RANKING OF THE FACTORS AFFECTING FORENSIC SCIENCE LABORATORY PERFORMANCE USING ANALYTICAL HIERARCHY PROCESS

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ABSTRACT
This paper presents the application of analytical hierarchy process (AHP) methodology in identification and ranking of the factors affecting the performance of a forensic science laboratory (FSL) as decision making problem. As part of multi-criteria decision-making (MCDM) tool AHP was selected due to its power in ranking the cause factors. Two sets of three performance indicators were identified based on employees perceptions (number of case-files backlogged, extended turnaround time and implementation of quality management system (QMS)) and (supply chain management (SCM) challenge, professional and academic development and high absenteeism rate), leading to a *3 x 3* comparison matrices. The performance factors were analyzed using two sets of cause factors (high sample influx, lack of specialized equipment and large number of case-files per analyst) and (lack of funds/budget, low number of competent/qualified staff and lack of motivation for self-development). After evaluation of consistency vectors (*CV*), consistency index (*CI*) and random index (*RI*), the consistency ratio (*CR*) was tested successfully ($CR < 0.1$) in both cases leading to the final ranking of the cause factors, which shows that the high sample influx was highly ranked in the first set of cause factors and lack of funds/budget for the second set. The AHP method allows the management to focus on solving the problems related to these highly ranked cause factors in order to finally improve the FSL performance.

KEYWORDS: *Forensic science laboratory, performance measures for FSL, ranking of cause factors, multi-criteria decision-making, analytical hierarchy process, comparison matrix, consistence index,*

1.0 INTRODUCTION
A forensic science laboratory (FSL) receives crime scene samples, processes them and analyzes to give results for use in the judiciary systems. The management of the FSL requires engineering decisions in order to keep the laboratory operational in good performance. The performance of the FSL is measured in terms of number of case-files processed per unit time (weekly, monthly or annually) (Omari *et al.,* 2018a) or number of sample processed per unit time. Other measures of performance include turnaround time (Omari *et al*., 2018), backlogs generated (Omari *et al*., 2017), supply chain management, all of which are affected by absenteeism (Omari *et al*., 2019) and staff engagement. Attaining good performance will put the FSL at competitive level, however, there are factors which hinder good performance.
Sample management is part of process control, one of the essentials of a quality management system, implemented to ensure that the samples received are handled within the right time without jeopardizing the requirements needed to produce accurate test results in the valid time

called the turnaround time (TAT). The term TAT describes the interval when a test is requested to the time when the client or the requesting authority collects the results. In the FSL, backlogged case-files leads to work stress and frustration of both analysts and clients (Hurst and Lothridge, 2010; Nelson, 2011; Omari *et al*., 2018a). Moreover, criminal cases remain unsolved for the whole period a case-file is backlogged, defeating the purpose of FSL. On the other hand, backlog elimination paralyzes other FSL functions which are also costly operations (Hurst and Lothridge, 2010). Causes of backlogs extend from internal (lack of specialized equipment, low staffing levels and lack of professional staff) to external causes (such as submission of compromised samples, wrong samples, etc.). Extended TAT has been reported to depend on large sample influx (Manyele, 2017), lack of specialized equipment, competence among analysts and large number of case-files received per unit time.

There is no industry wide agreement about what constitutes a backlog; National Institute of Justice (NIJ), U.S. Department of Justice defines a backlogged case as one that has not been tested 30 days after submission of case-file to the FS laboratory. Many FS laboratories, however, consider a case backlogged if the final report has not been provided to the agency that submitted the case. Extended TAT for completed case-files occurs when a case-file takes too long to complete that expected by both FSL management and the clients (Steindel, 1995; Hawkins, 2007). While clients are aiming at making fast decision on cases, delay in receiving the analytical results (Shamim *et al*., 2014; Kaur *et al*., 2015) can lead to unmet targets, withdrawn cases by judges, and failure to complete investigation on time. As a result, complaints from stakeholders disrupt the powers of the FSL in presence of competitors. Together with lack of specialized equipment that can take many samples per unit time, lower number of analysts and lack of skills among analysts, other causes of extended TAT include lack of staff engagement and poor integrity of submitted samples (Westbrook *et al*., 2006; Chien *et al*., 2007; Manyele, 2017a). Competitiveness of the FSL can also be enhanced through implementation of quality management system (QMS). Factors hindering QMS implementation resemble those affecting accumulation of backlogs and extended TAT, making AHP application the best tool for identifying and prioritizing solutions.

In the progressively competitive and challenging environment within which FSLs operate today, absenteeism is a complex matter. Resulting from absenteeism, analytical services from FSL are faced with impeded productivity, inefficient service delivery due to extended turnaround time (TAT), and, thereby negatively affecting sustainability, as well as reduced performance and competitiveness. Absenteeism is, therefore, a significant concern in the field of human resource management. The prevalence of absenteeism in the laboratory services necessitates research so that valuable contributions may be made that will, ultimately, empower management and positively contribute to the discipline being studied. The aim of this study was to investigate the impact of absenteeism, the extent to which it negatively affects FSL performance and hence develop a framework for improving performance of FSL. Supply Chain Performance Measures (SCPM) serve as an indicator of how well the supply chain system is functioning. Measuring supply chain performance can facilitate a greater understanding of the laboratory services and improve its overall performance (Charan *et al*., 2008). There is an emerging requirement to focus on the performance measurement of the supply chain (Charan *et al*., 2008).

To achieve competitive edge, the laboratory management has to assess the current situation and establish the critical factors hindering such a move. Thus, this study employed AHP methodology to rank the rather many interrelated and complex factors and tackle the bottlenecks in a well-informed function. The AHP gives laboratory management a scientific means of

identification, ranking and strength in making engineering decisions as to which factors to place more efforts. To start with, a large number of cause factors (up to six) for three main performance measures were identified and incorporated in a questionnaire filled by FSL staff to collect their perceptions on the ranking of main causes (Kagonji and Manyele, 2016) and provide a guide to pairwise comparison (Saaty, 1980). The perceptions were then grouped according to staff categories to identify disparity in views among them. This paper presents a complete and thorough analysis of performance factors for a laboratory performing forensic science services using step by step application of the AHP methodology.

2.0 LITERATURE REVIEW

2.1 Introducing AHP

AHP is a multiple criteria decision-making tool. The MCDM plays a critical role in many real life engineering problems. It is not an exaggeration to argue that almost any local or central government, industry or business activity involves, in one way or the other, the evaluation of a set of alternatives in terms of a set of decision criteria. Moreover, application of AHP to laboratory management is a new research undertaking. Very often these criteria are conflicting with each other for example; the main factors are the same for all the performance measures increasing complexity of the problem in terms of the evaluation matrices. Even more often, the pertinent data are very expensive to collect leading to use of AHP.

Modeling of FSL performance parameters with very high sensitivity to competiveness will be extended to analysis of the dependency of FSL performance parameters in the SCM, case flow management and backlog management using AHP. Modeling of TAT sensitivity (overall or specific to laboratory activities), for example, will be implemented to establish its response to different FSL performance factors such as sample influx, staff academic and professional development (complex longevity (Omari *et al*., 2019) and staff academic development indices (Manyele *et al*., 2017).

In order for the laboratory Managers not to have a limited understanding of methodologies about real laboratory business, they need to recognize how important it is to understand the dynamics and complexity of the management problems. Such methodologies include AHP and system dynamics (SD) in bringing deep insight of engineering problems.

In *multifactor decision making,* engineers subjectively and intuitively consider the various factors in making their selection of performance measures and main factors. For FSL where difficult decisions must be made more often, a quantitative approach is recommended. All of the important factors such as productivity, TAT in sample movement steps, personnel and responsibility interaction and academic developed, etc., can then be given appropriate weights and each alternative, such as TAT, sample movement, stress backlog, supply chain and human resource planning can be evaluated in terms of these factors. This approach is called the *multifactor evaluation process* (MFEP), and works for situations in which we can assign evaluations and weights to the various decision factors.

Laboratories and management in particular have difficulties in accurately determining the various factors that affect their performance. However, the AHP can be used. This process uses pairwise comparisons and then computes the weighting factors and evaluations (Durso and Donahue, 1995). The AHP is a multiple criteria decision-making tool which was introduced by researchers (Saaty, 1994; 2008). This is an Eigenvalue approach to the pair-wise comparisons. It also provides a methodology to calibrate the numeric scale for the measurement of quantitative as well as qualitative laboratory performances. The scale ranges from 1/9 for “least valued than”,

to 1 for "equal", and to 9 for "absolutely more important than" covering the entire spectrum of the comparison (Vaidya and Kumar, 2006).

2.2 Key Steps in the Application of AHP

Analytic Hierarchy Process (AHP), since its invention, has been a tool at the hands of decision makers and researchers; and it is one of the most widely used multiple criteria decision-making tools. (Saatty, 1980).

Some key and basic steps involved in this methodology are:

a) Stating the problem, such as laboratory performance improvement.
b) Broaden the objectives of the problem or consider all actors, objectives and its outcome.
c) Identify the criteria that influence the behavior.
d) Structure the problem in a hierarchy of different levels constituting goal, criteria, sub-criteria and alternatives.
e) Compare each element in the corresponding level and calibrate them on the numerical scale. This requires $n(n-1)/2$ comparisons, where n is the number of elements with the considerations that diagonal elements are equal or '1' and the other elements will simply be the reciprocals of the earlier comparisons.
f) Perform calculations to find the maximum Eigenvalue, consistency index (*CI*), consistency ratio (CR), and normalized values for each criteria/alternative.
g) If the maximum Eigenvalue, CI, and CR are satisfactory then decision is taken based on the normalized values; else the procedure is repeated till these values lie in a desired range.

AHP helps to incorporate a group consensus where engineering projects involve teams of different opinions. Generally this consists of a questionnaire for comparison of each element and geometric mean to arrive at a final solution. The hierarchy method used in AHP has various advantages (Saatty, 1980; Vaidya and Kumar, 2006), such that its use of pairwise comparisons has inspired the creation of many other decision-making methods. There are some problems with the way pairwise comparisons are used and the way the AHP evaluates alternatives. Belton and Gear (1983) observed that the AHP may reverse the ranking of the alternatives when an alternative identical to one of the already existing alternatives is introduced. In order to overcome this deficiency, it is also proposed that each column of the AHP decision matrix to be divided by the maximum entry of that column. Thus, they introduced a variant of the original AHP, called the revised-AHP. Later, Saaty (1994) accepted the previous variant of the AHP and now it is called the Ideal Mode AHP. The fact that rank reversal also occurs in the AHP when near copies of projects alternatives are considered, has also been studied by Dyer and Wendell (1985).

Themes in the first group are selection, evaluation, benefit–cost analysis, allocations, planning and development, priority and ranking, and decision-making. Chosen areas of applications of AHP are: personal, social, manufacturing sector, political, engineering, education, industry, government, and others which include sports, management, etc. Some of the industrial engineering applications of the AHP include its use in integrated manufacturing (Putrus, 1990), in the evaluation of technology investment decisions (Boucher and McStravic, 1991), in flexible manufacturing systems (Wabalickis, 1988), layout design (Cambron and Evans, 1991), and also in other engineering problems such as selection of proper location for investment (Wang and Raz, 1991). So far, the AHP has not been applied to FSL and laboratory management problems in general.

2.3 The Use of Pairwise Comparisons

One of the most crucial steps in many decision-making methods is the accurate estimation of the pertinent data. An approach based on pairwise comparisons which was proposed by Saaty (1980) has long attracted the interest of many managers. In this study, pairwise comparisons are used to determine the relative importance of each alternative in terms of each criterion for FSL. In this approach the FSL managers has to express his opinion about the value of one single pairwise comparison at a time. The values of the pairwise comparisons in the AHP are determined according to the scale introduced by Saaty (1980). According to this scale, the available values for the pairwise comparisons are members of the set: {9, 8, 7, 6, 5, 4, 3, 2, 1, 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9}.In today's global marketplace characterized by globalization, increasing customers' value expectations, expanding regulatory compliance, global economic crisis, and intense competitive

Pressure, to thrive and survive, FSLs must critically evaluate the key factors affecting competitiveness. Analytic Hierarchy Process (AHP) was originally introduced by Saaty (1990) as an excellent MCDM tool which was acknowledged by many researchers. One of the main advantages of Saaty's AHP is its simplicity compared to previous decision support methods. It also enables qualitative and quantitative analysis into the same decision making methodology by giving a basis for eliciting, discussing, recording, and evaluating the elements of a decision. It uses hierarchal way with goals, sub goals or factors and alternatives.

The structure will then be translated into a series of questions of the general form, 'How important is criterion A relative to criterion B?'. This was also introduced via a questionnaire to the FSL staff as an initial step. The input to AHP models is the decision maker's answers to a series of questions which is then termed pairwise comparisons. Questions of this type may be used to establish, within AHP, both weights for criteria and performance scores for options on the different criteria.

2.4 Advantages and Disadvantages of Using AHP Method

One advantage of AHP is that it illustrates how possible changes in priority at upper levels have an effect on the priority of criteria at lower levels. Moreover, it provides the decision maker with an overview of criteria, their function at the lower levels and goals as at the higher levels. A further advantage of AHP is its stability and flexibility regarding changes within and additions to the hierarchy. In addition, the method is able to rank criteria according to the needs of the decision maker which also leads to more precise decisions concerning for example, supplier selection. The main advantage of AHP in the supply and demand is that the buyer is able to get a good picture of the supplier's performance by using the hierarchy of the criteria and evaluating the suppliers (Omkarprasad and Kumar, 2006). The strength of the AHP method lies in its ability to structure complex, multi-person, multi-attribute, and multi-period problems hierarchically and it is simple to use and to understand. It necessitates the construction of a hierarchy of attributes, sub-attributes, alternatives and so on, which facilitates communication of the problem and the recommended solutions. In addition, the AHP method provides a unique means of quantifying judgmental consistency.

2.5 Challenges of using AHP

However, AHP also has some weak points. One of these is the complexity of this method which makes implementation quite inconvenient. Moreover, if more than one person is working on this method, different opinions about the weight of each criterion can complicate matters. AHP also

requires data based on experience, knowledge and judgment which are subjective for each decision maker. A further disadvantage of this method is that it does not consider risks and uncertainties regarding the performance measures (Yusuff *et al*., 2001).AHP has been applied for a vast number of areas, but it was not applied for the problem that has been taken up in this paper that is Forensic Science Laboratory management. Despite the focus on forensic science laboratory management, this study paves way to assisting laboratory directors for different kinds of laboratories receiving samples from the public including the society/public, industry and especially the private sector. Saaty (1980; 1978) has explained about hierarchies, multiple objectives and fuzzy sets. Ramanathan and Ganesh (1994) used group preference aggregation methods employed in AHP by deriving members' weightages. AHP has been applied to many areas but problem of FSL competitiveness was not taken into consideration earlier in the literature.

2.6 Identification of the Factors affecting other Laboratory Performance Measures

Together with the three first performance measures of FSL competitiveness used in the AHP methodology, other measures were also considered in this study, with completely different major or cause factors. To start with, supply chain management (SCM) was identified to be an important measure of performance (Charan *et al*., 2008; Taticchi *et al*., 2010; 2013). The factors affecting supply chain management (SCM) performance were identified, such as lack of funds/budget (Gunasekaran *et al*., 2004; 2015), lengthy SCM procedures (Lambert and Pohlen, 2001), lack of competent staff in the SCM processes, in laboratory processes and lack of engagement among staff. Other main factors were large number of ad-hoc requests and lack of competent suppliers within the country.

The professional and academic development for FSL staff is also a performance measure towards competitiveness. This was assumed to be affected by poor staff development plan, lack of funds (for promotion and training), lack of specialized courses on FSL within the region/country, lack of incentives and tendency of staff to accept developmental plateau (stagnation).Finally, absenteeism among the FSL employees was also identified to be a measure of performance (Rasasingham, 2015; Vanneste *et al*., 2015), whose cause factors include family, and economic issues (Net *et al*., 2004), lack of staff engagement to their positions and the FSL as an organization and lack of circulars and administrative sanctions. Other factors affecting absenteeism were poor leadership, accepting the absenteeism culture in workplaces.

3.0 METHODOLOGY

3.1 Development of AHP Methodology

FSL competitiveness improvement involved identification of performance measures and detailed analysis of current situation and setting of goals. This method of AHP helped to rank the main factors hindering good performance, so that efforts can be made to eliminate those challenges in a well-informed manner. The process involved the determination of qualitative and quantitative factors imperative for debottlenecking the performance measures to higher scores. Table 1 summarizes the performance measures and major factors for each measure. The first row shows the same major factors for the three performance measures, that is, case-file backlogs, extended TAT and implementation of QMS. These are perceived to be the key measures of performance in this research. Any other set of performance measures can be created by using different views, for example those listed at the bottom of Table 1.

Table 1: Factors considered for different performance measures

Performance measures	**Major factors**
Case-file Backlogs in FSL; Extended Turnaround Time (TAT) in FSL; and, Implementation of QMS in FSL	Large number of samples per case-file
	Lack of specialized equipment/Instruments
	Lower number of competent staff/analysts
	Large number of case-files received
	Poor integrity of submitted samples
	Lack of employees' engagement
Supply Chain Management (SCM) Performance	Lack of funds/budget for procurement
	Lengthy supply management procedures
	Lack of competent and qualified staff
	Lack of staff engagement and need for self-development
	Large number of requests some of which ad-hoc
	Lack of competent suppliers
Professional and Academic Development (P_d, A_d) among staff	Poor professional and academic development plan
	Lack of funds for training and acquire promotions
	Lack of staff engagement and need for self-development
	Lack of institutions for specialized courses locally
	Lack of competent and qualified staff
	Staff accepting development plateau
Absenteeism rate among Laboratory staff	Lack of staff engagement and enthusiasm towards their positions and the organization
	Family issues
	Lack of funds to motivate staff
	Lack of circular and administrative sanctions
	Poor leadership accepting the culture in workplace
	Lack of competent and qualified staff

The hierarchy was structured from top (competitiveness problem) through the intermediate level (performance measures) to the lowest level (main factors) as shown in Figure 1 Thus, the decision problem was stated to be improvement of FSL competitiveness from current level to allow the laboratory to compete in the currently vigor market of service delivery (receiving samples from clients and analysis and giving good quality and timely results). The second level of problem analysis was identification of the key performance measures which critically affect the FSL performance (level Y) but which in turn are affected by similar factor that is level Z. The most important part of the AHP analysis is the top part of the flow chart in Figure 1 (Levels X, Y and Z), which comes from thorough analysis of the problem at hand. As summarized in Table 1, this problem solution comes from the first row such that all the three performance measures are affected by the six factors, from which only three most important (that is, high sample influx, lack of specialized equipment and large number of case-files received). The implementation of computations starts with pairwise comparisons and establishment of the matrix A, forming the heart of the AHP.

The alternative or main factors at the lower level of Figure 1 (Level Z) when solved, improves the performance of the FSL since they were selected from a large number of factors, but which affect all the three performance measures (in Level Y), which in turn will improve competitiveness (at Level X). The main cause factors were identified based on a questionnaire prepared to gather information on ranking of factors from employees, based on their perceptions which were assessed for consistence using pairwise comparison. The main cause factors considered in this research were six, from which two sets of three highly ranked factors were selected, that is, large number of samples per case-files (sample influx) (Manyele, 2017) and large number of case-files received (Omari *et al*., 2017), lack of specialized equipment or instruments, lower number of competent staff/analyst, poor integrity of submitted samples and lack of employees' engagement.

3.2 The Structure of the Decision Making Problem

The structure of the typical decision problem consists of a number, say *M*, of alternatives and a number, say N, of decision criteria. Each alternative can be evaluated in terms of the decision criteria and the relative importance (or weight) of each criterion can be estimated as well. Let a_{ij} (i = 1, 2, 3, ..., m, and j = 1, 2, 3, ..., n) and denote the performance value of the i^{th} alternative (i.e., A_i) in terms of the j^{th} criterion (i.e., C_j). Also denote as W_j the weight of the criterion C_j. Given the decision matrix, the decision problem considered in this study is how to determine which the best alternative is. A slightly different problem is to determine the relative significance of the M alternatives when they are examined in terms of the N decision criteria combined. For simplicity, m = 3 or 6 and n = 3 or 6, that is, 3 x 3 matrices will be used in this study (as shown in Figure 1).

3.3 Application of AHP Methodology

In AHP multiple pairwise comparisons are based on a standardized comparisons scale values of which are listed above. In this case, the comparison scale used nine levels, giving a 3 x 3 matrix. Let $C = \{C_{jj}= 1,2, ..., n\}$ be a set of criteria. The result of the evaluation matrix in which every element a_{ij} (i,j = 1,2, …, n) in the quotient of weights of the criteria can be created as (for n = 3), as per Equation (1):

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \quad (1)$$

where a_{ij} = 1 when $i = j$, $a_{ji}= 1/a_{ij}$ and $a_{ij}\neq 0$.

3.4 Eigenvalue and Eigenvector

According to Saaty (1990), it is recommended that the maximum eigenvalue, λ_{max}, is determined such that Equation (2) is satisfied:

$$\lambda_{max} = \sum_{j=1}^{n} a_{ij} \times \frac{W_j}{W_i} \quad (2)$$

Where λ_{max} is the principal or maximum eigenvalue of positive real value in judgment matrix, W_j is the weight of j^{th} factor and W_i is the weight of i^{th} factor. If A represents consistence matrix, then the eigenvector X was determined as per Equation (3):

$$(A - \lambda_{max} I)X = 0 \quad (3)$$

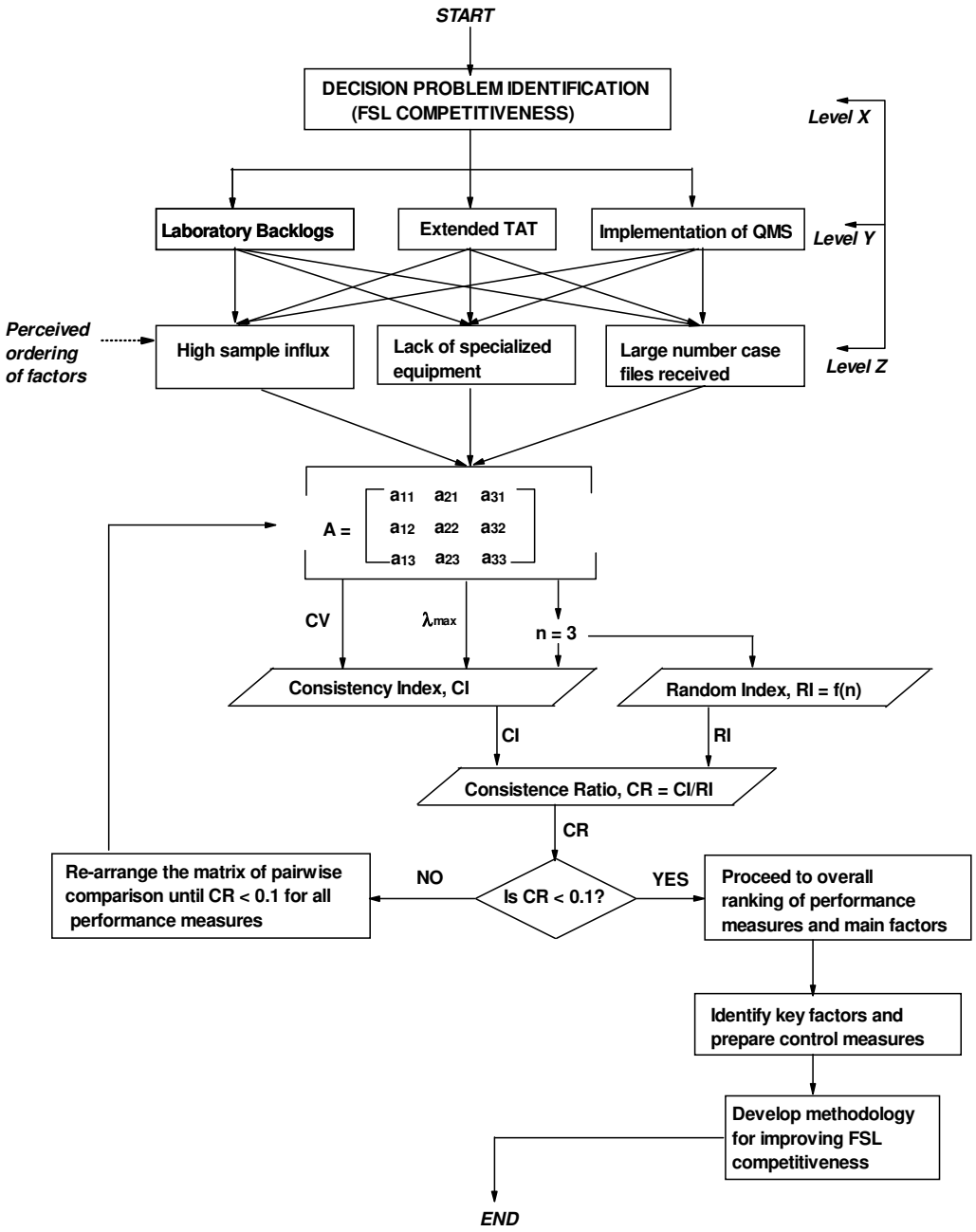


Figure 1: Flow chart for implementation of the AHP procedure for improving FSL competitiveness (CV = Consistency vector).

3.5 Consistence Test

A consistence test is performed in AHP methodology to examine the extent of consistence as well as each judgement once the priorities are determined. Saaty (1990) recommended the use of consistence index (CI) and consistence ratio (CR) to check for the consistence associated with the operation matrix. To ascertain that the priority of elements is consistent, the maximum eigenvector or relative weights, denoted as λ_{max}, can be determined. Specifically, as shown in Figure 1, CI for each matrix order *n* is determined by using the formula for consistency index, as per Equation (4):

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (4)$$

Where n is the matrix size or the number of items that are being compared in the matrix, in this case (n = 3). Based on Equation (4), the consistence ratio (CR), as per Figure 1, can be determined as:

$$CR = \frac{CI}{RI} \quad (5)$$

where RI represents the random index or the average consistence index over a number of random entries of some order reciprocal matrices shown in Table 2.

Table 2: Values of random index (RI)

N	2	3	4	5	6	7	8
RI	0.00	0.58	0.90	1.12	1.24	1.32	1.41

For n = 3, RI is thus equal to 0.58. CR is acceptable if is not greater than 0.10 otherwise the judgement matrix will be considered inconsistent and has to be rectified. To rectify the judgement matrix that is inconsistent decision maker's judgements should be reviewed and improved. However, Byun (2001) suggested that 0.20 might still be acceptable. The AHP procedure described above was also presented in the flow chart form as shown in Figure 1.

4.0 RESULTS AND DISCUSSION

4.1 Workers Perceptions on the Factors Affecting Laboratory Performances

a) Causes of high case-file backlog in the laboratory

The challenges facing case-file backlog management can be best resolved internally within the laboratory rather than being imposed externally, since the laboratory staffs are the ones who are face to face with most of the challenges identified in Figure 2. The factors ranked by respondents were large number of sample per case-files, lack of specialized equipment and instruments, lower number of competent staff or analysts, large number of case-file received, poor integrity of sample received and lack of employee engagement. Moreover, for the purpose o mitigation, the employees of the FSL will be the processes owners during backlog elimination process. In this study, it was identified that large number of samples per case-file could be the main factor in causing high case-filebacklog (B_{gc}) in FSL as shown in Figure 2.

In Figure 2 it is evident that, large number of samples per case-file scored the highest ranking of 2.15, as the factor that affects case-file backlog in FSL, followed by lack of specialized equipment/instruments. Also, the large number of case-files received compared to the number of

available employees that manage the case-file and sample influx was another factor which was ranked third. The least factor being perceived of causing case-filebacklog (B_{gc}) in FSL was poor integrity of samples submitted and lack of employees' engagement. Poor sample integrity affects performance of most laboratories in health sector, engineering as well as biological sciences. The best solution is always to engage analysts in sampling operations where situation are complex and demanding.

b) The causes of extended TAT in the Laboratory

The causes of extended TAT were also ranked during employees perceptions as shown in Figure 2. Most of the FSL services are directed towards providing a rapid, reliable report at a reasonable cost. However, it is also important to stress on how soon (TAT) a report would be available to the requesting authority or the client. A large portion of the complaints received at the FSL in Tanzania is directed towards delayed analytical reports. This affects the criminal justice system. Despite a significant overall decrease in crime in the society, the judiciary experience more cases than before due to the contributing factor of delayed results from the FSL. For high-tech laboratories meant to serve the public and private sector, industry and the businesses, long TAT affects strongly economic decisions. It is therefore important to analyze outliers in TAT which gives the insight of causes of extended turnaround time as shown in Figure 2.

Figure 2 shows also that sample influx and the large number of case-files received are the most highly ranked factors that affect the extended turnaround time (TAT) in FSL. This is followed by lack of specialized equipment/instruments and lower number of competent staff/employees. The current problems cannot be fixed through simple improvements in efficiency, the integration of management, or by tampering with Forensic science services processes or its independence. Instead, what is needed is a real commitment to forensic science services through adequate funding for purchasing more specialized equipment and instruments, as well as strategic reforms that increase the number of competent staff or analysts.

In addition, there should be policies that encourage reduction of turnaround time in laboratory processes. The Government has also a big role to play by overseeing the importance of staffing and funding, which in turn will make the FSL to work more efficiently. A poorly functioning criminal justice system for example which includes the FSL, allows crimes and forensic issues to go in liberty, separating victims and their families, compromising the assurance of the public and intensifying the risk of being highly alert. For a national economic growth through industry, on the other hand, timely release of results is crucial.

c) Causes of weaknesses in implementation of QMS in any given laboratory settings

The problem relating to the functioning of quality management system in FSL is caused by problems related to QMS implementation process in each of the forensic science disciplines. Many problems affect QMS implementation, such as those outlined in Figure 2 to mention only a few. There has been little concentration on an organizational improvement mechanism, omitting issues related to competitiveness.

Figure 2, shows that the highest score observed was due to lack of specialized instruments followed by large sample influx and increased number of case-files received. The employees have limited knowledge and skills in the area of quality management, effectiveness of which can boost the business conditions into which the FSL operates. Lack of training programs on QMS may also present major obstacles in development and implementation of QMS in most laboratories (Lipovatz *et al*., 1990). Furthermore, Palel and Randell (1994) detailed that, proper quality training for FSL professionals is crucial for the purpose of managing the QMS.

Economic crisis in the implementing and certification of quality management system in laboratories involves sustaining certain expenses. Supplies such as consumables and reagents are always not available to manage a large number of case-files and the same for validation of methods towards the certification or accreditation. As results, certification bodies try to keep their clients by lowering the prices for their services which leads to forced shortening of audit procedures leading to weaknesses in the implementation of QMS. Also, during this crisis, organizations tend to find possibilities to cut down costs whereby, certain audits may be suspended waiting for better circumstances. This includes suspension of purchase of specialized equipment/instruments which would improve the quality of the FSL services. Therefore, the Government intervention and financial support by allocating more funds to the FSL towards implementation of QMS is important. For non FSL labs which operates in business oriented environment, such a performance factor can be easily sorted out. In addition, it is important to have stronger relationship between investment in specialized equipment or instruments and training in order for the laboratory to achieve its strategic objectives towards quality management system.

d) ***Perceived causes of lower performance in SCM***

Figure 2 shows that lack of competent suppliers and competent and qualified staff are the most factors causing lower performance in supply chain management in the FSL which is true for other laboratories as well. Lack of staff engagement and large number of requests (most of which being ad-hoc) are second highly ranked cause factors affecting performance. Supplier affiliation, supplies collection criteria, number of suppliers list and supplier participation in current or new product or technologies used in the laboratories and period of relationship could be factors causing the low performance in supply chain management. In addition, Fuentes *et al*. (2000) observed that reduced cooperation from suppliers is a barrier towards the implementation of a proper supply chain.

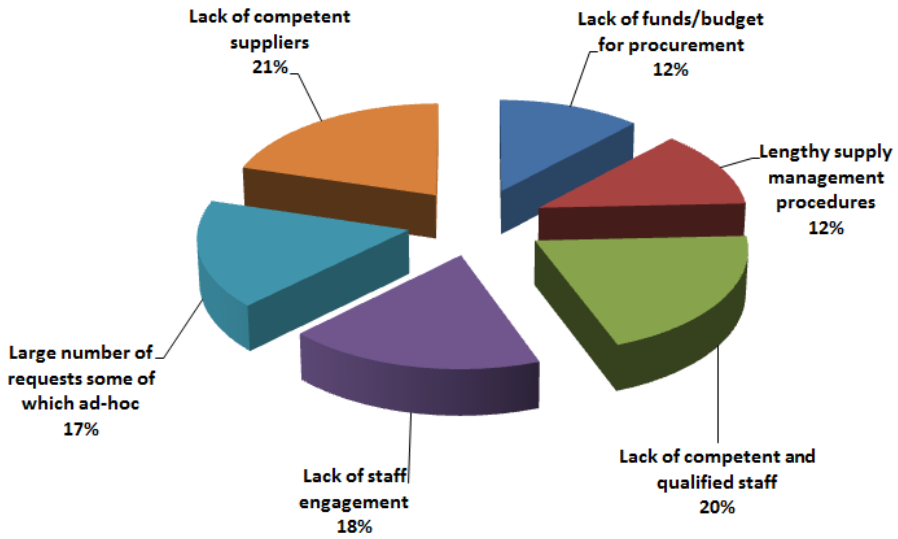


Figure 2: Ranking of the factors affecting SCM performance based on staff perceptions.

Figure 2 shows also that, large number of ad-hoc purchase orders and lack of engagement affects the performance of supply chain in laboratories. If the laboratory staff are not fairly engaged with the process of supply, the supply chain responsiveness is reduced which makes the laboratoryless

dynamic in its business hence less competitive. Lately, because of globalization and the use of Forensic results in criminal justice system, there has been an increase in ad-hoc logistics services required by the laboratory. In other words, an increasing number of case-files and high sample inflow require supplies to be procured on time. This creates a significant challenge to planning and performance, which is the principal concern for supply chain management, but also high costs or poor visibility are few of the many problems related to the ad-hoc procurement request orders.

e) Causes of poor professional and academic development among laboratory staff

Figure 3 represents the distribution of scores for the factors leading to poor professional and academic development among the laboratory staff. It should be noted that such a ranking applies to most organizations in the public service, regardless of functions. Figure 3 shows that lack of funds for training with score of 2.76 was the highest ranked factor affecting professional and academic development plan, according to employee's perceptions. Another factor is lack of budget for staff promotion (2.00) followed by poor professional and academic development plan (which scored 1.72).

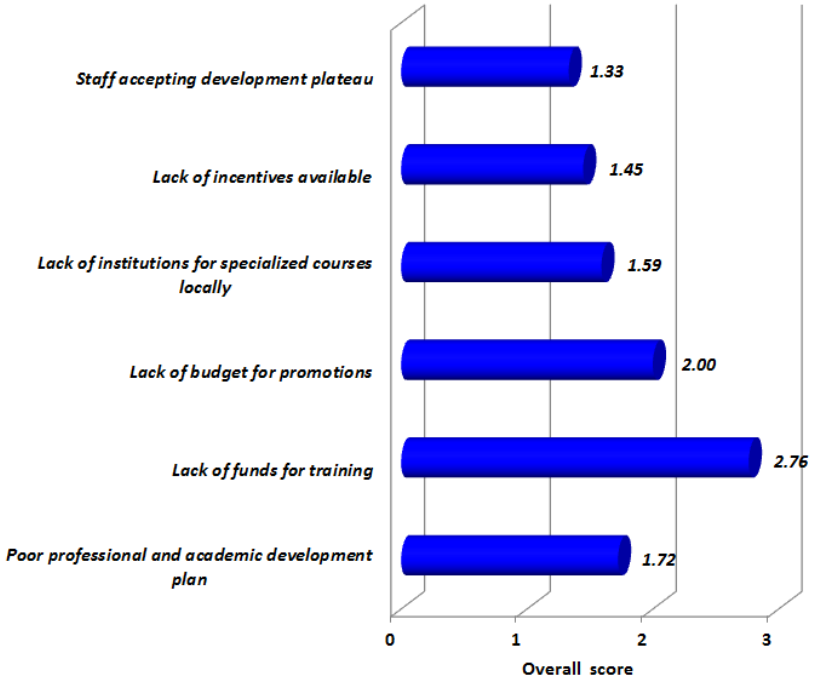


Figure 3: Ranking of the factors affecting the performance of laboratory staff professional and academic development.

Funding the staff development plans ought to take account of the significance of staff development towards laboratory competitiveness. A promotion for a staff means additional funding for the FSL in terms of expenditure for upkeep of allowances to the staff and increase pay to the staff work into the laboratory. The additional costs are related to the higher salary and other benefits of the staff starting from the year of promotion. However, the fact that the government does not commit to a sustainable funding on the needs basis, the promotions are not

implementable which ruins morale and laboratory performance. It should be noted also that professional development is a strategy which ensures continuity of strengthening the laboratory practices throughout the career where staff skills and competences are requirement for an outstanding results of laboratory competitiveness. The fact that staff development and its outcomes are not easy to correlate, brings a challenge in its implementation.

f) Causes of absenteeism among laboratory staff

In this study, findings highlight just how complex the root causes of workplace absence can be and how difficult they are to manage. The problem of family issues is a wide subject and ranked the highest by FSL employees, while personal issues and economic issues mixed with lack of staff engagement(were ranked second) contributing strongly to absenteeism. Managers and directors expect the laboratory staff to miss certain number of workdays in each year; however, excessive absences cause decreased productivity and have an effect of FSLs competitiveness as shown in Figure 4.

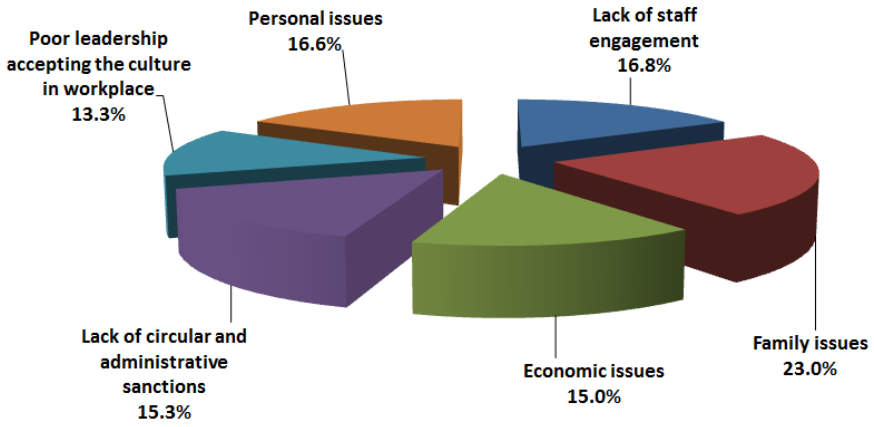


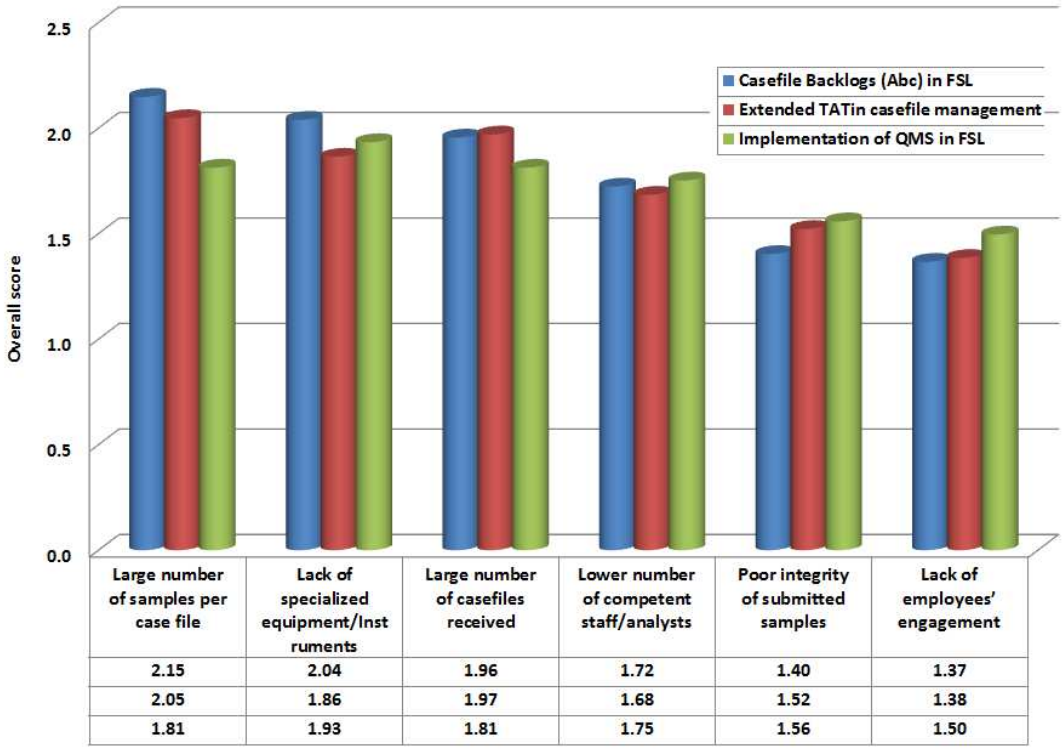
Figure 4: Ranking of the factors perceived to cause absenteeism among FSL employees

It was observed in this study that employees' perceptions were in favor of family issues as the top cause for workplace absence. These include breast feeding mothers, attending sick family members, managing children matters, etc. By contrast, 19% said personal issues was the main culprit and 14% of workers said economic issues were the most common reason for staff absence. The laboratory management has to make new initiative in putting greater emphasis on employees practicing absenteeism and getting them back to work. The need to minimize these harmful effects is of particular importance to employers with the laboratory competitiveness at stake. There should be an improvement framework geared towards facilitating employees' timely return to work as soon as they are deemed fit to work in any capacity and link it with the requirements for employers to make reasonable adjustments especially in welfare and economic status of the FSL staff.

4.2 Ranking of the Main Performance Factors

As stated above, the overall ranking of the main factors for each of the performance factor, based on employees perceptions are summarized in Figure 5. The first two performance factors have the same sequence of the ranking for the first three main factors, with exception of the implementation of the QMS, where lack of specialized equipment was ranked the highest, as

shown by arrows. Figure 5 shows the summary of ranking before a 3 x 3 AHP implementation. Other performance factors are also included to indicate that the ranking was as well lower compared to the first three main factors. Based on Figure 1, the main factors at Level Z for each of the three performance measures were ranked by the FSL employees.



Large number of samples per case file	Lack of specialized equipment/Instruments	Large number of casefiles received	Lower number of competent staff/analysts	Poor integrity of submitted samples	Lack of employees' engagement
2.15	2.04	1.96	1.72	1.40	1.37
2.05	1.86	1.97	1.68	1.52	1.38
1.81	1.93	1.81	1.75	1.56	1.50

Figure 5: Ranking of cause factors affecting performance measured based on increased case-file backlogs, extended TAT and QMS implementation in the FSL based on employees' perceptions.

Each of the three bars represents ranking of factors based on the performance measure. Efforts were made in Figure 5 to arrange the ranking in descending order, based on which, an overall ranking gives a highest score for large number of samples per case-file, lack of specialized equipment an large number of case-files received. These main factors were then used to create matrix *A* using Equation (1). However, each of the performance measure had its own ranking of the main factors which was considered during the matrix creation as per Figure 5.

4.3 Application of AHP to the Laboratory Performances Problem

4.3.1 Creation of Pairwise Comparison Matrices

The first step is creation of the three matrices (A_1, A_2 and A_3) in relation to the values of rankings from the employees' perceptions (Figure 6) and Table 3, for each main factor and performance measures. As an example, Figure 6 shows a sample matrix A1 with entries of the pairwise comparisons for the first performance measure, that is, case-file backlogs. To address Equation (1), three 3 x 3 matrices were developed based on the flow chart presented in Figure 1(for the case-filebacklogs, TAT and QMS problems), as summarized in Figure 6, whereby the numbers in the matrix of pairwise comparisons (A_1, A_2 and A_3) were later on converted to decimals to make them easier to work with (normalized).This was followed by converting the numbers in the

matrices of pairwise comparison to decimals to make the numbers easier to work with (that is, normalized), leading to matrices N_1, N_2 and N_3, as shown in Figure 6.

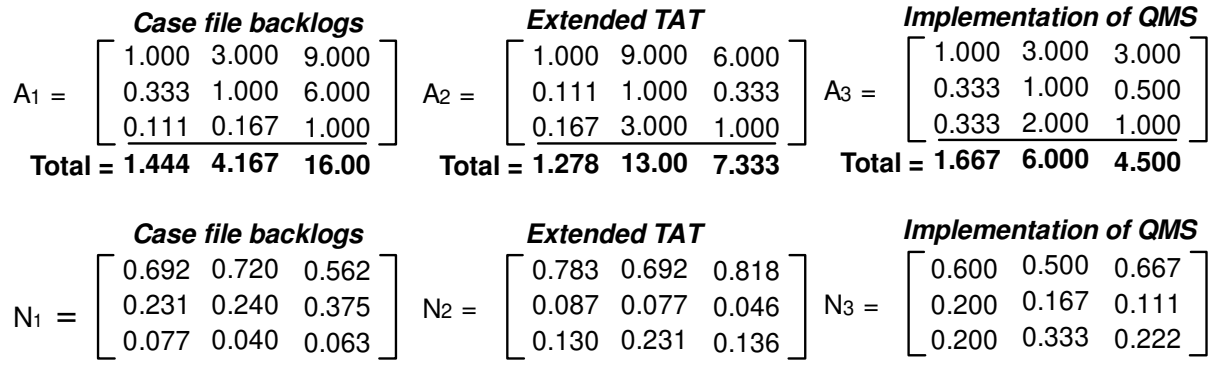


Figure 6: Normalized pairwise comparison matrices for the three performance measures increased case-filebacklogs (B_{gc}), extended turnaround time (TAT) and quality management system (QMS) implementation in the FSL

4.3.2 Manipulation of the Pairwise Comparison Matrices

To determine the priorities for the three main factors, the average of the rows of the normalized matrices were determined leading to a single matrix A_{vg}. The consistence ratio matrix, C_v, starts with the weighted sum vector matrix, W_{sv}, as shown in Figure 7.

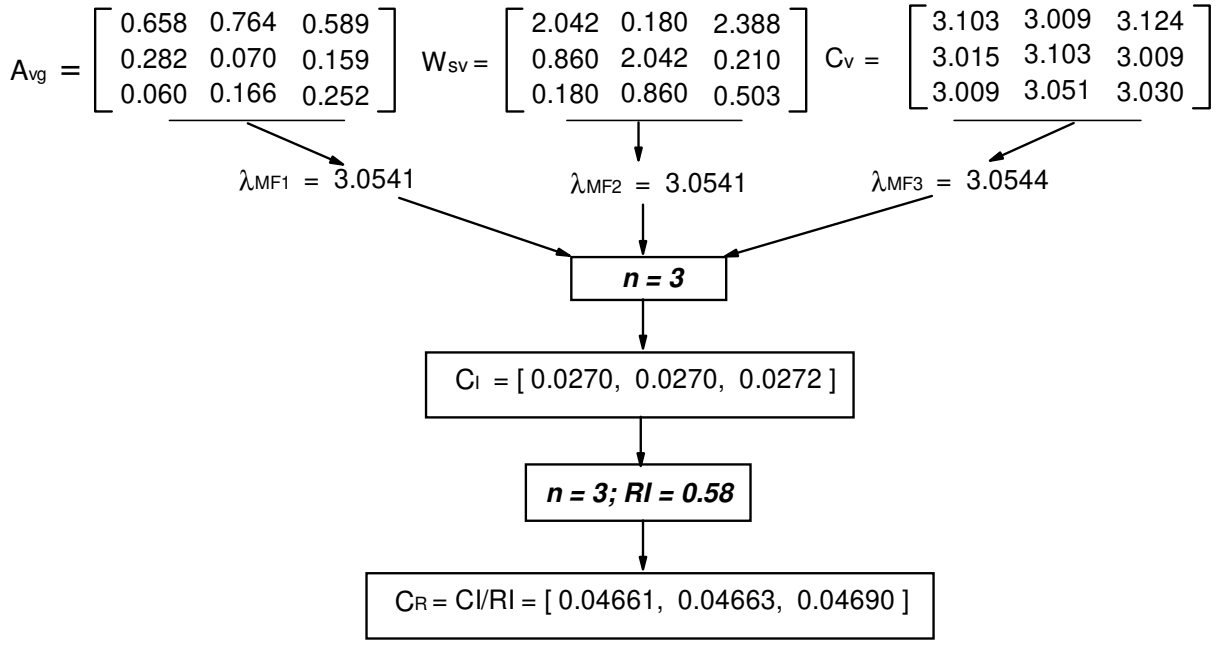


Figure 7: Determination of consistence ratio (consistence test)

Since all the values of CR are higher than 0.1, then, it was concluded that the matrices A_1, A_2 and A_3 are consistent. The last step was to determine the weighted evaluation values, W_E, by multiplying the factor evaluations by the factor weights, and summing up the columns to

complete the analysis. The overall ranking is given as SWE, values of which are then plotted to provide a graphical view, as shown in Figure 8.

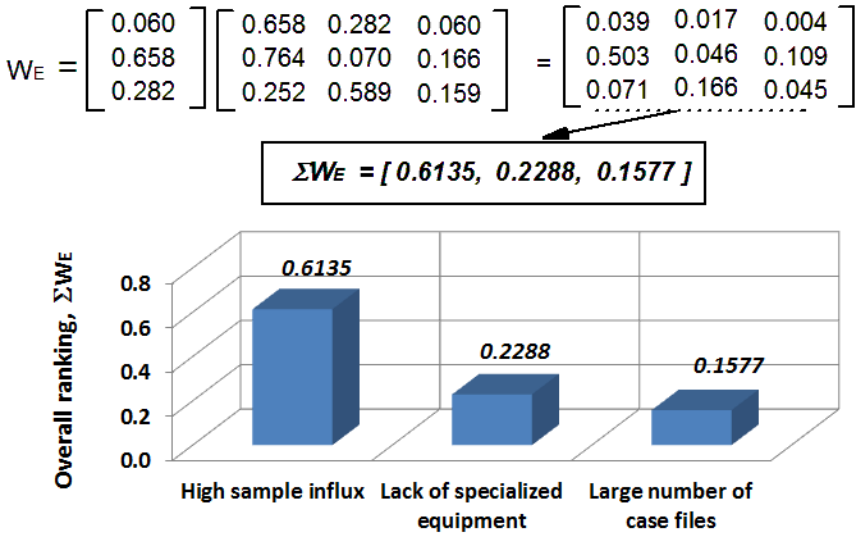


Figure 8: Overall ranking from the AHP methodology

Results presented in Figure 9 show that high sample influx (number of samples per case-file) was a critical factor affecting laboratory performance (Manyele, 2017). This is logical because high sample influx leads to both extended TAT and increases backlogs due to unfinished or incomplete laboratory work. Using AHP, the second factor was established to be lack of specialized equipment. For example, if sophisticated equipment is available, that can accommodate many samples per run and provide accurate results in a short time, it will lea to reduced TAT as well as backlogs. This will give ample time for report writing and implementation of QMS in a long run. Large number of case-files received, despite of being ranked the lowest, is also a significant factor. This is because, large number of case-files increases workload to rather fewer analysts (large number of case-files per analyst) as each case-file require a separate report (Omari *et al.,* 2017), despite of different case-files being analyzed at once when sophisticated machines are available.

4.3.3 Overall Rankings for other Performance Measures

According to Table 1, the three performance measures (SCM, professional development and absenteeism) are affected by the same three cause factors, that is: lack of funds/budget, lack of competent/qualified staff and lack of engagement and motivation for self-development, such, of these cause factors are solved, the performance of the FSL can be highly improved. Note that, in Table 1, the major factors have been selected from a large list of other factors compared to the first scenario (Figure 8). Thus, the tope part of Figure 1 is modified as shown in Figure 9, in order to present the second set of matrices.

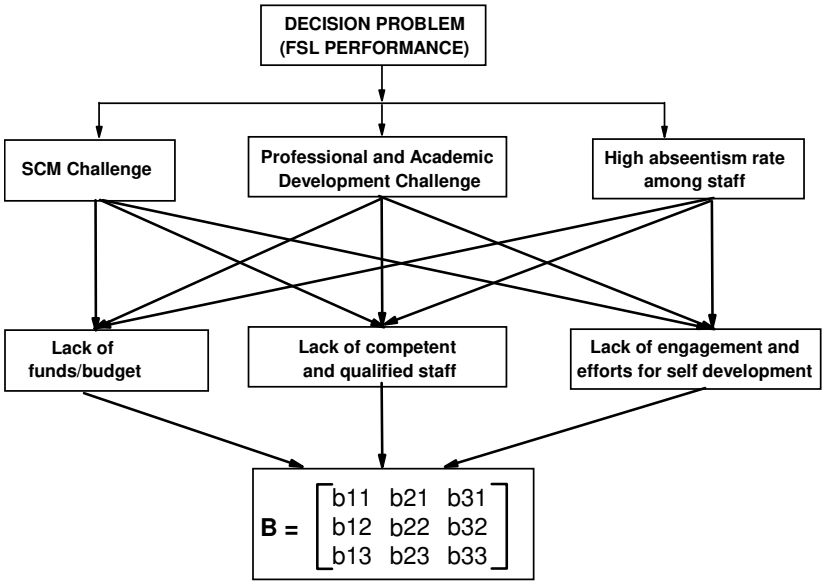


Figure 9: Flow chart for implementation of AHP for second set of performance measures (supply chain management, professional and academic development, and high absenteeism rate).

Similar steps shown in Figures 6 and 7 were repeated for the matrices B, leading to the overall ranking shown in Figure 10.

Table 3: Entries in the pairwise comparison matrices for the three performance measures (supply chain management, professional and academic development, and high absenteeism rate) in the FSL

B1: SCM Challenge	**Lack of funds/budget**	**Lack of competent/qualified staff**	**Lack of engagement and motivation for self-development**
Lack of funds/budget	1.0000	8.0000	8.0000
Lack of competent/qualified staff	0.1250	1.0000	2.0000
Lack of engagement and motivation for self-development	0.1250	0.5000	1.0000
B2: Professional/academic dev challenge			
Lack of funds/budget	1.0000	8.0000	6.0000
Lack of competent/qualified staff	0.1250	1.0000	2.0000
Lack of engagement and motivation for self-development	0.1667	0.5000	1.0000
B3: High absenteeism rate among staff			
Lack of funds/budget	1.0000	3.0000	3.0000
Lack of competent/qualified staff	0.3333	1.0000	0.5000
Lack of engagement and motivation for self-development	0.3333	2.0000	1.0000

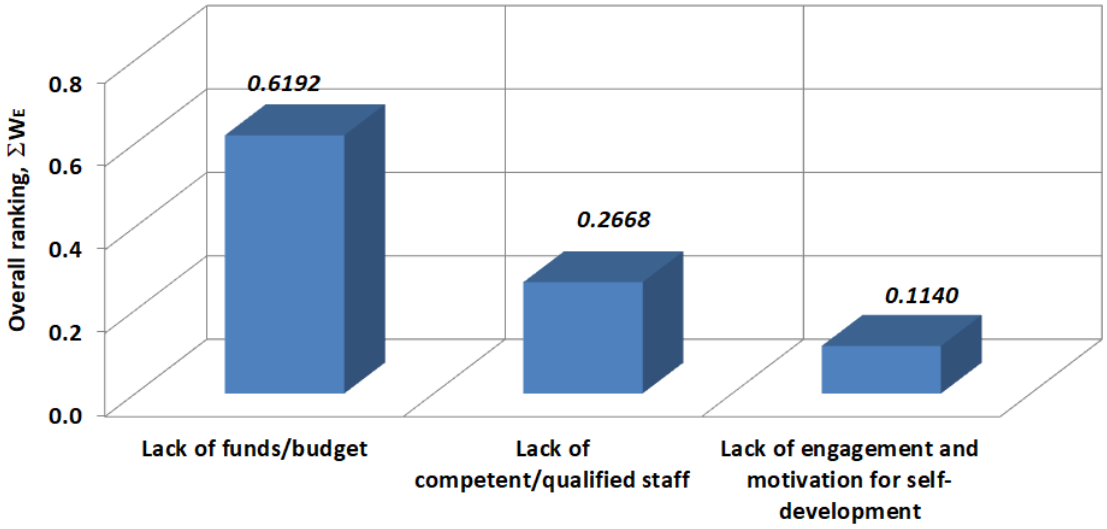


Figure 10: Overall ranking of the cause factors affecting performance (supply chain management, professional and academic development, and high absenteeism rate) from AHP methodology.

Different from Figure 8, the results presented in Figure 10 show that lack of funds/budget was a critical factor affecting laboratory performance (Manyele, 2017). This is logical because lack of funds causes backlogs to accumulate as reagents are not purchased on time, machines stay idle and un-serviced for an extended time, professional and academic development of the analysts is impeded and implementation of QMS slows down as systems cannot be maintained. Using AHP, the second factor was established to be lack of competent and qualified staff which remain few, and cannot be increased due to lack of funds and budget. Lack of engagement among staff will always cause high absenteeism rate, and diminished professional and academic development efforts. Similar to the way the arrows interact between the cause factors and performance measures, the same applies a complex interaction of the cause factors and performance measures in real organizational challenges.

Comparing Figures 8 and 10, the values of overall ranking, $\sum W_E$, are comparably similar and for each set of cause factors, the indication is given as to which factors need to be dealt with first in order to improve performance of the laboratory. The next question is how the cause factors can be solved in order to improve performance. Based on laboratory management experience, Table 4 shows the proposed means of solving the cause factors.

Table 4: Proposed means of minimizing the impact of the cause factors on laboratory performance.

	Overall ranking ($\sum W_E$)	**Performance factors to be improved**	**Means of minimizing the impact on laboratory performance**
1) High sample influx	0.6135	1) Case file backlogs, 2) Extended TAT 3) Implementatio	- Train criminal investigations on proper sampling - Policy on maximum number of samples per case file - Expand workforce

2) Lack of specified instruments	0.2288	n of QMS	- Proper procurement planning, and implementation - Lobbing, political will and budgeting for instruments
3) Large number of case-files	0.1577		- Increase/expand workforce for analytical work (decrease case-files/analyst year)
1) Lack of funds/budget	0.6192	1) Supply chain management challenges 2) Professional and academic development 3) High absenteeism rate among staff	- Develop new sources of revenue, improve and maintain old sources of revenue - Implement entrepreneurial strategy - Employees to work extra hours in revenue generation areas
2) Lack of competent/qualified staff	0.2668		- Proper training program implementation - Service contracts with suppliers - Links with manufacturers for spares and troubleshooting - Employ and retain competent staff
3) Lack of engagement and motivation for self-development	0.1140		- Motivate staff and raise their morale - Encourage staff to undertake further studies related to their jobs - Award staff initiative for self-development

5.0 CONCLUSION

The AHP methodology is suggested for decision making in the laboratory management environment to solve decision making problems from a large number of available list of cause factors and performance measures. Two cases were includes to illustrate the AHP methodology. Using this method it was possible to assign the values of relative importance to the cause factors based on preferences and experience. In this study, we proposed two sets of performance factors and cause factors, leading to 2x3=6 comparison matrices based on 3x3 AHP methodology. By using multiple performance variable and cause factors incorporated in the AHP, an appropriate pair-wise comparison of AHP is proposed for constructing weighting scheme for laboratory performance variables. After ranking the cause factors, we propose the means of minimizing the impact of the cause factors on laboratory performance. Also, using AHP, the performance problem was established to be lack of specialized equipment due to lack of budget and high sample influx. For instance, availability of sophisticated equipment can accommodate many samples per run and provide accurate results in a short time it will lead to reduced TAT as well as backlogs. After quantifying the essential criteria, the final decision was easier to see, than workers perception which resulted in varying levels of importance and preference alone.

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