Study on Factors Impacting the Implementation of Structural health Monitoring (SHM) systems in India

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Abstract- The purpose of this research is to look into the factors that influence the implementation of structural health monitoring (SHM) systems in India. SHM is a rapidly expanding field that uses various sensors and monitoring technologies to monitor and predict the health of structures in real time. Despite the numerous advantages of SHM, their implementation in India has been slow and limited. The purpose of this research is to identify the factors that have hampered the implementation of SHM systems in India and to make recommendations for overcoming these obstacles. The study will collect data through surveys and interviews with experts in the field, and the results will be analysed to determine the most important factors influencing SHM implementation in India. The study's findings will provide valuable insights for construction industry stakeholders and aid in the development of strategies to promote the implementation of SHM systems in India.

Key words: Structural Health Monitoring (SHM), Construction Technology, Damage Assessment, Quality of Structure, Life cycle Assessment, Indian Construction Industry

INTRODUCTION

Structural Health Monitoring (SHM) is a fast expanding discipline that uses a variety of sensors and monitoring technologies to continually monitor the health and safety of structures in real time. The deployment of SHM systems has the potential to greatly enhance structure safety and dependability, minimise maintenance costs, and extend structure lifespan. Despite the obvious benefits of SHM, deployment of these systems in India has been gradual and restricted. The purpose of this research is to investigate the variables influencing the introduction of SHM systems in India and to make solutions for overcoming these obstacles. This study will collect data through a combination of surveys and interviews with experts in the area, and the results will be analysed to discover the most important elements influencing SHM adoption in India. The study's findings will give significant insights for construction industry stakeholders and aid in the creation of initiatives to encourage the deployment of SHM systems in India. The goal of this research is to contribute to the progress of knowledge in the field of SHM and to help the construction industry in India thrive.

The findings of this study will have far-reaching ramifications for the construction sector as well as the general safety and dependability of structures in India. The findings will give vital insights for industry stakeholders, such as engineers, contractors, and policymakers, on the most major hurdles to SHM system deployment in India. Furthermore, the recommendations for overcoming these obstacles would be valuable in encouraging the implementation of SHM systems and assuring the safety and dependability of structures in India. This research will assist to develop knowledge in the field of SHM and determine the future of the building sector in India.

METHODOLOGY

The following steps will comprise the methodology for the study on factors influencing the implementation of structural health monitoring systems in India:

1. Literature Review: To gather information about SHM systems, their implementation, and the factors influencing their implementation, a comprehensive review of existing literature will be conducted.
2. Survey development: Based on the findings of the literature research, a survey questionnaire will be constructed to collect information from important stakeholders in the Construction sector.

3. Data Collection: A selection of specialists and practitioners in the sector, including structural engineers, contractors, and SHM system vendors, will get the survey questionnaire. To guarantee maximum participation, the survey will be administered online.
4. Data Analysis: The obtained data will be evaluated statistically using methods such as descriptive statistics and factor analysis to determine the most important variables influencing the installation of SHM systems in India.
5. Interviews: To augment the survey results and give further insights into the variables influencing the deployment of SHM systems in India, in-depth interviews with a selected number of experts and practitioners in the area will be performed.
6. Recommendations: Based on the results of the survey and interviews, recommendations for overcoming the hurdles to the installation of SHM systems in India will be created.
7. Validation: The study's results and suggestions will be evaluated by professionals in the area to confirm their correctness and usefulness.

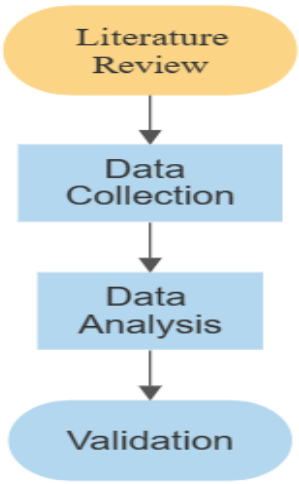

Fig.1 Methodology Flowchart

LITERATURE REVIEW

Structural Health Monitoring (SHM) is a fast expanding area that involves the continuous monitoring and assessment of structural state. SHM's major goal is to offer real-time information on the health and performance of structures, allowing for the early detection of any damage or degradation that might lead to failure. This data may be used to enhance the safety and durability of structures, lower the cost and time necessary for maintenance and repair, and optimise resource utilisation. Given the country's expanding infrastructure and growing demand for safe and dependable buildings, the adoption of SHM systems in India is becoming increasingly crucial.

Several research on the installation of SHM systems in India and the variables influencing their implementation have been undertaken. Kiremidjian et.al [1] performed a study on the current condition of SHM in India, emphasising the need for enhanced SHM awareness and knowledge. Moaveni et.al[2] assessed the potential of SHM for Indian infrastructure, highlighting the significance of incorporating SHM into structural design and construction. The Farrar et.al [3] examined the problems and prospects for implementing SHM systems in India, such as a lack of technical competence and the need for standardised procedures and standards.

Naderi et.al [4] studied the role of wireless sensor networks in SHM, emphasising the benefits of wireless SHM systems such as real-time data gathering, simplicity of implementation, and cost-effectiveness. The use of data fusion techniques for SHM was described in Li, H. Et.al [5], highlighting the need of merging data from numerous sensors to increase the accuracy and reliability of SHM systems. Guo et.al [6] investigated the application of machine learning methods in SHM, indicating their potential for automated structural monitoring and analysis.

Bao, J. et.al [7] examined the application of deep learning algorithms in SHM, emphasising their potential for increasing the accuracy and efficiency of SHM systems. The application of big data analytics in SHM was examined in Farrar et.al [8], highlighting the significance of efficiently managing and evaluating the huge quantity of data created by SHM systems. Bose, N.K [9] examined the application of artificial intelligence in SHM, emphasising AI's potential for automating structural monitoring and analysis.

A summary of the numerous sensors utilised in SHM, such as strain sensors, accelerometers, and optical sensors, may be found in Li, H. Et.al [10]. Guo, X et.al [11] examined the data collection methods used in SHM, highlighting the significance of dependable and

efficient data collecting for effective SHM. A description of the many techniques utilised in SHM, including signal processing algorithms, feature extraction strategies, and damage detection algorithms, may be found in Bao, J.et.al [12].

In Jian, H et.al [13], a case study on the installation of SHM systems in India was undertaken, illustrating the practical issues of applying SHM in real-world circumstances. Li, H et.al [14] assessed the cost-effectiveness of SHM systems in India, highlighting the necessity of economic considerations while adopting SHM systems in infrastructure. The relevance of standards and regulations for the installation of SHM systems in India was explored in Sengupta et.al [15], highlighting the necessity for defined processes and protocols to assure the quality and dependability of SHM systems.

The influence of the physical environment on the functioning of SHM systems in India was explored in Sengupta et.al [16], underlining the need of addressing the environment while developing and deploying SHM systems. The influence of cultural and sociological aspects on the adoption of SHM systems in India was analysed in Choudhury et.al [17], underlining the significance of addressing these elements while adopting SHM in the nation. Patil, S. Et.al [18] investigated the influence of economic variables on the deployment of SHM systems in India, highlighting the need of taking into account the cost of SHM systems as well as the return on investment when installing them in infrastructure. The importance of interdisciplinary collaboration for the successful implementation of SHM systems in India was discussed in Shukla, P. et.al [19], emphasising the need for collaboration among professionals from various fields, such as engineering, computer science, and information technology, to effectively implement and utilise SHM systems.

Given the country's expanding infrastructure and growing demand for safe and dependable buildings, the adoption of SHM systems in India is becoming increasingly crucial. The literature evaluated in this study focuses on the different aspects influencing the deployment of SHM systems in India, such as technological obstacles, a lack of technical competence, and the need for standardised processes and protocols. The literature also emphasises the benefits of SHM systems, such as real-time data collecting, ease of deployment, and cost-effectiveness, as well as the need of taking the cost of SHM systems and the return on investment into account when installing them in the infrastructure. Furthermore, the literature underlines the significance of multidisciplinary collaboration and taking cultural, sociological, and economic variables into account while implementing SHM systems in India.

DATA COLLECTION

As mentioned in the methodology we conducted literature review and mentioned the factors affecting the usage of structural health monitoring systems in India.

1. Cost: The high cost of SHM equipment and installation may be an impediment to their adoption and deployment in India.
2. Technical Competence: In India, a lack of technical competence and qualified experts might stymie the successful adoption of SHM systems.
3. Awareness: In India, a lack of understanding of SHM systems and their advantages among engineers, decision-makers, and the general public might be a barrier to their implementation.
4. Regulations: The absence of clear laws and norms for SHM systems in India might make their deployment difficult.
5. Infrastructure: The present infrastructure in India may not be adequate for the installation and usage of SHM systems, which may impede their adoption.
6. Data Management: Large volumes of data created by SHM systems might be difficult to store, handle, and analyse in India, which lacks the essential infrastructure and resources.
7. Maintenance: In India, where resources for maintenance and upkeep may be scarce, continual maintenance and upkeep of SHM systems might be difficult.

And later we conducted focus group interviews among 6 Professionals in the industry and recorded the responses and did Qualitative data analysis using Python and found out the common the common factors given by everyone and recorded their frequency too. We are eliminating the factors which are taken from the literature study.

1. Funding
2. Standardisation
3. Integration with other systems

4. Lack of trust
5. Resistance to change
6. Limited Research and Development
7. Lack of Case Studies
8. Interoperability
9. Integration with Existing Systems
10. Data privacy and Security
11. Dependence on Foreign Technologies
12. Government Support

And for validating all these factors taken from literature study and interviews we are conducting a survey for validating the factors and ranking them.

These factors are classified as per the below criteria based on the mean of the responses taken from the Likert scale. where all the factors are equally important for achieving 100% Utilization of SHM Systems in India.

- High Impact Factors (5-4.3)
- Moderate Impact Factors (4.3-4)
- Low impact Factors (less than 4)

RESULTS AND DISCUSSION

Closed group survey was conducted among 50 people who are involved in the construction industry, by circulating questionnaire based on the factors taken from literature study and interviews are rated on likert scale as.

- Strongly Agree (5)
- Agree (4)
- Neutral (3)
- Disagree (2)
- Strongly Disagree (1)

And the obtained results are analysed Using mean and standard deviation and ranked as per the criteria defined before.

In the analysis process we evaluate the mean of all the results taken from the survey and we arranged them in the order as per our stratification method and then we calculated standard deviation for knowing the more impactful factors in the stratified list and ranked them accordingly.

Sno.	Factors	Mean	Standard Deviation	Classification
1	Cost	4.346154	0.561591146	High Impact Factors
2	Awareness	4.346154	0.628796164	
3	Resistance to Change	4.461538	0.646886032	
4	Government support	4.5	0.64807407	
5	Standardization	4.5	0.64807407	
6	Lock of Trust	4.384615	0.697247335	
7	Regulations	4.346154	0.745241314	
8	Maintenance	4.307692	0.788377106	
9	Funding	4.307692	0.788377106	
10	Infrastructure	4.153846	0.674821914	Moderate Impact Factors
11	Dependence on Foreign Technologies	4.153846	0.731699812	
12	Integration with Existing Systems	4.192308	0.7493587	
13	Interoperability	4.153846	0.833897245	
14	Integration with other Systems	4.038462	0.958363991	
15	Data Management	4	1.13137085	
16	Technical Competence	3.884615	0.816182483	Low Impact Factors
17	Limited Research and Development	3.961538	0.823687768	
18	Data Privacy and Security	3.884615	0.993052791	
19	Lack of Case Studies	3.576923	1.026570092	

Table1: Data Analysis for Factors

As the classification made by us are of very small bands because all the factors listed by us are taken from experts so all the factors are very much important, So we classified the very important factors into 3 bands.

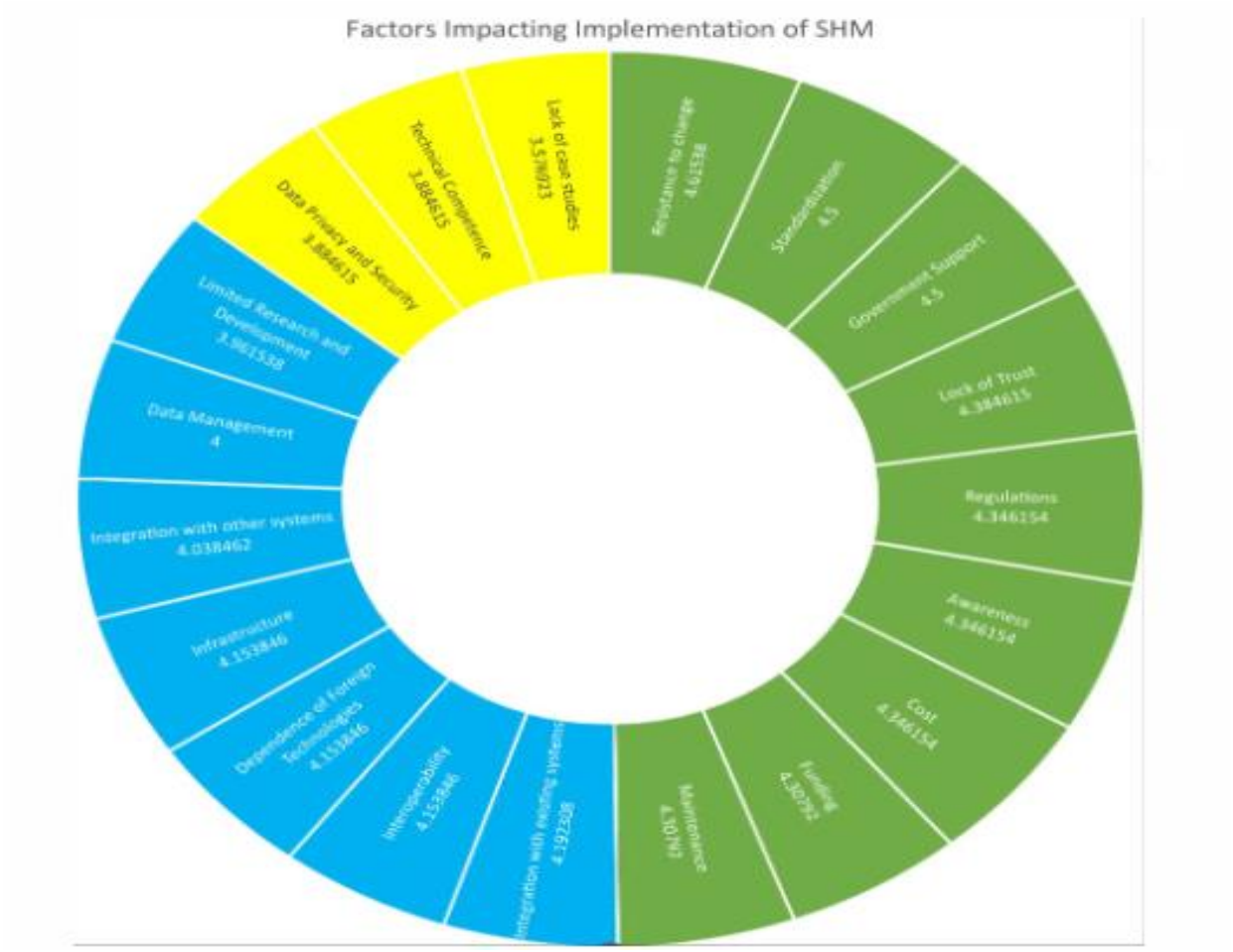

Fig2. Stratification of Factors

CONCLUSION

This study's conclusions will have far-reaching implications for the building industry as well as the overall safety and reliability of structures in India. The findings will provide critical information to industry stakeholders such as engineers, contractors, and politicians on the most significant barriers to SHM system deployment in India. Furthermore, solutions for overcoming these barriers would be beneficial in stimulating the installation of SHM systems and ensuring the safety and reliability of structures in India. This study will help to increase knowledge in the field of SHM and decide the future of the Indian construction industry.

SUGGESTIONS

As we listed many factors which are impacting the usage of SHM Systems in India, Now we are noting down the suggestions to overcome the impacting factors and the suggestions are:

1. Education and Awareness: Educating and raising awareness about SHM systems among professionals in India might assist them better comprehend these systems and their benefits.
2. Case Studies and Success Stories: Sharing case studies and success stories from SHM systems in India might assist to enhance trust in these systems and their deployment.
3. Research and Development: Investing in SHM system research and development in India can assist boost their efficacy and dependability while also providing a deeper knowledge of these systems.
4. Interoperability and Integration: Ensuring interoperability and integration between SHM systems and other systems and technologies can aid in the success of their adoption.

5. Local Development of Technologies: Encouragement of local development of SHM technologies in India can assist minimise reliance on foreign technology and make their adoption more cost-effective.
6. Developing Industry Standards: Developing industry standards for SHM systems in India can assist boost their dependability and efficacy, as well as facilitate their adoption.
7. Government Support: In India, encouraging government support and investment in SHM systems can aid in their adoption and success.

The above mentioned are some of the suggestions which can help to overcome the factors which are impacting the adoption of structural health monitoring systems in India.

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