The Application of Ternary AHP in Adopting Security Certifications into Vocational Cyber Security Course

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Abstract

This study presents progress in revising curriculum of the Cyber Security course by integrating international security certifications from Cisco, ECCouncil and ISACA in a vocational education. The main objective of establishing a new Cyber Security curriculum is to improve the quality of learning materials and updating its contents in order to enhance student competitive advantages at international levels. Considering the issue involves multi criteria perspectives, the study proposes the application of Ternary Analytic Hierarchy Process (Ternary AHP) technique as a novel approach in dealing with the problem. Final result suggests selecting 14 topics from Cisco, ECCouncil and ISACA for the formation of the new curriculum of Cyber Security course.

Keywords: Cyber security, security certification, Cisco, ISACA, ECCouncil, decision making, curriculum revision, Ternary AHP.

1 Introduction

It is imperative for higher education institutions to keep pace with science and technology advancements through curricula development. Nguyen and Pudlowski emphasize the importance of addressing the impact of globalisation on engineering curricula design [1]. This is in line with the case of ASEAN countries, in which ASEAN Free Trade Area (AFTA) has been applied since 2003. As a result, higher education institutions are pushed to make necessary improvements on their current curricula to prepare students with competitive skills and knowledge to embrace AFTA era [1][2].

Curriculum improvements might be performed in several ways, from revising some parts of a course's contents up to changing the whole contents of a course due to dramatic changes in industry that requires immediate responses. All of these revisions have the same objective of achieving better quality of education [3].

As mentioned in [1], suggestions for revising a curriculum might be sought from industrial, societal or professional point of views as presented in figure 1. In this case, we obtain such input from professionals who works in related industries both national and international ones. Vocational education in Indonesia such as State

Polytechnic of Ujung Pandang, Makassar, Indonesia has a strong relationship with industry where experts from industry are welcome to give insights or recommendations as well as best practices on how industry requirement might be met through such curriculum revisions [1][4][5][6].

Among several courses recommended for curriculum revision is Computer and Network Security course. Since the name and content of Computer and Network Security course is considered outdate, then course name was changed to Cyber Security as a reflection to recent challenges to cyber security expertise and increasing globalization of computer engineering education that need to be addressed in the new curricula [7][8][9].

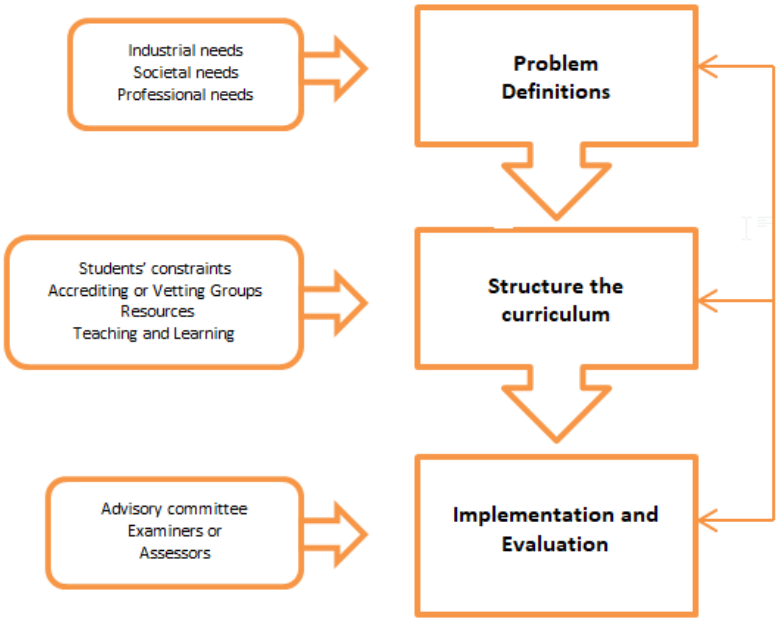

Figure 1: Curriculum design stages

In terms of the course content, it is suggested to integrate course topics from several international certification standards to form new Cyber Security curriculum as currently being required by related industry both national and international levels. There are three certifications suggested to be adopted in the new curriculum of Cyber Security, namely Cisco [10], ISACA [11] and ECCouncil [12].

Curriculum changes that incorporate several references such as Cisco, ISACA and ECCouncil as suggested by industry expert might be considered as multi criteria decision making (MCDM) problem. MCDM methodology suggests the selection of the most important and relevant topics from the three certifications should be carefully done by considering various learning conditions by experts before making final decision.

Several benefits might be obtained through the adoption of international certifications into Cyber Security curriculum in this study such as:

- Updated learning contents from reputable international sources of cyber security,
- Availability of clear and concise guidelines from the certification bodies,
- Higher chances to pass real examinations from Cisco, ISACA and ECCouncil.
- Better competitive advantages at international level with international certification

The paper is structured as follows. Section 1 is the introduction, followed by materials and method description in section 2. Section 3 presents results and discussion. Finally, the conclusion is given in section 4.

2 Materials and Method

Multi criteria decision-making (MCDM) is a methodological tool to deal with complex problems. Among several techniques, Analytic Hierarchy Process (AHP) is a well-known method for solving decision-making problems. It was proposed by Saaty [13] as a flexible technique for both qualitative and quantitative approaches with respect to many criteria to solve MCDM problems. AHP has successfully been applied in various MCDM problems such as selection, prioritization, ranking, resource allocation, benchmarking and many others [14][15].

Basically, AHP resolves complex decisions by structuring the alternatives into a hierarchical framework. The hierarchy is constructed through pairwise comparisons of individual judgments rather than perform prioritization to the entire list of decisions and criteria at the same time [13][15]. Pair wise in AHP uses 1 to 9 scales to guide

decision makers express their preferences (see table 1). However, using this scale has led to some criticisms for example longer time required for pairwise comparison and more possibility of inconsistency made by the decision makers [16][17][18].

Several approaches were introduced to deal with limitations addressed to traditional AHP, such as Ternary Analytic Hierarchy Process or Ternary AHP [19]. The Ternary AHP was firstly introduced by Takehashi [19] as an alternative to traditional AHP method. Ternary AHP novelty is based on reduced decision time and potential mistakes in pairwise comparison by the decision maker since it has three (3) conditions only, namely 1, θ, and 1/θ (significantly lesser than AHP which has 1-9 scale). The basic idea comes from sport game cases where there are only three possible results, win (represented by θ), defeated (represented by 1/θ) and draw (represented by 1). As a result, Ternary AHP offers faster operation and less possibility of inconsistency in comparison to the traditional AHP method [19][20]. In case of selection of complex options, Ternary AHP shows faster and accurate results [21][22].

Despite theoretical literature on curriculum development and design, there is a scarcity of literature available for curriculum revision process that incorporates multi criteria decision making (MCDM) perspectives in making the curriculum revision [23][24]. While both studies of [23] and [24] presented the use of Analytic Hierarchy Process in curriculum changes, there has been no studies yet implement Ternary AHP in this specific area. Hence, this study proposes the applicability of Ternary AHP method [19] to deal with curriculum revision of Cyber Security course.

The hierarchy of curriculum revision is structured into three levels. The first one is the goal of curriculum revision for Cyber Security course, the second layer is criteria which consists of three international certification bodies namely Cisco, ISACA, and ECCouncil, and finally is the alternative layer which consists of several cyber security topics offered by each certification. The following are actual course topics offered by each certification body.

Cisco Security includes the following topics [10]:

- Security Concepts
- Secure Access
- Virtual Private Network
- Secure Routing and Switching
- Cisco Firewall Technologies
- Intrusion Prevention System
- Content and Endpoint Security

ISACA CSX Certification includes the following topics [11]:

- Protocol Parsing
- ARP Analysis
- Initial Connection
- Interesting Searches
- Additional Pets
- GET Request and Response Dissection
- Nefarious Employee
- Playing Around
- Probe Request Analysis
- Beacon Analysis
- Network Topology
- Wireless Network Topology
- Blaster Worm Analysis

EC Council CEH Certification includes the following topics [12]:

- Social Engineering
- Denial-of-Service
- Session Hijacking
- Evading IDS, Firewalls, and Honeypots
- Hacking Web Servers
- Hacking Web Applications
- SQL Injection
- Hacking Wireless Networks
- Hacking Mobile Platforms
- IoT Hacking
- Cloud Computing
- Cryptography

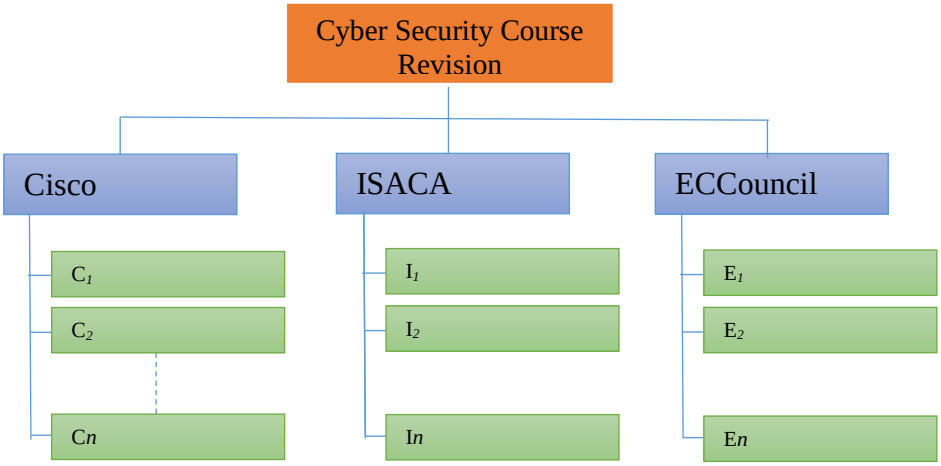

Figure 2: Cyber Security curriculum revision hierarchy

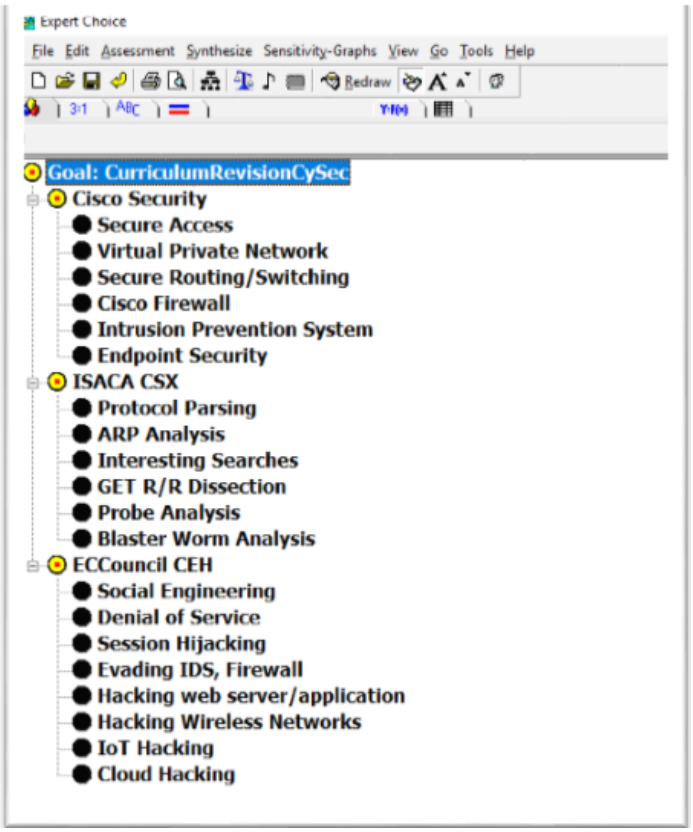

Figure 3: The decision hierarchy in Expert Choice.

In this study, experts from industry and lecturers involved who picked up six topics from Cisco, six topics from ISACA CSX, and eight topics from EC Council CEH considering lab facilities, access to the certification body and current industry requirement.

Based on these, we develop the decision hierarchy according to standard Ternary AHP approach. It consists of three layers of structure, namely goal (first layer), aspect (second layer), and alternative (third layer) as depicted in figure 2. The goal is determined as new Cyber Security course, the aspect consists three international certification bodies (Cisco, ISACA, and ECCouncil), and the alternative represents all topics to be selected to achieve the goal of decision hierarchy.

Based on the hierarchy structure (figure 2), then we construct the actual decision hierarchy in Expert Choice (the official software to conduct AHP analysis) for further analysis using Ternary AHP approach. It can be seen in figure 3, that there are six alternative topics from Cisco, six alternative topics from ISACA and eight alternative topics from ECCouncil.

3 Results and Discussion

First pairwise comparison is performed between all criteria with respect to the goal. As can be seen in figure 4, all criteria are considered similar by decision makers (represented by 1) and the calculated consistency ratio is 0.00. Then, the process is continued to perform pairwise comparison between all alternatives (course topics) with respect to each criteria (certification). The result of pairwise comparison for all course alternatives with respect to Cisco Security criteria is depicted in figure 5 with 0.04 inconsistency ratio.

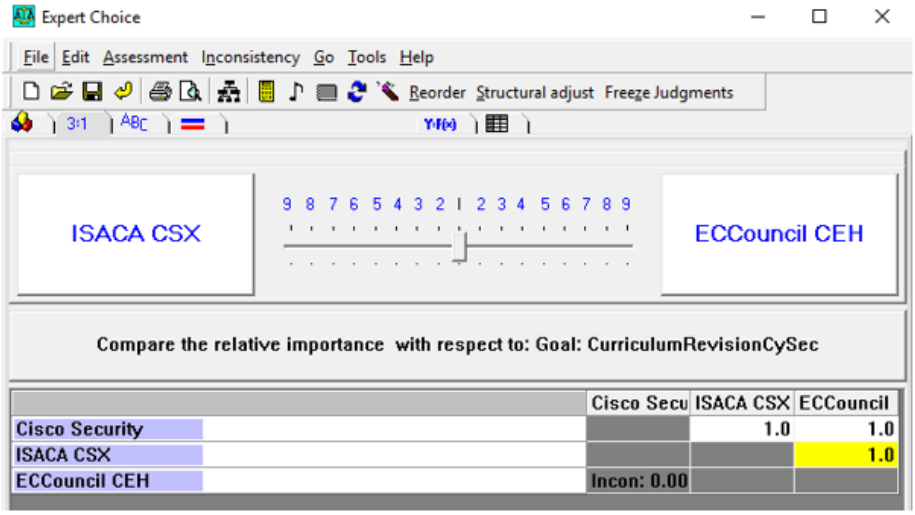

Figure 4: Pairwise comparison of criteria with respect to the goal

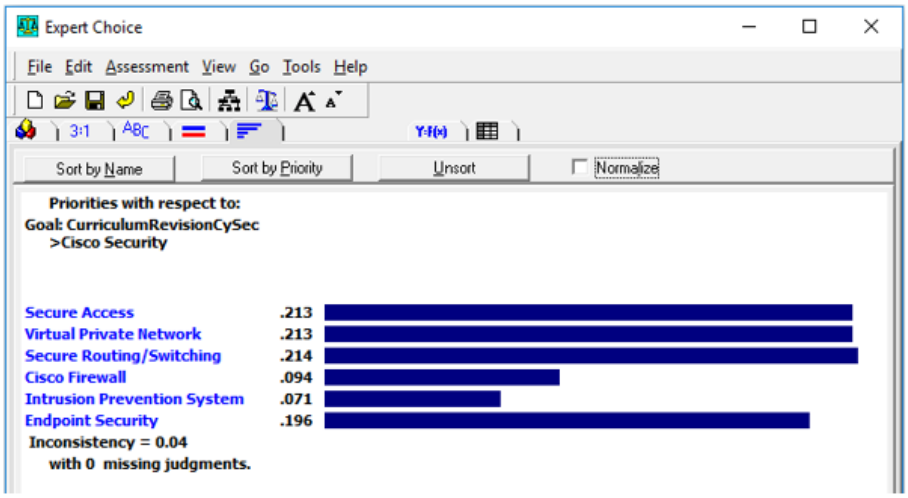

Figure 5: Pairwise comparison for all course alternatives with respect to Cisco Security criteria

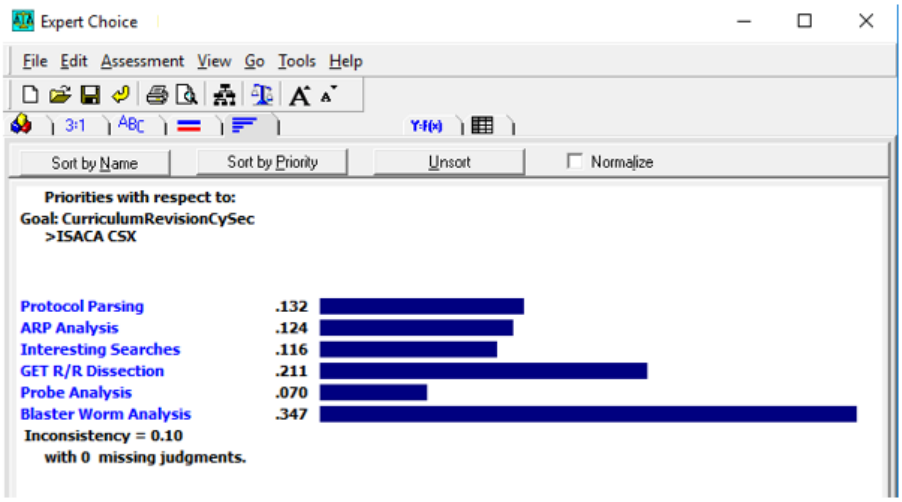

Figure 6: Pairwise comparison for all course alternatives with respect to ISACA CSX criteria

Figure 6 shows the results of pairwise comparison for all course alternatives with respect to ISACA CSX criteria with inconsistency ratio of 1.00, while pairwise comparison of all course alternatives with respect to EC Council CEH criteria with 0.08 inconsistency ratio is illustrated in figure 7.

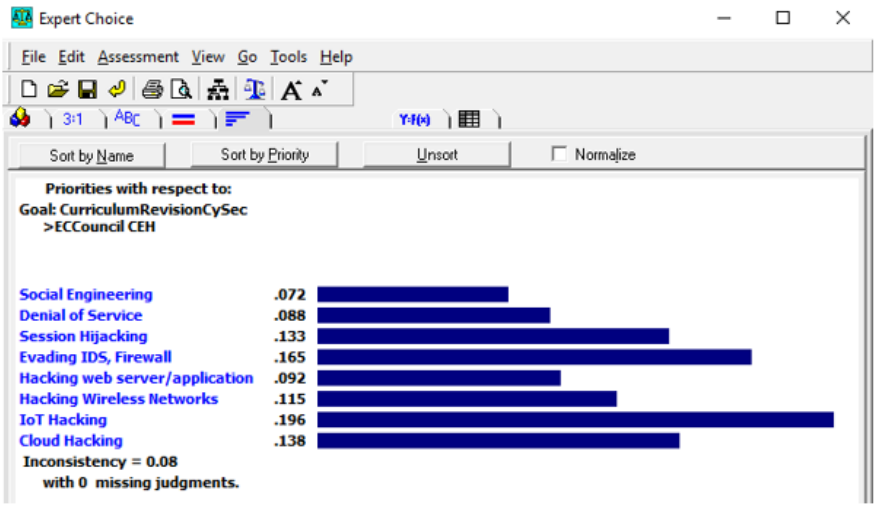

Figure 7: Pairwise comparison for all course alternatives with respect to EC Council CEH criteria

Basically, the Expert Choice software applies the entire traditional AHP calculation process starting from pairwise comparison which compares head to head between each available option (in this case the course topic), to determining the level of validity of decision results by referring to the inconsistency ratio formula formulated by the founder of AHP, namely Prof. Saty [17][18]. The ability to detect the invalidity of the results of this decision is the main advantage of the AHP method which is a reference from Ternary AHP [19][22].

Once all pairwise comparisons finished, the last step is to rank all alternatives' weights from all criteria from the highest to the lowest ones. The objective of ranking is to find out the most important course topic to choose for new Cyber Security curriculum. The list of course topic ranking is presented in table 1.

Table 1: Ternary AHP result

Rank	*Weight*	*Course Topic*	*Source*
1	0.347	Blaster Worm Analysis	ISACA
2	0.214	Secure Routing and Switching	CISCO
3	0.213	Secure Access	CISCO
4	0.213	Virtual Private Network	CISCO
5	0.211	GET Request and Response Dissection	ISACA
6	0.196	IoT Hacking	ECCOUNCIL
7	0.196	Endpoint Security	CISCO
8	0.165	Evading IDS, Firewalls	ECCOUNCIL
9	0.138	Cloud Computing	ECCOUNCIL
10	0.133	Session Hijacking	ECCOUNCIL
11	0.132	Protocol Parsing	ISACA
12	0.124	ARP Analysis	ISACA
13	0.116	Interesting Searches	ISACA
14	0.115	Hacking Wireless Networks	ECCOUNCIL
15	0.094	Cisco Firewall Technologies	CISCO

16	0.092	Hacking Web Server/ Applications	ECCOUNCIL
17	0.088	Denial-of-Service	ECCOUNCIL
18	0.072	Social Engineering	ECCOUNCIL
19	0.071	Intrusion Prevention System	CISCO
20	0.07	Probe Request Analysis	ISACA

Considering the maximum number of lab and class meetings of 14, therefore only the top 14 topics out of 20 are chosen from the final result to be included in the revised curriculum of Cyber Security course. They consist of 5 topics from ISACA CSX certification, 4 topics from Cisco Security certification and 5 topics from EC Council CEH certification as represented in Table 2.

Table 2: Selected courses

Cisco	*ISACA*	*ECCouncil*
Secure Routing and Switching	Blaster Worm Analysis	IoT Hacking
Secure Access	GET Request and Response Dissection	Evading IDS, Firewalls
Virtual Private Network	Protocol Parsing	Cloud Computing
Endpoint Security	ARP Analysis	Session Hijacking
	Interesting Searches	Hacking Wireless Networks

Finally, the new curriculum of Cyber Security course is formed which include the most important topics from three certification bodies through expert decision making process using Ternary AHP approach. This study shows the applicability of Ternary AHP in establishing a brand new Cyber Security course for vocational education needs. The implementation of the new curriculum is strongly expected to enhance students' knowledge and qualification that in turn they will have competitive advantages to compete at international levels [24][25].

4 Conclusion

This study presents a new approach to deal with multi criteria decision problems in revising curriculum of Cyber Security course by applying Ternary Analytic Hierarchy Process. Industry experts advise adopting three worldwide security certificates, notably Cisco Security, ISACA CSX, and EC Council CEH certifications, to update the current curriculum while taking into account lab facilities, lecturer capabilities, and access to the certifying organizations. Ternary AHP is applied to deal with the issue considering its lower processing time and lesser possibility of inconsistency by the decision maker. All pairwise comparisons and extended analysis using Ternary AHP are finished using Expert Choice software.

Finally, 14 topics from Cisco Security, ISACA CSX and EC Council CEH certifications with highest weight are selected for the new curriculum of Cyber Security course. It is envisaged that the revised curriculum will greatly increase students' competitive advantages at the worldwide level.

In the future, after applying the new curriculum based the current study, we aim to conduct academic evaluation on its impact to students' ability to pass actual exam of Cisco Security, ISACA CSX and EC Council CEH certifications.

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