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EVALUATION OF THE READINESS FOR INTEGRATED "SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS" EDUCATION IN MOROCCO

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ABSTRACT

This paper aims to evaluate the readiness for STEM integration in Moroccan educational programs using the hybrid A'WOT method. The analysis was conducted relying on a group of experts representing the different stakeholders involved. The obtained results show that the existing Strengths and potential Opportunities of the evaluated scenario outweigh the Weaknesses and Threats that may occur. Among the most significant factors identified, we find the availability of infrastructure and resources in schools with the incentive of the alignment with international best practices in STEM education (resp. Strength and opportunity), the required supplementary investment costs and potential resistance to change (resp. weakness and threat). To improve Morocco's readiness for STEM integration we recommend achieving commitment of all relevant stakeholders through effective communication and a collaborative approach, the development of a relevant curriculum based on best practices in integrated STEM and responding to job market needs, providing STEM teachers with the necessary support, professional development, training and resources, building partnerships and gaining industry support for better learning opportunities for students.

Keywords: *Education; STEM Integration; AHP; SWOT; Readiness*

1. INTRODUCTION

The concept of integrated STEM education with STEM being: Science, Technology, Engineering, and Mathematics; has known multiple definitions that vary according to the numerous stakeholders: educational institutions, the government, enterprises, teachers, parents and students [1]. This concept evolved from attempts to connect mathematics and science in k-12 education to a more global approach comprising other disciplines [2]. Integrated STEM refers to "the seamless amalgamation of content and concepts from multiple STEM disciplines." [3]. The integration of STEM occurs through the synthesis and application of skills and knowledge from several STEM disciplines often in a project-based view, to solve a problem or realize a task. This integrative approach fosters problem solving as in real world challenges, creativity and inquiry instead of the classical lecture-based approach [4].

In the Moroccan context, curriculum implementation is managed by the corresponding authorities at the ministerial level (with the detailed content, teaching strategies and sequence). In the last few years, the Moroccan educational market has known the emergence of a variety of stakeholders such as STEM centers created by STEM passionate entrepreneurs that offer STEM programs, such as robotics classes. The growing interest expressed by schools willing to establish partnerships or even directly by parents and the students themselves rises the question of Morocoo's readiness for STEM integration. The importance of this research lies in the understanding of the perceptions of the different stakeholders involved as well as studying the scenario in an anticipatory approach, to help identify improvement areas for a better readiness for change. Therefore, our aim is to evaluate Morocco's readiness for the integration of STEM through the assessment of strengths, weaknesses, threats and opportunities that this integration scenario has to offer. The research questions that will be addressed by our paper are: What are the most significant strengths, weaknesses, threats and opportunities of the integration of STEM? What are the areas that need

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to be reviewed and recommendations to improve Morocco's readiness for STEM integration?

2. LITERATURE REVIEW

Integrated STEM education has numerous purposes such as to enhance scientific literacy from a young age and create a scientific interest and curiosity among the youngest, through an interesting learning experience "more relevant, less fragmented" [5]. It helps the students gain a deep understanding of STEM concepts and the way they are interrelated [6], and offers the opportunity to address simultaneously several STEM ideas through a richer learning environment than one with separated disciplines [7], thus gaining in efficiency [8]. Some studies also highlighted a positive impact on student's performance [9,10]. STEM integration will allow students to achieve readiness towards the fast evolving and competitive job market by reducing the gap between how science "is taught" in retrospect to how it is really "done" [11], this will also help meet the companies growing needs especially in advanced scientific and technical skills, thus contributing to the overall economic growth, development and innovation.

Experiences with integrating STEM in the world, show that one of the main challenges lies in the complexity of connection-making between the content and skills studied and real-world applications for students [2]. It is important to achieve a balance between teacher input relatively to new concepts and its application by students in their learning [12]. In the same regard to connection-making, a study on integrating life science and engineering design Emilie A. Siverling et al (2017) [6] highlighted the importance of considering learning objectives and outcomes while designing the curriculum and thus defining in advance if a discipline would only provide context or be part of the construction of the solution. Another study about the integration of technology in science teaching in Benin [13] focuses on the difficulty met by teachers in designing lesson plans and the importance of providing improved teaching conditions (class size, student's prerequisite, teaching materials). Another challenge for STEM integration is related to the assessment of programs and their success, an experiment held at Southeast high in the United states John, et al. (2016) [14] emphasized three components: Engagement, capacity and continuity to assess a STEM program and its success. A study based on the integration of science and engineering [15] hints to the importance of designing curriculum's units and activities in a way that allows for adequate documentation of the student's work especially concerning knowledge and process understanding that is difficult to assess in contrast to content assessment that can be evaluated with factual questions.

The conducted literature review emphasized the opportunities that comes with a STEM integration approach, some of the challenges that may arise as well as the recommendations of some existing STEM integration studies across the world. The main focus for our paper will be about the integration of STEM in school curricula revolving around students in the K-12 system, especially since primary and secondary education plays a vital role in orienting the student's future choices such as a career within a STEM field or not [3,16].

3. METHODOLOGY

3.1 Swot Analysis

The Strengths, Weaknesses, Opportunities and Threats SWOT analysis, is a well know method used for the analysis of internal and external environments through a systematic approach that offers support for strategic decision making situations [17, 18, 19]. However, this technique is known for having a number of limitations, such as, the general and brief nature of factor's identification [17], questionable exhaustiveness of identified factors which depends mainly on the quality of the participants. Another downside to SWOT is that it does not quantify the importance of factors [18,19]. To surpass this issue, we used a combination of the SWOT and the AHP technique that we will further detail in the following section.

Striving to better analyze the scenario of the integration of STEM in school's curricula in Morocco, we selected a panel of experts composed of school's directors and administration members, teachers of STEM related fields (of both the public and private sector), parents (representatives from parent's associations) and activity centers for children specializing in STEM activities (directors and technical or commercial referees). The SWOT analysis was carried out during a focus group, with at least 2 representatives from each category of the above-mentioned stakeholders, so a total of 10 experts.

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We started the focus group by explaining the aim of the study and the research questions, we then asked the participants the following questions: -What does STEM integration mean to you? Followed by the literature review definition after a group discussion, to be sure that everyone had the same understanding of the concept. -What are the strengths, weaknesses, opportunities and threats that may affect STEM integration in Morocco? Here, we allowed each expert to separately identify the relevant factors according to the SWOT technique categories. After that, we conducted a global brainstorming session to identify factors, with each stakeholder explaining its point of view. After that, we applied the AWOT methodology, described in the following section. -How do you view Morocco's readiness to STEM integration? What areas need to be addressed to improve it?

3.2 The hybrid A'WOT Methodology

The hybrid A'WOT methodology is a combination of the SWOT technique with the AHP technique. It was introduced for the systematic evaluation of SWOT factors, making them commensurable in respect to their intensities [20]. The AHP or the Analytic Hierarchy Process used in this methodology is a multicriteria decision making method developed by Thomas L Saaty (1990) [21]. It relies on the construction of a hierarchical structure of the decision problem referred to as the evaluation index system. This method relies on pairwise comparison matrixes based on expert's opinions, followed by a consistency test to give each of the index system's criteria a corresponding weight. The hierarchical structure of the evaluation index system (EIS) helps to simplify the complexity of the decision problem. We used the structure of the SWOT analysis to build our EIS, before using the AHP to make the identified factors more commensurable. This hybrid method is based on the elaboration of SWOT analysis for the identification of internal and external factors, then using the AHP through pairwise comparisons between the factors, we calculate the priorities of each factor and group of factors. Finally, we evaluate the STEM integration strategy in regard to each SWOT factor and we calculate the strategy's global priorities. The steps for the A'WOT method are presented below:

Step 1: Conducting the SWOT analysis for the identification of the factors that are relevant to the integration of STEM within school programs.

Step 2. Using the AHP technique, pairwise comparisons are conducted between the factors within every SWOT group and between the four SWOT groups.

After structuring the evaluation index system (Table 1) we use L. Saaty's scale (Table 2) to establish the pairwise comparisons.

Table 1: A'WOT general hierarchy for the implementation of integrated STEM

Goal	**Integration of STEM within school programs**
Level 1: group of factors	Strengths
	Weaknesses
	Opportunities
	Threats
Level 2: Factors	Identified using the SWOT method and validated by the experts of the Focus group

Table 2: L Saaty scale for pairwise comparisons

Intensity of importance	**Definitions**
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate values

Then, we proceed to the construction of the judgment matrices through pairwise comparison relying on expert's knowledge and using L. Saaty's scale. These matrices are presented as the following, with aij the relative importance of element i to j and aij>0, aij=1/aji , aii=1.

$$A=(aij)_{nxn}=\begin{bmatrix} a11 & \cdots & a1n \\ \vdots & \ddots & \vdots \\ an1 & \cdots & ann \end{bmatrix}$$

To determine the weights of each criteria, we solve the following equation:

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$$AW=\lambda_{max}W \quad (1)$$

with λ_{max} the principal eigenvalue of A (the largest), and W the associated normalized eigenvector, its components are the weights of the criteria.

To test the consistency of each of the matrices, we calculate the consistency index (CI) and the consistency ratio (CR), with n: the matrix order and RI: the random index (Table 3).

$$CI=\frac{\lambda max-n}{n-1}, \quad (2)$$

$$CR=\frac{CI}{RI}, \quad (3)$$

If the CR is less than 0.10, the matrix is reasonably consistent, otherwise the preferences need to be reviewed.

Table 3: Random Index Table

n	RI
1	0
2	0
3	0,58
4	0,9
5	1,12
6	1,24
7	1,32
8	1,41
9	1,45
10	1,49

Relying on this procedure, we calculated the weights of all levels and criteria of the EIS.

Step 4. Evaluation of STEM integration strategy using AHP's pairwise comparisons across all SWOT factors.

a) The proposed framework for the evaluation of STEM integration readiness in Morocco

The framework provided in Figure 1 summarizes the above described methodology for the evaluation of the readiness of STEM integration in Morocco.

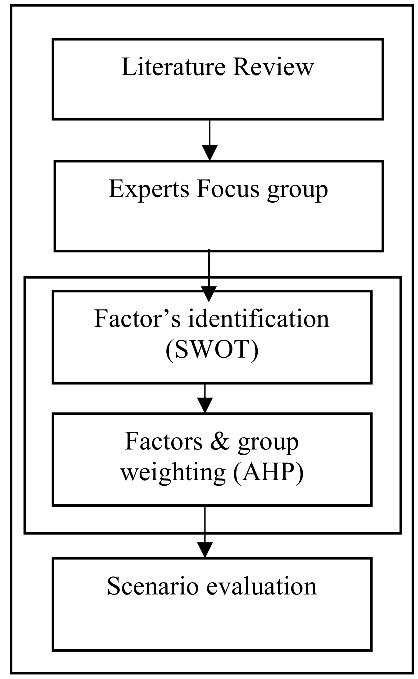

Figure 1: Framework for the evaluation of STEM integration readiness in Morocco

4. RESULTS

4.1 Factors' Identification Using SWOT Analysis

In this section, we will present the results of the SWOT analysis validated by the focus group.

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Table 4: SWOT Analysis Results

	Factors	Stakeholder's perceptions
Strength factors	• S1: Existing infrastructure and resources (pooling of resources) • S2: Existing processes and procedures • S3: Strong ethical values and mission (Trustworthiness, knowledge diffusion…) • S4: Experience in teaching and pedagogical ways	• S1: School's directors and administration members: "a part of the needed equipment is already available: science labs and computer rooms…" • S2: Administration members: "Existing processes and procedures will still be relevant" • S3: School's directors: "we want to provide the best education possible for our students and help them achieve excellence"
Weakness factors	• W1: Supplementary investment costs (Equipment, educational tools and software…) • W2: Challenges related to STEM training and skill development for teachers and educators (technical and pedagogical ways, availability of teaching materials and resources…) • W3: Increased workload	• W1: School's directors: "will the investment be within the allocated budget?" STEM activity centers: "The initial investment in equipment, educational tools and software can be relatively high, especially if the number of students is important…Good organization of classes' schedules often helped reduce our investment costs" • W2: Teachers: "we will need training and professional development program to better grasp how to make the integration successful"…."We will need to collaborate with other teachers from other fields to better prepare for our classes, and simplify explanations for students" • W3: Teachers: "We will definitely need time to adapt and prepare as there will be an increased workload for teachers"
Threat factors	• T1: Dependence to suppliers of equipment and educational tools • T2: Resistance to change • T3: Unclear concept and lack of the public's awareness to the benefits	• T1:STEM activity centers: "From our experience, planning procurement and supply are crucial, it's better to avoid depending on suppliers (delays, price increase, quantity negotiation…)" • T2:School's directors: "There might be some initial resistance to change" • T3:STEM activity centers: "Some parents are not aware of the benefits of integrated STEM, they may view it as a trend effect"
Opportunity factors	• O1: Preparing a fitting workforce for the job market needs through improved STEM knowledge and skills for students • O2: Research and program development (Providing the right context for learning the content, STEM related skills identification, no redundancy…) • O3: Alignment with international best practices in STEM education • O4: Organization and participation in national or international STEM	• O1:Parents: "It is interesting to give our children a rich learning environment that will open their eyes to different STEM fields and help orienting their studies and career and improve their chances of getting a job" • O2:STEM activity centers: "It is important to have a good program, with no redundancy of concepts, that helps the students make a connection across STEM disciplines and apply their knowledge with clear learning outcomes and objectives". Teachers:" We need a program with rich teaching materials" • O3:School's directors: "STEM integration will help align our education of STEMs with international best practices and standards" • O4: School's directors: "STEM integration will encourage the organization of competitions and events, which will further motivate students" • O5: School's directors: "Integrated STEM will also rely

	competitions and events • O5: Possible strategic partnerships with STEM-centers and the industry	on making partnerships with the STEM centers, the industry…which will be highly beneficial for students with new learning opportunities: Sponsorships, field trips, learning projects inspired from a real issue in the workplace".

4.2 Results of the Hybrid A'WOT Methodology

Table 5: Priorities definition for SWOT groups and factors using the hybrid A'WOT methodology

SWOT Group	Group priority	SWOT Factors	Consistency Ratio	Priority of factor within group	Overall priority of factor
Strengths	0,466	**S1: Existing infrastructure and resources**	0,042	**0,536**	**0,250**
		S2: Existing processes and procedures		0,157	0,073
		S3: Strong ethical values and mission		0,077	0,036
		S4: Experience in teaching and pedagogical ways		0,229	0,107
Weaknesses	0,161	**W1: Supplementary Investment costs**	0,033	**0,633**	**0,102**
		W2: STEM training and skill development challenges		0,260	0,042
		W3: Increased workload		0,106	0,017
Opportunities	0,277	O1: Preparing a fitting workforce to the job market needs	0,015	0,262	0,073
		O2: Research and program development		0,161	0,045
		O3: Alignment with international best practices in STEM education		**0,416**	**0,115**
		O4: Organization and Participation in national or international STEM competitions and events		0,062	0,017
		O5: Possible strategic partnerships with STEM-centers and the industry		0,099	0,027
Threats	0,096	T1: Dependence to suppliers	0,064	0,120	0,012
		T2: Resistance to change		**0,608**	**0,058**
		T3: Unclear concept and benefits for the public		0,272	0,026

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We present the scenario evaluation of STEM integration within school's curricula in the radar diagram in figure 2.

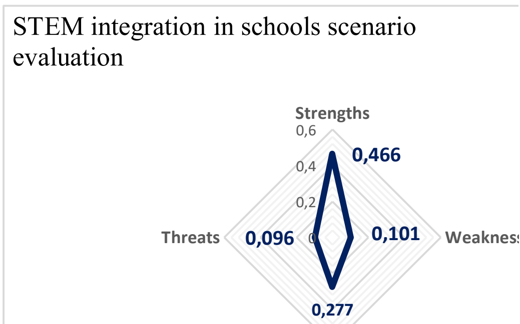

Figure 2: Radar diagram of SWOT's groups priorities for the proposed scenario

The table 5 presents the obtained results from conducting the A'WOT methodology, an important degree of consistency (≤10%) characterizes the Saaty matrixes obtained during the focus group with the experts demonstrating the validity of the obtained results, the matrixes are given in the Appendix. Fifteen relevant factors for STEM's integration in schools were identified and grouped according to the four SWOT categories. The factors in bold represent the greatest weight for each SWOT group. We calculate the expected average priority value for all factors, we find an average of 6,66% (1/15*100=6,666).

5. DISCUSSION

After comparing the priority of each factor to the expected average priority we find that the most relevant factors for the Opportunity SWOT group are; the existing infrastructure and resources (0,250) since all existing schools to be authorized have to follow thorough specifications as quoted by school's director and administration members "part of the needed equipment is already available", followed by the experience in teaching and pedagogical ways (0,107), STEM activity centers confirmed that their educators that were previously teachers in a STEM related field could easily adapt with the right program and training. And finally, we have the existing processes and procedures responsible for the planning and organization necessary for the school management (0,073), school administrators see that this part will mostly remain relevant without much change. All these existing factors in schools lay a strong foundation for the potential integration of STEM within school's curriculums.

For the Weaknesses category, the factor exceeding the average priority is the supplementary investment cost (0,102) that may be necessary to support the transition towards STEM integration. We also find this concern in a study [7] that proposed appropriate planning of funds and the definition of a standard STEM equipment as a response to budget issues, it also states that budget does not limit STEM integration as much as school's hesitation. However, despite "the relatively high initial investment" as related by STEM activity centers, they affirm that there are ways to reduce the cost such as the careful scheduling of classes. The financial investment will also surely contribute to "the improvement of the quality of the learning experience" as required by teachers. Another study [13] also indicates the need for providing suitable teaching conditions for a successful integration. The second ranked factor in this category relates to STEM training and skill development challenges (0,042), this factor displays teachers needs for "training and professional development program to better grasp how to make the integration successful", in the same regard, there is a study by McFadden & Roehrig (2020) [22] that addressed the integration of coaching support for STEM teachers, this study however alerted to potential tensions between teachers and coaches due to misaligned expectations and recommended to encourage for coaches qualification and a cycle of pre-planning, execution and reflection. Another interesting fact is teacher's realization of the "need to collaborate with other teachers from other fields to better prepare for our classes, and simplify explanations for students". This factor was also present in a study [7] and referred to as interdisciplinary collaboration and was deemed necessary for a successful STEM integration as well as quality professional development for teachers by another study by Moore, et al. [23].

Regarding the Opportunities category, and according to the experts notation of preferences, the two main opportunities above the average priority are the alignment with international best practices in STEM education (0,115) which will improve the quality of proposed educational curriculum according to international standards, and preparing a fitting workforce to the job market needs (0,073) as this is a shared concern by the educational system as well as the industry and job market. Student's parents seemed particularly interested by the prospect of "orienting their children towards a

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STEM career" thanks to the broad and rich learning environment provided by integrated STEM, thus improving their future employability. The other factors of the opportunity group were also widely present in the literature, such as research and program development (0,045) that is ranked third in this category. STEM activity centers shared their insights about the subject: "It is important to have a good program, with no redundancy of concepts, that helps the students make a connection across STEM disciplines and apply their knowledge with clear learning outcomes and objectives", the teachers also expressed their needs for a curriculum "with rich teaching materials", in the literature this factor was often associated with concerns regarding the types of integration [24], as well achieving the right balance between STEM disciplines [25]. Another study highlighted the need to develop a program that "touches the lives of the students" in order to improve their motivation and interest [26], this vision is also shared by a recent study that explored the use of social media in evaluating student generated content in STEM education through a contest, the results impacted positively student's motivation and learning [27]. The importance of providing an appropriate program and lesson plan as well as necessary teaching material was also present in Kelani & Gado's study [13]. The fourth factor of this category concerns the importance of the involvement of the industry (0,027), there are studies such as Flynn's study [7] that stressed on its importance, some participants like school directors found that this factor presented many "learning opportunities: Sponsorships, field trips, learning projects inspired from a real issue in the workplace…".

All factors from the Threats category fall below the calculated average. Regarding resistance to change (0,058), school directors were preoccupied by potential "initial resistance to change" due to the increased workload, especially for teachers. However, the present teachers insisted on their interest in undertaking the STEM integration adventure, given that they have the necessary support and resources. A study by Gardner & Tillotson (2019) [28] insisted on giving teachers ample time for reflection as well as instructional opportunities for an effective STEM integration. The present STEM activity centers members also pointed to the lack of engagement displayed by some school staff that they had partnerships with, however this may be explained by their activity being mainly an extracurricular one and not part of the official curriculum. The second factor of this category is the unawareness of the public to the STEM integration concepts and its benefits (0,026), as part of their experience with STEM integration programs, STEM activity centers mentioned that some parents are unaware of the concept of integrated STEM and tend to view their activities as a trend effect, which reflects in a lack of continuity in undertaking their programs. Once more this can be due to the fact that parents only regard their activities as extra-curricular or that the concept is not well-known among parents and a lack of communication.

The radar diagram in figure 2, shows that the Strengths and Opportunities offered by the integration of STEM activities within schools based in Morocco outweigh the Weaknesses and Threats identified. Therefore, it becomes clear that this scenario deserves to be further studied.

This study allowed the opportunity assessment of integrated STEM education in Morocco, it should be completed by the development of a suitable STEM integration model that takes the specificities of Morocco into consideration. Therefore, future research should focus on curricula development, the pedagogical methodologies and the identification of the required didactic materials and tools and relevant training programs for teachers and administration employees in schools. The challenging part would be to ensure the readiness of teachers and their supportive behaviors for this change to succeed.

In response to the last questions: How do you view Morocco's readiness to STEM integration? Globally, participants consider that Morocco is ready to undertake a STEM integration approach, which is coherent with the result of our study where strengths and opportunities are greater than weaknesses and threats. The later question: What areas need to be addressed to improve it? The group formulated the following recommendations: Commitment of all relevant stakeholders through effective communication and a collaborative approach, the development of a relevant curriculum based on best practices in integrated STEM and responding to job market needs, providing STEM teachers with the necessary support, professional development, training and resources, building partnerships and gaining industry support for better learning opportunities for students.

CONCLUSION

The use of the hybrid methodology A'WOT allows for a more in-depth analysis in comparison to a classical SWOT analysis. The expert's quantification of the priority of each factor according to every SWOT group of factors reflects their opinions, expectations and preferences in a quantitative manner, thus providing a strategic decision support. This methodology gave us an interesting insight for the evaluation of the readiness for a potential STEM integration scenario in Morocco. It unfolded from the obtained results that the existing Strengths and potential Opportunities of the evaluated scenario outweigh the Weaknesses and Threats that may occur. Therefore, we recommend to further study potential implementation scenarios. This study could also benefit other countries or different stakeholders in improving their strategic planning process and contributes to the assessment of the country's readiness for the integration of STEM in its curricula.

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APPENDIX

PAIRWISE COMPARISONS MATRIXES

Strengths

	S1	S2	S3	S4
S1	1	4	5	3
S2	1/4	1	3	1/2
S3	1/5	1/3	1	1/3
S4	1/3	2	3	1

λmax: 4,112 ;CI: 0,037 ;

CR: 0,041 ≤ 0,10

Weaknesses

	W1	W2	W3
W1	1	3	5
W2	1/3	1	3
W3	1/5	1/3	1

λmax: 3,038; CI: 0,019;
CR: 0,033 ≤ 0,10

Opportunities

	O1	O2	O3	O4	O5
O1	1	2	1/2	4	3
O2	1/2	1	1/3	3	2
O3	2	3	1	5	4
O4	1/4	1/3	1/5	1	1/2
O5	1/3	½	1/4	2	1

λmax: 5,068 ; CI: 0,017 ;
CR: 0,015 ≤ 0,10

Threats

	T1	T2	T3
T1	1	1/4	1/3
T2	4	1	3
T3	3	1/3	1

λmax: 3,074 ;CI: 0,037 ;

CR: 0,063 ≤ 0,10

SWOT Groups

	S	W	O	T
S	1	3	2	4
W	1/3	1	1/2	2
O	1/2	2	1	3
T	1/4	½	1/3	1

λmax: 4,031 ;
CI: 0,010 ;
CR: 0,011 ≤ 0,10