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A Structural Equation Modelling (SEM) approach on Construction Noise Related Perception and Behavior among the Workforces

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Abstract

Noise pollution from the construction industry is unpredictable and harmful to workers over the long term. There has been a lot of research on noise pollution at construction sites throughout the world, but India lacks research on construction noise and its perceived impacts on workers. This study aims to look into how Indian construction workers perceive noise and behave to protect themselves. From previous research, the noise-related perception parameters were identified and a questionnaire was created. In the questionnaire survey, 520 responses from white- and blue-collar workers were gathered. The SPSS tool was used to analyze the responses. The Pearson correlation analysis determined how closely the perception parameters are associated. The relationship between noise sensitivity and involvement in preventive measures, as well as awareness perception, was also supported by structural equation modeling. The study's findings thus revealed that workers' behaviour can be influenced depending on their level of awareness. The implications of the findings help to improve our theoretical understanding of how construction workers involve in preventive measures and will aid in the development of safety policies and training programs to increase worker knowledge and curb risk-taking behaviour. The study's novelty lies in the development of a framework for construction noise assessment and abatement in India that is suggested and validated by construction industry professionals in real time projects.

Keywords: Construction Noise Pollution; Occupation Noise Perception; Statistics; Structural Equation Model.

1. Introduction

Unlike noise from other industries, construction noise is erratic and variable. Many countries agree that noise from construction is a serious problem that could be harmful to both workers and those nearby [1]. Like many other industries, the construction sector faces significant noise-related occupational safety and health issues [2]. India's construction industry is peculiar because it combines the formal and informal sectors. Most workers in the industry don't consistently work for the same company or in the same place. The industry has a high migration rate and insecure employment. The primary challenges encountered by migrant workers are subcontracting, poorly enforced safety regulations, pressure at work to disregard safety, and different attitudes resulting from linguistic and cultural barriers [3]. Due to these factors, occupational noise exposure risk is a critical but underreported problem in the construction sector [4].

Occupational noise-induced hearing loss (NIHL), the most prevalent Occupational Safety and Health problem, can be brought on by prolonged exposure to loud noise at work [5]. It has been found that there is a stronger correlation

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between hearing loss and impulse noise parameters [6]. In addition to NIHL, high noise exposure can also lead to sleep disruption, irritability, stress, tension, distraction, a higher risk of ischemic heart disease, an impact on quality of life, communication difficulties, behavioral changes, and decreased performance [7].

Depending on the activity, construction noise typically ranges from 80 to 120 dBA, exceeding the standard of 85 to 90 dBA over 8 hours [8–10]. The occupational permissible exposure limit in India is 90 dBA for an 8-hour time-weighted average [11]. Since the majority of construction sites in India work six days a week, total exposure is exceeding 40 hours per week, and cumulative exposure is therefore greater than the limit permitted in developed nations. The majority of previous studies found that workers, particularly in the unorganized sector, lacked hearing protection devices [12]. Workers don't care about personal protective equipment because they are unaware of it [13]. The most common reasons for not wearing a hearing protection device include discomfort and negligence [14]. On the other hand, current construction noise standards only provide a threshold level of noise exposure without considering the long-term health impact [15]. This emphasizes the research gap in understanding the importance of individual workers taking personal protection for their own safety and health. Therefore, the question at hand is how to evaluate how construction noise is perceived and what effect it has, as well as how to determine and mitigate the health effects it has. The relationship between perceptions of occupational noise and personal protection behavior among Indian construction workers is being investigated in order to develop a framework for construction noise assessment and abatement in India.

2. Research Methodology

Figure 1 represents the research methodology for the study. To document noise perception and personal protection behaviour on the construction site, personal interviews with white-collar and blue-collar workers were conducted. Focus group interviews and literature reviews were used to collect the factors, and a questionnaire was developed. A survey was conducted, and 520 samples from various construction personnel were collected. To determine the strength of the correlation between the factors, Pearson correlation coefficient analysis was used. The relationship between the factors and their impact on personal protection behaviour was validated using SEM analysis.

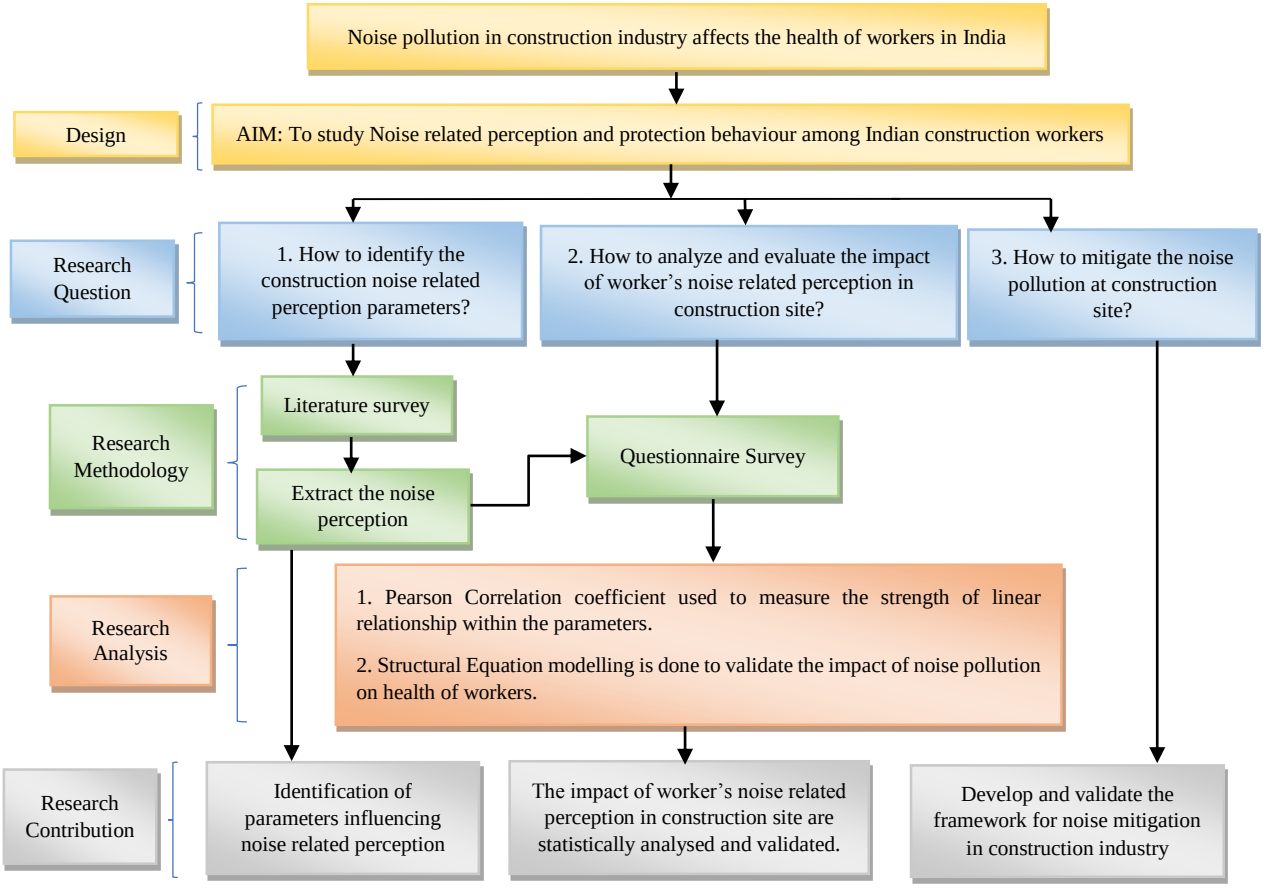

Figure 1. Research Methodology

3. Literature Review

Numerous studies have been conducted to determine the factors that have the greatest impact on workers' behaviour at work. These factors include personal traits, psychological aspects, safety climate, risk perception, awareness and education, and economic factors [16, 17]. Noise sensitivity is primarily an individual trait that causes them to increase

their degree of response to general noise stimuli, resulting in physiological or psychological changes as well as influencing their lifestyles and activity patterns [18]. In Finland, subjects were divided into two groups based on their noise sensitivity. The high noise sensitivity group showed greater changes in heart rate and frequency of electrical activity under the same noise source, intensity, and duration [19]. Noise sensitivity can affect individual physiological performance and inner feelings [20]. According to one study, the safety climate can influence protection behaviour in the construction context [21]. Working environment and organization factors has a direct impact on safety behavior [22]. While few studies states that safety climate influences safety behaviour by acting as a moderator through variables such as pressure and other environmental stressors [23]. In another study, attempts were made to empirically evaluate the relationship between training, hazard recognition, and awareness level. Workers from projects that valued training were more likely to recognize hazards, resulting in a higher level of awareness [24]. The workers' perceptions of risk to their physical and mental health were investigated. It is critical to comprehend workplace factors that influence the physical and mental health of construction workers of various genders and ages [25].

Safety behavior means personal actions taken for self-protection [26]. Involvement in preventive measures emphasizes the importance of individual workers taking personal responsibility for their own safety and health. The safety infrastructure must encourage workers to take an active role in safety engagement. People change their attitudes and beliefs to match their actions when they decide to change their behavior [27]. In China, researchers investigated the relationship between occupational noise perception and personal protection behaviour among construction workers. According to the findings of the study, individual factors had little impact on workers' perceptions and protection regarding occupational noise exposure [28]. Based on the Health Protection model divides behaviour determinants were divided into three groups: (a) noise sensitivity, (b) noise awareness perception and physical and mental effects, and (c) internal management or management commitment in this paper [29-31].

Research into construction workers' risk perception revealed that it could be used as a sort of aptitude test so the management could customize training programmes to workers in order to increase their awareness [32]. Workers' attitudes and behaviours will show in how they internalize and perceive risk [33]. The perception of workers in recognising hazards is critical to the success of any safety programme. To understand the impact of noise on workers and personal protection behaviour, possible personal factors and associations between perception-cognition must be investigated. Six perception parameters, namely 'Noise Sensitivity of The Individual', 'Awareness perception', 'Physical and Mental effects caused due to noise at work', 'Involvement in preventive measures', 'Management/ company commitment' and 'Work pressure' are taken to understand the link among these variables.

4. Data Collection

Through literature review 32 perception parameters were identified shown in Table1 six key parameters were outlined, including the individual's level of noise sensitivity, perception of awareness, the physical and mental effects of noise at work, involvement in preventive measures, management/company commitment, and work pressure. Responses to the questionnaire were collected using a 7-point Likert scale. The responses were analysed using multivariate statistical analysis. All the response were collected individually by conducting interview with the construction personnel.

Table 1. Measurement variables in the questionnaire

Number of Items	Perception parameter	Key parameter
A1	I get anxious and annoyed by noise.	Noise sensitivity level of the individual
A2	I am noise sensitive	
A3	I can quickly get used noises.	
A4	I am now more concerned about noise.	
B1	I am not aware of the hazard of noise in my job	Awareness perception
B2	I am not aware how to use PPEs & follow standard work procedure	
B3	When near heavy equipment, there is a high risk of exposure to noise.	
B4	Noise at site can reduce the working efficiency	
C1	Stress	Physical and mental effects caused due to noise at work
C2	Head ache	
C3	Sleep disturbance	
C4	I experience a brief loss of hearing	
C5	Cardiovascular Disease	
C6	Blood Pressure	
C7	Miscommunication/Misinterpret Information	
C8	Unable to focus causing Productivity losses in the workplace	
C9	After completing some construction work, I notice that my ears are buzzing.	

D1	I know safety rules & procedure while carrying out my job	Involvement in preventive measures
D2	I am aware that noise prevention at workplace is a critical issue	
D3	I feel that it is necessary to put efforts into reducing noise at workplace	
D4	I feel that it is vital to encourage others to be cautious about noise hazard	
D5	I voluntarily perform tasks that lower workplace noise.	
E1	The management actively employs engineering strategies to lessen noise, such as choosing low-noise equipment and utilising sound insulation and absorption.	Management/company commitment
E2	The company would issue enough ear muffs, ear plugs and other PPEs	
E3	Regular noise monitoring is done at my work place	
E4	Management is ready to correct noise pollution irrespective of cost	
E5	Management ensures that awareness is created related to noise pollution hazard	
E6	The PPE provided is inadequate for my safety	
F1	I am working in an environment where work pressure is consistent	Work pressure
F2	I don't have enough time to complete the task safely	
F3	It becomes necessary to deviate from safety requirement for the sake of on time completion of project	
F4	It is normal for me to take shortcut at expense of safety	

A reliability test was carried out by distributing 50 questionnaires to construction workers and response received was analysed using Cronbach Alpha test (Table 2). Each factor's coefficient was greater than 0.8, indicating that the parameters are reliable.

Table 2. Reliability Test

Sl. No.	Parameter	Cronbach's Alpha
1	Noise Sensitivity of The Individual	0.832
2	Awareness perception	0.814
3	Physical and Mental effects caused due to noise at work	0.905
4	Involvement in preventive measures	0.831
5	Management / company commitment	0.902
6	Work pressure	0.825
	Average	**0.852**

The sample size for this study is determined by conducting a pilot study with 50 samples and using the standard deviation of the sample. The sample size calculation formula is as follows:

$$Sample\ size\ n = \left(\frac{ZS}{E}\right)^2 \quad (1)$$

where Z is Standardized value corresponding to a confidence level of 95% = 1.96, S is Sample SD from Pilot study of 50 sample 0.5817, and E is Acceptable Error = 5% = 0.05. Hence:

$$Sample\ size = n = \left(\frac{ZS}{E}\right)^2 = \left(1.96 \times \frac{0.5817}{0.05}\right)^2 \rightarrow \boldsymbol{N = 520} \quad (2)$$

520 responses were collected from 26 construction site in person with the signature of the respondent and facsimile of the company. The frequency of the samples concerning the type of job, gender, age of respondent, Experience of Respondents, Working days per week and Working hours per day is given in Table 3.

Table 3. The frequency distribution of each of the respondents

Demographic Profile	Frequency	Percentage
Type of Job		
White Collar	168	32.4
Blue Collar	352	67.6
Gender Classification		
Male	423	81.3
Female	97	18.6

Age of Respondents		
18-29	204	40.8
30-39	161	32.2
40-49	131	24.2
Above 50	24	2.8
Experience of Respondents		
Less than 5 years	121	24.2
5-10 years	251	48.2
10-20 years	104	18.8
More than 20 years	44	8.8
Working days per week		
5	97	18.7
6	291	56
7	132	25.4
Working hours per day		
8	54	10.4
9	66	12.7
10	82	15.8
11	318	61.2

4.1. Pearson Correlation Coefficient Analysis

Table 4 shows the linear relationship between the parameters. According to Pearson correlation coefficient, 'noise sensitivity level of the individual' and 'Awareness perception' is 57.8% positively associated among each other. The 'noise sensitivity level of the individual' and 'Physical and mental effects caused due to noise at work' 50.2% positively associated among each other. The correlation coefficient among 'noise sensitivity level of the individual' and 'Involvement in preventive measures' is 40.1% positively associated among each other. Similarly, the other parameter is also correlated with each of the others.

Table 4. Pearson Correlation Coefficient between parameters

Parameters	Noise sensitivity level of the individual	Awareness perception	Physical and mental effects caused due to noise at work	Involvement in preventive measures	Management / Company commitment	Work pressure
Noise sensitivity level of the individual	1	0.578**	0.502**	0.401**	0.354**	0.402**
Awareness perception	-	1	0.696**	0.676**	0.534**	0.308**
Physical and mental effects caused due to noise at work	-	-	1	0.582**	0.528**	0.434**
Involvement in preventive measures	-	-	-	1	0.531**	0.235**
Management / Company commitment	-	-	-	-	1	0.678**
Work pressure	-	-	-	-	-	1

4.2. Structural Equation Modelling

Amos 26.0 was also used to create a structural equation model to investigate the relationship between the variables. It analyzes how perceptions of noise exposure and factors like awareness and preventative measures affect the model's results (Figure 2).

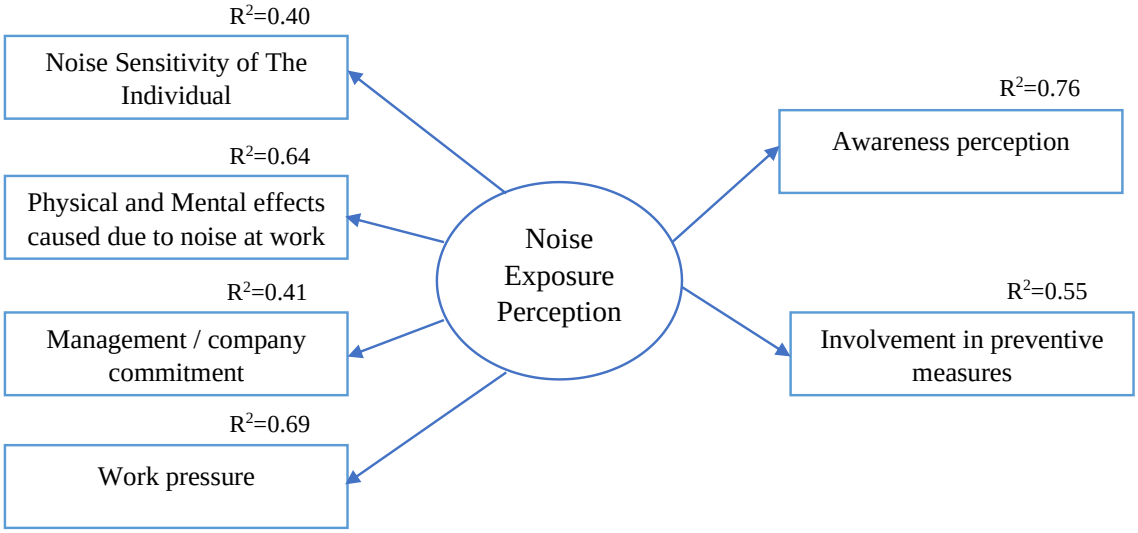

Figure 2. Structural Equation Model (SEM) based on Standardized Coefficient on Noise exposure

Table 5 shows that (**) indicates significant at the 1% level. An unstandardized coefficient of "awareness level" (1.176) is the most significant cause, followed by "management/company commitment" (0.935), noise sensitivity level of the individual (0.899), physical and mental effects caused by noise at work (0.770), work pressure (0.699), and involvement in preventive measures (0.560). A standardized coefficient's purpose is to compare the relative contributions of a predictor variable and an actual variable. Noise sensitivity was discovered to have a significant impact on construction workers' awareness level and involvement in preventive measures using Structural Equation Modeling (SEM). Since the values in the table are within the range, the model is a good fit and is validated.

Table 5. Variables in the Structural Equation Model Analysis

Parameters	Unstandardized coefficient (B)	S.E of B	Standardised coefficient (Beta)	P value
Noise sensitivity level of the individual	0.889	0.047	0.630	<0.001**
Awareness perception	1.176	0.051	0.872	<0.001**
Physical and mental effects caused due to noise at work	0.770	0.041	0.745	<0.001**
Involvement in preventive measures	0.560	0.058	0.437	<0.001**
Management / Company commitment	0.935	0.063	0.641	<0.001**
Work pressure	0.699	0.047	0.803	<0.001**

A good fit is indicated by the Table 6 Goodness of Fit Index (GFI) value of 11.623 and the Adjusted Goodness of Fit Index (AGFI) value of 0.944, which are both higher than 0.959 and 0.9. It is discovered that the calculated Root Mean Square Residuals (RMR) value (0.071) and Root Mean Square Error of Approximation (RMSEA) value all indicate that it is a perfect fit, as do the Normed Fit Index (NFI) value (0.927) and Comparative Fit Index (CFI) value (0.932). (0.076).

Table 6. Model fit summary of Structural Equation Model

Indices	Value	Suggested value
CMIN/DF	11.623	< 5.00 (Hair et al., 1998)
GFI	0.944	> 0.90 (Hu and Bentler, 1999)
AGFI	0.902	> 0.90 (Hair et al. 2006)
NFI	0.927	> 0.90 (Hu and Bentler, 1999)
CFI	0.932	> 0.90 (Daire et al., 2008)
RMR	0.071	< 0.08 (Hair et al. 2006)
RMSEA	0.076	< 0.08 (Hair et al. 2006)

5. Discussion

While few studies in the field of workplace safety argue that people tend to perceive risk based on rational formulation, another study finds that workers' safety behaviour is primarily based on emotional perception rather than rational calculations [34]. Specifically, this study examined the effects of noise on the personal protection behaviour of construction workers. According to Pearson correlation analysis, the strength of the association between the noise perception parameters is around 50%. It states that ruling out these parameters will contribute only 50 % of the success to noise exposure perception. Noise sensitivity can lead to individual protection behaviour; in other words, groups that are more sensitive to noise tend to engage in active self-defense [35]. The significance of the study states that the remaining percentage can be solved only if preventive measures are taken by each individual. The study is validated by representing the impact of physical and mental effects caused by noise (R^2=0.64), is related to involvement in preventive measures (R^2=0.55). According to a study conducted in Sri Lanka, site workers' behaviour can be affected when they are aware of the effects of noise pollution and presume responsibility for minimizing it [25]. There is direct positive impact on awareness perception (R^2= 0.76) and involvement in preventive measure. Moreover, work pressure (R^2= 0.69) on construction sites, combined with poor management, will make it more difficult to implement precautionary measures. The study shows a link between management commitment and construction workers' participation. The safety behavior of construction workers who adopted coping strategies is higher, as evidenced by their willingness to assist co-workers and carry out voluntarily safety-improving tasks [36]. This study found that the physical and mental effects of noise played a mediating role between awareness level and involvement in preventive measures. The findings of this study were anticipated to contribute to the literature on construction workers' protection behaviour as well as aid construction management in creating efficient initiatives to lessen construction workers' risk-taking tendencies.

5.1. Proposed Framework for Assessing and Mitigating Construction Noise

Although the majority of construction noise cannot be avoided, steps can be taken to significantly reduce it. The construction industry must implement preventive administrative changes to reduce worker noise exposure. The findings will also help to refine India's national OHS regulations for construction workers by defining the requirements for dealing with construction noise. The proposed framework for assessing and mitigating construction noise in the Indian construction industry is depicted in Figure 3. The framework was validated by distributing open-ended questions to 12 industrial experts from reputable organizations, and the experts agreed that the narration provided regarding problem analysis is properly placed in the framework and includes all means of analyzing the existing problem. Given the narration about problem solving, the theme is appropriately placed in the framework. Due to varying site conditions, experts advise that implementation be site specific. A comprehensive hearing protection program must be implemented, including training, audiometry, and job rotation, and the use of hearing protection devices should be enforced. According to expert opinions, this framework will be an effective tool for reducing construction noise in developing countries such as India.

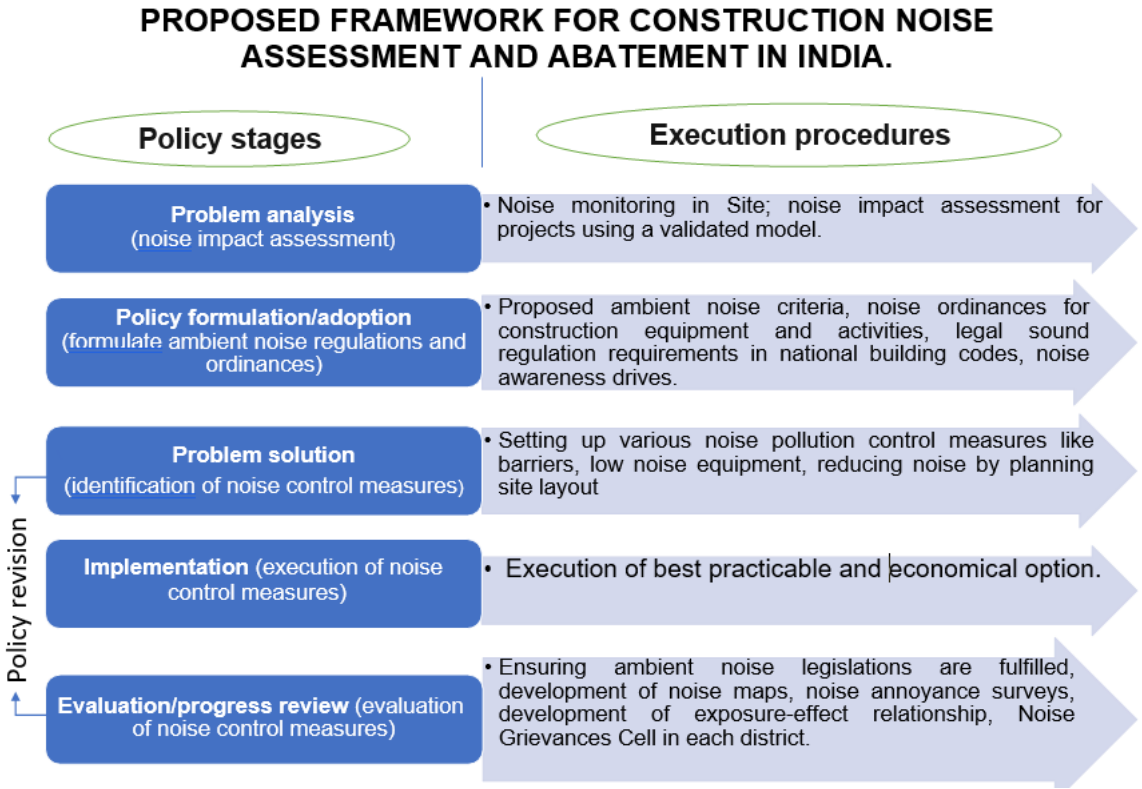

Figure 3. Proposed framework for construction noise assessment and abatement in India

6. Conclusion

This study looked into construction workers' perceptions of noise. The survey responses were analyzed using the Pearson correlation coefficient. The strength of association between noise perception parameters is approximately 50%, implying that the remaining percentage can only be solved if each individual takes preventive measures. The SEM revealed that the values of the indices perfectly fit the suggested value, indicating a positive association between noise sensitivity and involvement in preventive measures as well as awareness perception. The most sensitive parameter causing involvement in preventive measures is reported to be 'physical and mental effects caused by noise at work,' followed by 'individual noise sensitivity level' and 'management/company commitment.' As a result, construction workers must adopt protective behaviours to protect their health from damage brought on by construction noise. Finally, a framework for assessing and mitigating construction noise is developed and validated by industry experts. This framework can be used as a regulatory solution for construction noise to protect the health of workers. The future scope lies in examining worker's health to ensure accurate measurement of physical and psychological effects due to noise pollution in construction site. The study is limited to the country's southern region, limiting the ability to assess differences in worker perceptions in the northern region.

7. Declarations

7.1. Author Contributions

Conceptualization, K.C.V.P. and K.Y.; methodology, K.C.V.P. and K.Y.; writing—original draft preparation, K.C.V.P. and K.Y.; writing—review and editing, K.C.V.P. and K.Y. All authors have read and agreed to the published version of the manuscript.

7.2. Data Availability Statement

Data sharing is not applicable to this article.

7.3. Funding

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7.5. Conflicts of Interest

The authors declare no conflict of interest.

8. References

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Appendix I: Questionnaire

A-1. Noise Sensitivity Level of the Individual

Kindly, answer all the questions in the survey after reading carefully.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6	7

S. no	Item	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
A1	I get anxious and annoyed by noise.							
A2	I am noise sensitive.							
A3	I can quickly get used noises.							
A4	I am now more concerned about noise.							

A-2. Individual Noise Pollution Knowledge

Awareness necessary to understand the fragility of the site environment and the implications of self-protection.

S. no	Item	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
B1	I am not aware of the hazard of noise in my job.							
B2	I am not aware how to use PPEs & follow standard work procedure.							
B3	When near heavy equipment, there is a high risk of exposure to noise.							
B4	Noise at site can reduce the working efficiency.							

A-3. Physical and Mental Effects Caused Due to Noise at Work

The effect refers to the subjective feelings and objective physiological responses of the worker observed during noise exposure. It assesses the perceived susceptibility of construction personnel/workers to noise exposure.

S. no	Item	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
C1	Stress							
C2	Head ache							
C3	Sleep disturbance							
C4	I experience a brief loss of hearing.							
C5	Cardiovascular Disease							
C6	Blood Pressure							
C7	Miscommunication/Misinterpret Information							
C8	Unable to focus causing Productivity losses in the workplace							
C9	After completing some construction work, I notice that my ears are buzzing.							

A-4. Involvement in Preventive Measures

Please indicate the level of protection behaviour you show in site.

S. no	Item	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
D1	I am unaware of safety rules & procedure while carrying out my job.							
D2	I answer that noise prevention at workplace is a critical issue.							
D3	I feel that it is necessary to put efforts into reducing noise at workplace.							
D4	I feel that it is vital to encourage others to be cautious about noise hazard.							
D5	I voluntarily perform tasks that lower workplace noise.							

A-5. Management / Company Commitment

Please indicate your perceptions of how much management value and supports safe working condition.

S. no	Item	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
E1	The management actively employs engineering strategies to lessen noise, such as choosing low-noise equipment and utilising sound insulation and absorption.							
E2	The company would issue enough ear muffs, ear plugs and other PPEs.							
E3	Regular noise monitoring is done at my work place.							
E4	Management is ready to correct noise pollution irrespective of cost.							
E5	Management ensures that awareness is created related to noise pollution hazard.							
E6	The PPE provided is inadequate for my safety.							

A-6. Work Pressure

Please indicate the level of safety concern shown under pressure.

S. no	Item	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
F1	I am working in an environment where work pressure is consistent.							
F2	I don't have enough time to complete the task safely.							
F3	It becomes necessary to deviate from safety requirement for the sake of on time completion of project.							
F4	It is normal for me to take shortcut at expense of safety.							

A-7. Which of the Following Activity Do You Feel Contribute More Noise

S. no	Item	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
G1	Ground Clearance/Excavation							
G2	Foundation							
G3	Reinforcement & shuttering							
G4	Concreting							
G5	Brick work							
G6	Electrical/ Plumbing							
G7	Carpentry							
G8	Demolition							

A-8. Following Would Help in Noise Management Measures

Give your view based on mitigation measures that would be most suitable for your workplace.

S. no	Item	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
H1	Construct noise barrier around construction area (Engineering Control)							
H2	Raising awareness							
H3	Setting a limitation on time period for workers							
H4	Well maintaining construction equipment and device							
H5	Wear Personal Protective Equipment (PPE)							
H6	Prediction of noise pollution during planning stage							
H7	Legal measures like Enforcement of regulations							

A-9. Visibility (Spirit of the Survey)

S. no	Item	Low	Average	Medium	High	Very High
1	At what level do you feel construction noise is affecting you Mentally and physically?					
2	At what level do you feel safety performance in your construction site?					

A-10. Company Profile

1) Name of the company/Organization _____
2) Site location*: _____
3) Nature of current Project*

Residential	Commercial / Industry	Heavy Engineering / Infra
1	2	3

Demographic Profile of the Respondent

Note: *Are compulsory questions, Please tick Where ever necessary

4) Name:_____
5) Employee code/ Ledger no*:_____
6) Gender*

Male	Female	Others
1	2	3

7) Age*

18-28	29-38	39-48	49-58	Above 58
1	2	3	4	5

8) Education Qualification*

10^{th}/ 12^{th}	Diploma/ITI	UG and above

9) Experience in construction industry*

< =5 years	5-10 years	10-20 years	More than 20 years
1	2	3	4

10) Type of Job*

white- collar workers	Blue-collar workers

11) Working Days per week*: _____
12) Duration of working hour per Day*: _____
13) Are you having any pre medical discomfort/ condition? *_____
14) Recently, have you consulted doctor? For what purpose_____
15) Any Suggestion/Expectation to/from Management, to improve the Site condition with respect to noise mitigation:

Thank You!