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Analysis of Management Participation and Economic Influence for a Re-Contextualization of Osha Portable Concept in the Industrial Sector in Nigeria Using Analytic Hierarchy Process

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Abstract

All attempts to reduce accident occurrence in the Oil and Gas sector have persistently been a discouraging task notwithstanding the enormous investments made by industrial societies in general. This paper seeks to review the Occupational Safety and Health Administration (OSHA) framework by selecting the most appropriate variables suitable for the overall safety of industrial workers in any developing nation. The purpose is to recognize the need for a re-contextualization of the OSHA portable concept to suit the particularity of the nation. In line with the study design, a questionnaire was designed and distributed among the respondents in the six geo-political zones in Nigeria to collect their opinions to conduct a pair comparison analysis. The statistical computations were carried out with the aid of (AHP -OS) Online software. Nine criteria were carefully identified and analysed. The result shows the contributing weights of individual criteria with the national economy ranking first, exerting a weight of 25.14% from its eigenvectors and consistency ratio (CR) ≈ 5% which is < 10%. Conclusively, the safety policy outlook in the industrial sector is limited to its prevalent economy, hence the need for a re-contextualisation of OSHA safety rules to reduce accident occurrence in the Oil and Gas sector in Nigeria.

1. Introduction

In industrialized countries (1st world) such as Japan and some of the former British colonies, principally Australia, New Zealand, South Africa, UK and USA have a viable national economy and a corresponding safety model which boosts the health and safety of their industrial workers. Also (2nd world) countries (communist) such as Eastern Europe (Poland), Russia and China have a safety policy that soothes their national economy [1]. Whereas the (3rd world) countries considering Nigeria as a representative developing country adopted a safety policy that is workable in developed nations. The faulty implementation and regulation of the existing safety framework, governing issues of protection of workers in workplaces in third world countries is a major concern that requires quick attention. looking at some factors of the Occupational Safety and Health Administration (OSHA) supervisory and implementation models to uncover tactical guidelines for Nigeria and other emergent countries. Some of the potential standards behind the overall safety of industrial workers for developments of management frameworks were identified. These drivers/criteria include: National Economy (NE), Health and Safety Environment (HSE), Political Factors (PF), Pre-planning (PP), Company Policy CP, Training (TN), Hazard Identification (HI), Prevention of Hazard (PH) and Record-Keeping (RK), using Analytic Hierarchy Process (AHP) to hand-pick that which wields the most influence for consideration in the re-contextualization of OSHA portable concept as an optimal safety model in the industry for the safety of workers. Although the Oil and Gas sector in Nigeria is used as a location study, the remarks and deductions drawn are common and valid to represent developing nations. A Multi-Criteria Decision-Making (MCDM) technique initially established by [2] is the Analytic Hierarchy Process (AHP). This process entails the evaluation of a derived -ratio scale from pair-wise assessments. The input is obtained from independent judgment such as approval, preference, endorsement, and models. Since human beings are not continually steady, AHP permits approximately small inconsistency in judgment to the harmony 0.1or 10%. AHP applications in real-world problems employ pairwise comparisons that are swotted and performed iteratively. This model is based on a hierarchical construction that makes decisions and computations easy [3]. This helps to validate the consistency of multi-criteria decision making. Pairwise comparisons were presented by [4] and applied by [5] for comparative judgement. AHP has recorded an upsurge in healthcare applications in a study by [6]. Another example of AHP methods in healthcare is [7]. It supports discrete verdict as well as group judgment as opined by [8]. [9] gave an examination based on the geometric mean method and proposed a method of geometric consistency interludes and [10], [11] and [12] proposed the method of detecting a pair-wise comparison mistake. [13] and [14] employed AHP to support shared decision. Decisions on clinical guidelines are as presented by [15]and [16]. Decisions on the development of new technology was explicitly presented by [17], and [18] aims at organizational decisions. [19] and [20] worked on decisions on health policy while [22] evaluated monitoring choices as well as compensating verdicts.

1.2 Governing Equations on Analytical Hierarchy Process (AHP)

The AHP is comprised of basic stages [23]

i. Develop a model for the comparison matrix.
ii. The goal and criteria must be connected.
iii. Collate responses into (m*m) matrix.
iv. Allocate the inverted value in the equivalent location of the matrix.

The inverted value is;

$$a_{ij} = \frac{1}{a_{ij}} \tag{1}$$

The entire amount of comparisons is;

$$\frac{n(n-1)}{2} \tag{2}$$

A pairwise comparison matrix is in the form;

$$A = \begin{array}{c} \\ E_1 \\ E_2 \\ \vdots \\ E_n \end{array} \begin{array}{c} \begin{array}{cccc} E_1 & E_2 & \cdots & E_n \end{array} \\ \begin{pmatrix} d_{11} & d_{12} & \dots & d_{1n} \\ d_{21} & d_{22} & \dots & d_{2n} \\ \vdots & \vdots & \vdots & \ddots \\ d_{n1} & d_{n2} & \dots & d_{nn} \end{pmatrix} \end{array} \tag{3}$$

Normalizing pair-wise comparison matrix, by dividing each element by column sum,

$$A=\begin{pmatrix} \mathbf{1} & \frac{d_{12}}{C_2} & \cdots & \frac{d_1 n}{C_n} \\ \frac{d_2}{C_1} & \mathbf{1} & \cdots & \frac{d_2 n}{C_n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{d_n}{C_1} & \frac{d_{n2}}{C_2} & \cdots & \mathbf{1} \end{pmatrix} \quad (4)$$

N is a normalized Eigenvector.

$$N = \begin{pmatrix} w_1 & w_1 & \cdots & w_1 \\ w_2 & w_2 & \cdots & w_2 \\ \vdots & \vdots & \vdots & \vdots \\ w_n & w_n & \cdots & w_n \end{pmatrix} \quad (5)$$

The Eigenvalue is obtained from the expression;

$$W = \begin{pmatrix} 1 & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & 1 & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & 1 \end{pmatrix} \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{pmatrix} = n \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{pmatrix} \quad (6)$$

The estimated relative weight ẁ is
AW=n_{max}ẁn_{max}≥ n (7)

The value of n_{max} is computed from equation (4)

$$\sum_{j=1}^{n}\left(\sum_{j=1}^{n} a_{ij}\, \grave{w}_j\right) = n_{max} \sum_{j=1}^{n} \grave{w} \qquad = n_{max} \quad (8)$$

RI = Random consistency Index of ‘A’ determined empirically as shown in table (2).

CDM of the geometric mean of the original comparison Matrix A= (a_{ij}) is computed;

$$GM = \sqrt[n]{\left(\prod_{j=1}^{n} a_{ij}\right)} \quad (9)$$

The principal eigenvalue is given by,

$$\lambda_{max} = \frac{\sum a_{jw_{j-n}}}{n} \quad (10)$$

The Consistency Index is obtained using;

$$CI = \frac{\lambda_{max-n}}{n-1} \quad (11)$$

The Consistency Ratio is,

$$CR = \frac{CI}{RI} \quad (12)$$

2. Methodology

2.1 Model Formulation

The goal of decision making is considered first, the other associated decision criteria are identified. The hierarchy is established by the decision makers as shown in (figure 1). A questionnaire with a nine-point scale was designed and distributed among the respondents (managers, experts, workers, and staff with greater than 15 years of experience) in the Oil and Gas industrial sector around the six geopolitical zones in Nigeria to abstract the needed information and their judgment. Significantly, decision-makers selected their favorite values as presented in the nine points Saaty's scale (Table 3) for each criterion and their responses were converted into a pairwise comparison matrix and analyzed. The statistical computations were carried out with the aid of (AHP -OS 2019). Equations (1-12) were used to simulate the MCDA, after 947 iterations, the model was validated with [11-12].

Table: 1: Nine (9) criteria were chosen for this survey, these are:

CRITERIA INDEX	CRITERIA DESCRIPTION	NOTATION
C1	National Economy	NE
C2	Pre-Planning	PP
C3	Training	TN
C4	Health Safety Environment	HSE
C5	Hazard Identification	HI
C6	Prevention of Hazard	PH
C7	Political Factors	PF
C8	Company Policy	CP
C9	Record Keeping	RK

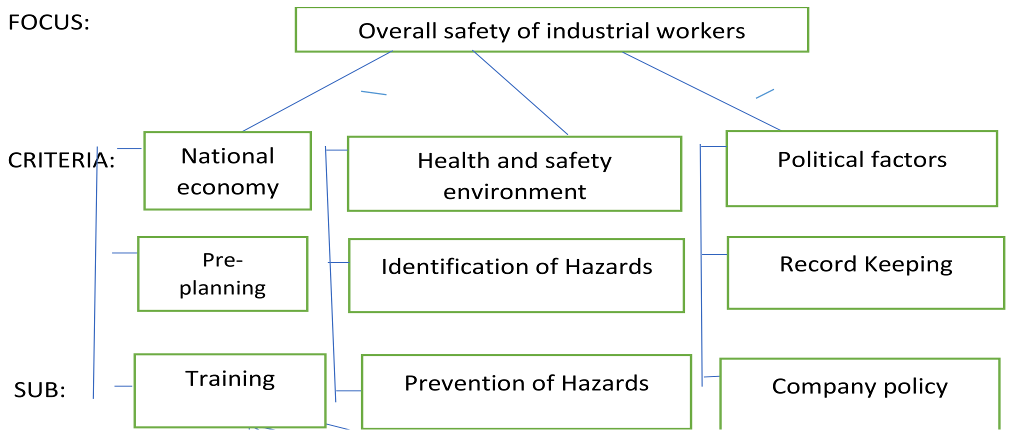

Figure 1 Hierarchical model of Criteria

2.2 Model Application

The decision matrix (DM) for the decision-makers is constructed and then normalized to obtain the individual weights of each criterion.
The decision- matrix equations are described in equations [13-16]
Matrix A is the original decision matrix;

A= ---------------- (13)

	NE	PP	TN	HSE	HI	PH	PF	CP	RK
NE	1	2	2	2	5	3	3	9	7
PP	0.5	1	2	1	3	3	3	4	6
TN	0.5	0.5	1	1	2	3	3	3	6
HSE	0.5	1	1	1	9	9	9	4	7
HI	0.2	0.33	0.5	0.11	1	0.33	0.33	0.5	4
PH	0.33	0.33	0.33	0.11	3	1	1	0.5	5
PF	0.33	0.25	0.33	0.25	2	2	1	1	3
CP	0.14	0.17	0.33	0.14	0.33	0.5	0.5	1	2
RK	0.14	0.17	0.17	0.14	0.25	0.2	0.2	0.33	1

Normalising pair-wise comparison matrix row sum;

RS= -------------(14)

	NE	PP	TN	HSE	HI	PH	PF	CP	RK
NE	1	2	2	2	5	3	3	9	7
PP	0.5	1	2	1	3	3	3	4	6
TN	0.5	0.5	1	1	2	3	3	3	6
HSE	0.5	1	1	1	9	9	9	4	7
HI	0.2	0.33	0.5	0.11	1	0.33	0.33	0.5	4
PH	0.33	0.33	0.33	0.11	3	1	1	0.5	5
PF	0.33	0.25	0.33	0.25	2	2	1	1	3
CP	0.14	0.17	0.33	0.14	0.33	0.5	0.5	1	2
RK	0.14	0.17	0.17	0.14	0.25	0.2	0.2	0.33	1
SUM	3.64	5.75	7.66	5.75	25.58	22.03	21.03	23.33	41

Normalized eigenvector N;

N=

	NE	PP	TN	HSE	HI	PH	PF	CP	RK
NE	0.2747	0.3478	0.2611	0.3478	0.1955	0.1362	0.1427	0.3858	0.1707
PP	0.1374	0.1739	0.2611	0.1739	0.1173	0.1362	0.1427	0.1715	0.1463
TN	0.1374	0.087	0.1305	0.1739	0.0782	0.1362	0.1427	0.1286	0.1463
HSE	0.1374	0.1739	0.1305	0.1739	0.3518	0.4085	0.428	0.1715	0.1707
HI	0.0549	0.0574	0.0653	0.0191	0.0391	0.015	0.0157	0.0214	0.0976
PH	0.0907	0.0574	0.0431	0.0191	0.1173	0.0454	0.0476	0.0214	0.122
PF	0.0907	0.0435	0.0431	0.0435	0.0782	0.0908	0.0476	0.0429	0.0732
CP	0.0385	0.0296	0.0431	0.0243	0.0129	0.0227	0.0238	0.0429	0.0488
RK	0.0385	0.0296	0.0222	0.0243	0.0098	0.0091	0.0095	0.0141	0.0244

-----------(15)

Normalized weight vector W;

W =

CRITERIA	WEIGHT	λ Eigenvector	Rank
NE	0.2514	2.3249	1
PP	0.1622	1.5335	3
TN	0.129	1.2488	4
HSE	0.2385	2.4264	2
HI	0.0428	0.3749	8
PH	0.0627	0.5746	5
PF	0.0615	0.5905	6
CP	0.0318	0.2871	7
RK	0.0202	0.1843	9

-----------(16)

3. Results and Discussion

The completed paired comparison matrix (A) was developed using the geometric mean method as proposed by [9] and calculated weights of criteria are shown using the expressions in equations (4 and 5). The sum of all elements in the priority weight vector is 1 (one) showing normalization. The priority vector shows relative weights and criteria rank (16). In the analysis above, National Economy (NE) ranked first with 25.14% in the decision thereby indicating that the issue of safety in the work world is dependent on the economy of the parent nation, hence the need for the re-contextualisation of the OSHA portable concept in Nigeria to suit the particularity of the nation. The priority vector shows relative weights among the items that were compared. Pre-Planning (PP) is 16.22%, Training (TN) is 12.9%, Health, Safety and Environment (HSE) is 23.85%, Hazard Identification (HI) is 04.28%, Prevention of Hazards (PH) is 06.27%, Political Factor (PF) is 06.15%, Company Policy (CP) is 03.18% and Records keeping (RK) is 02.02%. The results show the level of preference as depicted in equation (16) in this case, the national economy is the most important criterion to be considered in the model of safety policy to be adopted in any nation. Record keeping ranked the least with a criterion weight of 2%. Besides the ranking, the relative weight is a ratio scale that we can divide among them. Equation (13) is the Pair-wise comparison matrix from respondents. Aside from the relative weight, the consistency |is checked using the principal eigenvalue. The principal eigenvalue is obtained from the summation of products between each element of the eigenvector and the sum of columns of the reciprocal matrix. From equation 10, the maximum eigenvalue $\lambda_{(max)} = 9.5449$

But,

$$CR = \left(\frac{CI}{RI}\right)$$

$$CI = \frac{\lambda - n}{n-1}$$

where, n=9, Therefore,

$\text{CI}=\frac{9.5449-9}{9-1}=0.0681$

$$CR=\frac{0.0681}{1.4882}*100\%=4.6\%$$

Since the consistency is approximately 5% < than 10%. It is acceptable. [2]

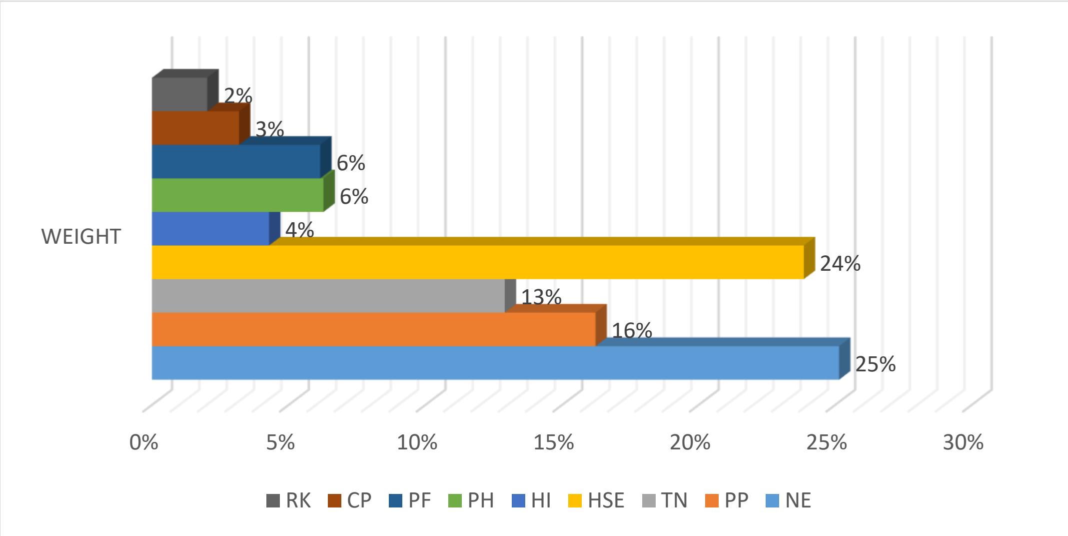

Figure 2: Level of preference of decision-makers.

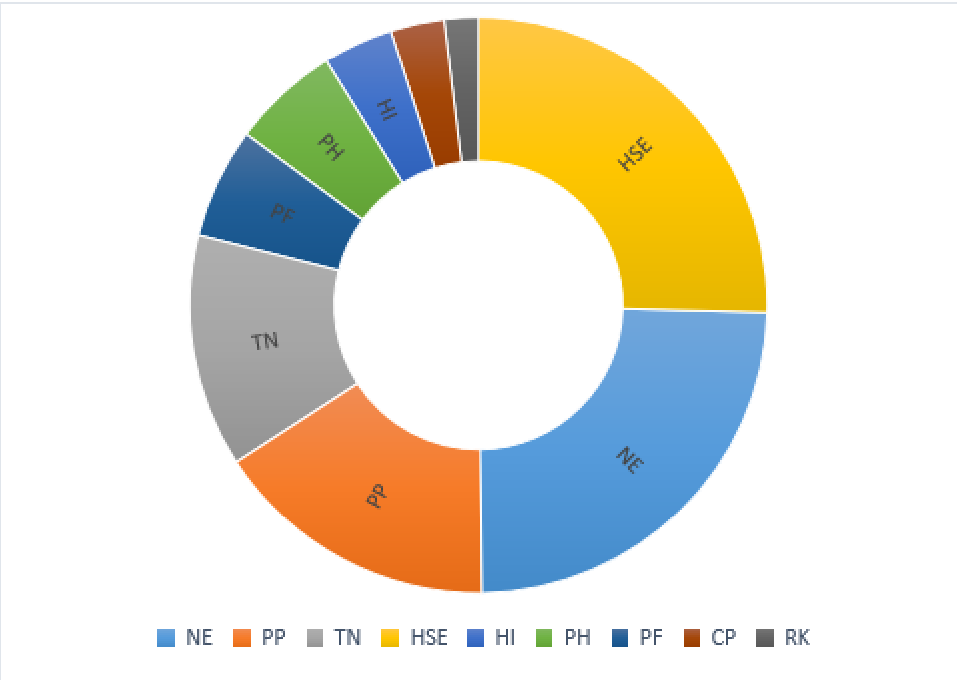

Figure 3: Eigenvector of Criteria

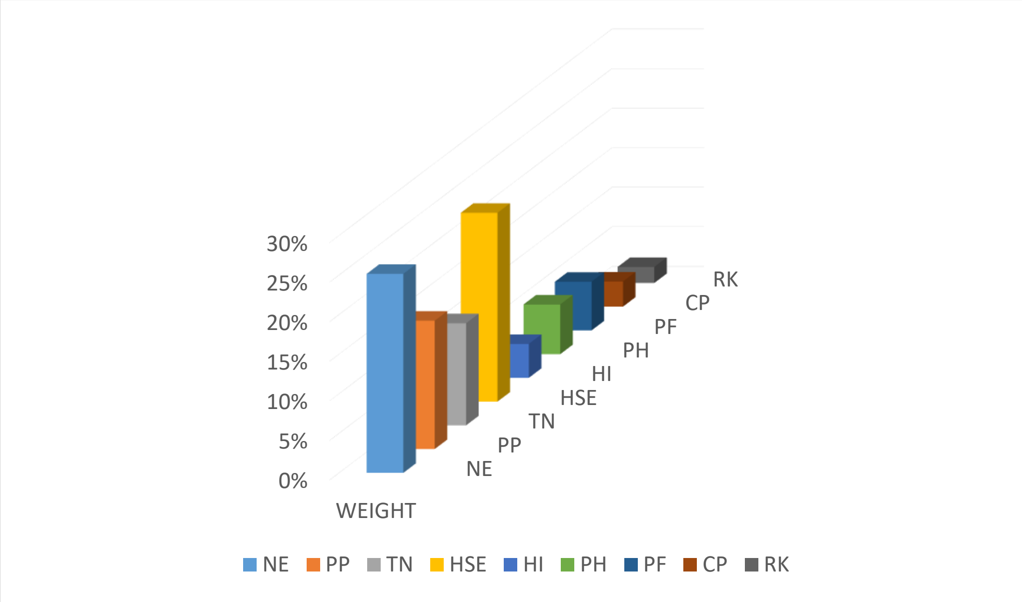

Figure 4: Cluster bar chart of criteria Weight

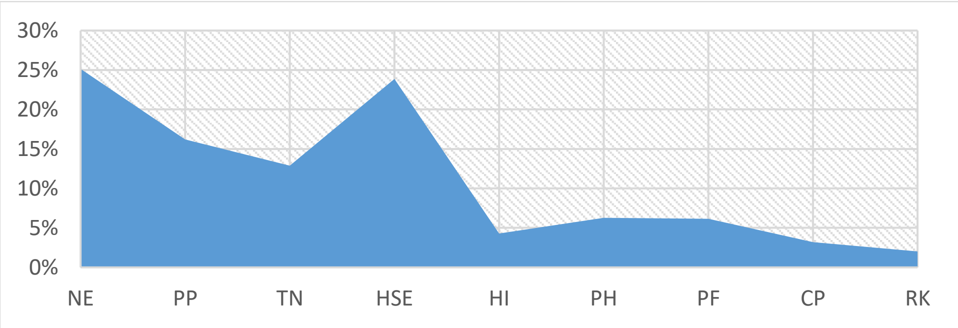

Figure 5: Criteria Priority Vector Area.

4. Conclusion

Arising from the foregoing results and discussions and on all counts, it is evident that safety in an organization within a nation depends on the prevailing national economy which predicts the safety culture and ground-rule guiding safety practices. Hence the AHP statistical model adopted has provided enlightenment on the complexion of the world of work. The study is therefore successful in explaining the dynamism of culture of the work world regarding the economic force. It is hoped that this would help to unwrapped the deeper meanings associated with the adoption and implementation of safety practices alternatives in any nation.

Nomenclature

A	Pair-Wise Comparison Matrix
AHP	Analytic Hierarchy Process
AHP-OS	Online Software by Klaus D. Goepel
CDM	Combined Decision Matrix
CI	Consistency Index
CP	Company Policy
CR	Consistency ratio
DM	Decision Matrix

GM	Geometric Mean.
HI	Hazard Identification
HSE	Health Safety Environment
MCDM	Multi-Criteria Decision Making
N	Normalized Eigenvector
NE	National Economy
n	Total number of selection criteria
OSHA	Occupational Safety and Health Administration
PF	Political Factors
PH	Prevention of Hazard
PP	Pre-Planning
RK	Record Keeping
RI	Random Index
RS	Row Sum
TN	Training
W	Criteria weight vector
$E_1 \quad E_2 \quad \cdots \quad E_n$	Criteria Element 1-n
$d_{11} - d_{nn}$	Respondent Scores 1-n
$w_1 - w_n$	Weight of Criteria 1- n
$C_1 - C_n$	Column Sum of respondent scores
a_{ij}	Value of candidate i on property j.

Greek letters

λ	Priority Vector of criteria
∑	Summation
∏	Product for all value of candidate i on property j.
ẇ	Estimated relative weight

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Appendix

Table 2: The value of Random Consistency Index

Dimension	1	2	3	4	5	6	7	8	9
RI	0	0	0.5799	0.8921	1.1159	1.2358	1.3322	1.3952	1.4882

Table 3: Scores for the importance of variable

Importance Scale	Definition of Importance Scale
1	Equally Important Preferred
2	Equally to Moderately Important Preferred
3	Moderately Important Preferred
4	Moderately to Strongly Important Preferred
5	Strongly Important Preferred

6	Strongly to Very Strongly Important Preferred
7	Very Strongly Important Preferred
8	Very Strongly to Extremely Important Preferred
9	Extremely Important Preferred