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Logistics Firms' Readiness and Strategic Opportunities in the Green Hydrogen Supply Chain: An Empirical Investigation

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Abstract- ***The concept of green hydrogen has recently gathered much traction due to its potential for application in hard-to-abate industries where conventional decarbonization solutions have proven insufficient. The primary question guiding this research was formulated out of practical curiosity: as the hydrogen supply chain starts to take shape, can logistics companies become participants? Based on the data obtained via the survey of 51 specialists working in logistics, energy, and manufacturing in India, the answer to this question is negative, or at least so far. This study employs a structured survey conducted among 51 representatives of logistics, transport, energy, and infrastructure sectors in India. The methods include chi-square test, Pareto analysis, Fishbone method, and Readiness Gap assessment, along with thematic analysis of free-response answers. All findings point to the fact that although the sector recognizes its potential, it lacks the necessary operational capabilities. Despite the overwhelming percentage (88.2%) of respondents who were aware of green hydrogen and expected to create new opportunities in hydrogen-powered transport (98%), their readiness for logistics operations involving this energy source was estimated to be slight or negligible by 96.1%. The three major factors preventing this were capital-intensive investments (72.5%), rigorous safety regulations (70.6%), and lack of infrastructure (60.8%), accounting together for 82.6% of all mentions. Moreover, according to chi-square analysis, industry experience has a significant correlation with knowledge of hydrogen supply chain (p = 0.005). The report calls for a strategic development process, which includes the development of skills in the workforce, infrastructure, digital integration, and collaborative efforts across various sectors. For logistics planners, energy organizations, and policymakers working towards implementing decarbonization, the identified gap constitutes a matter that needs to be addressed before hydrogen market maturity.***

Keywords: Green Hydrogen; Logistics Readiness; Supply Chain Management; Hydrogen Transportation; Operational Efficiency; Energy Transition; Strategic Opportunities

I. INTRODUCTION

Transport and logistics form a vital component of the supply chain, facilitating the process by which goods move from raw materials through processing stages up to final production, both within and between countries. However, as the economy grows more sophisticated, and with increasing complexity in international business transactions, it becomes necessary for the logistics sector to expand its activities beyond simple transport in order to respond to changes in energy paradigms. One significant innovation that has recently gained prominence as part of global supply chains includes the use of hydrogen energy as a fuel. Hydrogen is produced electrochemically, and if powered by renewable energy, does not produce any greenhouse gases as by-products. Its ability to be used effectively in the energy-intensive industry such as in the manufacturing of steel, petroleum, and other transportation purposes makes it a viable alternative.

Countries such as India, Germany, Australia, and the EU have started developing projects with hydrogen energy, along with investments to back them up. With the growing importance of hydrogen consumption, certain logistic factors also come into play. These include the transportation of high-pressure and cryogenic storage vessels, route planning for hazardous cargo, and coordinating multimodal connections between production facilities

and end-use locations. Therefore, the field of logistics will be able to play an instrumental role in providing logistics of hydrogen energy supplies. In order to examine this issue, the research conducted a survey of 51 professionals from the fields of logistics, transport, energy, and infrastructure in India in regard to their attitudes about hydrogen supply chains. This includes assessment of knowledge, readiness, opportunities, and challenges related to hydrogen supply chains.

This research examines attitudes towards hydrogen as well as future prospects of logistics. It is crucial to know such perspectives in order to prepare enterprises to the upcoming shifts. Green hydrogen is one of the key elements that has the potential to bring revolutionary changes in logistics, thus creating the need for preparing for these changes.

II. NEED FOR THE STUDY

Logistics operations have been subjected to transformation because of sustainability considerations, policies promoting clean energy, and rapid development of alternative fuel systems. The use of green hydrogen as an energy vector and its importance for industrial supply chains have recently received significant interest; yet, very little is known about how prepared the logistics sector is to participate in hydrogen business activities.

It is easy to understand why such research is required. Hydrogen logistics is much more than just another version of freight cryogenic operations, high pressure vessels transportation, and compliance with regulations in regard to hazmat. Early recognizers will acquire a competitive advantage, but those who fail to recognize that risk being left behind when all other companies will already dominate the market space. The majority of research conducted in the area was dedicated to issues related to economic considerations and policy making, but not transportation and logistics of hydrogen (Gorji, 2023). This means that practitioners have limited information needed to make important managerial decisions regarding hydrogen logistics.

The proposed research aims to fill this gap and identify the existing state of affairs in regard to logistics operations associated with hydrogen transport.

III. SCOPE OF THE STUDY

In its scope, this research will focus on the logistics and transport component of the green hydrogen supply chain, paying special attention to road transport, the factors affecting the effectiveness of logistics operations, and logistics companies' positioning related to new hydrogen-related activities. At the same time, this research consciously neglects engineering, chemistry, and production economy aspects concerning green hydrogen, and the discussion is confined solely to issues of supply chains and logistics.

Issues included in the scope of this research are the following: logistics operational efficiency in today's world, the level of knowledge and understanding about hydrogen supply chains held by logistics professionals, barriers to implementation, expected logistics services, and potential strategic opportunities. Hydrogen technologies, electrolysers, and energy policies, which do not fall into the scope of this study, will be mentioned only as they contribute to logistics needs. In terms of geographic scope, the study follows the characteristics of the respondent population that includes mainly people who work in logistics, energy, and manufacturing industries, primarily in India.

IV. OBJECTIVES OF THE STUDY

This research analyses the preparedness of logistics companies to participate in the green hydrogen supply chain. The study identifies specific objectives related to this main goal. Firstly, it describes the functioning and performance of logistics companies as a basis for understanding the current state of affairs. Secondly, it explores the degree of familiarity and involvement of respondents in relation to hydrogen supply chains. The main questions the research attempts to answer are whether respondents find their companies prepared for such activity and what prevents them from being prepared. The research also attempts to identify the prerequisites for

successful integration into hydrogen supply chains. Furthermore, the study analyses the possible impact of decision support and routing tools on the preparedness level. Lastly, conclusions drawn from the research will help to formulate recommendations for logistics companies and policymakers. The study will analyse the relationship between logistics companies and the green hydrogen supply chain.

V. REVIEW OF LITERATURE

The academic literature on green hydrogen has expanded considerably in recent years, though it remains predominantly concentrated on production technologies, environmental performance, and policy frameworks, with comparatively limited engagement with the logistics and transportation dimensions.

As far back as 2019, the IEA signalled that hydrogen's commercial viability would depend not only on how cheaply it could be produced but on whether distribution infrastructure could keep pace. The agency's landmark assessment explicitly named logistics and transportation as underdeveloped areas one of the earliest acknowledgements in a major policy document that the supply chain problem was at least as significant as the production problem (IEA, 2019).

IRENA's 2020 cost analysis offered a more cautious note. While falling electrolyser prices were expected to make green hydrogen increasingly affordable over the following decade, the report pointed to a structural mismatch that cost reductions alone would not fix: production capacity and logistics networks would need to be built in parallel rather than in sequence, since scaling one without the other would simply shift the bottleneck (IRENA, 2020). This coordination problem has received relatively little follow-up attention in the literature.

Gorji's (2023) supply chain analysis is one of the more practically useful contributions to the operational literature. Rather than treating hydrogen transport as a single problem, the study unpacked the trade-offs specific to each available mode pipeline, road, and sea freight and showed why no single solution dominates across all cost, safety, and distance combinations. For markets like India, where distance between production sites and industrial demand centres varies enormously, these trade-offs carry real planning implications.

Jayachandran et al. (2024) highlighted that getting green hydrogen to industrial users at an affordable cost hinge heavily on how well the distribution infrastructure is developed. This challenge is especially pressing in geographically spread-out markets like India, where the distance between hydrogen production sites and major industrial hubs adds significant logistical and economic pressure.

Agarwal (2022) found that the hydrogen economy continues to stall not because of a single barrier but because of three mutually reinforcing ones — elevated production costs, immature logistics infrastructure, and a demand base still too thin to justify large capital commitment. Solving anyone without the others simply moves the constraint.

Humphries (2022) addressed the intersection of logistics analytics and sustainable energy, investigating fuel efficiency in freight operations and the deployment of solar hydrogen systems in logistics contexts. The study demonstrated that data driven route optimisation and fleet management are foundational capabilities that must underpin any transition toward cleaner logistics operations, including those supporting hydrogen supply chains.

What this literature collectively points to is that moving hydrogen is not a secondary problem it is one of the central problems. What it does not address is whether logistics firms in markets like India are in any real position to do that moving. That gap is what this study works from.

VI. RESEARCH METHODOLOGY

To answer the main question, i.e., the level of preparedness and the potential opportunities identified by logistics professionals, a structured survey methodology seemed best suited. A structured survey consisted of 21 questions which were grouped into five themes as follows: respondents' profile, transportation processes, knowledge on green hydrogen, logistics involved in the hydrogen supply chain, and possible opportunities. The survey

questions were posted on Google Forms for data collection.

For this study, the target audience consists of logistics and transportation specialists, experts in supply chains management, energy and infrastructure managers, and executives in the manufacturing sector. A convenience sampling method was used. Probability sampling was impractical given that the population of Indian logistics professionals with meaningful hydrogen exposure is too small and too dispersed to enumerate making purposive convenience sampling the only viable approach. There are 51 responses that can be considered analysable. The nature of the sample, where 76.5% respondents are in management/leadership positions and the same percentage of professionals have more than five years of experience, adds credibility to this study.

Percentage analysis and tabulation were used in the descriptive analysis of data while chi-square analysis was done in order to establish the relationships between categorical variables using 5% level of significance. For establishing root cause analysis, the Fishbone (or Ishikawa) Analysis was adopted while the Pareto Analysis method helped in identifying logistics obstacles. The Readiness Gap Analysis technique was adopted in comparing opportunity realization and readiness while the Opportunity-Readiness matrix method was used in categorizing the logistic services according to attractiveness and readiness. Thematic Analysis was conducted for the open-ended data collected.

VII. ANALYSIS AND INTERPRETATION

7.1 Respondent Profile and Operational Context

The majority of respondents came from an operational background: 52.9% worked as Operations Executives, while 21.6% had Logistics Manager positions. The rest of the sample comprised of individuals who took Supply Chain Manager, Transportation Coordinator, or any other positions. As far as industries are concerned, 52.9% represented Energy and Infrastructure, while 29.4% belonged to Logistics and Transportation and 17.6% to Manufacturing industries. This proportion perfectly matches the study focusing on energy transition logistics.

Road transportation was identified as the predominant method of transporting goods, with 86.3% of respondents using roads exclusively and 13.7% utilizing multimodal transport. Route optimization was found out to be the primary variable that determined efficiency of operations (51%), while fleet management followed second (29.4%) and fuel costs were third (17.6%). Route optimization was regarded as crucial by 96.1% of respondents (Very Important/Important).

7.2 Digital Adoption and Operational Challenges

The digitalization level is high, since 76.5% of the respondents have GPS tracking/TMS already implemented in their business operations, and 21.6% will implement it. This digital environment can serve as a platform for ensuring real-time monitoring and compliance with regulations associated with hydrogen logistics. The most critical problems encountered during operation are related to infrastructure (52.9%), price changes of fuel (51%), traffic jams (51%), and the lack of drivers (47.1%).

7.3 Green Hydrogen Awareness and Supply Chain Familiarity

A considerable number of 88.2% of those surveyed were knowledgeable about green hydrogen being a new form of clean energy, while 94.1% believed that hydrogen would play a crucial part in future energy and transportation systems. However, when it came to the operational knowledge of hydrogen supply chains, there was a much smaller percentage of people who were well-informed. Only 7.8% of participants reported being highly knowledgeable about hydrogen supply chains, while 49% said they were somewhat knowledgeable, and 39.2% said they were slightly knowledgeable. Green hydrogen and the idea that it would be important were not enough to know how to transport it efficiently and effectively.

Table 1: Awareness vs. Preparedness – Key Indicators

Indicator	Positive Response	Interpretation
Awareness of green hydrogen	88.2%	High general awareness

Indicator	Positive Response	Interpretation
Belief hydrogen will be significant in future systems	94.1%	Strong strategic confidence
Perceived logistics opportunities in hydrogen transport	82.4%	Clear opportunity recognition
Hydrogen supply chains to create new business	98.0%	Near unanimous optimism
Logistics firms moderately prepared	3.9%	Critically low readiness
Firms slightly or not prepared	96.1%	Major readiness gap confirmed

7.4 Logistics Requirements and Perceived Opportunities

The movement of hydrogen storage tanks (66.7%) and the distribution logistics management (66.7%) ranked highest in terms of their logistics tasks in hydrogen logistics networks. Specialized cargo transportation (60.8%), infrastructure logistics (47.1%), and industrial equipment transportation (31.4%) followed respectively. Concerning services, cryogenic tank transportation (39.2%) and heavy equipment transportation (35.3%) were seen as the most essential services for hydrogen infrastructure development projects.

A large majority (82.4%) of the respondents indicated that logistics organizations have a valid presence in hydrogen-based transportation, and 98% agreed that hydrogen logistics networks will create new opportunities in transport. Additionally, all 98% of the respondents forecasted an increased energy-logistics partnership, and none disagreed with this.

7.5 Readiness Gap and Barriers

However, the readiness findings were quite telling. First, no one ranked the logistics companies as "Very Ready." Second, only 3.9% of participants viewed the firms as being "Moderately Ready." However, 60.8% found that the companies were "Slightly Ready," while 35.3% considered the logistics firms to be "Not Ready." In total, 96.1% rated the companies poorly.

Table 2: Pareto Analysis of Barriers to Hydrogen Logistics Participation

Rank	Barrier	Selections	% of Respondents	Cumulative Share
1	High investment requirements	37	72.5%	29.4%
2	Safety regulations	36	70.6%	58.0%
3	Infrastructure limitations	31	60.8%	82.6%
4	Lack of technical knowledge	22	43.1%	100.0%

As shown by the Pareto analysis, the major three barriers—funding, safety laws, and infrastructure issues—account for 82.6% of all barrier responses. The barriers are monetary, legal, and infrastructural, which means that logistics preparedness is beyond the scope of any campaign or process improvement effort. These barriers can only be overcome by extensive financial planning, active regulation engagement, and simultaneous creation of infrastructure together with manufacturing capabilities.

7.6 Chi-square Analysis

Four chi-square tests were conducted to examine associations between key study variables. Significant findings are summarised below.

Table 3: Chi-square Test Results Summary

Test	Variables	Chi-square	p-value	Outcome
Test 1	Experience & H_2 supply chain	8.058	0.005*	Significant – H_0 rejected

Test	Variables	Chi-square	p-value	Outcome
	familiarity			
Test 2	H_2 familiarity & preparedness	0.019	0.889	Not significant – H_0 accepted
Test 3	Sector & future participation	1.187	0.276	Not significant – H_0 accepted
Test 4	Digital tool usage & preparedness	0.026	0.871	Not significant – H_0 accepted

Test 1 proves that those who have more than five years of experience in the industry have higher knowledge levels of the hydrogen value chain ($p = 0.005$). Therefore, hands-on experience can be considered an important predictor for theoretical knowledge about hydrogen. On the other hand, the results of Tests 2, 3, and 4 prove that neither awareness nor digitalization skills or industry sector membership play any role in defining whether or not a company is ready for hydrogen adoption. In other words, even if one has extensive experience in logistics and access to digital tools, it does not guarantee readiness for hydrogen adoption.

7.7 Opportunity–Readiness Matrix

Upon analysing the juxtaposition of service areas, a pattern is evident where there is a combination of a strategically attractive area alongside poor readiness at present, in most instances. In terms of hydrogen transport services, cold tank logistics, logistics for distribution, and energy-logistics interaction, these four segments hold significant strategic importance but are poorly ready in terms of the present day. The heavy equipment transport and infrastructure logistics segments have better opportunities due to the presence of logistics companies who currently offer transportation for industrial goods and could build upon that competency.

VIII. FINDINGS

Based on the collected data, the following main results of the analysis have been obtained:

Firstly, there is a noticeable mismatch between the level of awareness of green hydrogen and the knowledge about it as an instrument of logistics activities. According to the results, 88.2% of the respondents were aware of green hydrogen, but only 7.8% had high awareness of the supply chain of hydrogen. The mismatch between the two types of awareness seems to be a crucial point around which other findings revolve.

Secondly, the levels of preparedness for adopting hydrogen technologies are extremely low. None of the participants thought that logistics companies were ready to do so completely. As many as 3.9% of the respondents believed that logistics companies were prepared adequately, while 96.1% stated that logistics companies were slightly prepared or not prepared at all to do so. Such results acquire additional meaning given that 98% of the respondents expected to gain new business opportunities related to hydrogen.

Thirdly, the use of route optimization tools (as 96.1% considered them important or very important) and digitalization (as 76.5% used GPS or TMS) is the most advanced practice that can be utilized by logistics companies.

Fourthly, based on the Pareto analysis, it was found out that three major barriers to introducing hydrogen in logistics accounted for 82.6% of all answers provided. The industry's experience shows a substantial connection with hydrogen supply chain familiarity ($\chi^2 = 8.058$, $p = 0.005$). On the other hand, digital adoption, sector membership, and familiarity do not show any significant relationship with preparedness, which means specific capability gaps should be addressed with specific solutions.

Root cause analysis has revealed seven categories, which include lack of infrastructure, high initial costs, inadequate safety measures, lack of skills, and virtually zero collaboration between the energy and logistics industries.

Logistic operations expected to have the most significant role in the hydrogen supply chain are hydrogen storage transportation (66.7%), cryogenic transport (39.2%), and heavy equipment transportation (35.3%).

It was reported by all respondents (100%) that operational efficiency is considered either very important or extremely important for participation in the new energy supply chains, and it can be considered one of the basic requirements.

IX. SUGGESTIONS

Based on the findings of this study, the following recommendations are made to logistics firms, policymakers, and other industry actors:

- Phased entry into the market is the more practical option for most companies. Instead of trying to implement the entire spectrum of hydrogen logistics from the outset, it is recommended to begin work with nearby, readily available services such as heavy hauls, oversize freight transport, and project logistics of industrial facilities prior to moving to cryogenic tanks and hydrogen distribution proper.

- Investment in hydrogen logistics-specific equipment is more productive when done gradually rather than at once. Cooperation with energy companies and entering partnerships with governmental bodies will help alleviate any financial burden that comes with purchasing hydrogen logistics equipment at one go.

- GPS and TMS systems represent the first, but not last step of readiness for hydrogen logistics firms. In regard to the latter, it requires a range of additional features, including safety monitoring in real time, route analysis, hazardous materials tracking, etc., none of which are currently provided by general freight GPS/TMS solutions.

- Staffing is a crucial element of hydrogen logistics. It is worth mentioning that developing staff competency may prove to be the most time-consuming task. Handling of hydrogen, cryogenic loads, hazmat regulations, emergencies, and high-pressure cargo handling cannot be learned using standard logistics training programs.

It seems improbable that the most feasible companies within the logistics sector are capable of delivering these objectives alone. The creation of partnerships with green hydrogen production firms, storage companies, energy firms, and governmental institutions involved in infrastructure planning is crucial in addressing this capability gap. Since 98% of the respondents expected a greater level of cooperation between the energy and logistics industries, establishing such relationships at present may prove fruitful prior to industry maturity.

At the current stage, hydrogen transportation regulation is yet to be established. This gives rise to a great opportunity, as companies willing to actively participate in the standardisation committees, safety discussions, and policymaking sessions concerning hydrogen transportation can influence future legislation, rather than adapt to it.

In all probability, the largest share of hydrogen logistics work at the early stages of industry maturity will fall upon road transport companies. However, it must be considered that scale-dependency of supply chains and export orientation in particular would eventually demand integration of different types of transport and infrastructure into one logistics chain.

X. CONCLUSION

The survey conducted among 51 professionals working in the logistics and energy industries in India reveals a relatively simple result – while the sector understands that green hydrogen is around the corner, it lacks readiness to accommodate it on its own terms currently. Such barriers as large-scale investments, security issues, and infrastructure lack seem to persist in the dataset and are not going to disappear soon. However, it should be noted that according to the research results, those companies who have already mastered transport services for heavy industrial goods could become closer to becoming a starting point than one could initially assume.

From an operational perspective, capability in route optimization, fleet management, and use of digital technology represents a strength that serves as a valid basis for readiness in the field of hydrogen logistics. However, such capabilities need to be strengthened

for hydrogen logistics because it requires having specific safety measures, special equipment, skilled workers, and collaborations with energy companies that do not exist in many organizations.

There is a rich and evolving literature on the relationship between logistics and energy transition, and this paper provides one empirical data point within that body of knowledge based on the Indian case. More importantly, the practical takeaway from this discussion is that logistics infrastructure needs to be developed for the hydrogen economy to be fully realized; the best time for doing so is before the market takes shape, not after. Future studies can investigate whether the gap identified in this analysis closes when national hydrogen programs become operational.

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