-being, ensure energy security, and enhance job and skill development. Combining fuel cell-based mobility with sustainable energy goals will contribute to the decarbonisation of the transportation sector. If fuelled by cleaner fuels, HFCVs may improve the proportion of renewable sources in the energy mix (SDG Target 7.2) and combat air pollution and its associated health consequences (SDG Target 3.9). The connections do not end here; HFCV production will also contribute to job creation, entrepreneurship, and the formalisation and expansion of Micro, Small, and Medium-sized Enterprises (SDG Target 8.3). A strong push toward clean transportation is essential to assist India in achieving its SDG targets, and HFCVs provide renewed hope in this regard. They cut tailpipe emissions, reduce reliance on fossil fuels, promote community health, protect energy security, and enhance job and skill development. It may encourage inclusive and sustainable industrialisation (SDG Target 9.2) and enable the incorporation of small-scale industrial businesses into the supply chain and economies (SDG Target 9.3). Fuel cells and electrolysers used in HFCVs may be mined for valuable metals at the termination, contributing to sustainable waste management and effective use of natural resources (SDG Target 12.2). Recycling and appropriate disposal of these components may also significantly minimise trash output (SDG Target 12.5) compared to conventional automobiles' scrap materials.

HFCV can become cost-competitive with conventional vehicles and EVs only if the government brings down the cost of green hydrogen to approximately $1/Kg [12]. To achieve economies of scale, the Indian government plans to waive off interstate transportation charges and permit a well-balanced (30 days) banking period for green hydrogen near seaports. Despite these steps, there remains room for more intervention on this front. The SDGs may serve as a guide once again, establishing ideals that might motivate policy. Target 7.1 of the SDG should serve as the normative foundation for all HFCV-related decision-making. By 2030, the Indian government must ensure access to safe, inexpensive, equitable, and sustainable modes of transport (SDG Target 11.2) by integrating HFCVs into all vehicle categories, primarily buses, for emission-free public transportation. There is a high need to facilitate hassle-free and suitable lands for hydrogen station establishers and vehicle manufacturers so that more refuelling stations could be set up across the country. When it comes to ensuring sustainable modes of transportation, the government must design appropriate tax umbrellas and financial benefits for initial HFCV buyers. The interest rate charged on loans to peruse HFCV must not be more than 3–4%, and other associated charges like road tax, toll tax and registration cost must be waived off for the next 15–20 years.

The industrial sector needs to be pushed to improve infrastructure and use environmentally promising technologies (SDG Target 9.4). The Indian government proposes to set up green hydrogen/green ammonia in manufacturing zones. However, we suggest that these zones be designed strategically to result in well-balanced supply-chain management and effective hydrogen ecosystem development. The hydrogen ecosystem here refers to the process from green hydrogen manufacturing to its infusion in HFCVs. Renewable rich and industrially balanced states like Gujarat, Karnataka, Maharashtra and Tamil Nadu must be the first set of choices for the Indian government to set up green hydrogen manufacturing zones.

Given its ever-growing population and economy, India must aim to be a global exporter of hydrogen. The country must get above the bare minimum mindset of ensuring safe and sustainable energy access to its citizens in the transport sector. One way to do this is by adopting HFCVs for freight transportation and shipping industries by 2040. It will thus increase technology competence (SDG Target 9.5) to disrupt current value channels and position India as a hub for HFCV manufacture and export.

The SDGs are not merely ideas to adhere to but also pledges to our upcoming generations for a stable and comfortable future. HFCVs powered by renewable sources may be a silver bullet for achieving various SDGs while remaining consistent with current measures specified for the country's cleaner economic expansion.

Conclusion

This empirical research suggests that mass adoption of HFCVs is the ultimate pathway for attaining a clean and affordable energy supply (SDG 7) in the long run and for decarbonisation in industrial processes (SDG 11). The ability to effectively store hydrogen and its successful application in HFCVs constitutes a pivotal moment for higher renewable integration with favourable implications for various SDGs through lower carbon emissions. However, the Indian hydrogen economy currently requires an adequate strategy to establish a level playing ground that investigates the current challenges as identified in this research, (a) cost, (b) infrastructure, and (c) risk perception. Along with the challenges, this study also identifies valuable prospects of adopting HFCVs in India and examines how the country may embrace alternative greener technologies, such as HFCVs, to fulfil its SDGs. Viable implementation strategies focusing on demand regulation and supply-side policies must be pursued through low-carbon pathways and other sustainable initiatives. First, both centralised and decentralised green hydrogen models require significant trade-offs regarding cost-effectiveness, storage and transit demands, and energy literacy. Government and other stakeholders must examine which framework addresses the trade-offs in the most favourable approaches to achieving SDGs. Second, picking the model would need a complete examination of how green hydrogen influences, indirectly, not just SDG7,9 and 11 but also other SDGs. If regional stability, capital backing, and innovation aren't shared evenly, developing countries with a lot of renewable potentials may not be able to grow their economies effectively and efficiently.

In conclusion, the current cost forecasts for environmentally friendly hydrogen should not inspire excessive hope. Considerable uncertainty on the rate at which the planet is nearing climatic thresholds, and the macroeconomic ramifications of the Covid-19 outbreak makes it impossible to create rational forecasts on the potential capital and operational cost of HFCVs. This research explores the Indian context as an empirical study; nevertheless, similar policy recommendations may be useful in other developing nations where vehicle emissions are substantial, and the need for alternative energy sources is a critical concern. There are numerous scopes that future studies can explore through the limitations of this research. In this study, we have employed only seven SDGs out of seventeen; thus, future studies can attempt to establish a link between other SDGs and hydrogen-based transportation. In future, this study's research model and conceptualisation can be used to associate with other Hydrogen Energy Technology appliances rather than only being limited to HFCVs. Also, in this research, we have investigated the consumer aspects of adopting HFCVs; future studies can build upon the industry readiness to adopt HFCVs, as this remains an unexplored sector.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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