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Assessment Of Critical Environmental Risk Factors In Building Construction – An Analysis By AHP & WS Approach

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Abstract:
Background*: The protection of the environment is the matter of utmost concern to achieve the sustainable development goals, if not dealt scientifically and logically would impact ecosystems within the boundary of urban area as well as outside it, with implications for the quality of life of people. The construction is one of the main source of environmental pollution. The construction activities affect the environment negatively throughout the life cycle of the constructed building, starting from period of construction period, period of its use to its demolition at the end of its service life. Although the period of construction of building is too less in comparison to its useful life, but the activities in short time impose significant impact on environment. There are no explicit comprehensive references by the law enforcing agencies at local, state and national level to the building planners, designers and contractors. It create huge challenges for urban local bodies for maintaining the environmental quality without compromising the safety and quality of life of people.*
Materials & Methods*: This study is aimed to ascertain the priorities of various factors impacting the environment, in order of their impact level, in case of building construction. The objective of this research is to identify the various environmental risk factors which are arising from the construction of buildings in urban area. Their impacts in the four elements of environments i.e. health of people, atmosphere of area, ecology of surrounding and the society where the building construction is taking place, is studied through the perception of various stake holders. The different risk factors affecting the four elements of environment are finalized through literature survey and discussion among the focus group consisting of experts from various groups of stakeholders. The main factors are further bifurcated into sub factors.*
Results & Conclusions*: The importance ratings are obtained for each risk factors by using analytical hierarchy process for elements and weighted score approach for environmental risk factors, which are analyzed and presented. The critical environmental risk factors and their impacts are obtained, which may be useful for finalizing the risk management strategy.*
Key Word*: Environmental Impact Assessment (EIA), Environmental Risk Assessment (ERA), Environmental Risk (ER), Severity of Impact, Weighted Score (WS).*

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I. Introduction

Background

Many researches have shown through their research that the construction activities are not environmental friendly. These activities are responsible for environmental disruptions and pollutions. The complexities involved in activities and the demand of the natural resources add the dimensions to it. In the most of the developing nations the construction activities are being carried out without giving due consideration to environment, even if it is done it is customary in nature. It is responsible for significantly decline in the air, water and land quality. The noise pollution is another side effect of such activities. These issues have had a detrimental effect on the health of the people, if construction activities are being carried out in densely populated area. In addition, the unplanned urban development is causing the significant environmental challenges. If the size of the project is large, then the construction activities may harm the existing biodiversity and ecosystem. It may also affect the cultural and heritage value of the monuments and heritage sites, if take place near to them.

Environment & Construction

The severity of impact of the environment may be classified broadly in three categories i.e. Direct Impact, Indirect Impact & Cumulative Impact. The nature of impacts on environment may further be classified as Negative and Positive impacts, Predictable & Un-predictable impacts, Local and widespread (i.e. regional or global) impacts, and Temporary and permanent impacts. All these categories and natures of the environmental impacts should be considered while doing the analysis. [Deulkar Ranjit M., et al (2017)]

The construction projects involves the varieties of activities such as levelling of site, excavation, form work, concreting of different elements of structure, erection of steel frames, brick works, plastering, fitting of doors and windows, plumbing, drainage system, installation of heavy machineries for construction etc. A breakdown of all activities and their individual impacts on the environment is essential for analysis. The other relevant information which are significant for impact analysis are quantum of demolition of existing structure, clearance of site, storage of construction materials, transportation of construction materials, location of sites for disposing off materials and other solid waste and its reuse, if possible. The some of the prominent issues which are affected by the impact of construction activities are drainage pattern of land, the quality of soil, water and air, noise levels of the area, the density and diversion of traffic of the area, demography, surface and groundwater resources, flora and fauna i.e. the biological environment. The change in socio-economic and socio-cultural environment are the other dimension of the impact, which needs to be analyzed properly.

Environmental Risk Assessment (ERA) & Need for Assessment

The ERA is a process for estimating the likelihood or frequency of an adverse outcome or event due to pressures or changes in environmental conditions resulting from human activities. ERA is complementary to methods used in State of Environment Reporting (SoE), Environmental Impact Assessment (EIA) and Risk Management (RM). The approach involves identification, analysis and presentation of information in terms of risk to environmental values to inform planning and decision making processes — it does not presume to provide all social and economic information relevant to making decisions, nor is the approach intended to supplant planning and management processes. [Hamid Sepehrdoust et al (2022)]

ERA is a flexible tool that can be applied at a variety of scales and levels of detail appropriate to those scales (e.g., provincial to site specific), for a variety of environmental issues (e.g., from wildlife to water), at various levels of funding (i.e., for quick overviews to in-depth comprehensive studies); and, for short, medium or long-term time scales.

At the heart of ERA is an assessment of the interactions between management regimes and environmental values. The assessment and reporting of risk to environmental values can then be used to identify risk reduction strategies. Subsequent revisions to management plans and actions will then — hopefully — be undertaken to reduce risk. The process by which ERA can be used to model and assess management regimes is depicted in figure 1.

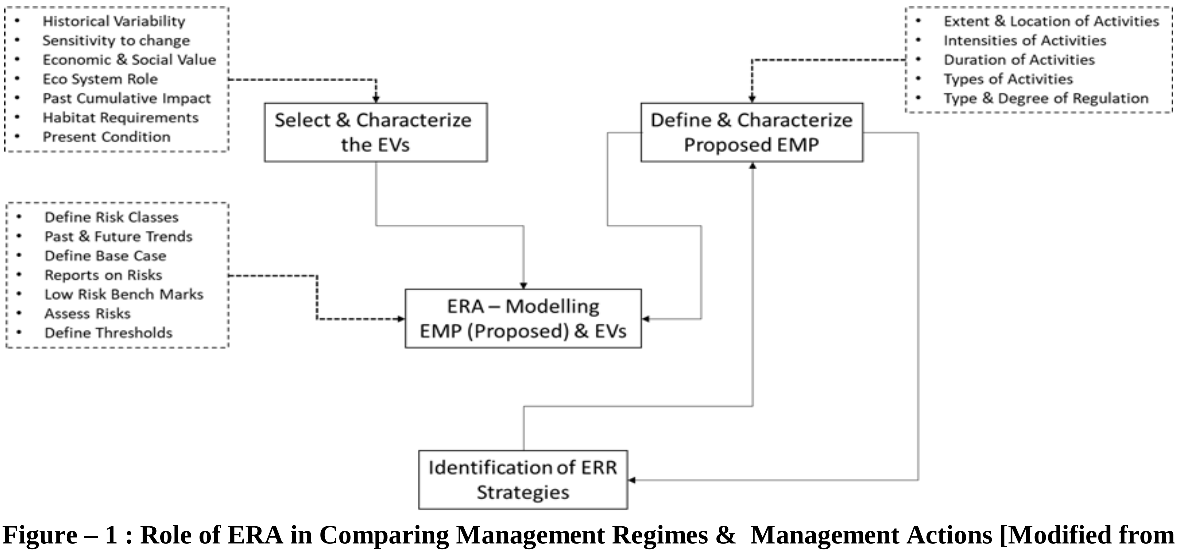

Figure – 1 : Role of ERA in Comparing Management Regimes & Management Actions [Modified from Habitat Branch (2020)]

As increasing pressures on the environment necessitates for logical understanding about the environmental risks. The forecasts of risk to the environment could provide basic information needed for sustainable resource development decisions. In response to this need, the ERA is required for assessing and reporting on environmental risk. The approach has application at a variety of scales or levels.

Strength and Limitations of ERA

The ERA is valuable because it emphasizes that how the decisions may impact on the environment. As a result, the ERA moves the emphasis from defending the virtues of a certain course of action or strategy to illuminating possible outcomes and their desirability. The ERA mandates that hazards to the environment be acknowledged both before and after decisions about the projects are made. It is expected that decisions made as a result of risk awareness will encourage, the sharing of accountability and responsibility for managing that risk. The ERA can be used in different time scales i.e. short medium or long time frame for different environmental issues. Some of the strength of ERA are the risk is well comprehended by all the stake holders; gives the unambiguous criteria for decision-making; developing the cause and effect between the environmental changes and human activities; making the assumptions and data used, and ensuring scientific validity, justification, and replication and identifying the effects of different strategies for risk management.

The ERA spell out the risk from a decision, but it cannot set automatically an acceptable threshold of risk, for which the process of risk management is required. It does not assure the acceptability of impacts and it is the responsibility of the decision makers to choose the desired/acceptable level of risk. The major limitation in addition that it is relative and every individual stake holders and concerned institutions may have different perceptions about the risk tolerance and its acceptance and thus may have difficulty in isolation among decisions and associated risks.

Environmental Risks in Construction

The construction industry of developing nations like India has not yet achieve the maturity. The basic philosophy of the sustainability are ignored, if not their use is customary. The risks are quite high in the case if construction takes place on elevated lands, steep slopes, on bank of rivers, lakes and coastal areas. A proper site selection should be done with greater thoroughness and deliberations in the light of the probable consequences. The conservation of water bodies, flora and fauna, heritage structure (if any) should be kept in mind. According to Tam et al (2004) the local construction practices should be analyzed properly. The inputs from stakeholders such as developers, contractors, architects, planners, and others should be taken in cohesive and willingly manner. [Gangolells et al. (2011); Christini et al.(2004)]. The major environmental impacts in the building construction projects are shown in figure -2.

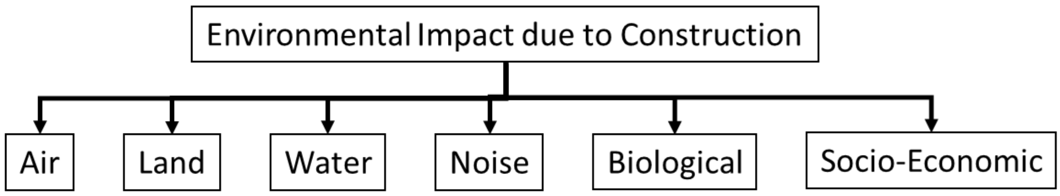

Figure – 2 : Major Environmental Impacts due to Construction

Expert Elicitation

In risk assessment, expert judgment is always required, whether it is determining that whether a conceptual model is representative, eliciting specific data from a selection of possible choices, or assessing whether specific exposure scenarios are plausible. As well as estimating quantities and lacking data, it can be used to quantify uncertainties. An expert working in an office can estimate and document the data for a parameter value for use in a model informally. It can also be elicited from one or more experts using a formal, structured process such as a workshop for expert opinions. Many risk problems are so complex and uncertain that a formalized approach is often adopted using experts from a variety of fields. In order to elicit expert judgment, the methods which may be used are Statistical distributions; Comparisons of preferences, rankings, or pairs; Qualitative information (links, relationships); Point values (most likely, minimum, maximum, quartiles); Statistical probabilities. [Patel Kishan, et al (2014)]

II. Methodology

The term environment is qualitative term and is subjective in nature, perception of which may be different for different persons. The building during its construction and thereafter during its operation phase affect the environment. The impact of building construction activities in its construction phase only is taken for this study.

Identification of Factors & Sub-factors

The focus group of constructional professionals, who participated in finalizing the sources and factors to be taken for the study, are 12, out of them 1 is contractor, 2 are planner and designer, 2 are the project managers, 2 are the material manager/supplier and 5 are field engineers. All participants of the focus group (FC) are experienced in the field of building construction and well acquainted with the environmental risks from various construction activities. The experts of focus group are taken, from construction companies which are having more than 50 regular employees. The statistical description of the focus group is shown in figure – 1.

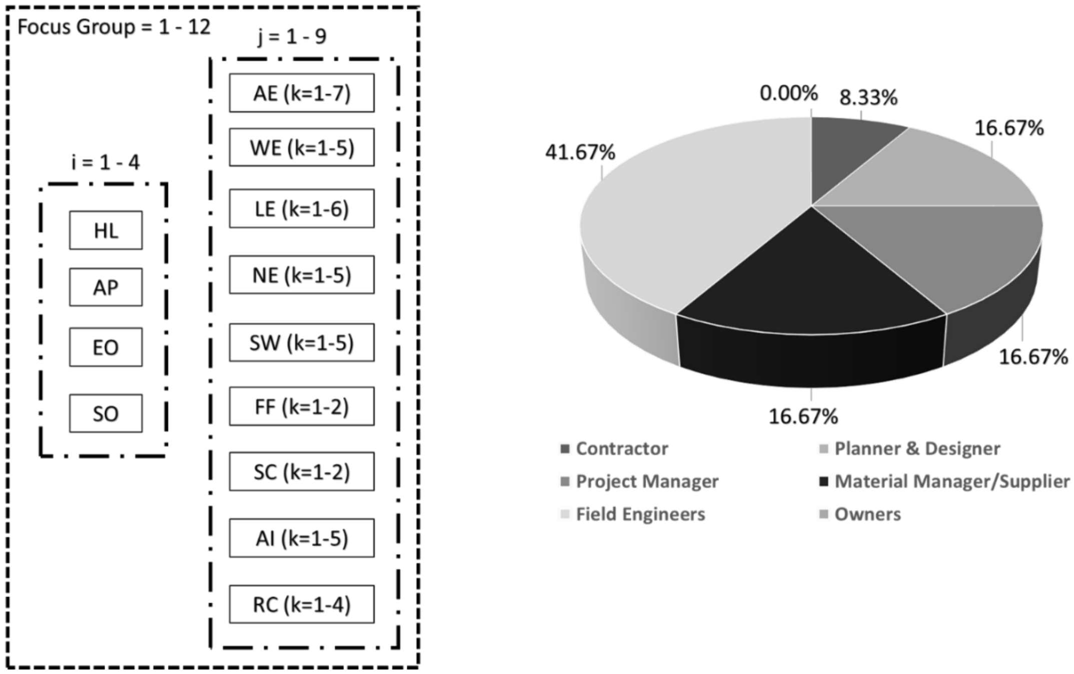

Figure - 3 : Description of Focus Group and Identification of Elements, Factors & Sub-factors for Study

The four elements of environment are identified by the focus group, to assess the environmental impact of various construction activities. These are health (HL), atmosphere (AP), ecology (EO) and society (SO). The nine number of factors are considered, each of them having the sub-factors as mentioned in figure – 3 and table – 1. The total number of sub-factors for different factors are 41.

Estimation of Weight of Elements by AHP

The weights of the four elements health (HL), atmosphere (AP), ecology (EO) and society (SO) are estimated by using the Analytical Hierarchy Process (AHP). The pairwise comparison judgment matrix is prepared with the expert opinions of the members of focus group. The outcome of the comparison for each factors pair are described in term of integer values from 1 i.e. equal importance to 9 extreme different importance, higher or lower, higher on left side means the chosen factor is considered more important in greater degree than other factor being compared with and higher on right side means vice versa, as shown in the table-2.

Table – 1 : Factors and Sub Factors of Risk Estimation

FC	Factor	Sub Factor	SFC
1	Air Environment (AE)		
		Emission from Fossil Fuel	11
		Emission from Plants & equipment	12
		Odor from Construction Material	13
		Odor from Waste Water/Sewerage	14
		Dust from Construction/Demolition	15
		Emissions due to slow traffic because of traffic congestion	16
		Emissions of VOCs & CFCs	17
2	Water Environment (WE)		
		Deposition of Dust/Fine Particles	21
		Waste Water/Sewerage	22
		Cleaning of Surface	23
		Curing of RCC/Brickwork/Plaster	24
		Spillage from making of Concrete/Mortar	25
3	Land Environment (LE)		
		Deposition of Dust/Fine Particles	31
		Change of Land Use	32
		Change of Drainage Pattern	33
		Diversion of Roads	34
		Soil Erosion	35

		Soil Pollution due to Chemicals/Agents	36
4	Noise Environment (NE)		
		Noise from Operation of Equipment	41
		Noise Construction/Demolition	42
		Noise Blasting & Piling	43
		Noise Vehicular Movement	44
		Vibration from Equipment, Demolition, Blasting, Piling etc.	45
5	Solid Waste (SW)		
		Excavated Soil	51
		Inert Construction Material Waste	52
		Domestic Waste	53
		Packaging Waste	54
		Hazardous Waste	55
6	Flora & Fauna (FF)		
		Clearing of existing Vegetation	61
		Displacement of fauna	62
7	Socio Cultural (SC)		
		Change in the demographic structure	71
		Adverse effects on cultural values	72
8	Accident & Incident (AI)		
		Fire outbreaks	81
		Water Supply Pipe Breaking	82
		Disruption in Communication Network	83
		Accident due to traffic congestion	84
		Accident in Construction Work	85
9	Resource Consumption (RC)		
		Electricity	91
		Water	92
		Fuel	93
		Raw Material	94

Table – 2 : Scale of Importance of factors A above B [Rearranged from Satty & Vargas (1991)]

CRITERIA	← MORE IMPORTANT THAN								EQ	LESS IMPORTANT THAN →								CRITERIA
A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**B**

The flow diagram showing the methodology for AHP to find the weights of four criteria are shown in figure-4.

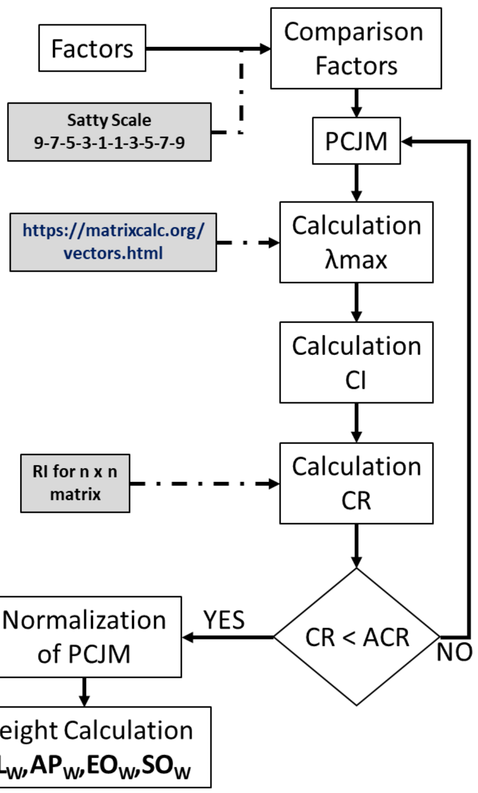

Figure – 4 : Weight Calculations of Environmental through AHP

Survey and Responses

A total of 102 number of constructional professionals are surveyed. Out of which 28 (i.e.27.45%) are having the experience of 15 years and above, 40 (i.e.39.22%) in between 10 years to 14 years and 34 (i.e.33.33%) in between 5 years to 9 years. The acquaintance with environmental risks assessment environmental impact assessment of the respondents are questioned in survey. The respondents are asked to respond in Likert's scale (LS) 1 to 5 as given in table – 3. The responses as received are 11.76%, 17.65%, 46.08%, 13.73% & 10.78% for scale 1 to 5 respectively. The statistical analysis of the category, experiences and their perception towards the environmental risks are shown in figure – 5.

The respondent, responded about the frequency and severity of impact on Likert's scale as described in table 4 & 5 respectively.

Table – 3 : Description of acquaintance of Respondents with ER & EIA Ratings on Likert's Scale

Likert's Scale	Description
1	Not know about it.
2	Perceived about it
3	Recognized but never used
4	Recognized but barely used
5	Recognized & recurrently using

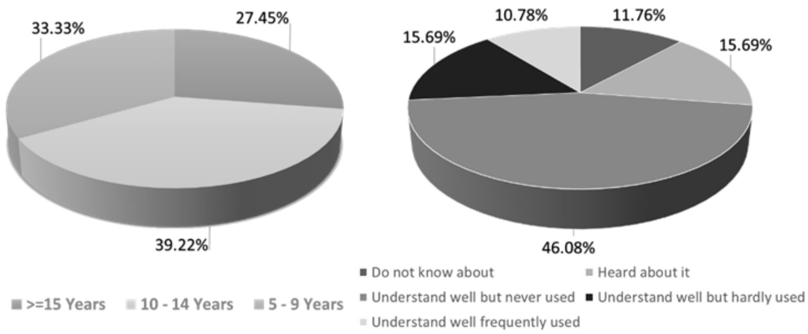

Figure - 5 : Description of Respondents – Experience & Perception about Environmental Risk

Table – 4 : Description of Frequency Ratings on Likert's Scale
[Modified from Alberto, D. M. and Muhammad, J. T. (2013)]

Rating	Frequency	Description
5	Almost Certain	Expected to occur in most circumstances.
4	Likely	Probably occur in most circumstances.
3	Possible	Might occur at some time.
2	Unlikely	Could occur at some time.
1	Rare	May occur only in exceptional circumstances.

Out of the total respondents 10 (9.80%) are owners, 12 (11.76%) contractors, 10 (9.80%) planner and designer, 20 (19.61%) project managers/management consultant, 20 (19.61%) material suppliers/manager/management consultant and 30 (29.41%) engineers working in field, who are conversant with the construction practices and its negative on environment. The statistical analysis and the subject of responses are given in figure -6.

Table – 5 : Description of Severity of impact Ratings on Likert's Scale
[Modified from Alberto, D. M. and Muhammad, J. T. (2013)]

Rating	Severity of impact	Description
5	Critical	Extensive long term environmental harm and / or harm that is extremely widespread. Impacts unlikely to be reversible.
4	Major	Widespread, unplanned environmental impact on or off the site. Major detrimental long term impacts on the environment.
3	Significant	Significant, unplanned environmental impact contained within the site or minor impact that is off the site.
2	Moderate	Moderate, unplanned localized environmental impact (maybe of a temporary nature) or discharge contained on-site or with negligible off-site impact.
1	Minor	Minor environmental impact. Any impacts are contained on-site and short term in nature. No detrimental effect on the environment.

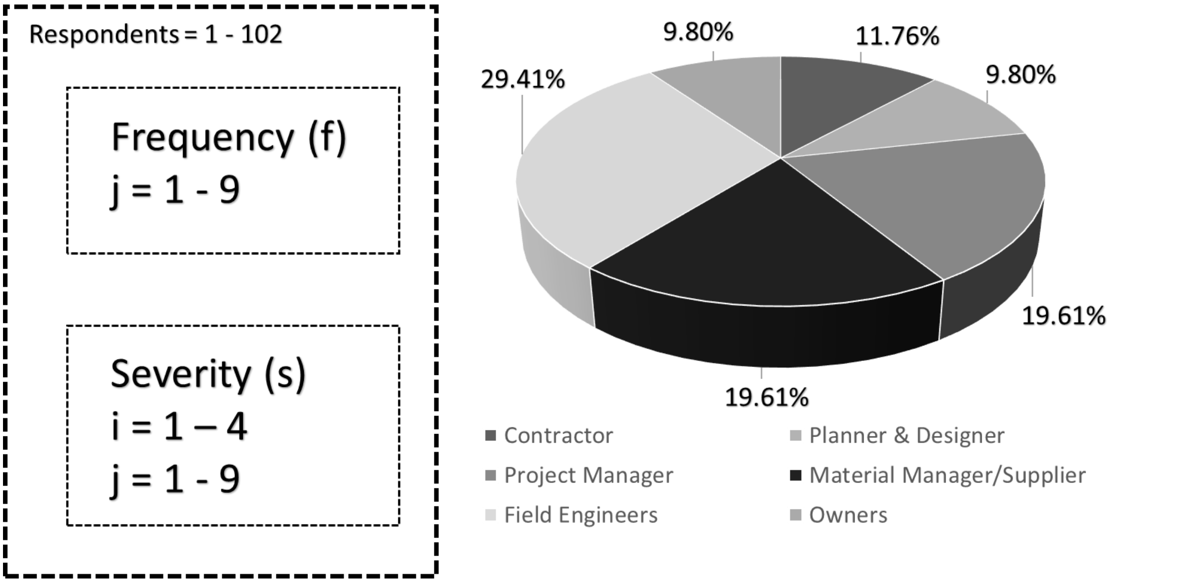

Figure - 6 : Description of Respondents & the subject of responses

Weighted Score Approach

The weighted score are used for assessment of the frequency and impact of each factor. The concept of weighted score for frequency and impact are shown in equation (1). [Dalya Ismael & Tripp Shealy (2018)]

$WS_{(f)} = \sum[NRLR_{(f-j)} \times LR_j]$ ….(1-a)

$WS_{(i)} = \sum [NRLR_{(i-j)} \times LR_j]$ ….(1-b)

Where; $WS_{(f)}$ = Weighted Score for frequency, $NRLR_{(f-j)}$ = Number of Respondent corresponding to value of Likert Scale (j = 1-5) and; LRj is the corresponding Likert Scale (j=1-5)

Similarly; $WS_{(i)}$ = Weighted Score for severity of impact, $NRLR_{(i-j)}$ = Number of Respondent corresponding to value of Likert Scale (j = 1-5) and; LRj is the corresponding Likert Scale

The relative values of frequency "f_w" and severity of impact "i_w" are obtained in the scale in between 0 to 1 by using the equation (2) as mentioned below –

$f_w = WS_{(f)} / (TNR \times 5)$ ….(2-a)

$i_w = WS_{(i)} / (TNR \times 5)$ ….(2-b)

Where; TNR is the total number of respondents participated in survey.

The risk is quantified in terms of the degree of risk R_w and is the product of f_w and i_w and may be expressed as given by equation (3) -

$R_w = f_w \times i_w$ ….(3)

The values fw, iw and Rw as obtained from above mentioned calculations are normalized in the scale of 0 to 10. In this scale of 0 to 10, the values are highest i.e. close to 10 and lowest i.e. close to 0. [Modified from Akintoye, A.S., and MacLeod, M.J.(1997)]

III. Results & Analysis

The weights of the four elements of environment i.e. HL, AP, EO and SO are obtained through AHP through the perceptions of members of focus groups. These weights are 0.548, 0.200, 0.086 and 0.166 respectively for HL,AP, EO and SO.

The responses on the sub-factors by the respondents are recorded for frequency and severity of impacts and are shown in table – 6. The weighted scores of frequency and severity of impacts are calculated, as per equation (1) and thereafter their relative values are calculated, as per equation (2) and are shown in the table – 6. The values of fw & iw are normalized and the degree of risk Rw is calculated and shown in the same table and is normalized for 0 to 10.

The values of degree of risks i.e. Rw as obtained for four elements i.e. HL, AP, EO and SO are weighted with the AHP weights. The cumulative weights of Factor(Elements) e.g. AE(HL), AE(AP), AE(EO), AE(SO), WE(HL),…….. i.e. total 36 in numbers, are arranged in descending order and their cumulative values are obtained.

The significant or critical environmental risk factors are those, which contributes up to 80% cumulative value of Rw. The analysis as conducted is shown in the figure-7. It is evident from the table i.e. the 20 numbers of factor(element) are critical contributing 80% (8.136 out of 10).

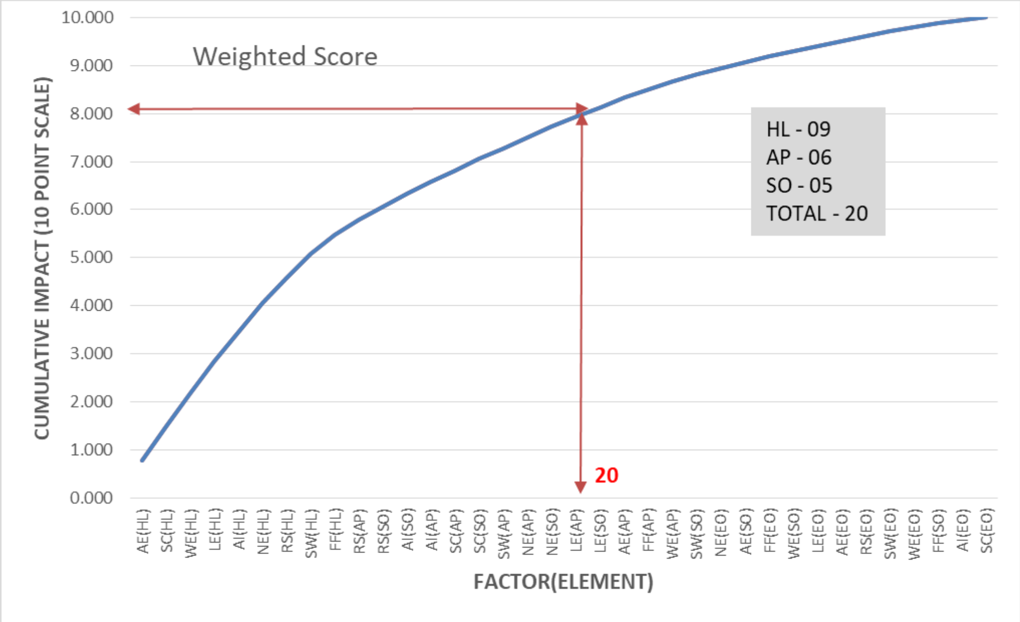

Figure – 7 : Identification of Critical Factor(Element)

The critical Factor(Element) are summarized for number and values and the plot is shown in figure – 8.

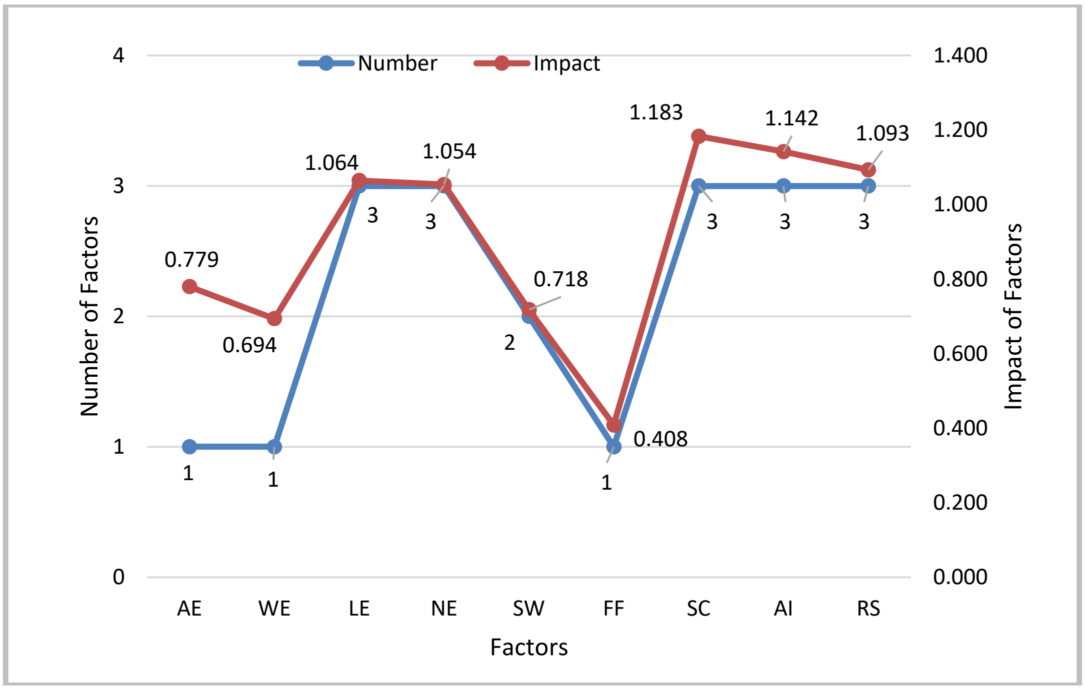

Figure – 8 : Critical Factors – Number and Values

Similarly the critical Factor(Element) are summarized for four elements and their numbers and impact values are plotted in figure – 9.

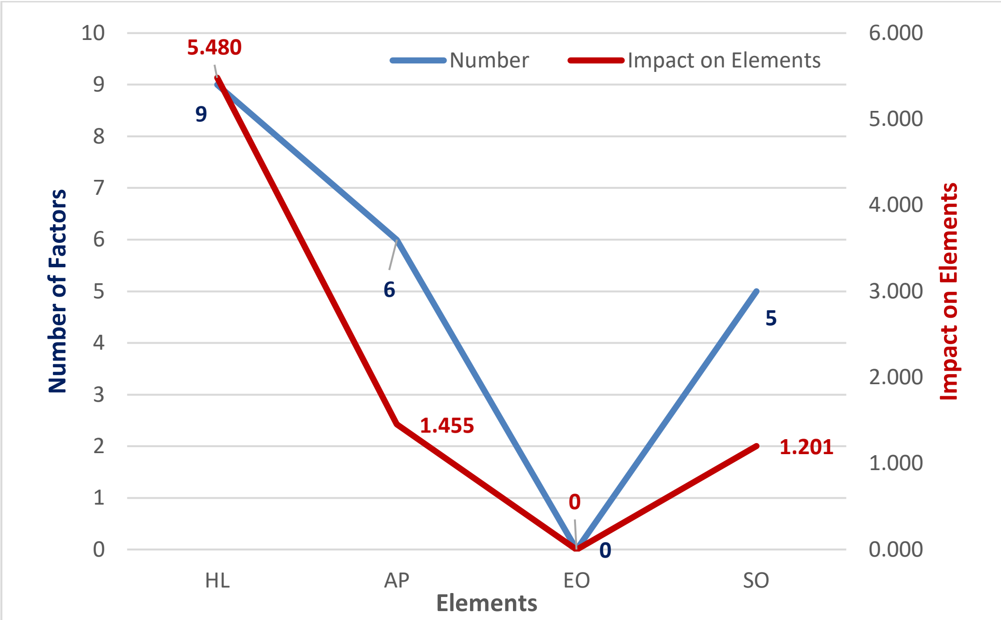

Figure – 9 : Elements – Number of Critical Factors and Impact

IV. Conclusions

The aim of the research is the identification of environmental risk factors for the four elements of environment due to the construction activities of buildings. The categorization of the critical factors and elements among the identified environmental risk factors, pave the path of finalizing the strategy for risk managements. The following conclusions are drawn from the analysis –

a) There are 20 combinations of factor(element), out of total 36, which are critical and needs attention.
b) The critical combinations are all nine risk factors for health, RS, AI, SC, SW, NE & LE for atmosphere and RS, AI, SC and NE for society.
c) The health of people is affected by all the factors, followed by atmosphere and society. All the factors seems to be insignificant for the element ecology.
d) The magnitude of the impact exhibit that health of the people is affected most followed by atmosphere and society.

Scope of Research

The identification of the elements and the environmental risk factors are decided through literature survey and approved by a small focus group which are having expertize in the area of small residential and residential cum commercial building construction only. Thus the results, analysis and conclusions are limited to the mentioned field only. The large commercial, industrial and township projects may yield a better perspective about the environmental risk factors. The statistical analysis for diversity in the perception of different stakeholders are not included in the categorization of the critical factors.

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