LUT University
School of Engineering Science
Degree Program in Computer Science

Bachelor's Thesis

Vlada Haikara

APPLYING THE ANALYTIC HIERARCHY PROCESS TO SELECT WEB DEVELOPMENT TECHNOLOGIES

Examiner: Assistant Professor Antti Knutas

TIIVISTELMÄ

Lappeenrannan teknillinen yliopisto
School of Engineering Science
Tietotekniikan koulutusohjelma

Vlada Haikara

Analyyttisen hierarkiaprosessin (AHP) soveltaminen webteknologioiden valintaan

Kandidaatintyö

2019

24 sivua, 2 kuvaa, 8 taulukkoa

Työn tarkastajat: Apulaisprofessori Antti Knutas

Hakusanat: AHP, web-teknologiat

Tässä kandidaatintyössä tavoitteena oli luoda prosessi, jossa valittiin web-teknologioita ohjelmistoprojektille analyyttisen hierarkiaprosessin avulla. Tavoitteen savuttamiseksi oli tarpeen selvittää web-teknologioiden ominaisuudet ja valita tarvittamat kriteerit valintaprosessia varten. Prosessi toteutettiin käyttämällä Python-kieliä. Työn lopputuloksena oli valmis prosessi, jonka avulla voi valita sopivimman web-teknologian projektia varten. Analyyttisen hierarkkiaprosessin soveltamisessa havaittiin, että AHP itsessään on hyvä menetelmä, mutta sen heikko kohta on kriteerien valinta. Kriteerien virheellisen arvioinnin vuoksi tulos voi olla vääristynyt.

ABSTRACT

Lappeenranta University of Technology
School of Business and Management
Degree Program in Computer Science

Vlada Haikara

Applying the Analytic Hierarchy Process to Select Web Development Technologies

Bachelor’s Thesis

24 pages, 2 figures, 8 tables

Examiner: Assistant Professor Antti Knutas

Keywords: AHP, Web-technologies

The aim of this bachelor's thesis was to create a process for selecting web technologies for a software project using an analytical hierarchy process. In order to achieve this goal, it was necessary to identify the characteristics of the web technologies and to select the criteria for the selection process. The process was implemented using Python language. The result was a complete process that allows to choose the most appropriate web technology for project. In applying the analytical hierarchy process, it was found that AHP itself is a good method, but its weak point is the choice of criteria. Due to incorrect assessment of the criteria, the result may be distorted.

PREFACE

I would like to thank the assistant professor Antti Knutas for patiently waiting for the completion of this thesis, as well as for all his advice and explanations. I would also like to thank my family and friends for their help, support and faith in me.

TABLE OF CONTENTS

LIST OF SYMBOLS AND ABBREVIATIONS

AHP	Analytic hierarchy process

1 INTRODUCTION

1.1 Objectives and questions

Making decisions is a difficult process for most people. And the more important and more valid is the decision, the harder it is to make a choice. For example, if a person needs to decide what to eat for breakfast, the choice is quite simple and will not particularly affect future fate. But if a person needs to choose a city where to live, serious problems can begin here. Because cities have many selection criteria and the choice will affect the quality of human life. When a team of people must make a decision that influences the fate and performance of the project, everything becomes even more complicated. Because there is always a risk of doing something wrong and ruining a good project. It follows that choosing the right web technologies plays a key role in the success of the project, especially if the project's budget is limited (Nitin Agarwal, 2019). Also, the choice of web technology is what will affect the project throughout the entire time of its existence, so the choice becomes difficult.

There is many ways and methods to solve this problem and simplify choosing of web technologies. One of these methods is called the Analytic Hierarchy Process. In my bachelor thesis, I want to apply this method in practical field. Theme of work is Applying the Analytic Hierarchy Process to Select Web Development Technologies. The topic deals with decision making process based on this method. The task is to create a procedure or process by which it will be possible to make decisions about choosing web technologies based on the Analytic Hierarchy Process.

The Analytic Hierarchy Process (AHP) is a mathematical tool for a systematic approach to complex decision-making problems. The Analytic Hierarchy Process does not prescribe a "right" decision to a decision maker but allows him to interactively find an alternative that best fits his understanding of the nature of the problem and the requirements for its solution. Initially this method was developed by R. Bellman, B.N. Brook and V.N. Burkov, but was widely known for the work of T. Saaty, who called the procedure an Analytic

Hierarchy Process. (Saaty, 1980)

1.2 Goals and Limitations

To begin, it will be needed to study how the Analytic Hierarchy Process works and understand what criteria should be selected for further work on prioritization web technologies. After that, possible options for web technologies will be explored and understood what strengths and weaknesses they have. Further in the thesis it will be necessary to create a process and test it in practice. It will also be necessary to show the results obtained after the application of Analytic Hierarchy Process to solve this problem of choosing web technologies. In the thesis was planned to create a process for choosing the appropriate web technology. The process will be based on the Analytic Hierarchy Process method. When the question arises about which of the web technologies will be better suited for the project, it is difficult to make the right decision without analysis. Analytic Hierarchy Process can help with conducting this analysis. It will be also needed to choose the technologies from which the selection will be made using this method.

As stated earlier, the aim of the thesis is to create a process that will help solve the problems of choosing web technologies using Analytic Hierarchy Process. The thesis will not describe in detail how AHP works. There will be no detailed description about math and matrices which are the basis of this method. There will be a description of the procedure for using the method. Also, in the thesis will be a description of the selected web technologies and their properties, it was difficult to determine exactly what properties have different technologies. In the thesis, is shown how Analytic Hierarchy Process works in practice using the Python programming language or other support tool. Calculations can also be done by hand, but in this thesis, it was decided to use auxiliary tools.

Goals shortly:

- Select web-technologies and criteria for this work
- Understand what strengths and weaknesses web-technologies have
- Create a process of choosing web-technologies and test it in practice

- Conclude does AHP help with solving the problem of choosing right technology or not

1.3 Thesis Structure

This thesis is about the application of an analytic hierarchy process to select web technologies for the software project. In the beginning at theoretical background in section 2.1 is described the basics of AHP and in section 2.2 the properties of selected web technologies. Design phase of the process is described in section 3, the reverse side which is not visible to the user of the application of the AHP process is shown there. In the implementation phase in section 4, the work of a written program that uses AHP to select web technologies for the project is shown. At the end, in section 5 conclusions made during the work is described.

2 THEORETICAL BACKGROUND

2.1 Earlier research on AHP

The most famous Analytic Hierarchy Process researcher is Thomas L. Saaty, he developed this method at the Wharton School of Business of the University of Pennsylvania. Saaty wrote books about this method, developed software products, and has been conducting ISAHP (International Symposium on Analytic Hierarchy Process) symposia for 20 years. Over the years of research there have been many applications for AHP, and various developers have been actively improving the method. This method allows to structure the complex problem of decision making in the form of a hierarchy in a clear and rational way, to compare and quantify alternative solutions, method does not give the right answer, but allows people to determine the one based not only on mathematics, but also on human psychology. Analytic Hierarchy Process is used to make decisions in a variety of situations: in fields such as government, business, industry, healthcare and education. (Isahp.org, 2019) Saaty also developed a procedure for applying Analytic Hierarchy Process. At the start qualitative model of the problem should be built in the form of a hierarchy, including a goal, alternative options for achieving the goal, and criteria for assessing the quality of alternatives. The next step is prioritization of all members of the hierarchy should be done using the method of pairwise comparisons. After that goes synthesis of global priorities of alternatives by linear convolution of the priorities of elements on the hierarchy. Also, performing a consistency judgment should be done. Finally, after all steps decision making based on results can be done. (Saaty, 1999)

Analytic Hierarchy Process can be applied to many areas. For example, there is working paper about applying Analytic Hierarchy Process to support decisions for Information Systems Management. The paper says that decision making related to information systems has become more complex due to the wide variety of choices. And in the working paper decision support tools that use Analytic Hierarchy Process were studied. The writers concluded that the Analytic Hierarchy Process is suitable as a method that supports decision making, but independence and validity of the criteria can cause problems in

practice (Huizingh, E. and Vrolijk, H., 1995). In my work, I tried to foresee possible problems with the process of selecting criteria, if it was possible.

Continuing the theme of applying the method in the field of information technology, AHP can be used to select IT outsourcing. An article written by Godwin Udo describes the use of Analytic Hierarchy Process to select IT outsourcing. The advantages of this method are also described, such as the ability to process complex, multi-criteria, high-quality decision variables involved in the decision-making process. The same example in this article proves that AHP can be an effective method for analysing IT outsourcing. Also, the method can help reduce the level of uncertainty that is typically high for this area. (Godwin G., 2000)

Also, AHP can be used to, for example, prioritize projects in portfolio. A very important conclusion was made in an article about this topic, that methods such as Analytic Hierarchy Process are good as auxiliary opinions for decision making, but it is not worth making an important decision only based on the result of the application of Analytic Hierarchy Process (Vargas R., 2010). This work is closest to concept of my thesis, although it refers to a completely different kind of activity. This work is pleasant and easy to read, there is a lot of visualization in it that also helps the reader to better understand the essence of the work. In addition to being quite understandable to the reader, there is also a lot of auxiliary information in it.

All information about Analytic Hierarchy Process tells that it is well working method to prioritize things. To understand which method works better scientists made evaluation of six different methods (analytic hierarchy process (AHP), hierarchy AHP, spanning tree matrix, bubble sort, binary search tree and priority groups) and applied them to prioritizing software requirements. The study concluded that the analytical hierarchy process is the most promising method, although it can be problematic to scale. It also takes effort but is well worth the effort because of its ability to deliver reliable results, facilitate the transfer of knowledge and consensus among project participants. (Karlsson, Wohlin and Regnell, 1998)

Lai et al. (2002) employed AHP to support the selection of a multi-media authorizing systems (MAS). Three MAS products were compared and ranked. The group of software engineers participated in the study concluded AHP to be conductive to consensus. They also mentioned that it was easy to use and improved the quality of group decision by structuring the decision analysis. (Lai, Wong and Cheung, 2002)

Safari et al. (2015) applied AHP for ranking the determinants for the adoption of software-as-a-service (SaaS). The goal of this study was to investigate factors that affect SaaS adoption when the organization have to make a comprehensive decision about the adoption of new technologies. As ranking the decisive factors in the adoption can help organizations to better decision making, SaaS adopters were targeted to rank the criteria. The results of ranking showed that the three top influential factors for the adopters of SaaS are relative advantage, competitive pressure followed by security and privacy. (Safari, Safari and Hasanzadeh, 2015)

AHP is promising method and there is different software based on this method. A group of developers made software called My Open Source Software Toolkit (MyOSST) part of which is an analytic hierarchy process. Developers of this software also wrote article "Open source software selection using an analytical hierarchy process (AHP)" where they applied analytic hierarchy process and concluded that it is one of the best solutions methods used around the world. (Jusoh, Camili, Pa and Yahaya, 2014)

Also, another group of developers has developed software based on Analytic Hierarchy Process. In article "Web-based learning object selection software using analytical hierarchy process" they told about web-based SDUNESA software and how AHP helps to choose most reliable and appropriate learning object which fits selected criteria. (Yigit,Isik and Ince, 2014)

2.2 Earlier research on Web-technologies

In an article done by Adebukola et al. (2014) dynamic web scripting languages PHP and

ASP were compared. This study conducted a series of automated tests to measure the performance of these applications, such as a performance test, stress test and endurance tests. Authors concluded that both applications give a good result. But the response time of PHP is lower than that of ASP.NET, and PHP has good performance. However, in the stress test and endurance test, PHP also worked better than ASP.NET. Finally, the test result shows that PHP works best from these two scripting languages. (Adebukola and Kazeem, 2014)

Three web methods: PHP, Python-Web and Node.js were compared in research made by Kai Lei, Yining Ma, Zhi Tan. Their article concluded that Node.js works much better than the PHP technique in a situation of high concurrency, benchmark tests or scenario tests. PHP handles small requests well, but it takes effort to deal with large requests. In addition, Node.js prefers for use in an IO intensive situation, rather than in highly computational situations. Python-Web is also not suitable for a compute-intensive site. In general, Python-Web has many mature frames for the development of large websites such as, for example, YouTube. Node.js is a new technology and has many advantages in an IO-intensive situation, but it is a bit difficult for developers who are not familiar with asynchronous programming. As for PHP, this is an old technique, popular for small and medium-sized sites. (Lei at al. 2014)

A group of researchers from Portugal conducted a comparison of various programming languages. Criteria were runtime, memory usage and energy consumption. (Rui Pereira at al. 2017) This work formed the basis of my choice of criteria. Since all the criteria in it were detailed and analyzed so I could use them in my research.

3 DESIGN PHASE

To make procedure for selecting the appropriate web-technology, it is necessary to limit the list of different technologies. In this thesis, four technologies will be considered: Java, JavaScript, PHP and Python. The choice was severely limited by the fact that there was not so much of accurate data comparing web technologies. The analytic hierarchy process needs as accurate data as possible to work well. Most of the information was found exactly about comparing these four technologies. Also, the appropriate criteria should be selected. In this work it will be energy efficiency, memory usage, speed (time) and popularity. The criteria were also limited by the information available and its accuracy. For selecting criteria and conducting pairwise comparison, the work of scientists from Portugal was used. In their research, they compared different programming languages. Also, the TIOBE index data was used to determine the "popularity" criterion (Tiobe.com, 2019).

The process of applying AHP works in this way. The user launches the program and the program asks him questions. The user answers them and they will be saved in the document in the form of a matrix of criteria, this document already has a matrix of alternatives that the expert has filled in advance. After answering all the questions, the criteria matrix will be filled out completely and the file will be ready for processing by the pyAHP library. The library analyzes data and gives the weight of the alternative. The program shows the result to the user in the form of an ordered list, the most suitable alternative at the top, least at the bottom. How this process works can be seen on Figure 1. To make this diagram Aris Express (Version 2.4d) program was used.

In order to apply AHP in practice, pyAHP library for Python was used. To apply AHP to select web-development technologies, a code in Python that changes the matrix of criteria depending on the user's responses was written. All necessary calculations are performed by the pyAHP library (pyAHP, 2018). The written code only gives user questions and corrects the matrix of criteria according to user answers, thereby allowing to create a process in which the user can answer questions in order to get an answer which web technology suits his project the most. This process is showed on Figure 2. To make this diagram Visual

Paradigm Community Edition (Version 15.1) was used.

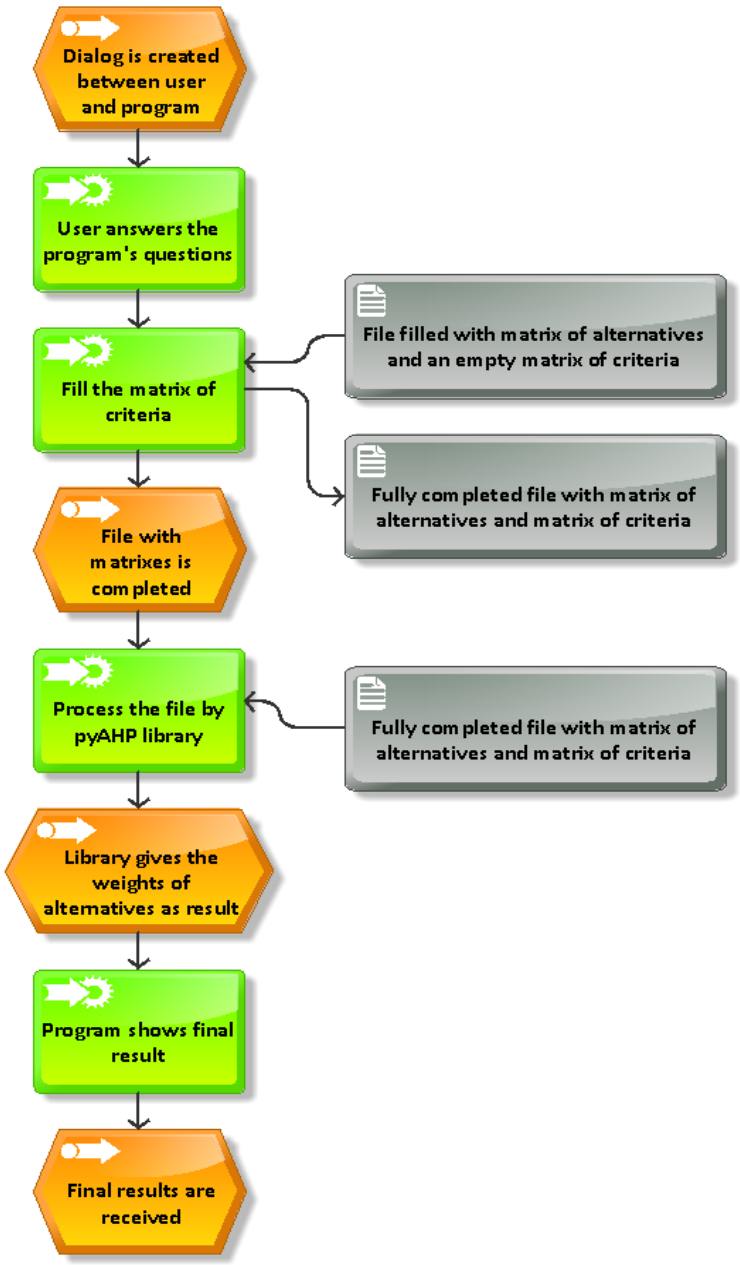

Figure 1

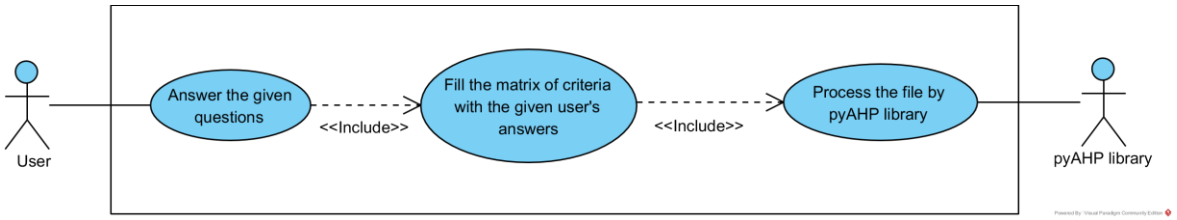

Figure 2

In addition to the criteria comparison table, which is set by the user, there are also tables of alternatives. The library I used uses pairwise comparison of alternatives. After studying the scientific works in order to find out how much different the selected web-technologies are among themselves according to different parameters, tables of alternatives were made. After pairwise comparing the alternatives results were recorded in the tables.

For pairwise comparison scale below were used:

1 - equivalence

3 - small superiority

5 - moderate superiority

7 - strong superiority

9 - the highest superiority

For example, in Table 1, at the intersection of the string Java and the column JavaScript, 3 is written. This expresses the view that the criterion applicable to Java is 3 times higher or it moderate superiority than the same criterion for JavaScript. It is easier to use the scale for pairwise comparison, because there is not always accurate data on how many times one alternative is better than another. But the term "be N times better" can be used, it is also acceptable. Also, further, simple fractions are converted to decimal, because the library needed it.

	Java	JavaScript	PHP	Python
Java	1	3	5	9
JavaScript	1/3	1	5	5
PHP	1/5	1/5	1	3
Python	1/9	1/5	1/3	1

Table 1 Criteria table Energy consumption

	Java	JavaScript	PHP	Python
Java	1	3	5	9
JavaScript	1/3	1	3	5
PHP	1/5	1/3	1	3
Python	1/9	1/5	1/3	1

Table 2 Criteria table Speed (Time)

	Java	JavaScript	PHP	Python
Java	1	1/3	1/5	1/5
JavaScript	3	1	1/5	1/5
PHP	5	5	1	3
Python	5	5	1/3	1

Table 3 Criteria table Memory usage

	Java	JavaScript	PHP	Python
Java	1	5	5	3
JavaScript	1/5	1	3	1/5
PHP	1/5	1/3	1	1/5
Python	1/3	5	5	1

Table 4 Criteria table Popularity

In addition to pairwise comparison of alternatives, the applying of AHP also requires pairwise comparison of criteria. In this thesis, the user makes a pairwise comparison himself. He is asked a question like “What is more important energy efficiency or popularity?”. If the user answered that energy efficiency is more important, the next question will be "How much energy efficiency is more important than popularity?". Using the user's responses, criteria comparison matrix will be built. And it is used further by the pyAHP library to give the final result.

4 IMPLEMENTATION PHASE

The process of choosing a web technology using written code and the AHP library is as follows: the user is asked questions, he answers them, and depending on the answers, the final result will also change. Questions were asked in turn to fill in the criteria matrix completely. For matrix 4x4, 6 questions are enough. First example can be seen in Table 6. To the question "What is more important?" there are answer options 0 or 1. 0 is the first alternative, 1 is the second alternative. To make results more understandable in tables below words were used, instead of numbers. After answering the question "What is more important?", the user must answer "How many times alternative 1 more important than alternative 2?". The answer should be from 1 to 9. As a result of data processing by pyAHP library, a number is calculated for each alternative (Table 6). The larger the number is, the more this web technology suits the project.

Question	Answer
What is more important: Energy consumption or Time?	Time
How many times Time is more important than Energy consumption?	3
What is more important: Energy consumption or Memory usage?	Memory usage
How many times Memory usage is more important than Energy consumption?	5
What is more important: Energy consumption or Popularity?	Popularity
How many times Popularity is more important than Energy consumption?	4
What is more important: Time or Memory usage?	Memory Usage

How many times Memory usage is more important than Time?	6
What is more important: Time or Popularity?	Time
How many times Time is more important than Popularity?	3
What is more important: Memory usage or Popularity?	Memory usage
How many times Memory usage is more important than Popularity?	6

Table 5

	Result	
1	PHP	0.366
2	Java	0.247
3	Python	0.241
4	JavaScript	0.146

Table 6

Watching at the user's answers at Table 5, it is possible to notice that memory is important for his project and energy is not important at all. Also, watching at the matrix of alternatives about memory, it is possible to notice that the most powerful there is PHP. The results of the program report that the most suitable web technology for the user's project is PHP. And after that goes Java, Python and JavaScript.

To make the process even more understandable, another example with other user responses will be considered. In Table 7, another user answered the same questions.

Question	Answer
What is more important: Energy consumption or Time?	Energy consumption
How many times Energy consumption is more important than Time?	6
What is more important: Energy consumption or Memory usage?	Energy consumption
How many times Energy consumption is more important than Memory usage?	3
What is more important: Energy consumption or Popularity?	Energy consumption
How many times Energy consumption is more important than Popularity?	7
What is more important: Time or Memory usage?	Memory Usage
How many times Memory usage is more important than Time?	7
What is more important: Time or Popularity?	Popularity
How many times Popularity is more important than Time?	4
What is more important: Memory usage or Popularity?	Memory usage
How many times Memory usage is more important than Popularity?	6

Table 7

	Result	
1	Java	0.405
2	PHP	0.231
3	JavaScript	0.213
4	Python	0.152

Table 8

As seen on Table 8 this time the user was advised Java technology as the best option. The second most suitable technology was PHP. While JavaScript and Python are less suitable. Looking at the answers of this user, it is possible to notice that energy efficiency and memory are important to him. According to the matrix of alternatives Java is the most energy efficient technology.

5 SUMMARY AND CONCLUSIONS

In this paper, the analytic hierarchy process was used to select web technologies for project. During the application, it was discovered that the analytic hierarchy process itself works fine. But it is very important that the criteria be evaluated by an expert in this field or information about the criteria was verified and reliable. Otherwise, the result may be distorted, depending on the assessment of the criterion. This can be called a weak point of the Analytic Hierarchy Process. Because the result depends on expert answers and on how the matrices of alternatives are filled.

About future work and how it would be possible to further improve the results of this one, I would like to say that this work could be better if I would have done all the background research by myself, for example, chose and tested web technologies by myself, and not relied on scientific work done by other authors. Then the results would be even more accurate, and we can safely say that the process that we have done works well. But in this work, this was not a goal, it was necessary to apply AHP and understand whether it works and how well the method works with the data that were provided to it.

REFERENCE LIST

1. Udo, G. (2000). Using analytic hierarchy process to analyze the information technology outsourcing decision. Industrial Management & Data Systems, 100(9), pp.421-429.
2. Huizingh, Eelko & Vrolijk, Hans. (1995). Decision support for information systems management: applying analytic hierarchy process. University of Groningen, Research Institute SOM (Systems, Organisations and Management), Research Report.
3. Lei, K., Ma, Y. and Tan, Z. (2014). Performance Comparison and Evaluation of Web Development Technologies in PHP, Python, and Node.js. 2014 IEEE 17th International Conference on Computational Science and Engineering.
4. Lai, V., Wong, B. and Cheung, W. (2002). Group decision making in a multiple criteria environment: A case using the AHP in software selection. European Journal of Operational Research, 137(1), pp.134-144.
5. Agarwal, N. (2019). Choosing a right Technology stack for your Web Application - Wildnet Technologies. [online] Wildnet Technologies. Available at: https://www.wildnettechnologies.com/choosing-a-right-technology-stack-for-your-web-application/ [Accessed 9 Oct. 2019].
6. Ogunrinde, Mutiat & Olorisade, Babatunde. (2014). Performance Comparison of dynamic Web scripting Language: A case Study of PHP and ASP.NET. 5. 78 - 89. International Journal of Scientific & Engineering Research, Volume 5, Issue 7, July-2014 ISSN 2229-5518
7. Pereira, R., Couto, M., Ribeiro, F., Rua, R., Cunha, J., Fernandes, J. and Saraiva, J. (2017). Energy efficiency across programming languages: how do energy, time, and memory relate?. Proceedings of the 10th ACM SIGPLAN International Conference on Software Language Engineering - SLE 2017.
8. Saaty, Thomas.L. (1980). The analytic hierarchy process: planning, priority setting, resource allocation. New York; London: Mcgraw-Hill International Book Co., ISBN 0070543712

9. Saaty, Thomas L. (1999) Decision Making for Leaders: The Analytic Hierarchy Process for Decisions in a Complex World. — Pittsburgh, Pennsylvania: RWS Publications
10. Safari, F., Safari, N. and Hasanzadeh, A. (2015). The adoption of software-as-a-service (SaaS): ranking the determinants. Journal of Enterprise Information Management, 28(3), pp.400-422.
11. Tiobe.com. (2019). TIOBE Index | TIOBE - The Software Quality Company. [online] Available at: https://www.tiobe.com/tiobe-index/ [Accessed 9 Aug. 2019]
12. Vargas Ricardo Viana (2010). Using the Analytic Hierarchy Process (AHP) to select and prioritize projects in a portfolio. PMI Global Congress 2010
13. pyAHP library for Python [Computer software]. (2018). Retrieved from https://github.com/pyAHP/pyAHP
14. ARIS Express [Computer software]. (2019). Retrieved from https://www.ariscommunity.com/aris-express
15. Visual Paradigm [Computer software] (2019). Retrieved from https://www.visual-paradigm.com/
16. Isahp.org. (2019). ISAHP2018 | About the Analytic Hierarchy Process (AHP). [online] Available at: https://www.isahp.org/about/ [Accessed 20 Oct. 2019]