Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 6, 2212-2231
2024
Publisher: Learning Gate
DOI: 10.55214/25768484.v8i6.2420

Development of a total quality management framework for the mobile network operations centre

Keabetswe Mogase[1], Felix Ale[2], Ilesanmi Afolabi Daniyan[3*], Khumbulani Mpofu[4]
[1,4]Department of Industrial Engineering, Tshwane University of Technology, Pretoria, South Africa.
[2]Engineering & Space Systems, National Space Research & Development Agency, Abuja, Nigeria.
[3]Department of Mechatronics Engineering, Bells University of Technology, Ota, Nigeria; afolabiilesanmi@yahoo.com (I.D.).

Abstract: Telecommunication is one of the most fast-paced and rapidly changing sectors globally. This study develops a total quality management (TQM) framework for mobile network operation centres (NOC) to aid in network surveillance and fault management processes for a 5G transmission network. A systematic literature review was conducted using academic articles in journals and conference papers sourced from the EBSCOHost database. A fuzzy analytic hierarchical process (FAHP) was used as a multi-criteria decision-making tool to determine which criteria and factors are of the highest ranking for the development of the TQM framework. Data collection and control sheets were ranked higher, making them critical to the framework. This shows that, without good data, no problems can be identified, visualised, analysed, and solved and processes will not be improved. Process improvement is ranked last, showing it is of the lowest priority compared to the other criteria. This however, does not imply that in TQM it is of lower priority, as it is needed to keep meeting the needs of the customers. The framework includes how the TQM tools and techniques can be used in collecting, visualising, analysing, solving problems, and improving processes.
Keywords: *5G, FAHP, NOC, Telecommunication, TQM.*

1. Introduction

Telecommunication is fast-paced and rapidly developing, and it is highly competitive; the user requirements of telecommunications services are continuously increasing and changing with evolving technology [1]. The network operations centre (NOC) in a telecommunication organisation is at the forefront, offering a service to internal and external customers. They monitor, detect, and analyse faults in order to identify the root cause [2]. The NOC ensures that the infrastructure is working at its optimum levels and not affecting customers adversely. Numerous NOCs fail to meet desired service levels due to the lack of a centralised support framework [3]. A framework is imperative for the success of the NOC, as it assists in making decisions and ensuring that actions are consistent across people, processes and tools. A NOC that is ineffective and inefficient drains management and financial resources and leaves the business exposed, due to a lack of performance and availability [3].

For telecommunication companies or any other organisation to survive and thrive in a globally competitive market, they need to provide superior quality to customers consistently over a long time. Seventy percent of the network manager's workday time is spent on troubleshooting: preventing, reacting, and resolving ongoing disruptions in the network, while only 30% is spent on business-driving activities [4]. Sixty-four percent of IT executives admit that insufficient skills are among the top barriers to emerging technology adoption [4]. According to the ITIC's 11th annual, 40% of enterprise survey participants estimated that an hour of outages cost an organisation $1 million to 5 million in revenue, end-user efficiency, and administrator remediation [5].

The NOC is an essential part of a telecommunications organisation, and it supports the efficient functioning of a business [2]. Companies that utilise a high level of TQM practices are rarely influenced by the forces that drive industry competition [6]. The inefficiency of the NOC affects network

* Correspondence: afolabiilesanmi@yahoo.com

availability and service availability and also the reputation of the business and its profitability [3], [7]. Numerous NOCs fail to meet desired service levels due to the lack of a centralised support framework, which is imperative for the success of the NOC, as it assists in making decisions and actions consistent across people, processes, and tools [3]. While 70% of a workday is used to troubleshoot faults in the network [4]. 35%-55% of network failures are due to human error. These can be lessened through training [8].

The aim of the study is to develop a TQM framework focusing on the management of faults on the 5G transmission network guiding the mobile NOC department in performing efficiently and meeting customer's needs.

This study contributes to the existing body of knowledge, with the focus being on the NOC in telecommunications. It also contributes to the understanding and use of quality TQM tools and techniques in telecommunication NOCs. The development of a TQM framework for the network operations centre adds value in the running of the department efficiently and, more importantly, will meet the needs of customers. Thus, the proposed TQM is therefore recommended for implementation by NOC. If the proposed framework is rightly implemented, telecommunication organisations may reap benefits, such as customer satisfaction, improved processes in network surveillance, fault management, improved decision-making and processes in general, giving the business a competitive edge.

Having the right organisational culture, company structure and resource support helps to improve the effective implementation of TQM [9].

Furthermore, the study also contributes to knowledge empirically through the implemetation of the FAHP framework was used as a multi-criteria decision-making tool to determine which criteria and factors are of the highest ranking for the development of the TQM framework.

2. Literature Review

Various research studies show that TQM tools and techniques are used to review and analyse current conditions and are used for planning and control in order to solve problems and bring about much-needed improvements in organisations [10]. The TQM tools and techniques help identify root causes of quality issues, which can then be solved [11], [12].

Evidence shows that TQM is an important tool, which contributes to an improved efficiency and increased financial performance [13]. TQM, TQM tools and techniques have various benefits in an organisation if implemented successfully and improve competitiveness [11], [12], [14].

2.1. TQM Tools

The seven and sometimes eight quality tools with the goal of assisting the organisation to meet the needs of the customer are Pareto analysis, cause-and-effect diagrams, check sheets, control charts, histograms, scatter diagrams, stratification and in some cases process flowcharts instead of stratification [15], [16], [17], [18], [19], [20], [21]. The following are TQM tools and techniques properties:

- Pareto analysis - Pareto analysis is a quality tool which was developed by an Italian economist by the name of Vilfredo Pareto for problem-solving [22]. It is called the 80/20 principle, where 80% of consequences are a result of 20% of the causes, which means that a minority of causes lead to the majority of problems [15], [22], [23], [24], [25]. It is also known as vital few and trivial many. The correct vital few need to be identified to be able to solve problems; if not, it will lead to an incorrect problem-solving approach. Pareto analysis relies on quality data from a stable process, as instability issues will lead to misinterpretation and the right problem might not be solved [22]. When depicted graphically or visually, it is called a Pareto chart. It was promoted by one of the quality gurus, Dr Joseph Juran; it is used to separate the important from the trivial [15]. Pareto charts prioritise the causes of problems [17]. Pareto analysis is used as an analysis tool for various applications [26]. In previous research where Pareto analysis was investigated, the research concluded that, if Pareto analysis fails to correct [23].

- Cause-and-effect diagram: A cause-and-effect diagram is a commonly used non-statistical quality tool. It is used to qualitatively map the relationship between a problem and its causes [15], [17], [27], [28]. The cause-and-effect diagram was designed by Dr Kaoru Ishikawa to effectively sort and organise the potential causes of a problem and to consider their interrelationship [15], [28]. A cause-and–effect diagram is used for problem-solving through the identification of problems and their root causes [10], [27]. It provides a systematic framework designed to help identify and isolate causes of problems that need to be solved. The cause-and-effect diagram is graphically represented in the form of a fish and hence its name fishbone diagram, where the spine is the problem investigated and where the ribs of the fish are the causes of the problem [15]. Data on the problem or process can be collected during a brainstorming session consisting of subject-matter experts such as engineers, technicians, and etc [15], [27], [29]. The brainstorming process is used to identify possible causes and yields a great deal of data, which will need to be analysed [15], [20], [27], [29]. The possible causes that may be associated with problems may be categorised as follows: machine, method, man (people) and mother nature (the environment) [27], [28]. A cause-and-effect diagram is a tool of analysis not of just problems but also of processes [28].
- Check sheets: A check sheet is used to collect data. This is done during inspection and the defects are recorded [27], [30]. It can be used in any environment to identify the root causes of a problem. Check sheets are used for data collection. This data collected can be used to solve problems or improve processes [15], [30].
- Control chart: A control chart is used to study or analyse a process over time and identify special causes of variation, so the process can be improved and problems can also be solved [27]. Dr Walter Shewhart developed the control chart to separate special causes from common causes [15]. For it to work effectively, it relies on sufficient data [31]. The data is visualised by plotting the data on a graph with an upper control limit (UCL) and a lower control limit (LCL). Special causes of process variations are easily picked up as they will be outside the UCL and LCL boundary [15].
- Histogram: A histogram is usually used for data visualisation and data analysis [16], [27]. It shows the frequency of occurrence; hence, it is also called a frequency distribution diagram [15]. Histograms should be used only for a short period of time, as the results may be blurred because many things could potentially affect a process such as maintenance of equipment, material difference, and operator influence, etc [15]. Processes are subject to variability. For example, a process can be repeated several times and yet produce a different output every time. This variation of a process is calculated by using the standard deviation (indicates the deviation from the mean value of the samples in a data set) and mean (it is the line from which the standard deviation is measured; it is at the centre of the bell curve) on a frequency distribution curve [15]. Trends can be determined from the frequency distribution, making a histogram a data analysis tool as well. A histogram is also used for problem-solving and it is not so popular for decision-making and process improvements [10].
- Scatter diagram: The scatter diagram is used to study the relationship or correlation between variables [15], [27]. When there is a strong correlation between variables, the data points will be grouped in a linear form. When there is a weak correlation, the data points will be loosely grouped. Lastly, if there is no correlation between variables, the data points will be in a disorganised configuration for example not linear or elliptical [15]. A scatter diagram is used to test the correlation between process factors and characteristics of the product flowing out of a process. Once the data has been plotted, it can then be analysed to see the relationships of variables in a process and to solve problems.
- Flowchart: A flowchart is used to graphically represent a process, so the process can be fully understood. Once the process has been drawn, it needs to be studied to see where the problems are and where it can be improved [15].

- Stratification (appears in some text as the seventh quality tool): Stratification is used to investigate causes of problems by classifying data into categories to reveal underlying patterns [15], [27]. This makes it easier to analyse the data and gain some insights that will assist in solving problems or improving processes. If one stratifies long enough, they will get to the root cause of the problem and be able to solve the problem [15]. Stratification is a favourite technique to classify data in order to reveal underlying patterns [27] to make improvements and for problem-solving but is a least favourite for decision-making [10].

2.2. Properties of TQM Tools

During the NOC operations of network surveillance and fault management, processes require the following: data collection, data analysis, data visualisation, problem-solving, and process improvement. These are the properties of the TQM tools and techniques.

- Data Collection: Data is usually collected to solve problems or improve processes [15], [30]. With sufficient data, problems can be identified, visualised, analysed, and solved and processes will be improved. Check sheets are used for data collection.
- Data Analysis: Data analysis involves the grouping and structuring of data so that important relationship, characteristics, trends and information that can provide valuable insights into the problem and how it can be solved can be determined [16], [27]. Data analysis can be done using frequency distribution, histogram etc.
- Data Visualisation: This process involves the presentation of data at a glance in tables, graph or charts so as to effectively communicate the information deduced from it [32], [33].
- Problem-Solving: This process encompasses problem definition, establishing root cause of the problem, identification of the possile solutions, and selection of the most feasible alternative from the solutions [32], [33].
- Process Improvement: This involves the analysis of existing process in order to optimize or enhance its performance. The process improvement is a systematic approach carried out to ensure that the that is process is achieved orderly, effectively and continuously manner with significant improvement over the existing or current process [32], [33].

2.3. Application of TQM

The articles consulted in this research have found that TQM has evolved over the years. The finding was that companies need a proper strategic roadmap along with suitable tools and techniques to ensure the successful implementation of TQM [9]. A proactive strategy, which is an internal strategic factor, ensures a stronger positive effect of TQM [9], [11], [34], [35]. There is, however, a need for research in strategic quality management (SQM) as an important area of TQM [9], [35].

Having the right organisational culture, company structure and resource support helps to improve the effective implementation of TQM [9], [35]. Quality-management programmes such as TQM contribute to organisational change in the organisation [13].

Various research studies show that TQM tools and techniques are used to review and analyse current conditions and are used for planning and control in order to solve problems and bring about much-needed improvements in organisations [10]. The TQM tools and techniques help identify root causes of quality issues, which can then be solved [11], [12].

Evidence shows that TQM is an important tool, which contributes to an improved efficiency and increased financial performance [13]. TQM, TQM tools and techniques have various benefits in an organisation if implemented successfully and improve competitiveness [11],[12], [14].

TQM was also critically assessed to identify areas of future research; this was carried out by utilising a systematic literature review of articles, obtained from various databases and also statistical methods. A Pareto analysis was used to capture the frequency of occurrence [26], [36]. The findings of the study are practices of TQM and the impact of TQM. The practices of TQM vary by sector and a Pareto analysis was applied to the practises of TQM to see the frequency of these practices in the literature. The impact of TQM is customer satisfaction and improved business performance, as they appeared more frequently in the literature [36]. The correct application of TQM tools and techniques can increase productivity and profitability, as not all tools can enhance efficiency [16]. Not many literature has extended the application of TQM to the telecommuication industry precisely the mobile network operation centres (NOC) which is the focus of this study. Furthermore, the application of fuzzy analytic hierarchical process (FAHP) for as a multi-criteria decision-making tool in relation to the mobile NOC has not been sufficiently highlighted by the existing literature. Thus, the novelty of this study lies in the development of a TQM framework for mobile NOC to aid in network surveillance and fault management processes for a 5G transmission network. In addition, the ranking of the criteria that constitute the framework in their order of importance using the FAHP approach has not been sufficiently discussed by the existing literature. The study is significant in that it will add value to any NOC department that uses the framework. The TQM principles, tools and techniques such as data collection, data visualisation, data analysis, problem-solving and process improvement were used to develop the TQM framework which will serve as a guide for the NOC department. The application of the proposed TQM framework will result in the seamless running of the NOC and in meeting the needs of the customer. It will assist in areas such as monitoring and surveillance as well as fault management. This will ultimately reduce downtime and assist the NOC department not to be a reactive department that spends the majority of its time on troubleshooting.

3. Methodology

Desk research (secondary data) is conducted for the research. Data is selected using a systematic literature review (SLR), which is evidence-based. Data is analysed using the fuzzy analytic hierarchy process (FAHP), which is used as a technique for supporting the selection of TQM tools and techniques and elements to use in the framework.

The analytic hierarchy process (AHP) is used as a technique for supporting the selection of TQM tools and techniques [37] [38]. AHP is a widely used multiple-criteria decision-making tool which uses pairwise comparisons of allocated weights to rank alternatives [37], [38], [39] [40]. The three main AHP methodology functions are:

- Structuring complexity: identify various factors that affect the decision and organise them in a hierarchical structure of homogenous clusters of factors.
- Measurement: is in ratio scale and is found by comparing the factors in pairs.
- Synthesis: each factor is compared with its parent factor.

This method is based on assigning numerical values for the subjective judgement of the relative importance of each variable, then synthesising the judgments to determine which variables have the highest priority [37]. AHP uses a consistency ratio to ensure the judgement exercised on the pairwise comparison is coherent and consistent [38]. Its limitations are:

- A pairwise comparison may introduce inconsistency, as it does not look at the global information but does a single pair comparison at a time [38].
- If there is only one decision maker, the results may be subjective.

To curb these limitations, a fuzzy analytic hierarchy process (FAHP) is used. FAHP is used to reduce uncertainty, vagueness, imprecision, and subjectivity of the expert's conclusion [41], [42], [43]. FAHP is also a multi-criteria decision-making tool and is a combination of fuzzy theory and AHP [41]. It converts linguistic definitions or variables into mathematical expressions [44]. The following are the steps of FAHP. They are similar to those of AHP [41]:

1. Identify the goal or objective.
2. Then break it down into criteria (Categories) and/or sub-criteria (Subcategories).
3. Establish a hierarchy structure framework for analysis.
4. Perform a fuzzy pairwise comparison for each level of the criteria (categories) and/or sub-criteria (Sub- categories).
5. Determine relative weights.

FAHP uses a crisp matrix. It is obtained by taking a central value from the fuzzy matrix instead of using a fuzzy number [44].

The FAHP scale has values, namely, the lowest value (lower, l), middle value (median, m), and higher value (upper, u). These are the triangular fuzzy numbers (TFN) [44]. Compared to the Fuzzy Analytical Network Process (FANP) which combines the Analytical Network Process (ANP) and Fuzzy methods, the FANP considers the interaction between criteria and the weight allocation process is more accurate and less subjective. However, the FANP model may present complex mathematical models [45]. The Fuzzy decision-making trial and evaluation laboratory (Fuzzy-DEMATEL) is considered as an effective model for the identifying the cause-effect chain components of a complex system through the evaluation of the relationships or interdependence among factors and finding the important ones via a visual structural model [46]. Unlike the FAHP, it might be difficult for decision makers to visualise the direct influence of the each of the criteria on the overall goal. Thus, based on the limitations of the AHP, FANP and Fuzzy-DEMATEL, the FAHP was selected for use in this study.

The key factors of TQM tools, techniques and methods are identified and compared; based on their weight, a selection is made that can be applied in the NOC environment.

3.1. Data Collection

The systematic literature review (SLR) is a research method and process of identifying and critically appraising relevant research and then producing the research findings in a systematic, transparent, and in a manner that can be reproduced or copied [47]. It aims to minimise bias and provide reliable findings by using predetermined inclusion and exclusion criteria to answer a particular research question [47], [48]. The sources used to conduct the systematic literature review are EBSCOHost database with peer-reviewed articles from journals and also grey literature such as company websites, standards organisation websites and textbooks on the subject matter.

Keywords were predetermined and used to search the databases and inclusion and exclusion criteria were constructed before the literature review was undertaken. The inclusion criteria:

- That are peer-reviewed.
- That are published.
- That are not older than 2012.
- Use at least 25 articles.
- EBSCOHost database.

The exclusion criteria:

- Articles that are not related to total quality management or quality tools.
- Articles that do not mention the NOC.

A total of forty-five (45) articles that satisfied the inclusion criteria were reviewed in this study.

3.2. Data Analysis

Fuzzy analytic hierarchy process (FAHP) is used for data analysis. FAHP is used to reduce uncertainty, vagueness, imprecision, and subjectivity of the expert's conclusion [41], [42], [43]. FAHP is also a multi-criteria decision-making tool and is a combination of fuzzy theory and AHP [44] It converts linguistic definitions or variables into mathematical expressions [45]. The following are the steps of FAHP. They are similar to those of AHP [44], [46].

- Identify the goal or objective.
- Then break it down into criteria (Categories) and/or sub-criteria (Subcategories).
- Establish a hierarchy structure framework for analysis.
- Perform a fuzzy pairwise comparison for each level of the criteria (Categories) and/or sub-criteria (Sub- categories).
- Determine relative weights.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 6: 2212-2231, 2024
DOI: 10.55214/25768484.v8i6.2420

FAHP uses a crisp matrix. It is obtained by taking a central value from the fuzzy matrix instead of using a fuzzy number [41], [42], [43], [44], [45]. The FAHP scale has values, namely, the lowest value (lower, l), middle value (median, m), and higher value (upper, u). These are the triangular fuzzy numbers (TFN) [42], [43], [44] [49], [50].

3.2.1. The FAHP Framework

Figure 1 presents the block diagram representing the framework followed for the FAHP method while Figure 2 shows the FAHP hierarchy model for the criteria and factors employed in the NOC TQM framework.

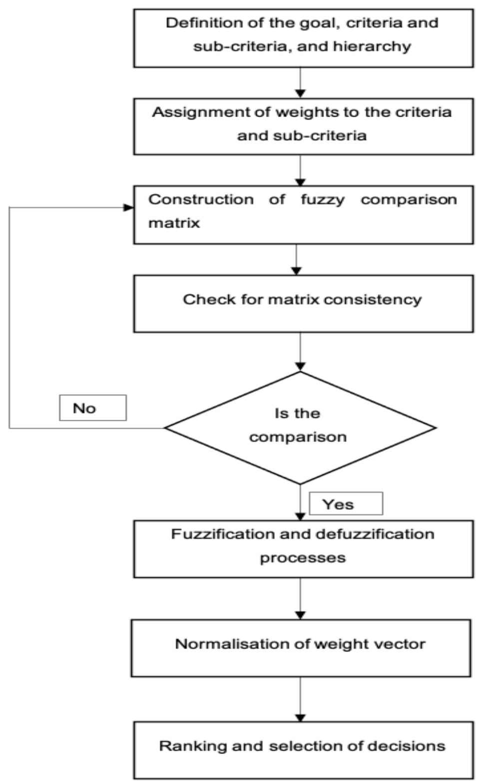

Figure 1.
The block diagram representing the framework followed for the FAHP method [44].

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 6: 2212-2231, 2024
DOI: 10.55214/25768484.v8i6.2420

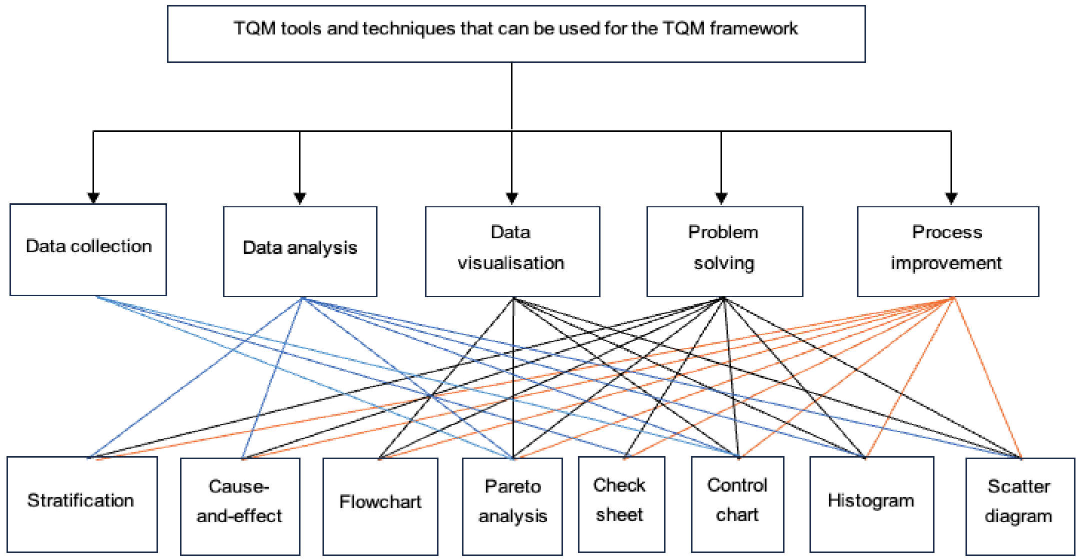

Figure 2.
The FAHP hierarchy model for the criteria and factors employed in the NOC TQM framework.

The literature reviewed highlighted the TQM tools and techniques. The results of the review are as follows:

- One tool is for data collection.
- Five tools are for data visualisation.
- Six tools are for data analysis.
- Eight tools are for problem-solving.
- Eight tools are for process improvement.

These properties are then used as the criteria for the FAHP. The results are then used to draw up the TQM framework for the NOC. The criteria are selected as follows:

- Data collection (DC).
- Data analysis (DA).
- Data visualisation (DV).
- Problem-solving (PS).
- Process improvement (PI).

The TQM tools and techniques are used as the factors for the FAHP process:

- Pareto analysis.
- Cause-and-effect diagram.
- Check sheet.
- Control chart.
- Histogram.
- Scatter diagram.
- Flowchart.

ISSN: 2576-8484
Vol. 8, No. 6: 2212-2231, 2024
DOI: 10.55214/25768484.v8i6.2420

3.2.2. Pairwise Comparison of the Quality Tools

A pairwise comparison is done and based on which criterion is of importance in the NOC. During the NOC operations of network surveillance and fault management, processes require the following: data collection, data analysis, data visualisation, problem-solving, and process improvement. These are the properties of the TQM tools and techniques. The criteria and factors are weighted using a triangular fuzzy number (TNF) scale of relative importance (see Table 1). Table 1 maps the linguistic variables to TNF and are used to conduct the pairwise comparison.

Table 1.
Linguistic terms for expressing relative priorities.

Fuzzy number	Linguistic variable	TNF
1	Equally important	(1,1,1)
2	Equally moderate important	(1,2,3)
3	Weakly important	(2,3,4)
4	Moderate important	(3,4,5)
5	Moderately strongly important	(4,5,6)
6	Strongly important	(5,6,7)
7	Very strongly important	(6,7,8)
8	Very strongly extremely important	(7,8,9)
9	Absolutely important	(8,9,9)

Source: [41].

The properties of the TQM tools and techniques are given weights based on which properties are common among all TQM tools and techniques. The one that is most common is given a higher weight and the least common one is given the least weight. The criteria and the factors are compared in pairs to see which one is of greater importance. Table 2 is populated using the TNF for the pairwise comparison. Table 2 is the pairwise comparison matrix for the criteria using FAHP.

The assumption underlying the F-AHP approach is that all the criteria and factors involved are independent of each other to minimise inconsistency in the weight allocation [49], [51].

Table 2.
The pairwise comparison of the criteria used.

	Data collection	Data visualisation	Data analysis	Problem-solving	Process improvement
Data collection	(1,1,1)	(8,9,9)	(8,9,9)	(8,9,9)	(8,9,9)
Data visualisation	(1/9,1/9,1/8)	(1,1,1)	(3,4,5)	(4,5,6)	(4,5,6)
Data analysis	(1/9,1/9,1/8)	(1/5,1/4,1/3)	(1,1,1)	(1,2,3)	(4,5,6)
Problem-solving	(1/9,1/9,1/8)	(1/6,1/5,1/4)	(1/3,1/2,1)	(1,1,1)	(1,1,1)
Process improvement	(1/9,1/9,1/8)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1,1,1)	(1,1,1)

Table 3 shows the results of the matrix calculations done. Defuzzification is done to get the centre of area, which is a fuzzy crisp number. The crisp number is normalised to get a total sum of 1. The criteria are also ranked as per below.

Table 3.
Defuzzification, normalisation and ranking of the criteria.

Properties	Fuzzy geometric mean value	Fuzzy weights	Centre of area (COA)	Norm-alise	Ranking
Data collection	(5.278,5.799,5.799)	(0.000556, 0.648803, 0.000728)	0.000428	0.735164	1
Data visualisation	(1.398,1.619,1.863)	(0.000147, 0.181137, 0.000234)	0.000078	0.133855	2
Data analysis	(0.617,0.774,0.944)	(0.000065, 0.086597, 0.000118)	0.000039	0.067826	3
Problem-solving	(0.359,0.407,0.500)	(0.000038, 0.045536, 0.000063)	0.000021	0.035925	4
Process improvement	(0.315,0.339,0379)	(0.000033, 0.037928, 0.0000476)	0.000016	0.027231	5

Table 4 is the pairwise comparison matrix for the factors used in FAHP. The factors are the TQM tools and techniques while Table 5 shows the results of the matrix calculations done. Defuzzification is done to get COA, which is a fuzzy crisp number. The crisp number is normalised to get a total sum of 1.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 6: 2212-2231, 2024
DOI: 10.55214/25768484.v8i6.2420

Table 4.
The pairwise comparison of the factors used in FAHP.

	Pareto chart	Cause-and-effect diagram	Check sheet	Control chart	Histogram	Scatter diagram	Flow-chart	Stratification
Pareto chart	(1,1,1)	(4,5,6)	(0.111, 0.111, 0.125)	(1,1,1)	(1,1,1)	(1,1,1)	(5,6,7)	(5,6,7)
Cause-and-effect diagram	(0.167, 0.200, 0.250)	(1,1,1)	(0.111, 0.111, 0.125)	(0.167, 0.200, 0.250)	(0.167, 0.200, 0.250)	(0.167, 0.200, 0.250)	(4,5,6)	(1,1,1)
Check sheet	(8,9,9)	(8,9,9)	(1,1,1)	(8,9,9)	(8,9,9)	(8,9,9)	(8,9,9)	(8,9,9)
Control chart	(1,1,1)	(0.167, 0.200, 0.250)	(0.111, 0.111, 0.125)	(1,1,1)	(1,1,1)	(1,1,1)	(5,6,7)	(0.167, 0.200, 0.250)
Histogram	(1,1,1)	(0.167, 0.200, 0.250)	(0.111, 0.111, 0.125)	(1,1,1)	(1,1,1)	(1,1,1)	(5,6,7)	(0.167, 0.200, 0.250)
Scatter diagram	(1,1,1)	(0.167, 0.200, 0.250)	(0.111, 0.111, 0.125)	(1,1,1)	(1,1,1)	(1,1,1)	(5,6,7)	(0.167, 0.200, 0.250)
Flowchart	(0.143, 0.167, 0.2)	(0.167, 0.200, 0.250)	(0.111, 0.111, 0.125)	(0.143, 0.167, 0.2)	(0.143, 0.167, 0.2)	(0.143, 0.167, 0.2)	(1,1,1)	(0.167, 0.200, 0.250)
Stratification	(0.167, 0.200, 0.250)	(1,1,1)	(0.111, 0.111, 0.125)	(0.167, 0.200, 0.250)	(0.167, 0.200, 0.250)	(0.167, 0.200, 0.250)	(4,5,6)	(1,1,1)

Table 5.
Defuzzification, normalisation and ranking of the factors.

Tools and techniques	Fuzzy geometric mean value	Fuzzy weights	Centre of area (COA)	Normalise	Ranking
Pareto chart	(1.351, 1.454, 1.569)	(0.115, 0.131, 0.153)	0.133	0.132	2
Cause-and-effect diagram	(0.369, 0.339, 0.482)	(0.0314, 0.0333, 0.0471)	0.037	0.037	4
Check sheet	(6.169, 6.839, 6.839)	(0.525, 0.617, 0.669)	0.604	0.599	1
Control chart	(0.594, 0.636, 0.695)	(0.0505, 0.0574, 0.0679)	0.059	0.058	3
Histogram	(0.594, 0.636, 0.695)	(0.0505, 0.0574, 0.0679)	0.059	0.058	3
Scatter diagram	(0.594, 0.636, 0.695)	(0.0505, 0.0574, 0.0679)	0.059	0.058	3
Flowchart	(0.184, 0.208, 0.298)	(0.0157, 0.0188, 0.0291)	0.021	0.021	5
Stratification	(0.369, 0.339, 0.482)	(0.0314, 0.0333, 0.0471)	0.037	0.037	4

The FAHP method is used as a multi-criteria decision-making tool. The criteria and the factors are assigned estimated weights based on their perceived importance. They are then compared, and calculations are done. Data collection has the highest ranking and is perceived to be of greater importance when compared to the other criteria. A check sheet (a data-collection tool) is also perceived to be of greater importance in comparison to the other factors.

Table **6** presents the proposed TQM framework for the NOC.

Table 1.
The TQM framework for the NOC.

Tools and techniques	Properties	Uses in the NOC
Check sheet	Data collection, problem-solving, process improvement	To collect the following data: • Record number of link failures per day/week/month • Record failed transmission devices per day/week/month • Traffic per aggregation node day/week/month • Traffic per core node day/week/month • Record packet loss • Record availability of the transmission network • Record link traffic • Record number of incidents • Record mean time to repair/restore faults

		Record mean time to acknowledge escalated faults
Pareto analysis	Data visualisation, data analysis, problem-solving, process improvement	To list top issues on the transmission network: • Packet loss • No throughput • Latency • Network availability • Congestion • Transmission-device failures Link failures
Histogram	Data visualisation, data analysis, problem-solving, process improvement	To visualise: • Traffic per aggregation node • Traffic per core node • Availability of the transmission network • Failure of links • Failure of transmission devices • Packets loss The trouble tickets, i.e., open vs closed
Cause-and-effect diagram	Data analysis, problem-solving, process improvement	Used to identify the root causes of issue that contribute to failures on a transmission network such as: • Human error • Technical factors • Lack of maintenance • Environmental factors • Vandalism Degradation of transmission links
Flowchart	Data visualisation, problem-solving, process improvement	Used to document the processes in the transmission network surveillance and fault management process. Uses: • To train employees For continuous improvement of processes

4. Results and Discussions

The use of FAHP allows for a decision to be made on which TQM tools and techniques are best suited for the TQM framework to be developed for the NOC. The goal is to determine which TQM tools and techniques can be used for the TQM framework. The criteria and factors were selected and a pairwise comparison and calculations were conducted. The results indicated which criteria and factor were of a higher ranking, indicating the importance to both the development of the TQM framework for the NOC.

Using the literature, properties of the TQM tools and techniques were found. These fit in with the NOC processes, being network surveillance and fault management. The properties that are common in all or most of the TQM tools and techniques are given a higher weight, using the TNF number from the FAHP method.

An FAHP was used because it caters for the imperfection of the analysis by reducing uncertainty, vagueness, imprecision, and the subjectivity of the expert's conclusion. Once the properties were assigned values, matrix calculations on the characteristics which are criteria in the FAHP analysis. This was done to see which criteria ranked higher. The factor ranked higher showing the importance of that factor in the framework developed.

The results of the criteria pairwise comparison revealed that data collection has a higher ranking. Data collection needs to be a priority in the framework because, without good data, no problems can be identified, visualised, analysed, and solved and processes will not be improved. The factor criteria ranking is seen in Figure 3.

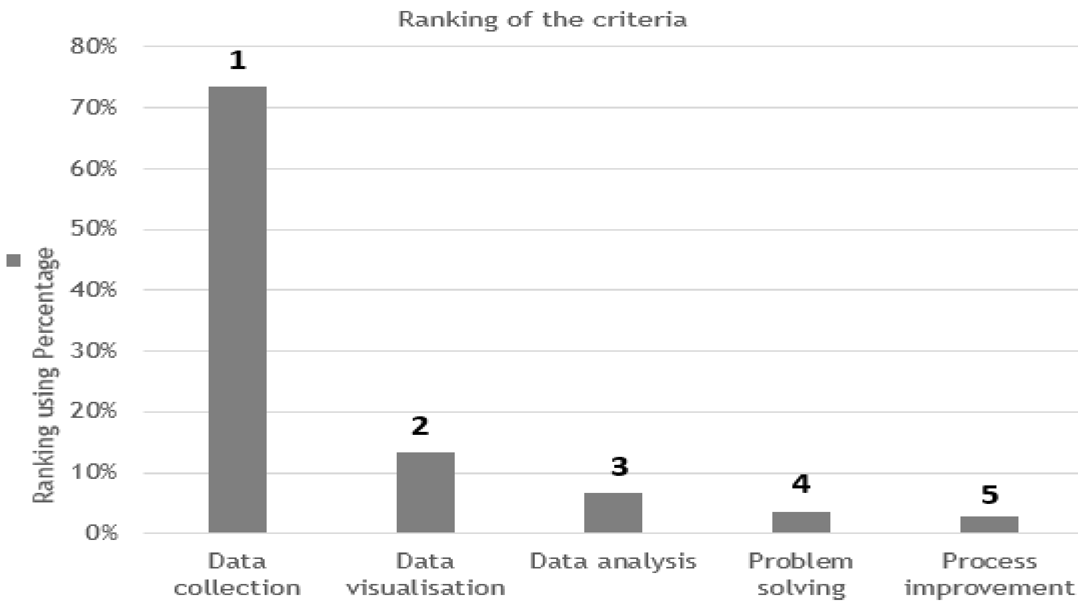

Figure 3.
The ranking of the criteria using FAHP.

The ranking of the criteria are the properties of the TQM tools and techniques. The same was done for the TQM tools and techniques; they are the factors in the FAHP analysis. The TQM tools and techniques that had many properties were ranked higher and the one with the fewest properties scored the least. These weights were used in the matrix calculations, which resulted in the ranking of the tools. The TQM tools and techniques that ranked the highest formed part of the TQM framework developed for the NOC. The results from the matrix calculation yielded factors with the same values. The researcher selected only one tool or technique based on the ease of use in the NOC environment. This judgement is catered for in the use of FAHP, as it is used in cases where there might be subjectivity based on the expert's conclusion.

Process improvement is ranked last, showing it is of lower priority than the other criteria. This however does not imply that it is of no importance in TQM. Existing studies indicates that process improvement is necessary for quality improvement and reduction in waste or other non-value adding activities [52], [53], [54]. There is also a concensus among existing studies that the implementation of TQM can improve the cost-efficiency, adaptability, performance, productivity and competitiveness of organisations [56], [56], [57], [58], [59], [60].

The results of the factors' pairwise comparison revealed that a check sheet has a higher ranking. A check sheet is a data collection tool, which coincides with the results found for the criteria listing data collection of high ranking. A flowchart was ranked last; this is a process improvement tool. The factor ranking is seen in Figure 4.

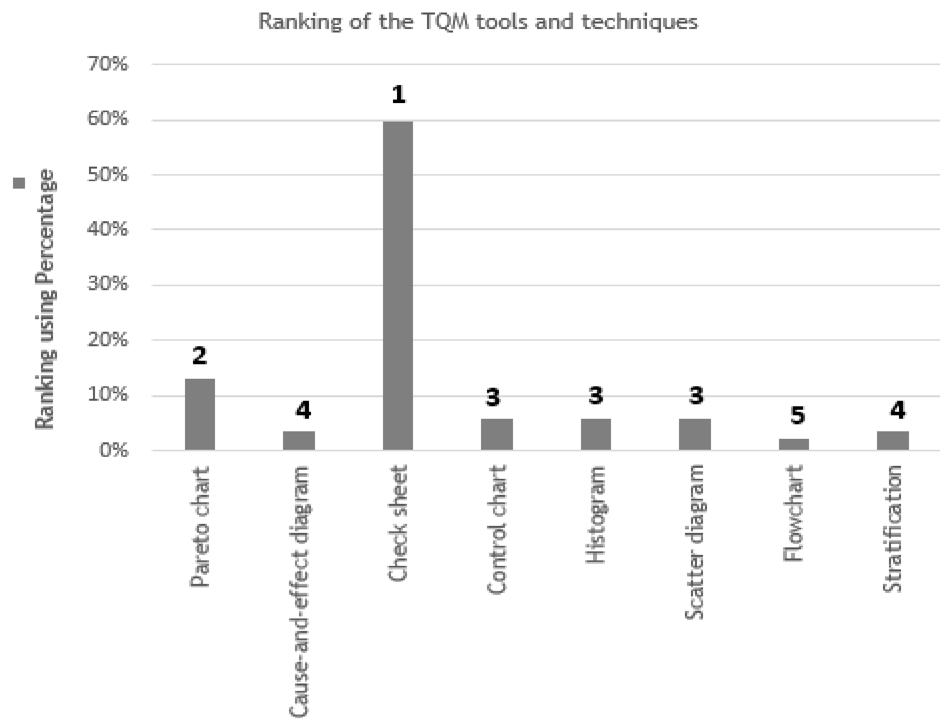

Figure 4.
The ranking of the criteria (factors) using FAHP.

The study by Brkic *et al.* [10] refutes the findings of the research, by small margins. The difference in the findings could be linked to the study being conducted in industrial firms.

When converting the factors, they used the percentage and we get the following:

- For problem-solving, a form of collecting data, is ranked at 28.3%, histogram at 76.1%, Pareto chart at 73%, cause-and-effect diagram at 61.4%, and flowchart at 28.5%, while data-processing and analysis is at 22.8%.
- For improvements, a form of collecting data, is ranked the highest at 32%, histogram at 21.5%, Pareto chart at 18.4%, cause-and-effect diagram at 44.7%, and flowchart at 54.9%, while data-processing and analysis is at 19.7% [10].

The results of this research are, however, supported by:

- Castello *et al.* [18] who used the Likert scale. They rated a data collection template at 76%, data analysis at 65% and process improvement and problem-solving at 55%. Data visualisation is not included in their ratings. They, however, rate a flowchart higher than the other tools and techniques, at 78%. Though the rating of the other tools is ranked like those found in this study, what varies is the percentage value. A Pareto chart at 70.5%, a histogram at 65% and cause-and-effect diagram at 67% percent. A check sheet is not included [18].
- According to Ali and Johl [22], quality management is dependent on data collection along with evaluation and decision-making. This is needed to address and solve problems. Quality data and analysis form an integral part of TQM infrastructure [22].
- An Uluskan [16] study states that the most frequently used tools are graphical analysis (which essentially involves transforming collected data into a visualised representation), a flowchart and a histogram; and the commonly used problem-solving tools are cause-and-effect diagrams and Pareto analysis (Pareto chart) [16].

This substantiates why these TQM tools and techniques form part of the TQM framework for the NOC. The TQM framework for the NOC for network surveillance and fault management utilises the properties of the TQM tools and techniques, namely, data collection, data visualisation, data analysis, problem-solving and process improvement. On the framework, the tools are laid out in the order of importance per characteristic and a recommendation is made of how the NOC can use these tools in the transmission-network surveillance and fault-management processes.

Figure 5 shows the data points which summarises the number of literature that supports the implementation of TQM in organisation including their area of focus. A total of forty-five (45) articles that satisfied the inclusion criteria were reviewed in this study.

The data points show the relevance of the TQM implemtation in organisations. However, some literature highlighted the need for proper planning, change in organisation's culture, deployment of adequate resources, continuous training and education, continuous monitoring and review, as well as commitment by top management as factors necessary for the successful implementation of TQM in organisations [52], [54], [56], [60].

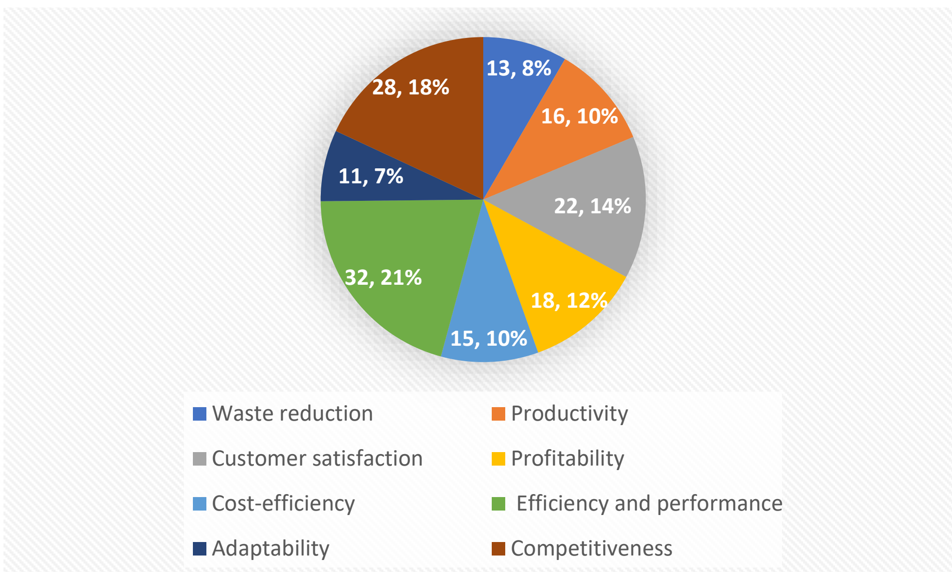

Figure 5.
The data points that support the implementation of TQM in organisation.

5. Conclusion

The aim of this study was to study develops a total quality management (TQM) framework for mobile network operation centres (NOC) to aid in network surveillance and fault management processes for a 5G transmission network. This was achieved with the aid of a systematic literature review conducted using academic articles in journals and conference papers sourced from the EBSCOHost database. The articles reviewed in this study found that TQM has evolved and is the extension of work done. The finding was that companies need a proper strategic roadmap along with suitable tools and techniques to ensure the successful implementation of TQM. Having the right organisational culture, company structure and resource support helps to improve the effective implementation of TQM. Furthermore, the FAHP was used as a multi-criteria decision-making tool to determine which criteria and factors are of the highest ranking for the development of the TQM framework. The results obtained indicated that data collection and control sheets were ranked higher, making them critical to the framework. This shows that, without good data, no problems can be identified, visualised, analysed, and solved and processes will not be improved. Process improvement is ranked last, showing it is of the lowest priority when compared to the other criteria.

The developed framework can be used in the following manner:

- It should be documented.
- The NOC staff should be trained to use it.
- All data should be recorded as per framework.
- The data should be translated into visuals.
- Once the data is in graphs, it can be analysed.
- The tools for problem-solving can then be applied to solve problems identified.
- The process flow should be documented.
- The process flow should be followed practically to see where it needs improvement.

Data collection is critical; without it there is no data visualisation or analysis. Problems cannot be solved and processes cannot be improved. The quality of data collection is critical to the framework developed.

This research contributes to the existing body of knowledge, with the focus being on the NOC in telecommunications. It also contributes to the understanding and use of quality TQM tools and techniques in telecommunication NOCs. The development of a TQM framework for the network operations centre adds value in the running of the department efficiently and, more importantly, will meet the needs of customers. Thus, the proposed TQM is therefore recommended for implementation by NOC. If the proposed framework is rightly implemented, telecommunication organisations may reap benefits, such as customer satisfaction, improved processes in network surveillance, fault management, improved decision-making and processes in general, giving the business a competitive edge.

The limitation to the study is that there was a lack of primary data. Secondary data was also scarce, since telecommunication is in the service industry. Articles in the service industry were considered in the study. To avoid such limitations, primary data can be sourced using a questionnaire for the NOC staff who do network surveillance and fault management of the transmission network. Future research can be done on an off-the-shelf application that automates TQM tools and techniques. Applications that can communicate with the transmission devices and are able to collect the data from devices, analyse them and visually display them on a dashboard in the form of TQM tools and techniques, i.e., a histogram, scatter diagram, and check sheet, etc.

References

[1] E. Menshikova, O. Khazanov & M. Styazhkin. 2016. 'Implementation of the Quality Management System in the telecommunications companies', *SHS Web of Conferences*, vol. 28, p. 01149, 2016, doi: 10.1051/shsconf/20162801149.

[2] D. Mgcina. 2020. The enhancement of network operations centres operating. Thesis submitted in fulfilment of the requirements for the degree Master of Technology: Business Information Systems in the Faculty of Business and Management Sciences at the Cape Pe', no. June, 2020.

[3] P. Rao. 'NOC Best Practices: 10 Ways to Improve Your Operation in 2023', INOC. Accessed: Feb. 28, 2023. [Online]. Available: https://www.inoc.com/blog/noc-best-practices-10-ways-to-improve-your-operation

[4] V. Poliakov. 'Telecom NOC Best Practices for Future-Proof Operations', Jan. 2023, Accessed: May 18, 2023. [Online]. Available: https://www.infopulse.com/blog/expand-telecom-noc

[5] Infrassist. 'Recent Developments in Network Operations Center and Potential for Enhancement - Infrassist', Oct. 2022, Accessed: May 18, 2023. [Online]. Available: https://www.infrassist.com/recent-developments-in-network-operations-center-and-potential-for-enhancement/

[6] K. Nasim. 2018. 'Role of internal and external organizational factors in TQM implementation: A systematic literature review and theoretical framework', *International Journal of Quality and Reliability Management*, vol. 35, no. 5, pp. 1014–1033, 2018, doi: 10.1108/IJQRM-10-2016-0180.

[7] Blue Prism. 'TRANSFORMING THE NOC TO MAXIMIZE THE 5G OPPORTUNITY How a digital workforce can optimize the Network', 2021. [Online]. Available: https://cdn2.assets-servd.host/lively-jackal/production/uploads/resources/white-papers/Whitepaper_5G_TransformingTheNOC2.pdf

[8] D. Tipper. 2014. 'Resilient network design: Challenges and future directions', *Telecommun Syst*, vol. 56, no. 1, pp. 5–16, doi: 10.1007/s11235-013-9815-x.
[9] S. M. Dahlgaard-Park, L. Reyes & C. K. Chen. 2018. 'The evolution and convergence of total quality management and management theories', *Total Quality Management and Business Excellence*, vol. 29, no. 9–10, pp. 1108–1128, doi: 10.1080/14783363.2018.1486556.
[10] V. K. S. Brkic, T. Djurdjevic, N. Dondur, M. M. Klarin & B. Tomic. 2013. 'An empirical examination of the impact of quality tools application on business performance: Evidence from Serbia', *Total Quality Management and Business Excellence*, vol. 24, no. 5–6, pp. 607–618, doi: 10.1080/14783363.2012.677306.
[11] G. J. Yu, M. Park, & K. H. Hong. 2020. 'A strategy perspective on total quality management', *Total Quality Management and Business Excellence*, vol. 31, no. 1–2, pp. 68–81, doi: 10.1080/14783363.2017.1412256.
[12] L. D. N. Gambi, H. Boer, F. Jorgensen, M. C. Gerolamo & L. C. R. Carpinetti. 2022. 'The effects of HRM approach on quality management techniques and performance', *Total Quality Management and Business Excellence*, vol. 33, no. 7–8, pp. 833–861, doi: 10.1080/14783363.2021.1903308.
[13] L. Pimentel & M. J. Major. 2014. 'Quality management and a balanced scorecard as supporting frameworks for a new management model and organisational change', *Total Quality Management and Business Excellence*, vol. 25, no. 7–8, pp. 763–775, doi: 10.1080/14783363.2014.904568.
[14] J. A. Gimenez-Espin, D. Jiménez-Jiménez & M. Martínez-Costa 2013. 'Organizational culture for total quality management', *Total Quality Management and Business Excellence*, vol. 24, no. 5–6, pp. 678–692, doi: 10.1080/14783363.2012.707409.
[15] D. L. Goetsch & S. Davis. 2014. *Quality Management for Organizational Excellence:Introduction to Total Quality*, 7th ed. Essex: Pearson.
[16] M. Uluskan, 2019. 'Analysis of Lean Six Sigma tools from a multidimensional perspective', *Total Quality Management and Business Excellence*, vol. 30, no. 9–10, pp. 1167–1188, doi: 10.1080/14783363.2017.1360134.
[17] S. Bhat, J. Antony, E. V. Gijo & E. A. Cudney. 2020. 'Lean Six Sigma for the healthcare sector: a multiple case study analysis from the Indian context', *International Journal of Quality and Reliability Management*, vol. 37, no. 1, pp. 90–111, doi: 10.1108/IJQRM-07-2018-0193.
[18] J. Castello, R. De Castro & F. Marimon, 2020. 'Use of quality tools and techniques and their integration into ISO 9001: A wind power supply chain case', *International Journal of Quality and Reliability Management*, vol. 37, no. 1, pp. 68–89, doi: 10.1108/IJQRM-07-2018-0171.
[19] M. R. S. Moghadam, H. Safari & N. Yousefi. 2021. 'Clustering quality management models and methods: systematic literature review and text-mining analysis approach', *Total Quality Management and Business Excellence*, vol. 32, no. 3–4, pp. 241–264, doi: 10.1080/14783363.2018.1540927.
[20] H. H. Berhe. 2022. 'Application of Kaizen philosophy for enhancing manufacturing industries' performance: exploratory study of Ethiopian chemical industries', *International Journal of Quality and Reliability Management*, vol. 39, no. 1, pp. 204–235, doi: 10.1108/IJQRM-09-2020-0328.
[21] M. Barsalou & B. Starzyńska. 2023. 'Inquiry into the Use of Five Whys in Industry', *Quality Innovation Prosperity*, vol. 27, no. 1, pp. 62–78, doi: 10.12776/QIP.V27I1.1771.
[22] K. Ali & S. K. Johl. 2022. 'Soft and hard TQM practices: future research agenda for industry 4.0', *Total Quality Management and Business Excellence*, vol. 33, no. 13–14. Routledge, pp. 1625–1655, doi: 10.1080/14783363.2021.1985448.
[23] A. Sarkar, A. R. Mukhopadhyay & S. K. Ghosh, 2013. 'Issues in Pareto analysis and their resolution', *Total Quality Management and Business Excellence*, vol. 24, no. 5–6, pp. 641–651, doi: 10.1080/14783363.2012.704265.
[24] N. Azam Haron, H. Abdul-Rahman, C. Wang & L. C. Wood, 2015. 'Quality function deployment modelling to enhance industrialised building system adoption in housing projects', *Total Quality Management and Business Excellence*, vol. 26, no. 7–8, pp. 703–718,: 10.1080/14783363.2014.880626.
[25] V. E. Kane. 2022. 'Useful paths for identifying Lean Six Sigma improvement opportunities', *International Journal of Quality and Reliability Management*, vol. 39, no. 8, pp. 2058–2077, doi: 10.1108/IJQRM-08-2020-0274.
[26] T. Mahboob, B. Tariq, S. Anwar & M. Khanum. 2015. 'Pareto Analysis of Critical Success Factors for Total Quality Management Targeting the Service Industry', *Int J Comput Appl*, vol. 121, no. 14, pp. 20–24, doi: 10.5120/21608-4678.
[27] M. Rodgers & R. Oppenheim. 2019. 'Ishikawa diagrams and Bayesian belief networks for continuous improvement applications', *TQM Journal*, vol. 31, no. 3, pp. 294–318, doi: 10.1108/TQM-11-2018-0184.
[28] D. P. Abellana. 2021. 'A proposed hybrid root cause analysis technique for quality management', *International Journal of Quality and Reliability Management*, vol. 38, no. 3, pp. 704–721, doi: 10.1108/IJQRM-11-2019-0356.
[29] B. Sarmah & Z. Rahman. 2018. 'Customer co-creation in hotel service innovation: An interpretive structural modeling and MICMAC analysis approach', *Benchmarking*, vol. 25, no. 1, pp. 297–318, doi: 10.1108/BIJ-09-2016-0145.
[30] I. Hoque & M. M. Maalouf. 2022. 'Quality intervention, supplier performance and buyer–supplier relationships: evidence from the garment industry', *Benchmarking*, vol. 29, no. 8, pp. 2337–2358, doi: 10.1108/BIJ-02-2021-0075.
[31] J. J. Dahlgaard, L. Reyes, C. K. Chen & S. M. 2019. Dahlgaard-Park, 'Evolution and future of total quality management: management control and organisational learning', *Total Quality Management and Business Excellence*, vol. 30, no. sup1, pp. S1–S16, doi: 10.1080/14783363.2019.1665776.

[32] Y. Magodi, I. A. Daniyan & K. Mpofu 2022. An Investigation of the Effect of the ISO 9001 quality management system on small and medium enterprises in Gauteng, South Africa. *South African Journal of Industrial Engineering*, Vol 33(1), pp. 126-138.

[33] I.A. Daniyan, A.O. Adeodu, K. Mpofu, R. Maladhzi & G. M. Kana-Kana Katumba. 2023. Improvement in the production process variations of bolsters spring of a train bogie manufacturing industry: a six sigma approach . *Cogent Engineering*, 10:1(2154004), pp. 1-23.

[34] E. K. De Miranda Kubo, & M. C. Farina. 2013. The quality movement in Brazil. *Total Quality Management and Business Excellence*, vol. 24(1–2), pp. 19–30.

[35] J. A. Garza-Reyes, L. Rocha-Lona, & V. Kumar. 2015. A conceptual framework for the implementation of quality management systems. *Total Quality Management and Business Excellence*, vol. 26(11–12), pp. 1298–1310.

[36] S. Bajaj, R. Garg & M. Sethi. 2018. Total quality management: a critical literature review using Pareto analysis. *International Journal of Productivity and Performance Management*, Vol. 67 Issue: 1, pp.128-154.

[37] R. de F.S.M. Russo & R. Camanho. 2015. Criteria in AHP: A systematic review of literature. *Procedia Computer Science*, vol. 55, pp. 1123-1132.

[38] S. Kubler,J. Robert, S. Neumaier, J. Umbrich, Y. Le Traon. 2018. Comparison of metadata quality in open data portals using the Analytic Hierarchy Process. *Government Information Quarterly*, vol. 35 (1), pp.13-29.

[39] I. A. Daniyan, K. Mpofu & B. I. Ramatsetse 2020. The use of Analytical Hierarchy Process (AHP) decision model for materials and assembly method selection during railcar development. *Cogent Engineering Journal*, vol. 7, 1833433: pp. 1-23.

[40] E. F. S. Zeferino, K. Mpofu, O. A. Makinde, B. I Ramatsetse & I. A. Daniyan 2021. Prioritizing factors Influencing the selection of a suitable quarantine facility for COVID-19 patients using Pareto-enhanced Analytical Hierarchy Process. *Facility Journal*. Vol. 39 No. 7/8, 2021 pp. 488-507.

[41] S. Bekesiene, A. V. Vasiliauskas, Š. Hošková-mayerová & V. Vasilienė-vasiliauskienė. 2021. 'Comprehensive assessment of distance learning modules by fuzzy AHP-TOPSIS method', *Mathematics*, vol. 9, no. 4, pp. 1–27, doi: 10.3390/math9040409.

[42] S. Bingol, 2022. 'Selection of Semiconductor Packaging Materials by Combined Fuzzy AHP-Entropy and Proximity Index Value Method', *Genet Res (Camb)*, vol. 2022, doi: 10.1155/2022/7901861.

[43] O.E. Akinbowale, P. Mashigo & Zerihun. 2023. Evaluating the impact of organisation's corporate social responsibility from banking industry perspective: A Fuzzy Analytical Hierarchy Process Approach. *International Journal of Management & Sustainability*, 12(2):159-176.

[44] D. M. Milošević, M. R. Milošević & D. J. Simjanović. 2020. 'Implementation of adjusted fuzzy ahp method in the assessment for reuse of industrial buildings', *Mathematics*, vol. 8, no. 10, pp. 1–24, doi: 10.3390/math8101697.

[45] M. A. Syakur, E. M. S. Rochman, A. Rachmad, W. Setiawan & S. S. Putro. 2023. Implementation of the Fuzzy Analytical Network Process Method in Decision Making on the Granting of Non-occupied Building Permits. In: I. H. Agustin (Ed.): ICONNSMAL 2022, AISR 177, pp. 71–80.

[46] S-L. Si, X-Y. You, H-C. Liu & P. Zhan. 2018. DEMATEL Technique: A Systematic Review of the State-of-the-Art Literature on Methodologies and Applications. *Mathematical Problems in Engineering*, 3696457, pp. 1-33.

[47] H. Snyder. 2019. 'Literature review as a research methodology: An overview and guidelines', *J Bus Res*, vol. 104, no. July, pp. 333–339, doi: 10.1016/j.jbusres.2019.07.039.

[48] A. Schwalbe. 2018. 'Systematic review or scoping review - Guidance for authors when choosing between a systematic or scoping review approach', *The Routledge International Handbook of Embodied Perspectives in Psychotherapy: Approaches from Dance Movement and Body Psychotherapies*, pp. 104–116, doi: 10.4324/9781315159416.

[49] H. K. Chan, X. Sun & S. H. Chung. 2019. 'When should fuzzy analytic hierarchy process be used instead of analytic hierarchy process?', *Decis Support Syst*, vol. 125, doi: 10.1016/j.dss.2019.113114.

[50] C. N. Wang, N. A. T. Nguyen, T. T. Dang & C. M. Lu. 2021. 'A compromised decision-making approach to third-party logistics selection in sustainable supply chain using fuzzy ahp and fuzzy vikor methods', *Mathematics*, vol. 9, no. 8, Apr. 2021, doi: 10.3390/math9080886.

[51] M. S. W. Putra, S. Andryana & F. A. Gunaryati. 2018. Fuzzy Analytical Hierarchy Process method to determine the quality of gemstones. *Advances in Fuzzy Systems*, 9094380, pp. 1-6.

[52] I. A. Daniyan, A. O. Adeodu, K. Mpofu, R. Maladhzi & M. G. Kana-kana Katumba. 2022. Application of lean Six Sigma methodology using DMAIC approach for the improvement of bogie assembly process in the railcar industry. *Heliyon*, vol. 8, no. e09043, pp. 1-14.

[53] A. Y. Magodi, I. A. Daniyan & K. Mpofu. 2022. Application of lean six sigma to a small enterprise in the gauteng province: A case study. *South African Journal of Industrial Engineering. vol 33, no. 1, pp. 190-204.*

[54] A. O. Adeodu, R. Maladzhi, M. G. Kana-kana Katumba & I. A. Daniyan, 2023. Development of an improvement framework for warehouse processes using lean six sigma (DMAIC) approach. a case of third-party logistics (3PL) services. Heliyon, vol. 9, no. e14915, pp. 1-19.

[55] S. Nekoueizadeh & S. Esmaeili, S. 2013. A study of the impact of TQM on organizational performance of the Telecommunication Industry in Iran. *European Online Journal of Natural and Social Sciences*, vol. 2, no. 3, pp. 968–978.

[56] D. Ortiz-Rangel, L. Rocha-Lona, L. M. Bada-Carbajal, J. A. Garza-Reyes & S. P. Nadeem, 2021. Implementation of quality management system ISO 9001 in a telecom network operation centre-A case study. Proceedings of the

International Conference on Industrial Engineering and Operations Management, Singapore, March 7-11,2021, pp. 81–92.

[57] J. J. Oschman. 2017. The role of strategic planning in implementing a total quality management framework: An empirical view. *Quality Management Journal*, vol. 24, *no.* 2, pp, 41–53. https://doi.org/10.1080/10686967.2017.11918508

[58] C., Jaca & E. Psomas. 2015. Total quality management practices and performance outcomes in Spanish service companies. *Total Quality Management and Business Excellence*, vol. 26, *no.* 9–10), pp. 958–970. https://doi.org/10.1080/14783363.2015.1068588

[59] V. E. Kane. 2022. Useful paths for identifying Lean Six Sigma improvement opportunities. *International Journal of Quality and Reliability Management*, vol. 39, *no.* 8, pp. 2058–2077. https://doi.org/10.1108/IJQRM-08-2020-0274

[60] P. A. Owusu & H. K. Duah. 2018. Evaluating total quality management as a competitive advantage tool in mobile. *European Journal of Research and Reflection in Management Sciences, vol.* 6, *no.*1, pp. 9–22.