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Application of Analytic Hierarchy Process (AHP) in Adoption of Quality Management System (QMS)

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Abstract

This paper develops a research methodology to rank Quality Management Systems (QMS). The QMS and its related tools and techniques are adequately investigated in current literature. However, determining the priority of adopting different QMS is less practiced along with Multiple-Criteria Decision Making (MCDM) methodologies. Furthermore, this combination is not vastly examined in developing countries. Also, famous MCDM model such as Analytic Hierarchy Process (AHP) can be easily linked with this problem. Hence, to fill this gap, this research has been completed in three phases as follows. The first phase provides a review on previous literature. To do so, a literature survey is conducted to find the common criteria to prioritize different QMSs. Next, the most frequently applied QMSs of previous literature are determined in the second phase of this research. Following, the third phase determines the priority level of different QMSs to be applied by companies. To do so, the third phase applies an AHP to investigate and prioritize the most frequently applied QMSs of the second phase. According to the obtained results, ISO 9001, ISO 14001, and ISO 50001 are the most important QMSs to be applied by companies, respectively. Finally, the last section of this study includes a summary and some directions for future research.

Keywords
MCDM, Quality Management System, and AHP.

1. Introduction
Decision making is an important process of any organization (Hashemzahi et al. 2020). In this regard, it can affect all processes which are directly and indirectly involved in final quality of products (Hemmati et al. 2018:2019). Therefore, adopting a proper Quality Management System (QMS) is important. In addition, there are numerous QMSs with different functions and obligations. To be more specific, different QMSs can be adopted by companies regarding their functions, obligations, results and many other features (Alawag et al. 2020). So, it is necessary to investigate and rank these QMSs, especially in developing countries as it affects the development of their performance. In addition to qualitative approaches to investigate and select QMSs, quantitative approaches such as Multiple-Criteria Decision Making (MCDM) tools are applicable to prioritize different QMSs (Lam et al. 2008).

Quality control, quality management, and QMSs contribute in quality of final products. In this regard, high quality products and services contribute in overall economic growth of companies, especially in developing countries. Furthermore, although applying QMSs is valuable in terms of revenue and output, it is essential to consider many obligations such as technical issues, quality considerations, safety, assessment, and others. However, among different alternatives, an appropriate QMS is beneficial as it decreases numerous expenses linked with poor quality. In other words, an applicable QMS forces companies to follow obligations to improve their quality, energy usage, performance and other issues of manufacturing companies. Furthermore, as it is essential to focus on quality related concerns in any organization, even small improvements are important and decrease extra costs of companies. So, QMSs are very necessary and should be applied by all companies (Priede, 2012). Recent literature shows that it is essential for all companies to apply a proper QMS and follow its obligations. To be more specific, an applicable QMS has been recommended as an appropriate tool to improve the performance of companies. In addition, all aspects of applying a QMS should be investigated in companies. These aspects include costs, operations, processes and required obligations. Next, as there are numerous QMSs, the problem can be considered as a MCDM. Hence, similar to other MCDM problems, it is necessary to apply different criteria, sub-criteria and alternatives to solve the problem (Khorramrouz and Galankashi 2019). Therefore, a proper prioritization of QMSs should concentrate on concurrent consideration of decision making criteria, MCDM techniques and final investigation of results.

The concept of quality, quality control, quality management, QMS and their related tools and techniques have been adequately investigated in previous literature (Samani et al. 2019). However, prioritization of different QMS is less investigated in developing countries. Furthermore, as the problem can be considered as a MCDM, it is recommended to be linked with its tools such as AHP. However, as there are many criteria to be ranked, and there are many QMSs to be considered by companies, the problem should be handled using the comments of different experts. In other words, group decision making process is suggested to enrich the problem. In addition, practitioners, managers and decision makers prefer simple MCDM tools as they are easy to be used (Khorramrouz et al. 2019; Rezaei et al. 2020; Galankashi et al. 2021). To be more specific, integrated MCDM tools might be hard to be understood by managers. So, common MCDM tools are strongly recommended in recent literature as they can simply be applied by decision makers. In addition, the consistency test of these approaches can be easily calculated.

Hence, investigating previous research on quality, quality engineering, quality management and QMSs, developing a proper data collection tool, prioritizing QMSs by MCDM tools, and investigating the results are the major issues of previous studies. There are numerous QMSs to be considered by companies. However, their specific characteristics, limitations and differences are not adequately investigated in previous studies, especially in developing countries. In this regard, many manufacturing companies of developing countries still consider cost as the main factor of QMS. It is therefore necessary to investigate and prioritize which QMS is more important to be applied by companies. Therefore, developing a research methodology to compare and rank different QMSs is important as:

1. The research framework is applicable in real case studies
2. The steps can be repeated to rank performance measurement frameworks

This research is organized as follows. Next section investigates previous literature. Then, different phases required to reach the objectives of research are explained in Section 3. Finally, the results, discussions and research directions are discussed in Sections 4 and 5, respectively.

1.1 Objectives

The scope of this study is limited to QMS of companies in developing countries. In other words, this study is limited to different QMSs which are proper to be used by manufacturing companies of developing countries. To be more specific, a research methodology is suggested to examine and rank numerous QMSs of manufacturing companies. Though, although this research is limited to QMS of manufacturing companies, the methodology, research framework, criteria and outputs are proper to be applied by managers, researchers and practitioners who are interested in ranking any performance or quality related framework. This study investigates and ranks QMSs by MCDM tools. Therefore, by using these approaches, this study provides a research framework to rank different QMSs of manufacturing companies. In summary, numerous steps are necessary to address the objectives of this study. Firstly, this research investigates previous literature on quality, quality engineering, quality management and QMS. Next, it finalizes different QMSs as the alternatives for further investigation. Finally, it applies an AHP to determine the ranking and final prioritization of QMSs.

2. Literature Review

This section presents ideas, descriptions, explanations, and recent literature comprising quality, quality engineering, quality management, and QMSs. In addition, an investigation of recent literature is presented in this section. Next, a conclusion and some direction for future research are presented at the end of section.

2.1 QMS

The scope, costs, obligations and other necessities of each QMS are unique. According to the scope of each QMS, these frameworks focus on different obligations which are necessary to improve the quality. Consequently, different manufacturers, organizations, and any entity involved in quality related issues can apply these frameworks. Hence, with regard to this fact, there are different QMSs to handle different characteristics of companies (Wardhani et al. 2009). So, it is essential to ensure that these companies are properly following different requirements of these QMSs. In other words, using a proper QMS assists companies to properly deliver final products to final customers in desired time, quality, quantity, location and price (Bidoki et al. 2021). Furthermore, as the users of these QMS frameworks operate in different industries, different characteristics and requirements of them should be seen in QMSs. So, a proper QMS should see both manufacturer and standard sides, concurrently. Hence, different issues of companies and QMSs should be investigated. However, among these issues, many companies still are not sure which QMS framework is more suitable to be followed. Therefore, to address this problem, according to previous studies, a proper and applicable QMS and its necessities should be selected by companies. Though, similar to other managerial problem, there might not be a single solution for all companies and the suggested framework can be revised during the time.

2.2 QMS Adoption

Previous literature shows that a major share of previous studies have focused on QMS adoption of developed countries. Hence, two important issues should be investigated. Initially, it is essential to extend the scope of adopting QMS in both developing and developed countries. Next, it is essential to suggest applicable QMSs to companies. Hence, as both issues are less investigated in developing countries, it is necessary to be addressed in this study. According to previous literature, both manufacturing companies and service organizations are involved in numerous quality related issues. In other words, these companies should enhance quality, price and other characteristics of their products to satisfy their customers. In this regard, there are many issues in addition to quality related problems such as time, cost, technology and manpower. Hence, concurrent consideration of all these issues requires time, cost and coordination. In this regard, a proper QMS can be used to handle all these issues concurrently. Hence, all potential QMSs should be developed and prioritized to assist practitioners, researchers and managers to manage different quality related issues.

2.3 Most Frequently Applied QMSs

According to previous literature, there are numerous QMSs available in research and practice. To be more specific, according to previous studies, different QMSs can be considered by manufacturing companies. Nevertheless, considering both cost and time limitations, simultaneous application of all these frameworks is impossible. Furthermore, there are many conflicting objectives in concurrent application of these frameworks. So, a literature review is used to find the most frequently applied QMSs as tabulated in Table 1.

Table 1. International Business Strategies

International Business Strategy	Sample Reference
ISO 9001	Sampaio et al. 2009
ISO 14001	Jiang and Bansal (2003)
ISO 50001	Marimon and Casadesús (2017)

2.4 Identification of research gap

As discussed in literature review section, considering the highlights of preceding literature, an integrated research methodology to investigate and rank different QMSs is not properly proposed, especially in developing countries. In addition, considering the availability of numerous QMSs, it is necessary to use the most applicable framework as simultaneous application of them is conflicting. Finally, as many practitioners, decision makers and managers prefer

quantitative approaches, it is recommended to apply common MCDM tools such as AHP to address the problem. Hence, to fill the gap of previous literature, this research develops a step by step procedure to examine numerous QMSs and prioritize them by AHP.

3. Research Methodology

This section presents the research methodology of this study. According to Figure 1, three linked phases must be completed to address different objectives of the study. The initial phase of this research investigates previous studies to develop the idea. To be more specific, the first phase of this research aims to find potential gaps of previous literature. To do so, different keywords such as quality, quality control, quality management, quality engineering, quality management system, and quality management frameworks were used to find related studies. Therefore, in summary, the initial phase of this research investigated previous literature to identify the research gap. Following, the next phase of this research develops criteria and alternative of this research. Next, final prioritization of QMSs will happen in the third phase. To do so, an AHP is applied as common and well-known decision making approach to rank different QMSs. Initially, it is necessary to define the problem. Similar to other MCDM approaches, the goal, criteria and alternatives are determined. Next, all criteria are compared with each other, and potential alternatives are evaluated according to all criteria. Following, the final ranking of all QMSs are determined. Finally, comparable with other MCDM models (Ziaei et al. 2013; Galankashi et al. 2016), it is essential to check the consistency of the results. All three phases and required steps are depicted in Figure 1. Furthermore, all required steps of AHP are shown in Figure 2 (Muhammad et al. 2021).

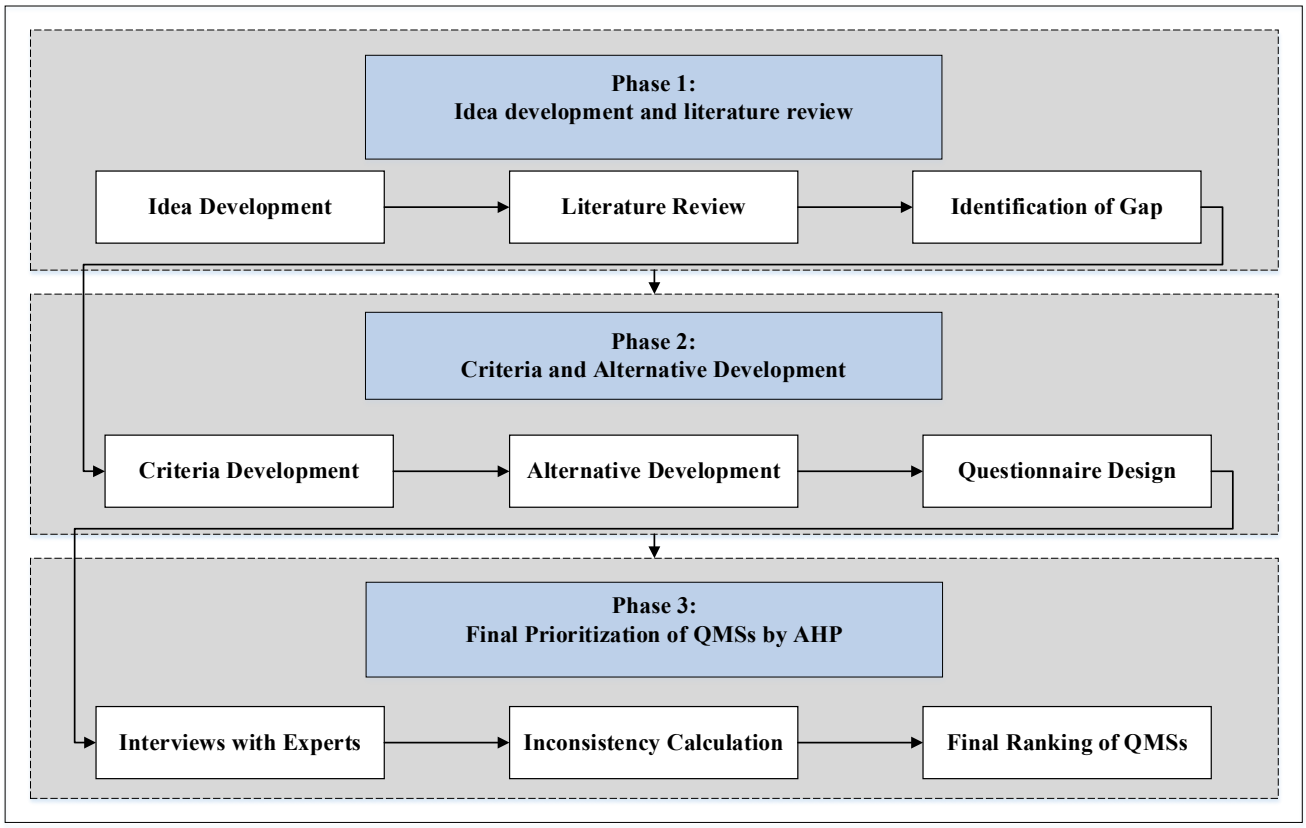

Figure 1. Research Steps

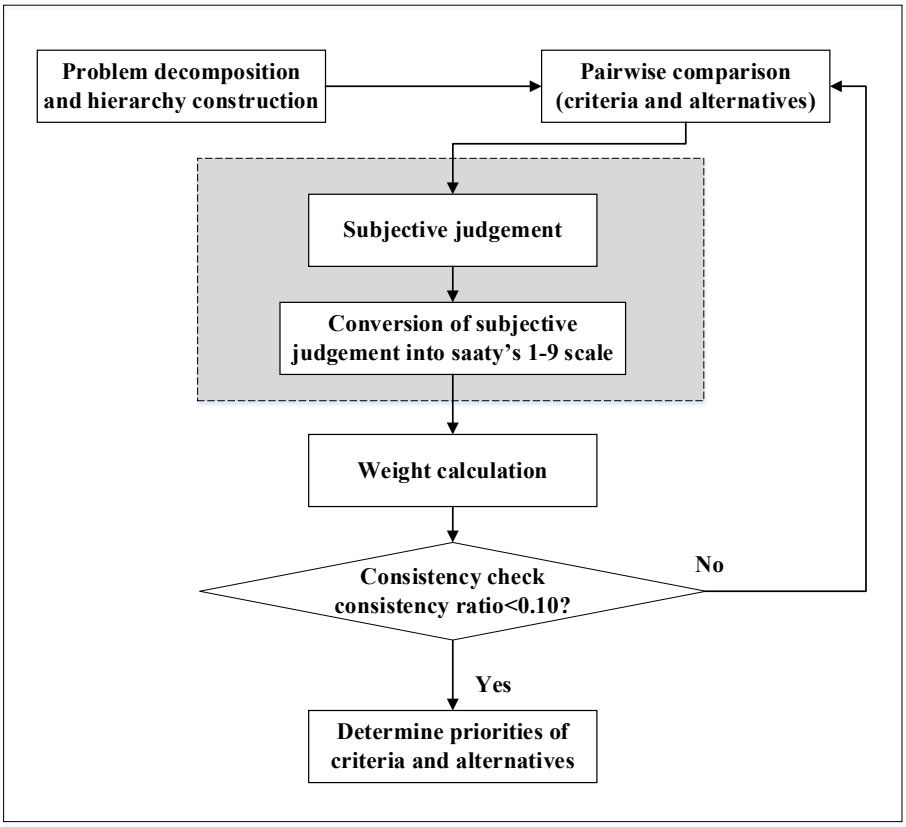

Figure 2. AHP Steps (Muhammad et al. 2020)

4. Results and Discussion

This section presents and discusses different outputs of this research. According to the developed research methodology, three linked phases are completed to address the objectives of research. Therefore, to ease the tracking of results, the results are also presented according to different phases of research methodology. Initially, it was essential to develop the initial idea of research. To do so, a literature review was applied to investigate previous studies. Following, different criteria and alternatives of the research were determined. Figure 3 displays the decision-making hierarchy of this research. Next, a questionnaire was designed according to different steps of AHP. Finally, the comments of experts were gathered and applied to prioritize different QMSs.

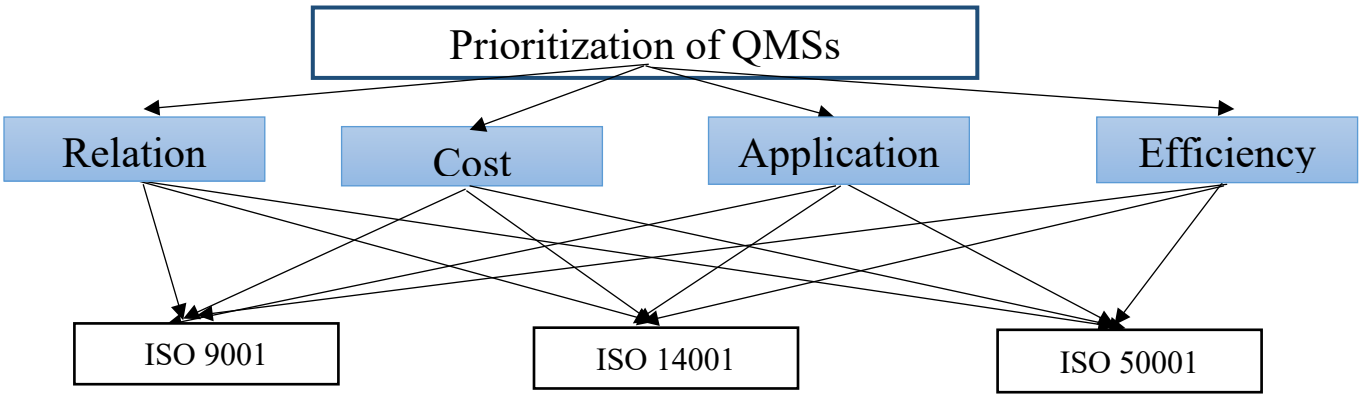

Figure 3. Decision Making Hierarchy

Following discusses different results of this study. As a reminder, the main alternatives of this research were tabulated in Table 1. According to this table, ISO 9001, ISO 14001, and ISO 50001 are the main QMSs to be ranked. Next, according to research methodology, an AHP is applied to prioritize these QMSs as follows. According to AHP, it is necessary to formulate the problem first. Hence, the considered problem prioritizes different QMSs. As depicted in Figure 3, different QMSs are investigated to find their final ranking. Next, it is necessary to determine the applied scale. Saaty 1-9 scale tabulated in Table 2 is applied to compare different alternatives (Saaty 1996).

Table 2. Saaty's 1-9 scale

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one over another
5	Strong importance	Experience and judgment strongly favor one over another
7	Very strong importance	Activity is strongly favored and its dominance is demonstrated in practice
9	Absolute importance	Importance of one over another affirmed or the highest possible order
2,4,6,8	Intermediate values	Used to represent compromise between the priorities listed above

Following, Tables 3 and 4 present the pairwise comparison matrices of criteria and alternatives, respectively.

Table 3. Pairwise comparison matrices of criteria

	Relation	Cost	Application	Efficiency
Relation	1	0.2	0.5	0.143
Cost	5	1	2	0.333
Application	2	0.5	1	0.25
Efficiency	7	3	4	1

Table 4. Pairwise comparison matrices of alternatives

Relation	ISO 9001	ISO 14001	ISO 50001
ISO 9001	1	7	4
ISO 14001	0.143	1	0.5
ISO 50001	0.25	2	1
Cost	ISO 9001	ISO 14001	ISO 50001
ISO 9001	1	8	3
ISO 14001	0.125	1	0.25
ISO 50001	0.333	4	1
Application	ISO 9001	ISO 14001	ISO 50001
ISO 9001	1	3	6
ISO 14001	0.333	1	4
ISO 50001	0.166	0.25	1

Table 4. (continued)

Relation	ISO 9001	ISO 14001	ISO 50001
ISO 9001	1	4	7
ISO 14001	0.25	1	3
ISO 50001	0.143	0.33	1

Furthermore, according to AHP, all pairwise comparison matrices should be consistent. In other words, the inconsistency score of each pairwise comparison matrix should be below 0.1. Table 5 tabulates the inconsistencies of all pairwise comparison tables. As it is clear, the inconsistency ratio of all judgments is below 0.1. Therefore, the calculations are consistent and can be applied to determine the final score of each QMS. Following, the normalized pairwise matrices of alternatives are tabulated in Table 6.

Table 5. Inconsistency Ratios of all pairwise comparison matrices

Matrix Name	**Inconsistency Ratio**	**Status**
Pairwise comparison matrix of criteria	0.03	Consistent
Pairwise comparison matrix of alternatives based on relation	0.002	Consistent
Pairwise comparison matrix of alternatives based on cost	0.02	Consistent
Pairwise comparison matrix of alternatives based on application	0.07	Consistent
Pairwise comparison matrix of alternatives based on efficiency	0.05	Consistent

Table 6. Normalized pairwise matrices of alternatives

Relation	ISO 9001	ISO 14001	ISO 50001
ISO 9001	0.718	0.7	0.727
ISO 14001	0.103	0.1	0.091
ISO 50001	0.179	0.2	0.182
Cost	ISO 9001	ISO 14001	ISO 50001
ISO 9001	0.686	0.616	0.706
ISO 14001	0.86	0.077	0.059
ISO 50001	0.229	0.308	0.235
Application	ISO 9001	ISO 14001	ISO 50001
ISO 9001	0.667	0.706	0.545
ISO 14001	0.222	0.235	0.364
ISO 50001	0.111	0.059	0.091
Efficiency	ISO 9001	ISO 14001	ISO 50001
ISO 9001	0.718	0.750	0.6363
ISO 14001	0.179	0.1875	0.2727
ISO 50001	0.103	0.0625	0.091

Next, the final weights of criteria are tabulated in Table 7. As it is clear, efficiency, cost, application and relation are the most important criterion to prioritize different QMSs, respectively. Following, Table 8 tabulates the score of each alternative according to each criterion. According to Table 8, ISO 9001 has the highest score according to all criteria. Finally, Table 9 tabulates the final score of all QMSs. The obtained results shows that ISO 9001, ISO 14001, and ISO 50001 are the highest ranked QMSs, respectively. In addition to Table 9, the final ranking of QMSs is also depicted in Figure 4.

Table 7. Final Weights of Criteria

Criteria	Relation	Cost	Application	Efficiency
Weight	0.065	0.251	0.129	0.554

Table 8. The score of each alternative according to each criterion

	Relation	**Cost**	**Application**	**Efficiency**
ISO 9001	0.715	0.669	0.639	0.701
ISO 14001	0.098	0.074	0.274	0.213
ISO 50001	0.187	0.275	0.087	0.085

Table 9. The score of each alternative according to each criterion

Alternative	**Score**	**Ranking**
ISO 9001	0.686	1
ISO 14001	0.179	2
ISO 50001	0.135	3

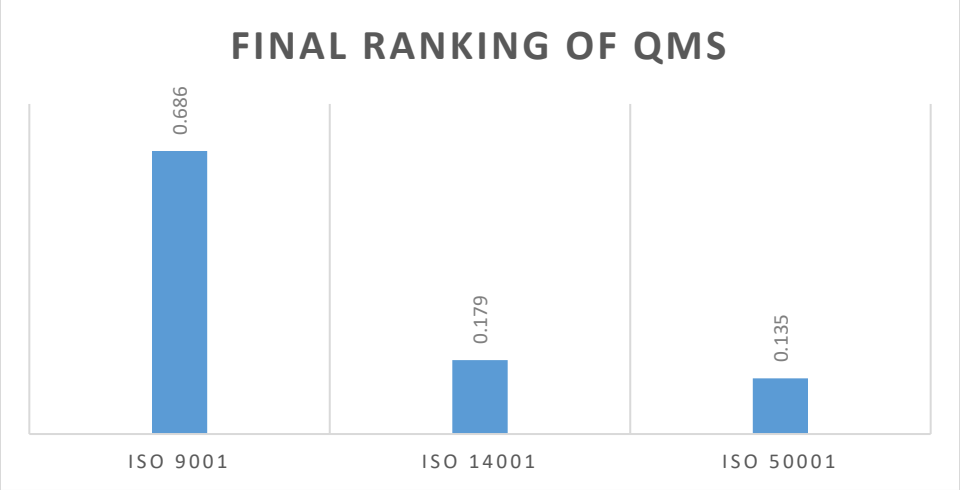

Figure 4. Final weight of QMSs

5. Conclusion

This study proposed a step-by-step procedure to rank different QMSs. The QMSS, their tools and techniques are properly examined in previous literature. However, the patriotization process of different QMS were less examined along with MCDM models. In addition, the problem was not adequately investigated in developing countries. Furthermore, well-known MCDM techniques such as AHP were less investigated to enrich the problem. Hence, this research applied following phases to fill the gap of previous literature. The initial phase reviewed previous literature to develop the initial idea. In this regard, a literature survey was conducted to develop the common criteria of prioritizing QMSs. Following, the most frequently applied QMSs of previous studies were determined in the second phase of this study. Finally, the third phase determined the priority of different QMSs to be used in companies. To be more specific, the third phase applied an AHP to develop and rank the most frequently applied QMSs of the second phase. The obtained results showed that ISO 9001, ISO 14001, and ISO 50001 are the highest ranked QMSs, respectively. As a direction for future research, the developed methodology of this research can be repeated in any study to prioritize different performance measurement frameworks.

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