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A grey relational analytical approach to safety performance assessment in an aviation industry of a developing country

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Abstract

Safety in aviation impacts the overall success of the sector. It depends on the effectiveness and efficiency of safety management systems (SMSs), which contain diverse and complex elements. Thus, a quantitative methodology for aviation SMS in developing countries, capable of prioritising resources with incomplete information, is needed. Grey relational analysis (GRA) is the most appropriate tool for this situation. This study assessed an existing SMS and determined its critical elements in a developing country's aviation industry. Questionnaires were framed from the SMS manual of the International Civil Aviation Organization and from previous literature. The robustness and the efficiency of the approach were tested with data obtained from airline operators in Nigeria. Assessment of SMSs was done among airline service providers ascertaining the important levels of SMS elements. GRA was then applied to this data to identify the most influential elements of an SMS. Several companies were examined. Company A needs for a focus on sharing safety information and sensitization techniques to enable SMSs to better permeate through all levels, making employees aware of their SMS roles and duties to pursue a better safety culture. Company B needs to focus on more in-depth safety information dissemination platforms and methods. Non-punitive reporting should be done and safety promotion, culture, training and education should be prioritised. Company A has a better safety record than B. Overall, from the grey model, 12 critical elements were found out of 22 revised SMS elements that affect SMS. The major critical component was the safety structure and regulation. This is needed to build long lasting and effective SMSs. The novelty of this work is its unique application of GRA for a developing country's airline safety.

Keywords: Grey relational analysis, Optimisation, Prioritisation, Airline operations, Airline services

1. Introduction

The safety management systems (SMSs) in aviation [1-6] are complex multi-element systems that are used in a wide range of aviation industries. They are systems that manage all the activities of the aviation organisation irrespective of the nature of output of the aviation system - tangible or intangible. Thus, whether the organisation of concern is moving airline passengers from one location to another, as in the case of aircrafts, jets, and helicopters, or offering consultancy services, counseling or support services, it is a legal requirement to maintain an effective and transparent safety management system. In the past, SMSs [7-9] are maintained by aviation organisation voluntarily and a mere demonstration of the airline's commitment to passengers' safety, by keeping records. However, in recent times, the situation has changed. It is now a legal requirement, as advanced by the International Aviation Organisation (ICAO) and other regulatory agencies [10], to keep safety records, improve on them, and constantly updating them for the most effective SMSs in aviation industries.

The regulation [11] to keep and maintain effective SMS records is compelling in the wave of high frequency of accidents worldwide leading to loss of lives, properties and money. While striving to keep to this legal requirement of achieving high performance SMSs by aviation industries, system managers in the aviation industry face huge challenges as the elements of the SMSs set-up by ICAO and other regulatory bodies are very complex. It is challenging for safety managers to effectively manage this complex system despite the wide range of activities that the manager is saddled with in the aviation organisation. This difficult must not be allowed to continually burden the safety manager. In this frustration, to solve this problem, the safety manager is tempted to misappropriate resources. More often, the manager channels resources to less significant elements of the SMS and ineffectiveness sets in. The result is that for the SMS as a whole, sub-optimal outcomes are obtained and the organisation is at loss financially. Even the airline passengers is at the risk of accidents since the most important elements in the SMS that could reduce or avoid accidents are identified and invested on for safety improvement practices. It is therefore urgent to address this problem of complexity of SMSs and misappropriation of safety system resources. To solve this problem, it is only scientific tools that could be used. The need to solve this problem has motivated the

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current research, which seeks to simplify SMSs in aviation. The approach adopted is to apply the merit-driven tool of grey relational analysis (GRA) in the identification of the most important SMS elements and mark this as one that is worthy of being invested into. With the scientific approach of GRA application in the aviation industry, the challenge faced by the safety manager will be resolved.

In spite of the important understanding developed from the extant literature on SMSs, this body of study still suffers from diverse important problems that limit the actualisation of its full potentials in development. First, the literature has clearly analysed the principal factors when considering the elements of SMSs but the relationships of these elements with the different cultural settings, across regions and continents, have not been treated in any details. Secondly, although the literature has shed light on SMS in certain countries, they are majorly in organised climes such as Canada where the records concerning safety are cautiously kept, examined, monitored and used for performance improvement purposes. Thus, SMS implementation has been largely ignored for most developing countries in Africa. Thirdly, most studies are qualitatively-based, and offer very limited help to safety managers who need guidance on quantitative measures as what gets measured gets improved.

Consequently, the current investigation targets at solving the above-mentioned issues concerning SMSs in developing countries by providing a quantitative approach based on grey relational analysis that is simplistic enough for the understanding of the safety manager in the aviation industry with special reference to the Nigerian environment. Specifically, the current investigation carried out an industry-wide survey, focusing on experienced safety managers or those charged with related responsibilities in safety that have a minimum of fifteen years of experience in safety, and are judged experts because of their versed experience in safety.

Numerous compelling and supporting reasons could be advanced for the execution of this study in the context of international safety management. Firstly, several government in Nigeria have shown commitment to safety improvement in aviation industry but the renewed efforts by the current government, in the wave of international pressure for top class performance in SMSs is unprecedented. Secondly, an increasing number of calls have been made for simplification of models developed by researchers for safety manager's usage. Thirdly, although merit-driven surveys have been done in the past concerning SMSs, the experience bracket in the 15 years and above for the respondents have been loosely kept in studies.

In order to illustrate the robustness and efficacy of the proposed approach, the GRA scheme was applied to airline industry in Nigeria as an example of its applicability to the aviation industry in developing countries. The work presented in this paper is novel in that it shows, for the first time in literature, the applicability of GRA to SMS performance improvement in the aviation industry for developing countries, and particularly Nigeria. It is unique in that developing countries have different SMSs' influencers compared to developed economies such as Canada that has been reported in literature. In addition, the level of control with respect to compliance of the developing countries' aviation industry may significantly differ from what obtains in developed countries. In this paper the aim is to develop a GRA scheme and apply it to the aviation industry in Nigeria with data collected from experts in the aviation industry.

Safety assessments and investigations have been largely dominated areas of research for decades [3, 6, 12-20]. The literature on SMS and related issues is quite enormous and has been established in various dimensions. Liou et al. [9, 21] were principal investigators that extensively utilised the concept of DEMATEL (decision-making trial and evaluation laboratory). Based on the utility of the concept, Liou et al. [9, 21] combined DEMATEL with fuzzy logic (as in Liou et al. [9] and with the analytical hierarchy process [21]). The efforts were to find out the relationship of the multiple factors that influence SMSs in aviation industry in both cited literature pertaining Liou et al. Still along the same line of research, ANP was similarly used as for Liou et al. [21]. By concentrating on the automobile industry, Further work on DEMATEL was by Hsu et al. [22], who attempted to hybridise DEMATEL, GRA and ANP in SMSs.

Another set of investigations were concerned with grey relational analysis. As an example, for more than a decade, Chang and Wang [23] selected in an optimal manner the initial training aircraft from the perspective of multi criteria decision making using GRA. Similar works were carried out by Kayacan et al. [24], Hui et al. [25], Tsai et al. [26] and Huang and Lin [27] as well as Lin et al. [28]. Out of this growing literature on GRA, an interesting diverse literature emerged, including Wen [29], Lin and Lin [30] and Sarucan et al. [31]. Existing literature hybridised GRA with AHP [21, 32-33]. GRA was also hybridised with RIDIT analysis as in Wu [34].

Another line of investigation centered on SMS performance with a novel methodology (tripod delta) that figured out two main perspectives of applications of the tool for effective assessment of the performance of safety with respect to SMSs. Hale et al. [1] in their work, presented a platform for evaluating SMSs as well as an audit tool for the SMS. Gill and Shergill [35] in their paper evaluated the perceptions of staff on safety management and an approach to smoothly implement SMSs. Tervonen et al. [36] examined safety management with respect to a steel production organisation. The authors considered SMS as a critical element hat determine the progress of the system. Uhuego et al. [37] worked on a survey to assess the perception of employees with respect to SMSs in airline organisations that are maintenance-oriented. The lack of training and education on safety management and other factors as safety performance-retarding factors were reported in the SMSs literature. Very recently, Onyegiri and Oke [38-39] appear to pioneer studies in the Nigerian aviation industry by employing prioritisation tools. Unfortunately, these studies are limited in that they only open up a fertile research that cries for rigorous knowledge contributions.

From the comprehensive literature review, the following principal observations were drawn (1) The aviation industry has experienced several safety performance enhancement efforts with diverse tool applications. Prominent tools are particle swarm optimization, grey relational analysis, fuzzy set theory, TOPSIS, analytical hierarchy process and factor analysis. However, most of these tools cannot perform effectively where there is partial or incomplete information except the grey relational analysis which stands out to this challenge; (ii) Very few effort were reported on the aviation sector in developing countries; (iii) Literature encourages studies in previously unexplored areas such as developing country, Nigeria.

It is necessary to focus on developing countries as information on developed countries reported in literature may substantially be different from what obtains in

developing countries. Thus, considering these literature perception and the perceived gaps in literature, the Nigerian aviation sector becomes critical and subject to investigation for necessary scientific analysis and prioritisation of its many complex safety management system components and elements. Consequently, practically investigating the exact state of the SMSs in the Nigerian aviation sector from the perspective of gathering expert opinions from survey are of concern to the current investigators. It is expected that understanding the dynamics of SMSs in the Nigerian aviation sector will enhance the performance of the industry.

The remaining part of this communication presents the methodological aspect of the work. Next is the data collection and analysis of results. The next section is then the discussion of results. The paper closes with the concluding remarks.

2. Methodology

This section outlines the data collection and analysis tools employed in this paper for the assessment of SMSs in airline companies and the optimization methods and techniques applied to the data collected using questionnaire in the survey.

2.1 Safety Management Systems (SMSs)

According to Hale et al. [1], a safety framework should synergize research with the implementation of safety management. Their framework was based upon insights from literature and current practice, and served as a gap between existing research and future research. It is in this light that this work will follow. SMS assumes that that systems and techniques have safety designed in from the outset, involving systematic technical and managerial skills for success [40]. According to ICAO [20], a SMS is a management process, with responsibility at two levels: the state level and the level of the individual service providers.

According to ICAO Annex 19 document, there exists three main characteristics of SMS, they are:

(1) *Organization and continuity*: Safety management activities must follow a certain framework, and have to be done according to an SMS implementation plan and must be set up in a systematic manner such that the plan is easily scalable and continuous.

(2) *Proactive and reactive*: SMS activities ought to have processes that identify actual and potential hazards and proffer effective prevention plans that are implemented and also have avenues for response in the case where incidents or accidents occur.

(3) *Clearly defined*: All SMS information must be properly documented and communicated clearly and explicitly to all levels of the organization.

The framework for SMS implementation has been defined, in terms of its component parts, by a number of authors, researchers and standard organizations into diverse components. According to ICAO Annex 19 document, the framework comprises four components and twelve elements as the minimum requirements for SMS implementation (see Appendix A): According to Hsu et al. [22], there are six major components of an SMS framework and 25 elements as the minimum requirements for SMS implementation (see Appendix B).

2.2 Revised components of SMS

After proper study and analysis of previous research work and the standard ICAO Annex 19 document, which was our core research reference document, about 6 components are extracted with 22 elements grouped under these. Table 1 shows the components, their respective elements and the definition and meaning of each element.

2.3 Pros and cons of the GRA and DEMATEL

Since GRA is being applied in this paper, it is essential to provide and discuss the pros and cons between it and DEMATEL, which is widely applied in scientific research globally. Table 2 outlines the characteristics of GRA and DEMATEL. None of these methods are perfect in every case of research; they both have their strengths and weaknesses. The application of any of these methods would depend greatly on the nature of the research to be carried out, in terms of the data resources available, the aims and objectives of the research work and the techniques employed and results required of the research.

In employing these models, it is essential to note that If there is insufficient data or a small amount of data available for study, then make use of grey relational analysis. However, if investigations are been made solely into the relative intensities and influence of various factors on a system, then use grey relational analysis since it is less complex. It should be further noted that if investigations are been made into both the impact and interdependence levels of the factors of a system, then use DEMATEL. Also, if a pictorial view of the system's breakdown is required and the ability to apply feedback is needed, then use DEMATEL.

2.4 Data collection

Data collection for the project was majorly done by the use of the research questionnaire (see Appendix C). A total of 50 questionnaires were sent out. The sample population was airline service providers. There were two questionnaires. The first questionnaire consisted of 40 questions framed from the standard ICAO document. The questionnaire was divided into four sections which sought to investigate and assess the degree to much the four major components of an SMS are being implemented in airline service provider companies. The respondents were to answer with either a "Yes", "No", or "I don't know". This served as a proper yardstick to ascertain their knowledge of SMS. There were also physical interviews conducted with respondents, especially with middle level and top level staff.The four categories that were being assessed were:

1. *Issues concerning policy and objectives on safety*: There were a total of 18 questions in this section, and they sought to address the following;
   - Investigate the degree to which staff are aware of SMS regulation and implementation.
   - Investigate the degree to which there is a knowledge of the SMS framework and the degree to which the company complies with it.
   - Investigate whether staff are aware of their SMS roles, duties, responsibilities, accountabilities and authorities.
   - Establish the existence of proper and explicit safety documentation and records systems.
   - Investigate the existence of ERP procedures and the degree to which employees are aware of these procedures

Table 1 Revised Components and Elements of an SMS

S/N	Component	Element	Definition
1	Safety structure and regulation	Safety policy and regulation	A formal, written statement containing the company's safety policy
		Safety objectives and goals	Safety objectives and goals are properly defined, time-oriented and realistic.
		Safety responsibilities, accountabilities and authorities	There is proper designation of safety roles and responsibilities
		Senior management commitment to safety	Senior management is actively involved and dedicated to the SMS.
2	Safety documentation	Documentation, implementation and continuous review of standard regulations	Regulations, standards and exemptions are periodically reviewed to ensure that information is available.
		Safety records control	There is proper archiving of safety data for later use.
		Documentation of all SMS information	All SMS information are clearly documented and available to all.
3	Safety risk management	Emergency response plan	There is reactive plan in place in the event of accident occurrence
		Hazard identification capability	There is a system in place for accurate and timely reporting of relevant information related to hazards, incidents or accidents.
		Safety data collection capability	There is a system in place for collection of safety information for processing
		Assessment of safety risks and hazards	There is a system in place for proper assessment of safety risks and hazards
		Investigation of incidents and accidents	Ability to investigate incidents and accidents
		Safety data analysis	Ability to properly analyse safety information and proffer preventive solutions
		Implementation of risk assessment and analysis results in hazard control	Whether and the degree to which safety recommendations are implemented
4	Safety monitoring and quality assurance	Ability to verify and monitor SMS effectiveness and performance	The degree to which SMS progress can be tracked
		Establishment of performance indicators	Establishment of performance standards
		Internal safety audits	Regular internal inspections of safety compliance within all units in the company
		Change management capability	A process to evaluate the effectiveness of corrective actions.
5	Communication of safety	Communication of SMS roles and duties to staff	Proper sensitization of staff about their SMS duties
		Effective safety information dissemination systems	Effective platforms that gender proper safety information dissemination
6	Promotion of safety	Safety training and education	Equipping of staff with necessary skills to perform their SMS roles
		Development of safety culture	Platforms that gender safety reporting and experience sharing

Table 2 Pros and cons of decision methodologies, GRA and DEMATEL

S/N	Attribute	Grey Relational Analysis (GRA)	DEMATEL
1	Amount of data required	Requires little data (at least four (4) values of the raw data) to be applied	Requires a large amount of data to be applied
2	Type/Nature of data	Interval	Interval
3	Data pre-processing	Requires normalization	Requires normalization
4	Weighted scales	Yes	Yes
5	Reference data series	This is required in GRA	Not required
6	Impact/Result Indicator	Grey relational grade, Γ	Impact relation map
7	Interpretation of the impact indicator	Relative degrees of impact, importance, influence, of the various factors on the overall system	Shows the impact and relation levels of each system factor on the overall system
8	User friendliness	Relatively easy to use	More complex than GRA
9	Ability to calculate factor interdependence	Does not calculate interrelation levels between factors of a system	Calculates interrelation levels by use of pairwise comparisons
10	Pictorial representation of results/Data post-processing	At best, the Grey Relational grades can be used to plot charts and graphs but they do not show the breakdown of the system's interdependence	The Impact Relation Map gives the user a clear picture of the system and its interdependence
11`	Ability to apply feedback	Not possible to apply feedback since it cannot calculate interdependence	Has the ability to apply feedback

- Ascertain whether senior management is committed to safety.

2. *Risk management issues in safety*: This section comprised 11 questions which sought to;
   - Investigate the existence of safety reporting systems, the procedures involved in safety reporting and staff involvement in the process.
   - Investigate the existence of a system for the identification, classification, assessment, analysis and mitigation of safety risks and hazards.
   - Ascertain the existence of a safety collection system in terms of reactive, proactive and predictive safety data collection.
3. *Assurance issues in safety*: This section comprised of 6 questions which sought to investigate the following:
   - If internal safety audits were carried out and the frequency and purpose of such audits.
   - Avenues and frameworks that assists continuous improvement of SMS.
   - Whether performance indicators are in place and if they are periodically reviewed.
4. *Promotion of safety in organisations*: This section comprised of 5 questions that sought to ascertain whether;
   - Safety information was properly disseminated throughout all levels of the organisation and the reasons for deficient systems.
   - Whether employees were properly trained to perform their SMS duties.

The second questionnaire was created and structured with the aim of ascertaining the relative importance and impact of the 22 elements of our revised SMS component system on the overall performance of an SMS. The questionnaire was a Likert type scale with 22 elements and a 1-5 response scale. The respondents were to assess the importance rating of the elements from 1 to 5, where: 1 - Not important 2 - Mildly important 3 - Important 4 - Very important 5 - Extremely important

The second questionnaire employed the use of the Likert scale. The Likert scale was developed by R. Likert in the 1920s by an American educator and organisational psychologist in order to facilitate and present better measurement levels in survey questionnaires. The Likert scaling utilises a subtle form of aggregating a respondent's opinion or attitude by the use of numerical values. This is why it is one of the most used. In a Likert scale survey, respondents are instructed to state their levels of agreement or disagreement with a particular subject matter, is presented in form of numerical values on a predetermined scale. Likert statements, in general, have a five or seven-point scale. In this investigation, we made us of the 5-point scale. In the appendix is the data questionnaire that was distributed.

2.5 Grey Relational Analysis (GRA)

Grey system theory, initiated by Deng [41], is based on the principle of random process. The word "grey" stands for incomplete, uncertain or poor. In Deng's [41] opinion, if a system has totally explicit information, it is a "white" system. On the other hand, if the information in a system is extremely unknown, it is a "black" system. In reality, a lot of systems are majorly "grey" instead of being classified as white or black. Moreover, the grey system consists of grey information for which a part of the messages are clear, but some are not.

GRA is useful in tracking the correlations that exist among factors and candidates that affect a system. An advantage of GRA is that quantitative and qualitative associations may be known from diverse factors having insufficient or partial information. The GRA expatiated in the following is an approach in grey system theory for analyzing discrete data series. According to Hsu et al. [22], a procedure for the GRA, which is appropriate for Likert scale data analysis, consists of the following steps:

- Produce reference data series x_0.
  $x_0 = d_{01}, d_{02}, \ldots, d_{0m})$ (1)

where m indicates the number of respondents. Typically, the x_0 reference data series consists of m values which show the responses with the best outputs.

- Produce comparison data series x_i.
  $x_i = d_{i1}, d_{i2}, \ldots, d_{im})$ (2)

where $i = 1, \ldots, k$ represents the number of scale items. Thus, k comparison data series exists and each comparison data series will have m values.

- Calculate the difference data series Δ_i,

$$\Delta_i = (|d_{01}-di1|, |d_{02}-d_{i2}|, \ldots, |d_{0m}-d_{im}|) \quad (3)$$

- Obtain the global maximum value Δ_{max} and minimum value Δ_{min} in the difference data series.

$$\Delta_{\max} = \max_{\forall i} (\max \Delta_i) \quad (4)$$

$$\Delta_{\min} = \min_{\forall i} (\min \Delta_i) \quad (5)$$

- Change each data point in each difference data series to grey relational coefficient (GRC). Let $\gamma_i(j)$ be the GRC of the j^{th} data point in the i^{th} difference data series, then,

$$\gamma_i(j) = \frac{\Delta_{\min} + \xi\Delta_{\max}}{\Delta_i(j) + \xi\Delta_{\max}} \quad (6)$$

where $\Delta_i(j)$ is the i^{th} value in the Δ_i difference data series. ξ is a value between 0 and 1. The coefficient ξ is used to compensate the effect of $\Delta_{\max}$ should $\Delta_{\max}$ be an extreme value in the data series. In general the value of ζ can be set to 0.5.

- Calculate grey relational grade for each difference data series. Let Γ_i be the grey relational grade for the i^{th} scale item and assume that data points in the series are of the same weights 1, then,

$$\Gamma_i = \frac{1}{m}\sum_{n=1}^{m}\gamma_i(n) \quad (7)$$

The dimension of Γ_i shows the total level of standardized deviance for the i^{th} original data series from the reference data series. Typically, an item having a scale of high values of Γ shows that the respondents, in totality, endorse it to a high degree on specific items.

- Arrange the Γ values obtained in either descending or ascending classification to permit proper deductions from the results for managerial purposes.

- Obtain the threshold grey relational grade Γ_{tr} , by taking the average of all the elements. This is obtained using the equation,

$$\Gamma_{tr} = \frac{1}{k}\sum_{i=1}^{k}\Gamma_i \quad (8)$$

This value indicates the value at which an element with grade equal to or greater than is said to be "critical".

3. Results

3.1 Determination of critical SMS elements using GRA

The survey served as the major collection tool. It was filled by 16 experts with about an average of 15-30 years of experience in aviation safety. They were asked to ascertain, to the best of their knowledge and experience the importance of each element to the implementation of an effective SMS. The survey was a Likert type scale with scale from 1-5 (1 indicates not important while 5 indicates extremely important).

The reference data series which represents the best case was set to 5 according to equation (1). After extracting the results from our survey, we obtained our comparison data series from the experts' surveys. The difference data series was obtained using equation (3). The grey relational coefficients were then obtained using equation (6) with the distinguished coefficient ξ set to 0.5. This decision was made based on past literature research in the field like Hsu et al. [22]. The grey relational grades for each element were then obtained using equation (7). After this, the threshold value was calculated using equation (8). The entire work was done using Microsoft Excel. Table 3 shows the elements and their corresponding grey relational grades, with elements in descending order.

To ascertain the most critical elements of an SMS, we will make use of the threshold Grey relational grade. This value indicates the grade at which an element is considered to be crucial. The threshold value was calculated from the average value of all the grey relational grades, given by equation (8). This gives us an idea of the grade at which a component is said to be "critical". The value was obtained to be 0.667. Based on this value, we obtained 12 major elements out of 22 that greatly affect SMS implementation. The most critical elements according to our research work are obtained to be, Table 4.

Table 3 SMS elements arranged in order of importance (from greatest to least)

SMS Elements	Grey Relational Grade, Γ	Ranking
Safety policy and regulation	0.793	1
Safety objective and goals	0.793	1
Safety responsibilities, accountabilities and authorities	0.743	3
Implementation of risk assessment and analysis results in hazard control	0.732	4
Safety training and education	0.729	5
Documentation of all SMS information	0.707	6
Effective safety information dissemination systems	0.704	7
Assessment of safety risks and hazards	0.704	7
Senior management commitment to safety	0.685	9
Hazard identification capability	0.673	10
Documentation, implementation and continuous review of standard regulations	0.671	10
Ability to verify and monitor SMS effectiveness and performance	0.668	12
Investigation of incidents and accidents	0.662	13
Emergency response plan	0.662	13
Development of safety culture	0.637	15
Safety data collection capability	0.624	16
Safety data analysis	0.607	17
Internal safety audits	0.607	17
Communication of SMS roles and duties to staff	0.601	19
Safety records control	0.596	20
Change management capability	0.554	21
Establishment of performance indicators	0.533	22

Table 4 Critical SMS elements

Ranking	Component	Element	Grade
1	Safety Structure and Regulation	Safety policy and regulation	0.793
1	Safety Structure and Regulation	Safety objectives and goals	0.793
3	Safety Structure and Regulation	Safety responsibilities, accountabilities and authorities	0.743
4	Safety Risk Management	Implementation of risk assessment and analysis results in hazard control	0.732
5	Promotion of Safety	Safety training and education	0.729
6	Safety Documentation	Documentation of all SMS information	0.707
7	Communication of Safety	Effective safety information dissemination systems	0.704
8	Safety Risk Management	Assessment of safety risks and hazards	0.704
9	Safety Structure and Regulation	Senior management commitment to safety	0.685
10	Safety Risk Management	Hazard identification capability	0.673
11	Safety Documentation	Documentation, implementation and continuous review of standard regulations	0.671
12	Safety Monitoring and Quality Assurance	Ability to verify and monitor SMS effectiveness and performance	0.668

Table 5 SMS components and their respective overall Grey grades

SMS Component	Overall GRG	Ranking
Safety Structure and Regulation	0.753	1
Promotion of Safety	0.683	2
Safety Risk Management	0.666	3
Safety Documentation	0.658	4
Communication of Safety	0.651	5
Safety Monitoring and Quality Assurance	0.590	6

In order to obtain a better picture with respect to SMS components, we seek to evaluate the grades component-wise so as to ascertain the most important SMS components. This will be done by taking the average grey relational grade of the various elements under a specific component. This will help us in determining the most influential SMS components. After performing this in Excel, we obtain the following results, Table 5.

4. Discussion of results

4.1 Assessment of SMS

After the analysis of the safety assessment questionnaire and from the deductions of the interviews, the respondents set was divided into lower level, the middle level and top level staff. The following observations were made based on this classification:

- *Lower level staff*: From the survey, there is a huge knowledge gap and ignorance in this level. Almost 90 percent of respondents in this category are unaware of SMS policy and regulation, on whether their companies are involved in its implementation and whether it is implemented according to ICAO standards. These respondents (90%) were however aware of the existence of a safety unit and manager in their organizations but unaware of their SMS roles, responsibilities and authorities in ensuring an overall system safety.

They showed a lack of knowledge of ERP procedures. About 50 percent of respondents were unaware of the existence of proper safety documentation systems. About 45 percent acknowledge that senior management is committed to safety while 30 percent do not even know if senior management is committed to safety. Regarding risk management issues, about 50 percent acknowledged the existence of safety reporting systems, and safety units and departments that identify, classify, assess, analyse and mitigate safety risks and hazards. They however had and could provide little or no knowledge of the intricacies of these systems. Regarding safety reporting systems, many acknowledge that these platforms are not open enough or conducive for their use. Some attributed their negligence of safety reporting to fear of punishment. This shows a lack of compliance with non-punitive reporting strategies.

In issues of safety assurance, about 20 percent acknowledged that safety audits were carried out but all they showed a lack of understanding of the frequency and purpose of these audits. All of the respondents showed no knowledge of frameworks that promote continuous improvement or of safety performance indicators. Regarding promotion of safety in the organization, about 90 percent acknowledge that they are not properly trained to perform their SMS duties. They also acknowledge that they are not properly sensitized of safety information as some are not exposed to safety dissemination systems like safety meetings, bulletins and memos. From these discoveries, there is a huge flaw and the issue is lack of knowledge and training. More efforts should be made to disperse and disseminate safety information by and through every means possible so that it penetrates through from top level even to the lower levels.

- *Middle level staff*: All respondents in this category were aware of SMS regulation and implementation in their various organisations. Only about 5 percent were not aware whether it was done according to ICAO standard guideline. About 20 percent said that there is a lack of compliance with ICAO in their safety activities. About 70 percent were aware of their safety roles, duties, responsibilities, accountabilities and authorities. They acknowledged the commitment of senior management to safety. About 40 percent said that there was a lack of proper safety documentation and record keeping. All respondents agreed on the existence of ERP and its procedures. However, about 50 percent were not familiarised with these procedures. In issues of risk management, there was much knowledge in this area. About 90 percent of the respondents acknowledged the existence of safety reporting systems but they were of the view that all staff were not tasked with safety reporting or rather that the system placed restrictions on safety reporting by all staff in this category. All respondents acknowledged the existence of a system for the identification, classification, assessment, analysis and mitigation of safety risks and hazards. About 70 percent acknowledged the existence of a safety collection system that collects data for reactive, proactive and predictive purposes.

In safety assurance, about 65 percent acknowledged the existence of safety audits. Among these, almost 90 percent knew of the frequency of these audits and acknowledged that they were for monitoring and corrective actions. Only about 50 percent were aware of platforms and structures that promote continuous improvement of SMS and that effectively manage change. About the same percentage were aware of performance indicators but only about 20 percent could specifically mention the manner in which safety performance was monitored and reviewed. The majority of respondents acknowledged safety information dissemination systems but were of the opinion that they were not effective enough. About 90 percent said that they and staff as a whole were not adequately trained to perform their SMS duties. These observations show that safety is taken seriously on this level to an extent but there is much more work to be done in safety training and information sharing.

- *Top level staff*: All respondents showed great knowledge of safety in all components that were accessed. The observations from the survey and interview showed that most problems in SMS penetration were due to lack of adequate resources and the misappropriation of these resources. This would mean that the usage of scarce resources was not efficient enough. They all acknowledge the need for better safety training and education on all levels and to every staff involved in an airline's activities. They

agreed that there needs to be more open access to safety reporting and that all staff should be actively involved, which is not the case. They were of the opinion that more efforts should be put into safety sensitization, promotion and development of safety culture. They also acknowledged the fact that more work should be done in the implementation of the results obtained from safety risk analysis and investigations.

From our observations, more work has to be done in sensitising staff of their SMS roles and duties, in safety training and education and in safety promotion. There has to be an improvement in the openness of safety reporting systems so as to promote better participation. Incentives can be used to do this. Non-punitive reporting should be upheld strongly. There should be more implementation of results from safety investigations and audits.

4.2 Assessment of SMS: Company-specific analysis

The questionnaires were distributed and interviews were held. This was done to ascertain that responses were accurate and not fraudulent. Companies were designated as Company A and B for confidentiality purposes as the purpose of the data was for research alone. For better interpretation of results, staff was divided into three sections: lower, middle and top level staff.

- Company A

A total of 16 questionnaires were distributed to this company. In the lower level, 8 personnel were examined, middle level 5 and top level 3. From our research, the following observations were made:

Concerning safety policy and regulation, which consists of 18 cross-examination questions, there is a lot of ignorance in the understanding of this SMS component. Questions 1-3 sought to establish whether there is knowledge of the legal nature of SMSs, whether SMS is being implemented and if it is done according to standard regulations. In lower level staff, about 80 percent are unaware of SMS policy and regulation, the same percentage are unaware of the implementation of SMS or whether it is done according to standards. Only 20 percent answered affirmatively to these questions. This shows that there is little knowledge of SMS regulation in the lower level staff. In middle level, 100 percent are aware of SMS policy and regulation, 85 percent agree that SMS is being implemented and the same percentage agree it is done according to standards. The remaining 15 percent are unaware. In top level staff, 100 percent answered affirmatively for these questions.

For questions 4-5, which sought to ascertain whether there is a guidance document for SMS, in lower level staff, only 40 percent agree that their organisation has a clearly written and documented safety policy. The others are unaware if it exists. In mid-level staff, 80 percent agree to the existence of a safety policy while the other 20 percent are unaware. For top level staff, 99 percent answered affirmative. For questions 6-7, for low level staff, about 70 percent acknowledge the fact that their company has set out goals and objectives for safety but 80 percent do not know if there is a step by step approach for SMS implementation to achieve these goals. More needs to be done in ensuring that there is sensitization on this level. For middle level staff, 90 percent answered affirmative while top level staff all answered affirmative to these questions. This shows that the company has done a good job in defining safety goals and objectives and relaying this information to its employees.

Question 8 sought to ascertain whether the company provides manuals for various tasks. For lower level staff, 90 percent acknowledge the existence of safety suggestive manuals which is a good safety mark. For mid-level and top level staff, all answered affirmative. This shows that the company is dedicated to ensuring there is ample information for guiding employees in their tasks.

Questions 9-12 sought to determine whether there are designated safety authorities in the organisation. For the low level staff, 75 percent, 65 percent, 85 percent and 60 percent answered affirmative for questions 9 to 12 respectively. The other respective percentages were not aware. This shows a fair record as a good percentage are aware of safety authorities. For middle level staff, 90 percent answered affirmative for these questions while all top level staff also answered affirmative. This shows that there are appropriate safety authorities and a safety manager to strategise, plan, coordinate and monitor safety activities in the organisation. Also, it shows that the safety manager is properly trained to fulfil his duty. Due to the fact that some are still unaware of safety authorities, this shows that more work needs to be done in communicating to all staff about their safety authorities.

For question 13, 75 percent of lower level staff agree that senior management is committed to safety while the rest disagree. 90 percent of mid-level staff agree while 10 percent do not. This is a good record as this will serve to encourage the development of a good safety culture. For question 14, only 40 percent of low level staff agree that there is proper documentation while the rest are unaware. 90 percent of mid-level staff agree that there is proper documentation of safety information. 99 percent of top level staff also agree. 85 percent of low level staff acknowledge the existence of a safety records unit which is an essential factor in data collection and analysis. 95 percent of mid-level staff also acknowledge the existence of a safety records unit. All top level staff acknowledge this also. This shows that there is a safety unit that handles safety records and information for use in safety development and support.

For questions 16-18, 50 percent of low level staff answered affirmative while 50 percent are not aware at all. This shows a need for further improvement in the communication of ERP procedures on this level. 90, 80, and 85 percent of mid-level staff answered “Yes” for questions 16, 17 and 18, respectively. All top level staff answered affirmative for all questions although they acknowledged that not all employees were aware of ERP procedures. This shows that more proper sensitisation needs to be done.

For risk management issues in safety, Question 19 sought to ascertain whether the company was capable to collect and process safety data effectively. In low level staff, eighty percent are unaware of the existence of a safety data collection and processing system. Among the 20 percent that acknowledge that such a system exists, none could give answers on the methods and tools used by these systems. However, 70 percent of mid-level staff answered affirmative for this question but they all encountered problems in mentioning the methods used. All top level staff answered affirmative. Only this section was able to provide answers to question 20. This shows that there is a lack of understanding the workings of the safety data collection system which shows that there is need for more safety education and communication.

Questions 21-23 sought to determine and investigate safety reporting systems and procedures. This element is crucial in the mitigation of risks and hazards and is pivotal to the implementation of SMS. For low level staff, 75 percent acknowledged the existence of safety reporting platforms while the remaining do not know if such systems exist. 50

percent agree that all employees are involved in safety reporting while 40 percent do not agree that all employees are tasked with safety reporting. The remaining 10 percent do not know if all employees are tasked with safety reporting. About 90 percent feel that the system is not conducive for the use of all staff. For mid-level staff, 90 percent agree that there is an incident and accident reporting system in place and that all employees are tasked with the duty of safety reporting. However, about 50 percent are of the opinion that the system is not conducive enough for all staff. Top level staff answered affirmative for all the questions. They also however, acknowledged that not all staff are involved in safety reporting due to the fact that some fear that they will be punished which is not the case. More work has to be done to convince all staff of their SMS roles of which safety reporting is one. Also, non-punitive reporting must be upheld and publicised to gender better participation.

Questions 24 - 26 sought to ascertain the existence of a system for analysis and assessment of the safety risks of identified hazards which is very key in ensuring that an SMS is proactive and preventive. Low level staff expressed little knowledge of these systems as a percentage of 85 do not know if these systems exist. The other 15 percent acknowledge the existence of such systems. Almost 95 percent do not know if reported cases are investigated or if there is a corresponding implementation of the recommendations from such investigations. Among mid-level staff, 85 percent answered affirmative for question 24 although this same percentage say that all reported cases are not investigated. About 70 percent do not know if there is an implementation of the results of the investigations. Top level staff all answered affirmative for question 24 but that not all cases are investigated. They also acknowledged that there was a corresponding implementation but not for all cases. This shows that more work has to be done in investigating all reported cases so as to keep safety at an acceptable level to the best of your SMS knowledge.

Questions 27 through to 29 assess the capability of the company to mitigate hazards and risks via its SMS. Almost all low level staff are not aware if there is a system in place that is tasked with reactive, proactive and predictive control measures of identified safety risks so they were also not able to answer questions 28 and 29. Mid-level staff, however, is aware of such systems. About 85 percent agree that there is a system in place that is tasked with reactive, proactive and predictive control measures of identified safety risks. Out of this percentage, only 50 percent were able to answer questions 28 and 29. They all answered “both” in question 29. Top level staff all answered affirmative for questions 27 and 28 and “both” for question 29. From our observations, we can see that there is a need for better safety communication of SMS information to lower level staff.

Questions 30 to 32 sought to assess whether there was a system for internal safety inspection which is crucial for SMS continuity, growth and assessment. For lower level staff, 80 percent acknowledge the fact that internal safety audits are carried out while 20 percent are not aware. However, almost all could not specifically state the frequency of such audits or the reasons behind such audits. About 95 percent of staff in this level could not answer questions 32 to 35. This shows that a lot has to still be done in safety communication. For middle level staff, about 95 percent agree that internal safety audits are carried out. About 70 percent answered that audits are done annually although they were not able to say whether the recommendations are implemented. They could not give clear answers to question 35. All top level staff agree that internal safety audits are carried out quarterly and at times impromptu audits are carried out for various reasons. They also said that though recommendations are implemented, not all are implemented. They also answered affirmative for questions 33 and 34. They were able to answer question 35.

Concerning promotion of safety in organisations, questions 36 through to 40 sought to assess how much SMS is promoted and the degree to which promotion efforts have helped in ensuring that SMS permeates through all levels of an organisation. For low level staff, about 70 percent acknowledge that there are platforms that help in safety information dissemination on the roles of all employees in the implementation of SMS. The various platforms mentioned were wall signs, notice boards, safety adverts, safety meetings and safety bulletins. This shows that there is significant effort put in conveying safety responsibilities, roles, duties and obligations to all staff. About 70 percent said that employees are not properly sensitized of their roles. Their reasons were mainly due to lack of proper communication and training. More effort must be put in place to sensitize staff of their SMS roles. About 60 percent were of the opinion that employees were trained to perform their SMS duties and roles. The others answered negative in this section.

For middle level staff, about 95 percent agree that there are platforms that help in safety information dissemination on the roles of all employees in the implementation of SMS. They mentioned the same platforms with additions like ICT which referred to online memos, bulletins, service letters, and manuals. About 50 percent said that employees are not properly sensitized of their SMS roles. This shows that a major safety gap lies in communication. Their reasons spanned from negligence on the path of the employee to inadequate safety communication platforms. About 65 percent are of the opinion that employees were trained to perform their SMS duties. This means that 35 percent are of the opinion that they are not properly trained to perform their SMS roles and duties. Top level all answered affirmative for question 36. For question 38, however, they acknowledged that more work is being done in creating and building more effective platforms for information sharing as this is directly linked with SMS communication. The major reason given for the lack of effectiveness of these platforms was lack of resources. About 90 percent said that staff are trained to perform their specific SMS duties and roles. They, however, admitted to the fact that staff are not as trained as they should be. This is due to scarce resources.

From our analysis, there is need for a focus on safety information sharing and sensitization techniques as this will enable SMS to permeate through all levels, enable employees be aware of their SMS roles and duties and gender a better safety culture. Also, much work has to be done in the area of safety promotion with focus on the development of a good safety culture that will gender participation on all levels of the organisation. They should also be a plan in place for proper safety training and education so as to equip staff with the necessary skills to perform their safety duties.

- Company B

A total of 21 questionnaires were distributed with 8 given to low level staff, 10 to mid-level staff and 3 given to top level staff. The following deductions can be made from the retuned questionnaires.

Questions 1-3 sought to establish whether there is knowledge of the legal nature of SMSs, whether SMS is being implemented and if it is done according to standard regulations. In lower level staff, about 95 percent are unaware of SMS policy and regulation, the same percentage

are unaware of the implementation of SMS or whether it is done according to standards. Only 5 percent answered affirmative for these questions. This shows that there is little knowledge of SMS regulation in the lower level staff. In middle level, 95 percent are aware of SMS policy and regulation, 70 percent agree that SMS is being implemented and only 50 percent of this agree that it is done according to ICAO framework and standards. The remaining 50 percent are unaware if their SMS contains the required components and elements as stated by ICAO. In top level staff, 100 percent answered affirmative for these questions.

Questions 4-5 sought to ascertain whether there is a well detailed and documented safety policy with reference to the activities that are carried out by the organisation. For lower level staff, only 20 percent agree that their organisation has a clearly written and documented safety policy. The others are unaware if it exists. In mid-level staff, 75 percent agree to the existence of a safety policy while the other 25 percent are unaware. For top level staff, 99 percent agree to the existence of a safety policy.

Questions 6-7 sought to ascertain whether the company has drafted out and identified its safety goals and objectives and the degree to which planning has been made for the achievement of these goals. For low level staff, about 30 percent acknowledge the fact that their company has set out goals and objectives for safety and only about 5 percent know that there is a step by step approach for SMS implementation to achieve these goals. A lot of work must be done to convey the company's safety targets to this level. For middle level staff, 80 percent answered affirmative while top level staff all answered affirmative to these questions. This shows that the company has done a good job in defining safety goals and objectives and relaying this information to its employees.

Question 8 sought to investigate whether the company provides safety literature that defines the various steps taken in achieving a specific task safely. For lower level staff, about 75 percent acknowledge the existence of safety suggestive manuals which is a good safety mark. For mid-level staff, about 90 percent agreed to the existence of safety suggestive manuals while for top level staff, all answered affirmative. This shows that the company is dedicated to ensuring there is ample information for guiding employees in their tasks.

Questions 9-12 sought to determine whether there are designated safety authorities in the organisation that are responsible for planning, coordinating, and monitoring safety activities in its respective departments. For the low level staff, 60 percent, 50 percent, 80 percent and 55 percent answered "Yes" for questions 9 to 12 respectively. The other respective percentages were not aware. This shows a rather fair record as a good percentage are aware of safety authorities. For middle level staff, 90 percent answered affirmative for these questions while all top level staff also answered affirmative. This shows that there are appropriate safety authorities and that, to an extent, employees are aware of these authorities. Also, it shows that safety managers are properly trained to fulfil his duty. Due to the fact that some are still unaware of safety authorities, this shows that more work needs to be done in communicating to all staff about their safety authorities.

For question 13, 50 percent of lower level staff agree that senior management is committed to safety while the rest disagree. 70 percent of mid-level staff agree while 30 percent do not. This shows that to an extent, senior management show commitment to safety although more work has to be done in this aspect. For question 14, only 25 percent of low level staff agree that there is proper documentation while the rest are unaware. 80 percent of mid-level staff agree that there is proper documentation of safety information. 99 percent of top level staff also agree that there is proper documentation of safety information. 70 percent of low level staff acknowledge the existence of a safety records unit which is an essential factor in data collection and analysis. 90 percent of mid-level staff also acknowledge the existence of a safety records unit. All top level staff acknowledge this also. This shows that there is a safety unit that handles safety records and information for use in safety development and support. There is also proper archiving of data for future use.

Questions 16-18 sought to investigate the existence of emergency response plans and procedures. 50 percent of low level staff answered affirmative while 50 percent are not aware at all. This shows a need for further improvement in the communication of ERP procedures on this level. 80, 70, and 80 percent of mid-level staff answered "Yes" for questions 16, 17 and 18 respectively. All top level staff answered affirmative for all questions although they acknowledged that not all employees were aware of ERP procedures. This shows that more proper sensitization needs to be done.

Question 19 sought to ascertain whether the company was capable to collect and process safety data effectively. In low level staff, eighty percent are unaware of the existence of a safety data collection and processing system. Among the 20 percent that acknowledge that such a system exists, none could give answers on the methods and tools used by these systems. However, 60 percent of mid-level staff answered affirmative for this question but they all encountered problems in mentioning the methods used. All top level staff answered affirmative. Only this section was able to provide answers to question 20. This shows that there is a lack of understanding the workings of the safety data collection system which shows that there is need for more safety education and communication.

Questions 21-23 sought to determine and investigate incidents and accidents reporting systems, procedures and platforms. This SMS element is crucial in the mitigation of risks and hazards and is pivotal to the implementation of SMS. For low level staff, 55 percent acknowledged the existence of safety reporting platforms while the remaining do not know if such systems exist. 35 percent agree that all employees are involved in safety reporting while 50 percent do not agree that all employees are tasked with safety reporting. The remaining 15 percent do not know if all employees are tasked with safety reporting. About 99 percent feel that the system is not conducive for the use of all staff. Most feel they might be punished for indulging in the process. For mid-level staff, 90 percent agree that there is an incident and accident reporting system in place and that all employees are tasked with the duty of safety reporting. However, about 65 percent are of the opinion that the system is not conducive enough for all staff. Top level staff answered affirmative for all the questions. They also however, acknowledged that not all staff are involved in safety reporting due to the fact that some fear that they will be punished, which is not the case. More work has to be done to convince all staff of their SMS roles of which safety reporting is one. Also, non-punitive reporting must be upheld and publicised to gender better participation.

Questions 24 -26 sought to ascertain the existence of a system for analysis and assessment of the safety risks of identified hazards which is very key in ensuring that an SMS is proactive and preventive. Low level staff expressed little knowledge of these systems as a percentage of 95 do not

know if these systems exist. The other 5 percent acknowledge the existence of such systems. Almost 99 percent do not know if reported cases are investigated or if there is a corresponding implementation of the recommendations from such investigations. Among mid-level staff, 80 percent answered affirmative for question 24 although this same percentage say that all reported cases are not investigated. About 80 percent do not know if there is an implementation of the results of the investigations. Top level staff all answered affirmative for question 24 but that not all cases are investigated. They also acknowledged that there was a corresponding implementation but not for all cases. This shows that more work has to be done in investigating all reported cases so as to make sure that all hazards are eliminated or brought to a level of acceptable risk.

Question 27 to 29 assess the capability of the company to mitigate hazards and risks through its safety management system. 95 percent of low level staff are not aware if there is a system in place that is tasked with reactive, proactive and predictive control measures of identified safety risks so they were also not able to answer questions 28 and 29. Mid-level staff, however, are aware of such systems. About 80 percent agree that there is a system in place that is tasked with reactive, proactive and predictive control measures of identified safety risks. Out of this percentage, only 40 percent were able to answer questions 28 and 29. They all answered "both" in question 29. Top level staff all answered affirmative for questions 27 and 28 and "both" for question 29. From our observations, we can see that there is a need for better safety communication of SMS information to lower level staff.

Questions 30 to 32 sought to assess whether there was a system for internal safety inspection which is crucial for SMS continuity, growth and assessment. For lower level staff, 65 percent acknowledge the fact that internal safety audits are carried out while 35 percent are not aware. However, almost all could not specifically state the frequency of such audits or the reasons behind such audits. About 99 percent of staff in this level could not answer questions 32 to 35. This shows that a lot has to still be done in safety communication. For middle level staff, about 95 percent agree that internal safety audits are carried out. About 50 percent answered that audits are done twice in a year although they were not able to say whether the recommendations are implemented. They could not give clear answers to question 35. All top level staff agree that internal safety audits are carried out quarterly and at times impromptu audits are carried out for various reasons. They also said that though recommendations are implemented, not all are implemented. They also answered affirmative for questions 33 and 34. They were able to answer question 35.

Questions 36 to 40 sought to assess how much SMS is promoted and the degree to which promotion efforts have helped in ensuring that SMS permeates through all levels of an organisation. For low level staff, about 50 percent acknowledge that there are platforms that help in safety information dissemination on the roles of all employees in the implementation of SMS. The various platforms mentioned were safety adverts, notice boards and safety bulletins. This shows that effort is being put into conveying safety responsibilities, roles, duties and obligations to all staff. About 85 percent said that employees are not properly sensitized of their roles. Their reasons were mainly due to lack of proper communication and training. More effort must be put in place to sensitize staff of their SMS roles. About 70 percent were of the opinion that employees were not properly trained to perform their SMS duties and roles. This shows a great need for safety training and education. For middle level staff, about 90 percent agree that there are platforms that help in safety information dissemination on the roles of all employees in the implementation of SMS. About 60 percent said that employees are not properly sensitized of their SMS roles. This shows that a major safety gap lies in communication. They attributed this to the lack of effective safety info dissemination platforms and efforts. About 65 percent are of the opinion that employees were not properly trained to perform their SMS duties. Top level staff all answered affirmative for question 36. For question 38, however, they acknowledged that more work needs to be done in creating and building more effective platforms for information sharing as this is directly linked with SMS communication. The major reason given for the lack of effectiveness of these platforms was lack of resources and the misappropriation of the scarce resources available. About 50 percent said that staff are trained to perform their specific SMS duties and roles. They admitted to the fact that staff are not as trained as they should be.

From our analysis, we see that there is great need for a focus on more in-depth safety information dissemination platforms and methods. This is because the major gap in safety here laid in ignorance and lack of knowledge of the SMS structure among staff. Improving this aspect of the SMS will go a long way in ensuring that staff are properly sensitized and kept up to date with SMS information. Also, much work has to be done in the area of safety promotion with focus on the development of a good safety culture that will gender safety participation especially in safety reporting on all levels of the organisation. Non-punitive reporting should also be stressed and enforced strictly. More resources should be focused on safety training and education so as to equip staff with the necessary skills to perform their SMS roles and duties.

4.3 Critical components and elements of an effective SMS

Safety in aviation is one of the key factors in having and sustaining a thriving airline business and the major tool of aviation safety is the SMS. It is defined as a systematic approach to managing safety, including the necessary organisational structures, accountabilities, policies and procedures [20]. According to Roelen and Klompstra [42], aviation safety management is becoming a regulatory requirement rather than an industry best practice. Gill and Shergill [35] stated that the effectiveness of a SMS depends on how well it penetrates through the organization. We therefore used GRA to determine the critical components and elements of a SMS. From our results, we can make the following deductions;

- All components of an SMS are important in implementing an effective SMS. This is because at least one element from each component is critical. We obtained 12 critical elements out of the 22 revised SMS elements that affect SMS, Table 3.
- Though all components of an SMS are important, they all vary in their degrees of importance to building an effective SMS, Tables 2.
- In building an effective SMS, safety structure and regulation plays a very pivotal role, in fact, it is the most important component. This is because all its elements are "critical" and it also has the overall best grey relational grade. The elements under this component are safety policy and regulation, safety objectives and goals, safety responsibilities, accountabilities and authorities and senior

management commitment to safety. Safety structure and regulation deals with activities that concern the company's dedication and commitment to safety imbibed in its core values. Safety must be reflected in its mission, vision and core values. It deals with the company's foundational loyalties to safety in all its activities and its compliance with law, regulation, and oversight authorities. This reflects what safety policy and regulation and Safety objectives and goals stand for. This also means that safety must be crucial to and be upheld by top level management as these are those which make the most important decisions. This reflects the senior management commitment to safety. This component also deals with organisation, that is, the hierarchal nature of businesses with staff at different levels, lower level, middle level and top level staff. Every member of the organization must be aware of their SMS duties and responsibilities and of the safety authorities that exist in their organization. This also means that there must be safety dedication, accountability and responsibility on every such level.

Promotion of safety comes next in importance with 1 critical element out of its 2 elements. Promotion of safety deals with safety activities information dissemination and encouragement in an organisation. The critical element under this component is safety training and education. This deals with equipping staff with the necessary knowledge and skills to perform their SMS duties. This is a critical part of an effective SMS, as without the skill needed to perform a task, an individual will always fall below the standard expected of him/her. Therefore, without proper safety training, there will always be a great tendency of a company falling short of an acceptable level of safety.

Safety risk management is third in importance having 3 critical elements out of is 7 elements. The critical elements under safety risk management are implementation of risk assessment and analysis results in hazard control, assessment of safety risks and hazards and Hazard identification capability. Safety risk management as a whole deals with all activities that deal with the proactive, predictive, reactive and corrective management of risks and hazards to safety. It deals with the identification, assessment, analysis, and mitigation of risks and hazards associated with the systems' activities and the implementation of recommendations and solutions deduced from the results of such investigations. Results showed that for an effective SMS, there is need for the implementation of the results of safety risk assessment and analysis in hazard control. This element encompasses the capability to identify safety risks and hazards, the ability to analyse and interprete this safety data, the ability to collect and process such data in order to proffer preventive and proactive solutions to mitigate safety risks and keep them at acceptable levels. It then emphasizes practical application of the results obtained from this processes. These mean that an SMS must be focused on preventive actions rather than curative actions. These results show that for an effective SMS, there must be a good hazard identification system, a system that seeks to assess safety risks and hazards, analyse them and proffer preventive and proactive solutions that will be implemented to prevent accidents and threats to safety from ever occurring.

Safety documentation comes next with 2 out of its 3 elements being critical. Safety documentation deals with the documentation of all safety related data and information and the safekeeping of this data for such a time when it will be needed. The critical elements were Documentation of all SMS information and Documentation, implementation and continuous review of standard regulations. These both deal with proper documentation of SMS information, internal safety information and external safety information from safety authorities. There must be proper detailed record taking of tasks, processes, activities, decisions objectives and so on. These lays a ground work for easy scalability and succession. It is also crucial for safety investigations and analysis. Therefore, for an effective SMS, there must be proper detailed documentation of all safety information, both internal information and external information. They must also be proper review of such information so that they are always up to date and relevant.

Communication of safety comes fifth in ranking with 1 out of its 2 elements being critical. Communication of safety deals with the activities that involve relaying safety information to those that need them. The critical element of this component is Effective safety information dissemination systems. For an effective SMS, there must be very effective and efficient platforms by which safety information is disseminated, platforms that ensure that every member gets the safety information that he needs.

Finally, safety monitoring and quality assurance comes in the sixth place with just 1 out of its 4 elements being critical. As the name implies, it deals with activities that help in monitoring safety and ensuring that safety standards are known and maintained. The critical element under this component is the Ability to verify and monitor SMS effectiveness and performance. These means that to a good extent a company must be dedicated to ensuring that it grows and improves in safety in its activities by having methods that they utilise in verifying and monitoring their safety progress so as to enable them ascertain areas that need to be improved upon and those that need to be maintained.

These results give the safety manager a clearer picture in helping him determine how to allocate his scarce resources in other to further build and develop an SMS and also serve as a framework for building new SMSs.

5. Conclusions

At a time when safety in aviation has become not just a voluntary practice but a legal requirement, the need for proper implementation and establishment of stable, effective and efficient SMSs becomes compelling and very necessary. From our safety assessment questionnaire and interview findings, it is seen that a major problem in the establishment of SMS is the complexity of these systems and the fact that there are inadequate resources. This therefore means that the safety manager or engineer is faced with a problem of optimisation and prioritisation. Company-wise, Company A has a better safety record than Company B due to the fact that SMS information has permeated better through all respective levels of the organisation. This is because a greater percentage of lower and middle level staff acknowledged and were aware of SMS in all its complexities. This shows that more effort was placed on SMS penetration and implementation. The findings showed that there is a knowledge of SMS in airline organisations but it is not detailed enough meaning that many are aware of SMSs but are not properly acquainted with its dynamics and intricacies. There should also be more open access to safety reporting on all levels.

A major downside to safety was the lack of proper safety training and education. This was a major problem. This would mean that more effort has to be put into this area of safety. Our results identified 12 major critical elements of

SMS and 6 components of an SMS. These provide a clear picture for management in their distribution and allocation of resources so as to make sure that the SMS penetrates through all levels of the organisation. Results show that having a thorough and proper safety structure and compliance to regulation is the most important component to building long lasting and effective SMSs. This deals with the company first dedicating itself to safety and conveying this image to all employees in its mission, vision and core values. The results from the optimization process agree with the gaps identified from our questionnaire findings. Our research work should be applied in order to make the SMS proactive, predictive and also reactive.

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7. Appendix

Appendix A: ICAO Annex 19 document: A framework
1. Safety policy and objectives
    1.1 Management commitment and responsibility
    1.2 Safety accountabilities
    1.3 Appointment of key safety personnel
    1.4 Coordination of emergency response plan
    1.5 SMS documentation
2. Safety risk management
    2.1 Hazard identification
    2.2 Safety risk assessment and mitigation
3. Safety assurance
    3.1 Safety performance monitoring and measurement
    3.2 Management of change
    3.3 Continuous improvement of the SMS
4. Safety promotion
    4.1 Training and education
    4.2 Safety communication

Appendix B: Hsu's et al. [22] SMS framework
1. Organization
    1.1 Safety policy
    1.2 Safety objective and goals
    1.3 Organizational structure, responsibilities and accountabilities
    1.4 Management commitment
    1.5 Performance measurement/baseline
2. Documentation
    2.1 Identification and maintenance of applicable regulations
    2.2 Documentation describing system component
    2.3 Records management
    2.4 Information management
3. Risk Management
    3.1 Investigation capability
    3.2 Hazard identification
    3.3 Safety analysis capability
    3.4 Risk assessment
    3.5 Recommending actions based on safety metrics
4. Quality assurance
    4.1 Safety performance monitoring
    4.2 Audits
    4.3 Change management
5. Safety Promotion
    5.1 Training
    5.2 Safety culture
    5.3 Safety lessons learned
    5.4 Communication
    5.5 Proactive process
6. Emergency response
    6.1 Emergency response plan
    6.2 Risk Management capability
    6.3 Emergency proactive action

Appendix C

THE QUESTIONNAIRE
ORGANISATIONAL BRIEF/INFORMATION
(Safety Questionnaire 1)

Name:
Address:
Location:
Products/Services:
Layout Area:
What is your position in your organisation?_____

S/N	ISSUES CONCERNING POLICY AND OBJECTIVES ON SAFETY	Yes	No	I don't know
1	Do you know of the SMS policy and regulation for all aviation service providers?			
2	If yes, is your organisation involved in the implementation of SMS?			
3	If yes, is it implemented according to ICAO guideline for SMS?			
4	Does your organisation have a clearly stated and documented safety policy?			
5	Are all employees aware of this policy?			
6	Does your company have set out goals and objectives for safety?			
7	Does your organisation have a laid out plan (step by step approach) for effective SMS implementation that would meet its safety goals and objectives?			
8	Are there safety suggestive literature and manuals for various tasks?			
9	Are you having any safety unit in your organisation?			
10	Is there any council responsible for safety issues in your organisation?			
11	If yes, is there a designated person in charge of SMS implementation and maintenance, like a safety manager?			
12	Has the safety manager been properly trained and equipped for such a task?			
13	Is senior management actively involved and committed to safety?			
14	Is there proper documentation of all SMS information (requirements, procedures, processes, policy and objectives)?			
15	Does your company have a unit that handles safety records and information for use in safety development and support?			
16	Does your company have an emergency response plan and procedure?			
17	Are the employees aware of such procedures?			
18	Are there schemes used to familiarise staff with such procedures?			

S/N	ISSUES CONCERNING POLICY AND OBJECTIVES ON SAFETY	Yes	No	I don't know
19	Is there a system in place for safety data collection and processing?			

20. If yes, what methods and tools are used for your safety data collection and processing? _____

S/N	RISK MANAGEMENT ISSUES IN SAFETY	Yes	No	I don't know
21	Is there a system in place for incidents and accidents reporting?			
22	Are all employees tasked with the duty of incident and accident reporting?			
23	If yes, do you feel the system is open and conducive for the use of all staff?			
24	Is there a system in place for analysis and assessment of the safety risks of identified hazards?			
25	Are all reported cases investigated?			
26	If yes, is there a corresponding implementation of the recommendations from the safety investigation?			
27	Is there a system in place for reactive, proactive and predictive control measures of identified safety risks?			
28	Are such hazards properly classified?			

29. If yes, in what manner, probability or severity or both?_____

S/N	ASSURANCE ISSUES IN SAFETY	Yes	No	I don't know
30	Do you have any system whereby internal safety is inspected?			

31. If yes, how often are internal safety audits carried out and to what end are they carried out?_____

S/N	ASSURANCE ISSUES IN SAFETY	Yes	No	I don't know
32	Are recommendations from such audits implemented?			
33	Is there any system in place for managing change and controlling the risks it might bring?			
34	Does your SMS framework have avenues for continuous improvement?			

35. In what ways does your organization monitor and validate safety performance and the effectiveness of their SMS? Mention specific safety performance indicators_____

S/N	PROMOTION OF SAFETY IN ORGANISATIONS	Yes	No	I don't know
36	Are there platforms for safety information dissemination on the roles of senior management and staff in SMS implementation?			
37	Are personnel, in your view, properly sensitized of their roles and duties in SMS implementation?			

38. If yes, mention the various platforms used to communicate safety information to personnel? _____

39. If NO, why? _____

S/N	PROMOTION OF SAFETY IN ORGANISATIONS	Yes	No	I don't know
40	Are employees trained effectively so as to enable them carry out their SMS duties?			

Determination of the Most Influential Elements in SMS Implementation ((Safety Questionnaire 2)

On a scale of 1-5 where:
1: Not important
2: Mildly important
3: Important
4: Very important
5: Extremely Important

Kindly assign grades for the following SMS components in view of their overall importance and necessity to the implementation of SMS in aviation.

SMS component	Grade
Safety policy and regulation	
Safety objective and goals	
Safety responsibilities, accountabilities and authorities	
Senior management commitment to safety	
Documentation, implementation and continuous review of standard regulations	
Emergency response plan	
Hazard identification capability	
Safety data collection capability	
Safety records control	
Assessment of safety risks and hazards	
Investigation of incidents and accidents	
Safety data analysis	
Implementation of risk assessment and analysis results in hazard control	
Establishment of performance indicators	
Ability to verify and monitor SMS effectiveness and performance	
Internal safety audits	
Change management capability	
Safety training and education	
Communication of SMS roles and duties to staff	
Development of safety culture	
Documentation of all SMS information	
Effective safety information dissemination systems	

8. Abbreviations

ISO – International Standard Organization
OSH – Occupational Health and Safety
HSE – Health, Safety and Environment
SMSs – Safety Management Systems
GRA – Grey relational Analysis
AHP – Analytic Hierarchy Process
OSHMS – Occupational Health and Safety Management Systems
SSP – State safety Programme
DEMATEL – Decision- Making Trial and Evaluation Laboratory
ERP – Emergency Response Plan
SARP– Standards and Recommended Practices
PAAN – Pan African Airline Nigeria
ICAO – International Civil Aviation Organization
NCAA - Nigerian Civil Aviation Authority
NAMA – Nigerian Airspace Management Agency
FAAN – Federal Aviation Authority of Nigeria