International School of Economics

Aubakirova Z. B.

Letava V. A.

Nuktabiyeva A. A.

Exploring the Role of Analytical Hierarchical Process to support the selection of Warehouse Management System

Thesis submitted for

the degree of Bachelor in

6B04106 Management

Supervisor: Baikanov V. A.

Astana, 2024

Abstract

The selection of a Warehouse Management System (WMS) is essential for optimising logistics and inventory processes, especially in light of the rapid development within the supply chain sphere. This project investigates how the Analytical Hierarchy Process (AHP) can support this selection. The AHP is a decision-making tool that helps to identify the most appropriate alternative by independently analysing provided criteria and sub-criteria. Given the significant role of WMS in Industry 4.0, where data must be processed immediately, the challenge of making informed decisions is highly relevant.

The research begins with a comprehensive investigation of prior studies and methodologies on the Warehouse Management System and Analytical Hierarchy Process, highlighting the limitations of the complex structure. One of the main advantages of AHP is the ability to break down a decision-making process into more manageable sub-parts. The method provides an ability to make an objective choice of WMS based on three main criteria: technical, administrative and cost value, each was divided into 3 sub-criteria. Each has been weighted according to its relative importance and overall the WMS has been evaluated based on weighted data. The results prove that AHP provides transparent and justified results and a well-observed decision-making process by using both quantitative and qualitative data.

The study also highlights the possible challenges, such as the sensitivity of data provided and the complexity of weighting the criteria, that lead to possible cooperation of AHP with other Milti-Criteria Decision Analysis and advanced technologies like Artificial Intelligence to improve the decision-making process and gain more credible results.

Eventually, this study contributes to the field of supply chain management by providing a detailed framework of how AHP can be used in choosing WMS, advising a detailed explanation to any company and providing a foundation for future research, which can improve and extend the application of AHP in logistics and beyond it.

Table of contents

1. Introduction

The Supply Chain Management Industry has been rapidly changing in the last decades which can be explained by the modern world Industry 4.0 growth in all the industrial and manufacturing processes. This trend mostly leads to the increase in the minimisation of companies' response time, from the second where the customer places a particular order to the moment he or she could collect the goods. For the successful running of such a complex process, several techniques have been developed for this specific need, one of them is the Warehouse Management System. Since business owners are involved in global trade in the current competitive environment, one of their goals is the up-to-date delivery and tracking of any piece of goods from the warehouse to the destination of the end consumer. The number of orders directly affects the processing time of the supply chain warehousing system for transfer to a further stage of transportation. The key objective of this study is to select the optimal warehouse management system for companies that need to register their products for quick access to information and its subsequent use.

1.1 Background Information

The issue with the existing research on a similar topic is that they mostly tend to use either qualitative methodology where researchers aim to see the problem as a phenomenon that has to be explained or as in the majority of quantitative models only the factors seen as the main influence to the outcome.

1.2 Problem Statement

The key problem in modern society is the decision-making process and theory in terms of scarcity of different resources, such as finance, time, and equipment. In large companies, the choice of WMS systems should take into account such key factors as accessibility in use, availability of necessary modules (functions) for employees from different departments, simplicity of functionality, appropriate product reputation, and much more. Nevertheless, each company is looking for a solution on the market that is

suitable for their specific needs, accordingly, the question arises about the prioritization of criteria in choosing a WMS.

1.3 Purpose of the study and research question

Our project aims to provide an analysis of the selection process of the warehouse management system in companies using an analytical hierarchy process. This work will understand how the criteria that have to be selected for a supply chain system functionality of the analytical hierarchy process can improve the effectiveness of the selection warehouse management system, avoiding potential bankruptcy by the rising costs of a WMS integration to the companies as it was with FoxMeyer in 1993 (Efthymiou, 2014).

The rational significance lies in the increasing monopolisation of enterprise resource planning, most companies because of the lack of access to information about other methods that can be used to optimise warehouse management systems in companies.

The scientific significance lies in the developing base of knowledge about the methodology types, and how they can be adapted to different fields in the company. Moreover, improving the warehouse management system will significantly affect the company's profit and competitiveness among other organisations, therefore people in the industry will also be interested.

The research is focused on answering the following questions:

- How does implementing the analytical hierarchy process influence companies' warehouse management system selection process?
- To what extent can data provided by the analytical hierarchy process be considered credible?
- What are the risks of implementing the analytical hierarchy process as a selection method?
- Does the Analytical Hierarchy Process help to identify the most important and least important functionality of the Warehouse Management system?

Hypothesis: Using a transparent analytical hierarchy process as a selection method for implementing warehouse management systems will help to identify the most objective criteria considering different

departments and come to a common agreement and will positively optimise the operating system in the supply chain department.

2. Literature Review

2.1 Warehouse Management System

The Warehouse Management System is a vital part of Supply Chain Management, as the main goal is to optimise processes, but such organisations have certain limits that narrow down the choices.

The Warehouse Management System includes a wide range of responsibilities, according to Noor Dhia Kadhm Al-Shakarchy “The purpose is the materials arrangement, management and control, the logical and financial levels of inventory are presented, the service level provided to customers, finally the control parameters and all the decision-related processes” (2015). Therefore, companies strive to choose the most suitable system type for their specific field and consider all the factors, including cost, efficiency, functionality etc.

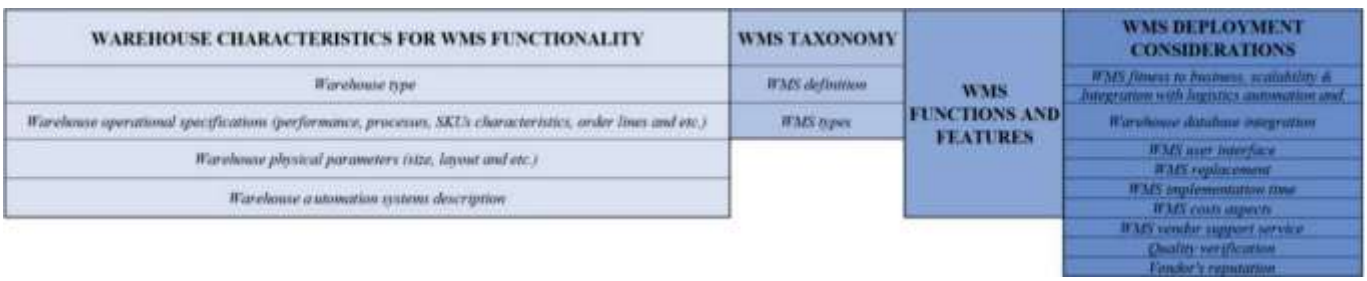
In the previous research on a similar topic, the following criteria were selected as key factors for any WMS software that will be used by a company (Table 1.):

- “WMS categories;
- WMS technical criteria;
- WMS-sensitive deployment issues” (Minashkina & Happonen, 2020).

According to Min's research (2006), the criteria were established with the potential to be utilized in pre-screening potential suppliers and determining the most appropriate software and its provider, assisting each company in selecting the software and vendor that best suits their needs (Figure 1).

Table 1.

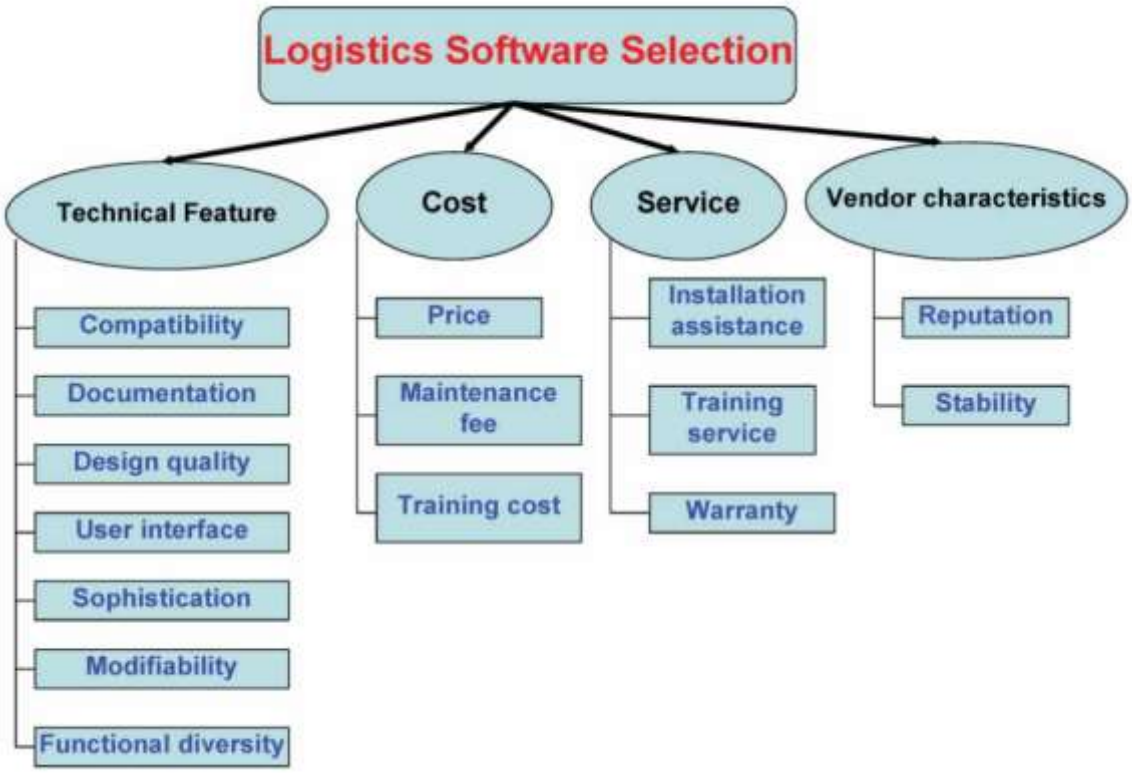
WMS-related topics and their topic aspects revealed from the SLR



Note. From "A development of the warehouse management system selection framework as academic-industrial collaboration work with sustainability considerations" by D Minashkina, & A. Happonen, 2020, 2233, No. 1, AIP Publishing.

Figure 1.

The generic criteria for selecting the logistics software



Note. "The applications of warehouse management systems: an exploratory study." by H. Min, 2006, *International Journal of Logistics: Research and Applications*, *9*(2), 111–126. https://doi.org/10.1080/13675560600661870

To alleviate this decision-making process, a lot of companies seek assistance in analytical techniques, such as the Analytical Hierarchy Process. This literature review will explore the role of AHP in enhancing WMS in companies considering the benefits, challenges, possible ways of further investigations and practical cases.

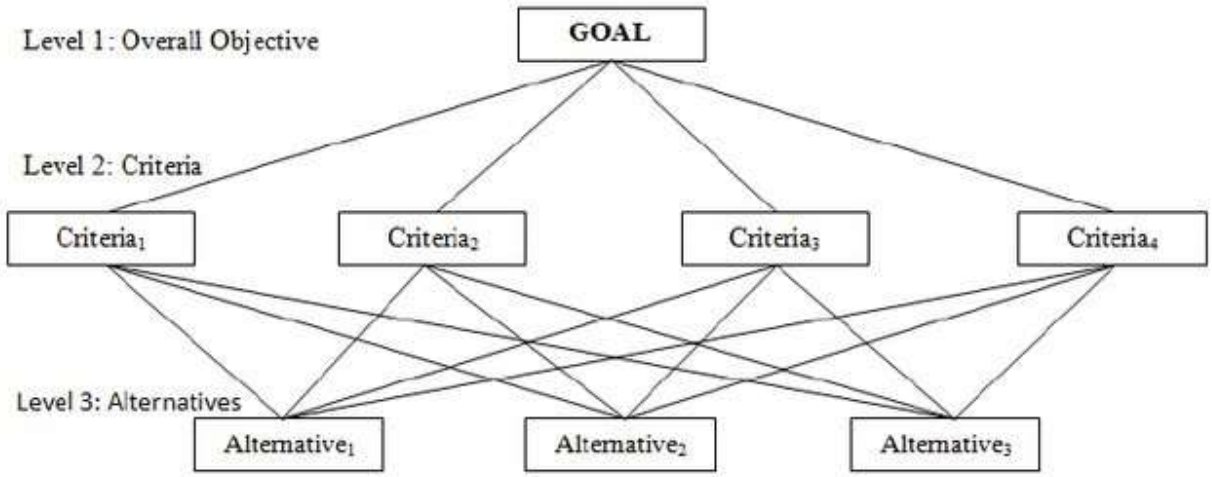
2.2 The Analytical Hierarchy Process

Thomas L. Saaty, a former professor at Pittsburgh University in 1980, developed the Analytical Hierarchy Process. According to his book "What is the Analytical Hierarchy Process?"(1988), the AHP is "a three-part process which includes identifying and organising decision objectives, criteria, constraints and alternatives into a hierarchy" (p. 110).

The AHP provides a possibility to make a pairwise comparison among alternatives and break down complex processes of choice, as shown in Figure 2.

Figure 2.

Example of a three-level hierarchy model of AHP (Agarwal et al., 2014).



2.3

Note. From “Supplier Selection in Dynamic Environment using Analytic Hierarchy Process.” by P. Agarwal, M. Sahai, V. Mishra, M. Bag, & V. Singh, 2014 *International Journal of Information Engineering & Electronic Business*, *6*(4).

The AHP in Logistics

The effectiveness of AHP in the Logistics field was demonstrated in different cases. For instance, Zapata, Arango and Adarme (2015) in their study used a more complex type of AHP, called fuzzy extended AHP to choose a logistic software. They divided the main criteria into two aspects: administrative and product. First considering vendor costs and set-up time, second focused on design, performance and adaptability. The FEAHP is a more complex process, a mix of fuzzy logic and AHP, usually used in unstable environments with non-exact values. In our case, classical AHP is more suitable as it will be considered crisp numbers and objective judgment. That study proves that the AHP process can be used in the WMS selection process and provide the most appropriate choice considering given conditions, as FEAHP “was able to include a large number of criteria, factors, attributes and evaluators because it was based on the AHP method.” (Zapata et al., 2015)

2.4 Advantages of AHP in the WMS Selection Process

One of the key advantages of AHP in the case of the WMS selection process is in “ using a weighting process within the current alternatives via pairwise comparisons.” (Erkan et al., 2014). It helps decision-makers make the right choice based on an overarching evaluation of different factors. Moreover, according to the work of Sanjay Kumar, Neeraj Parashar and Abid Haleem (2009), “AHP makes the selection process very transparent”, which means that all parties included in the transaction, such as vendors, suppliers, and clients will be more interested in selecting that particular company.

Another advantage of AHP in the case of the WMS selection process is that it has “the capacity to analyse both quantitative and qualitative evaluation criteria together…describes each alternative by

using multiple attributes" (Oguztimur, 2015). In this research, work will be done through mixed methods, by creating a complex evaluation considering all the aspects and making the most objective decision.

2.5 Challenges of Current Studies

However, as it's a complex process, it also comes with its challenges. Firstly, the reliability of information, "very often qualitative data cannot be known in terms of absolute values". (Triantaphyllou et al., 1995). It makes it harder to provide an exact weight to particular criteria, such as supplier reputation. Also, obtaining detailed information about alternatives for pairwise comparison will be hard. Any limits in information will affect on final results.

Another struggle is sensitivity to inputs. The AHP reacts to any change, as its hierarchy model, change in one aspect will influence the whole process and can lead to the absolute opposite result. In that case, decision-makers have to be extremely careful and evaluate the influence of each input or change.

2.6 Future investigations

Future development of investigation might be done in several ways:

1. Integration of AHP with other Multi-Criteria Decision Analysis (MCDA), such as Analytical Network Process or TOPSIS. (Das et al., 2019)
2. Integration with technologies. Nowadays rapid development in the IT sphere influences every field. For example, AHP can integrate with Artificial intelligence to speed up calculations and evaluation processes.
3. In the future trends, processes might change. It will be possible for others to provide similar research on implementing AHP in the WMS selection process and make a comparison among the times.

2.7 Conclusion

By concluding all the information above, the Analytical Hierarchy Process provides decision-makers with structured, transparent and objective results for Warehouse Management System choice. With the help of a hierarchical model, the main goal identified and structured criteria or sub-criteria will gain their weight according to the collective decision.

Real-life examples in the text demonstrate the wide range of uses and successful outcomes with the most relevant results for companies in the case of the Warehouse Management System selection process, even with challenges and limitations.

3. Research Methodology

After defining the aims and objectives of the research, the further development of the project is based on the following hypothesis ground on the important role of AHP in the selection of a WMS, there is a need for diverse development of the WMS process and experience. According to that, the most appropriate research method is a mixed-method study, which considers both quantitative and qualitative approaches. Moreover, the research design is pre-experimental, as there is no control group and it focuses on obtaining general information from participants to analyze the problem with different aspects. Regarding the data analysis method, the most applicable for that particular research work is inferential statistics, as the data collected will be provided by a sample (representative) and applied to the whole field, i.e answers and numeric data given by respondents will be counted as an opinion of the whole group.

On one side, the quantitative method is presented due to the collection of numerical data as a survey to test the hypothesis, respondents were given charts with criteria and sub-criteria to determine the priority of one criterion over the others in the opinion of each participant, priority on one criterion over other was identified by numbers from 1 to 9. After, data have been collected and used in mathematical calculations. On the other side, the qualitative method is presented, as except for the numeric data, there was a need to collect information about the personal experience of the group with WMS in the departments of Material and Technical Supply, Finance and Accounting, and Software Development. Moreover, it provided

information about areas for development and opinions from experts in different fields, the data was collected from the interviews conducted on online platforms, such as ZOOM and Google Meet. Each interview lasted for about 40-60 minutes, including both closed and open questions. The transcription of interviews is shown in Appendix 2.

Questions for interview:

1. What is your position?
2. Approximate turnover of goods in the company per year?
3. Do you currently have a WMS (like SAP) or third-party resource accounting services, if yes, which ones?
4. Have you experienced any difficulties in using these services, if yes, what are they?
5. What would you like to improve the most? And how important are these improvements to you?
6. As a percentage of the total budget, how much are you willing to allocate to purchase a WMS?
7. As a specialist, how much time will you need to adapt to the new service?
8. Do you receive training when new programmes are introduced? If yes, how much do you study the material, and if not, how much time do you personally take?
9. What are your main criteria when choosing a WMS?

To take into consideration all possible ethical limitations/problems, respondents were provided with a letter of confidentiality to avoid conflict of interests, presented in Appendix 1.

3.1 Explanation of criteria and sub-criteria of AHP

The Analytical Hierarchy Process (AHP) necessitates the pre-definition of criteria to effectively evaluate alternatives. Consequently, it is not possible to conduct an AHP evaluation without first defining these criteria. To identify the most appropriate criteria for evaluating the Analytical Hierarchy Process (AHP), a literature review was conducted, along with responses to open-ended interview questions from respondents with significant experience in warehouse management systems. The main criteria and sub-criteria that will be used in the evaluation were selected based on this analysis. During the interviews,

participants were asked to compare the selected criteria in pairs and assign relative importance to each criterion. It is important to note that although this study employed a set of generic criteria identified from the literature, it acknowledges that each company may prioritise different criteria based on their specific needs and operational requirements. Therefore, the criteria utilised in this study serve as a representative example of the application of the AHP method, illustrating how companies can tailor the criteria to meet their unique requirements. The criteria utilised in this study will be discussed next:

According to H. Min (1992): **"**Technical features determine how well the software can match the company's project needs and how effectively it can perform in the company's existing and planned information systems**"**. Under the technical specifications, the following sub-criteria were identified:

1. **The Integration Process** is the technical and functional ability of the WMS to connect and interact with systems such as Enterprise Resource Planning (ERP), Transportation Management System (TMS) and other tools for effective supply chain management. This process is evaluated in terms of the ease, speed and seamless integration of the system with existing systems within the company, as well as the interaction between the WMS and other existing systems within the organisation.
2. **User Experience (UX)**, according to H. Min (1992) user experience "determines how user-friendly the software is and how flexible it is in conducting "what-if" scenario analyses. Thus, the important requirements of user interfaces include user display and dialogue mechanisms, interactive query language, online data modifications, high-resolution graphics, and self-explanatory help commands". Also, user experience "...can lead to enhanced staff productivity and system acceptance" (Richards, 2011). A positive user experience (UX) has been demonstrated to facilitate faster adoption, reduce training time and minimise errors, which collectively enhances productivity and user satisfaction also If employees have difficulty finding the right information or completing tasks, it's a poor user experience.
3. **The Warehouse Characteristic** is the ability of the system to meet the characteristics and requirements of the company's warehouse. The system must be able to match the specific physical and operational characteristics of the warehouse. This matching is crucial to optimise the efficiency

of warehouse operations. As an example, if a warehouse has a lot of fragile goods, the warehouse management system must be able to correctly account for their storage or accommodate space and workflow constraints such as receiving, storage, picking and shipping.

Administrative criteria within this particular setting pertain to the facets of a Warehouse Management System (WMS) that are associated with its governance, assistance, and user-friendliness. These encompass the standing of sub-criteria such as the supplier, the extent of service rendered, and the extensiveness of training provided:

1. **Vendor reputation**. "Very often, a vendor's reputation in a business circle can be a good benchmark for assessing the vendor's credibility, goodwill and reliability" (Min, 1992). As G. Richards (2011) notes, "Choose a vendor you are comfortable working with. Try to find a vendor who is culturally similar to your company, is professional and well respected in the industry".A well-established provider is likely to offer the best support, training and updates, ensuring that WMS remains effective and relevant, which is vital for long-term success.
2. In the context of WMS, **Service Level** refers to the speed and quality of support provided after the system has been implemented. This ensures timely and accurate order processing. A high service level allows workers to be quickly assisted if problems arise.
3. The **Training Provided** by the WMS vendor to the organisation's employees encompasses both initial and ongoing training sessions. The objective of these training sessions is to ensure that users can utilise the WMS effectively, thereby facilitating successful implementation, user adoption, and ongoing operational efficiency.

The final criterion for illustrating the work of AHP in selecting the most significant criteria for selecting a WMS system is **Cost**. Definition of cost is defined as "the amount of inputs acquired in producing a product" (Olajide, 2016). In the context of the study, cost encompasses all the financial aspects associated with the acquisition, adaptation, maintenance and utilisation of the system. "If the expenses of purchasing the software from outside vendors exceed either the cost of developing an "in-house" software or the company's budget requirements (affordability), the commercial software would be

out of consideration" (Min, 1992). Consequently, it is imperative to assess the principal sub-criteria, such as:

1. **Development Cost**: According to G. Richards (2011): "Software development costs for requirements not catered for in the package, including interfaces to third-party systems". In the context of the study, it is implied that this is the cost of configuring and refining the system to suit the user's needs. For example, some systems may require additional configuration, which will consequently increase the cost.
2. **Support cost:** According to G. Richards (2011): **"**This is typically an annual cost based on licence costs and often development costs; look at this cost carefully: the scope of service and cost varies significantly from supplier to supplier. Evaluating service costs helps in understanding the long-term financial commitment required to maintain the WMS.
3. **Training Cost:** In the context of selecting a Warehouse Management System (WMS), the cost of training is the expense incurred by the company in training its staff and employees in the use of the system. For instance, respondents may be informed that the cost of training may include the remuneration of a trainer or the purchase of training materials, such as books, manuals, and so forth.

4. Research Results and Findings

4.1 Analysis of the current WMS in the local logistics company

Material and Technical Supply Manager

The first respondent's current position is Head of the Materials and Equipment Completion Department in company XYZ, the overall company's turnover is about 18000 "lines" of goods, that are shipped to 13 delivery locations.

For now, the company uses the SAP ERP system, which is one of the most widespread in the world, the main reason is that it has a high level of transparency and decreases the risks of fraud. Moreover, a respondent shared that SAP is well-developed in Planning and Delivery processes, focusing on efficiency and minimising expenses. Another advantage of that particular SAP is the ability to take into consideration items that are located in all the warehouses of the company and provide the final number of goods that have to be ordered or delivered.

However, a respondent also highlighted some challenges the company met during the integration process, due to the system's flexibility and adaptability and the huge role of how the company tailors the entire system to its processes, it doesn't have fixed, general solutions for the company's functions. For example, each company will have its action plan in SAP for one problem or case and during rotation between companies, employees will experience difficulties, as there is no fixed model. That's why users need more ready solutions in the system, that will decrease the probability of errors, which might lead to total breakdown, as happened in the company of our respondent, as developers code SAP according to the specifications of the company, and increase the risks due to human errors.

Moreover, SAP provides the company with the basic package, in case of any difficulties or changes, the company will need to buy additional modules or solutions that will significantly increase the expenses of the company. In additionally to the price of the module, the company will need to pay for

training, if a new employee has worked with Excel before entering a company and the employer provides him with SAP, an employee will continue to work with an already familiar platform rather than a new complex system with non-user friendly interface, consequently, there will be no automatization and inefficient allocation of resources.

Also, a respondent covered the issue of learning, as SAP is a complex system which includes processes of all the company, and every user has to go through training and manuals. Usually, the company provides employees with online/offline training conducted by SAP specialists before integration or during workflow in case of installing additional modules. However, during the training, employees can not stop the work processes, therefore the adaptation of gained knowledge is not fully efficient, as employee needs to continue according to its redirect responsibilities and try to understand new information and practice it. Another option is the SAP specialist inside the company, during the first period SAP distributor provides the company with its employees, who have to help and explain. According to a respondent's experience, most knowledge and skills were gained from another employee, who is already familiar with the system.

The last part was dedicated to criteria, that our respondent thinks are the most crucial in case of choosing the right WMS. The first criterion is credibility and accreditation of worldwide auditors, to constantly grow and develop. The second criterion is user-friendliness, every new employee has to understand the process flow intuitively, to minimize the risks of mistakes and make the adaptation process smoother. Lastly, the WMS has to be flexible and be able to integrate into company processes and make them easier, and faster to solve different cases.

Finance and Accounting Manager

The second respondent's current position is an economist, formerly an accountant in company XYZ. The respondent already has experience working with 1C and SAP, during the interview, he/she provided an analysis of the two systems.

The 1C is the most useful in all types of companies, due to its simple and understandable interface, anyone can learn how to use it in a short period. Especially applicable for workers in the finance and

accounting sphere, as it does not consist of a huge amount of other unuseful processes. Therefore, new employees can easily understand, and practice the main functions with the help of a manual that is included in the basic package, without special training. According to the experience of the respondent, if employees experience any kind of difficulties, the company can invite technical support at a lower cost than SAP and get the answers.

The transition process from 1C to SAP was accompanied by challenges, first of all, SAP has different codes that are used for accounting, as an example he advised about the debit/credit system, to insert an expense for debit, workers need to use special code, such as 31. Such significant changes lead to a decrease in efficiency. Overall, respondents highlighted that SAP is more complex due to the bigger range of functions that can cover almost every department of the company. Therefore, all the transactions/processes automatically link between different departments and make it easy to gather all the related information.

However, to cover the wide spectrum of functions of SAP, the company has to provide employees with training, and that depends on the signed agreement between the two sides. According to the experience of the respondents, their company provided them with SAP specialists to deal with technical issues.

The main criteria should include integrity within the company, almost every employee has to find useful processes or functions to make his work more structured and coherent. Secondly, there should be constant technical support service, at an average price range to deal with issues and not negatively influence workflow in the company.

Project Manager

The third respondent's current position is SAP Project manager, who works on the development of the system and deals with integration with companies.

The SAP system covers almost every process within the company, fully covering financial departments. The integration process is smooth, as all the departments may be involved in the system, as example, in the case of a new employee, after inserting the main information, the system automatically

initiates another process, such as employee order, signing to all thee platforms, salary transaction details, etc. However, it depends on the modules that the company decides to purchase. That led to the main area for development which is the license policy, the basic SAP covers the main functions, to cover more departments the company will need to buy additional modules and increase expenses on training, and installation. In that case, the company has a chance to choose among other ERP systems and choose the most appropriate for a specific department. Moreover, most of the users criticize the SAP due to not being user-friendliness, due to its complex interface and a huge amount of control points, on the other side it provides the company with the highest safety, as a person who does not know how to exploit the system won't be able to initiate any process. The worker won't be able to get inside the system and change anything, such as financial reports, that's why SAP has a high value among worldwide auditors, due to transparency.

The training is conducted individually according to the transactions of the company, there is a basic manual for SAP and specifically designed seminars for each company.

The main criteria are credibility, and how much the company can rely on the data provided by the SAP, the vendor reputation plays a huge role in the decision-making process, and the company has to fully transfer the confidential data and its gas to be sure that it will be kept safe, with no access to third parties. Moreover, the system has to cover the main processes of the company and the availability of partial integration, when changes appear in specific areas, not in the whole system. Lastly,

By concluding all three interviews, it clearly can be seen that the main criteria that were identified fully reflect the requirements of employees and developers. All three were focused on technical, administrative and price aspects.

4.2 Data Calculations

After successfully conducting interviews and collecting the necessary data in the studied areas, the direct processing of the obtained data begins, namely the practical application of AHP based on the specified methodology from Thomas Saaty. The first step was to fill in comparative tables with criteria for choosing WMS systems. An important point is that in addition to the main criteria, the respondents who took part in the survey also evaluated the sub-criteria. The assessment is carried out by each respondent on a scale from 1 to 9, where each of the assessments has the following definition:

Table 2.

The fundamental scale of absolute numbers

Intensity of Importance	*Definition*	*Explanation*
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	A reasonable assumption
1.1–1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities.

Note. From "Decision making with the analytic hierarchy process." by T. L. Saaty, 2008, International Journal of Services Sciences, 1, 1. https://doi.org/10.1504/IJSSCI.2008.017590

Table 3.

Completed Comparison Matrix of main criteria from the Supply & Chain Manager.

Tables with main criteria	Technical	Administrative	Cost Value
Technical	1.000	9.000	9.000
Administrative		1.000	9.000
Cost Value			1.000

Following the original methodology, the missing parts in pairwise matrices are obtained by simple calculations and opposite comparison, we identify the significance of the missing matrix cells.

Table 4.

Completed Comparison Matrix of main criteria from the Supply & Chain Manager.

Tables with main criteria	Technical	Administrative	Cost Value
Technical	1.000	9.000	9.000
Administrative	0.111	1.000	9.000
Cost Value	0.111	0.111	1.000

In case where the respondent estimated that Technical criteria are extremely important than Administrative ones, then to get an assessment of Administrative criteria concerning Technical Ones, we take the inverse ratio by simple mathematical division:

1/9 = 0.111

Thus, the entire assessment of the main and sub-criteria is filled in, during which we can continue to work with our matrices (Appendix 3). The next step in the calculations is to find the eigenvectors and eigenvalues in each matrix, for this we apply the following formula:

Figure 3.

The formula for calculations of Eigenvectors

$$e^T = (1,1,\ldots,1)$$

$$W = \lim_{k\to\infty} \frac{A^k . e}{e^T . A^k . e}$$

Note. From "Decision making using the analytic hierarchy process (AHP); A step by step approach." by H. Taherdoost, 2017, *International Journal of Economics and Management Systems*, *2*. https://hal.science/hal-02557320/document

Based on the methodology, we obtain the following eigenvectors (Appendix 3).

Table 5.

Comparison Matrix of main criteria from the Material and Technical Supply Manager and eigenvectors.

Tables with main criteria	Technical	Administrative	Cost Value	**Eigenvalue**
Technical	1.000	9.000	9.000	0.973
Administrative	0.111	1.000	9.000	0.225
Cost Value	0.111	0.111	1.000	0.052
				1.250

Normalising the weights of the criteria in the matrix is an essential step in the process. This is necessary to understand how important the criteria will be relative to each other in a particular matrix based on their initial pairwise evaluation. For this purpose, simple calculations are used, the value of each eigenvector is divided by the sum of eigenvectors:

0.973/1.250=0.779

In the same way, all other cells are filled in, the sum of the weights of all criteria in the matrix should be equal to one, which indicates the equal distribution of criteria weights.

Table 6.

Comparison Matrix of main criteria from the Supply & Chain Manager with eigenvectors and their weight.

Tables with main criteria	Technical	Administrative	Cost Value	**Eigenvalue**	**Weight**
Technical	1.000	9.000	9.000	0.973	0.779
Administrative	0.111	1.000	9.000	0.225	0.180
Cost Value	0.111	0.111	1.000	0.052	0.042
				1.250	1.000

The numbers indicate that in the main criteria matrix review by the Supply & Chain Manager, the Tecnical Criteria are the most valuable among all of them.

The previously discussed mathematical calculations must be done with the other comparison matrixes one by one with the evaluation by all the key specialists that were chosen as a focus group, as well as the assessment of each sub-criteria matrix (Appendix 20-30). Therefore, the scores from all three evaluators on the selected main criteria and sub-criteria will be normalised, which will subsequently provide a more objective picture in their final evaluation.

The final table in which we indicate the averaged criterion and sub-criterion is created to obtain the final results in the relativity of comparison of each criterion within the framework of their importance relative to each other:

Table 7.

Table with Global Weights of main criteria and sub-criteria.

Criteria	**Criteria Weights**	**Sub-Criteria**	**Sub-Criteria Weights**	**Global Weights**
Technical	0.772	Integration Process	0.319	0.246

		User Experience	0.460	0.355
		Warehouse Characteristics	0.221	0.170
Administrative	0.178	Vendor Reputation	0.694	0.124
		Service Level	0.238	0.042
		Training Provided	0.069	0.012
Cost Value	0.050	Development Cost	0.708	0.035
		Service Cost	0.221	0.011
		Training Cost	0.071	0.004
Sum	1.000		3.000	1.000

The figures show that the sum of the weights of each sub-criterion is equal to 3 since the scale of this study involved three key experts whose opinions were taken into account for the pair-wise comparison. To find the global weight of each of the sub-criteria it is necessary to perform simple calculations, namely multiply the weight of each sub-criterion by the weight of its corresponding main criterion. Integrational process is a part of Technical Criteria so the Global Weight will be:

0.319 * 0.772 = 0.246

In the same way, the weight of all other sub-criteria is found, and their total sum should be equal to one, which indicates the success of the calculations. As a result, we have normalised data evaluated within the framework of all three respondents with a conditional breakdown by a 100% evaluation system.

Based on the normalised data obtained in the matrices, the Consistency Ratio is calculated, which determines whether the data collected from respondents is unbiased and whether the estimates should be trusted.

To sum up all the criteria weights from all respondents, the matrixes shall be centred to get more specific and normalised data within it. The geometric mean is the product of multiplying all of the individual values and then redistributing them in equal portions, maintaining the same overall outcome, rather than the sum of the values (McAlister, 1879). The geometric mean formula demonstrates this:

Figure 4.

Formula of Geometric Mean (McAlister, 1879).

$$\tilde{x} = \left(\prod_{i=1}^{n} x_i \right)^{\frac{1}{n}} = \sqrt[n]{x_1 \cdot x_2 \cdots x_n} = (x_1 \cdot x_2 \cdots x_n)^{\frac{1}{n}}$$

Note. McAlister, D. (1879). *The Law of the Geometric Mean. Proceedings of the Royal Society of London, 29(196-199), 367–376.* doi:10.1098/rspl.1879.0061

After that, 4 main matrices are formed with centralized data from all respondents (Appendix 40-60).

To calculate CR, it is also necessary to find the value of λmax, which displays the largest or main eigenvalue of the matrix using the formulas provided:

Figure 5.

3 Lambda max formula, Consistency Index formula.

$Aw = \lambda_{max}\, w, \quad \lambda_{max} \geq n$

$$\lambda_{max} = \frac{\sum a\,jwj - n}{w1}$$

$A=\{a_{ij}\}$ with $a_{ij}=1/a_{ij}$

A: pair wise comparison
w: normalized weight vector
λ_{max} : maximum eigen value of matrix A
a_{ij}: numerical comparison between the values i and j

$$CI = \frac{\lambda_{\max} - n}{n-1}$$

Note. From "Decision making using the analytic hierarchy process (AHP); A step by step approach." by H. Taherdoost, 2017, *International Journal of Economics and Management Systems, 2.* https://hal.science/hal-02557320/document

The acceptable value of CR varies from 0 to 1, meaning that the overall decision obtained by AHP has no more than a 10% chance of inconsistency. Random Index value could be reached by addressing the original RI table by looking at the corresponding matrix size (n):

Table 8.

Random Index for n=15.

Random Index (RI)															
n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

Note. From "Analytic Hierarchy Process (AHP) for business site selection.", by J. Y. Yap, C. C. Ho, & C. Y. Ting, 2018, In *AIP Conference Proceedings* (Vol. 2016, No. 1). AIP Publishing.

Table 9.

Normalized Main Criteria Matrix with CR, CI, RI

Main criteria	**Technical**	**Administrative**	**Cost Value**	**Weighted Sum**	**Priority (average)**	**Lambda Index**	**Eigenvalue**	1.260
Technical	1.000	9.000	7.399	3.14	0.72	4.37	**CI**	0.31
Administrative	0.111	1.000	7.399	0.76	0.22	3.45	**RI**	0.58
Cost Value	0.135	0.135	1.000	0.19	0.06	3.06	**CR**	0.54

Thus in this study, the consistency index is equal to 0.54 which exceeds the acceptable norm of CR<0.1. Such a high CR value indicates that the matrix is inconsistent and decision matrix should be

revised. Received data also show that original pairwise comparison is better than randomly generated matrixes only for 4% (RI-CI=0.58-0.54=0.04).

4.3 Data Interpretation

This paper aimed to select the most important criteria for the WMS selection using process both for the company that will be integrating new systems as well as the developers for the software to understand which step of production requires more effort and in-depth control using analytical hierarchy theory as a key decision-making tool.

Table 10.

Sorted Global Criteria weights.

Sub-Criteria	Sub-Criteria Weights	Global Weights
Training Cost	0.071	0.004
Service Cost	0.221	0.011
Training Provided	0.069	0.012
Development Cost	0.708	0.035
Service Level	0.238	0.042
Vendor Reputation	0.694	0.124
Warehouse Characteristics	0.221	0.170
Integration Process	0.319	0.246
User Experience	0.460	0.355
Sum	3.000	1.000

The following data shows that in this particular study, the respondents are final customers of WMS more concerned about general aspects of the system's user experience than any other criteria. Since, the study was conducted between several departments that also have to be connected into the one tracking system for the following reports, such criteria as international process received second place among other sub-criterias. Only after that, the key characteristics of the WMS such as the existence of all work

modules and extended tools for daily-based workflow were mentioned not only by the respondents' interviews but also by the weight that they had provided. A slightly less important sub-criteria weight reflects the vendor reputation criteria. Following that the respondents were concerned about the provided service level that should come with each WMS since the software in most cases is complicated to understand. The respondents noted that the cost of developing the systems as well as subsequent service fees do not play a special priority for them in deciding on the selection of warehousing management systems. This could be explained by the fact that this research does not reveal the point of view of those employees who are responsible for the company's cost reduction. In regards to such criteria as provided training from the company, respondents noted that the overall understanding of the WMS itself could be achieved only by daily operation by the employees, which is why these criteria also have shown low priority among all of them.

5. Study Limitations and Conclusion

5.1 Study Limitations

Group decision-making is a complex procedure that may not lead to an ideal result, due to changes in the circumstances of a particular group or external factors. This paper aimed to develop and fulfil the knowledge about the practical use of AHP in logistics, however, due to the limited abilities there are some causes of lack of the consistency of the final results. Thomas Saaty developed the term "tolerable inconsistency" which states that the maximum acceptable value for CR should strictly be below 0.2 and the ideal solution would be between 0 and 0.1 (Muralidharan et al., 2003). The obtained CR result in this paper indicates that the provided estimate from the respondents has a margin of error of 54% which is higher than the acceptable norm (20%) but better than the result of the randomly generated matrix by 4% (RI=58%).

The reasons for such results were the methodological and research process limitations:

1. **Sample size**

Since this research has not been conducted in most companies among employees working directly with WMS systems, the respondents did not fully understand how their professional feedback could affect the outcome of decision-making in their company. As a result, it was complicated to recruit the target group of respondents due to the lack of sufficient time for the employees, as well as the personal desire not to participate in the survey. In case the company management is interested in this kind of practice for making complex decisions, it would directly influence a large sample of specialists from different departments who also use WMS systems.

2. **Measured data**

The respondents lacked the requisite training and experience to comprehend and analyse the AHP issues fully. This deficiency may have influenced the precision of the AHP estimates, as the respondents' estimates may not have reflected an informed assessment and suboptimal prioritisation of criteria. Consequently, a considerable margin of error can be observed in the final calculations. Notwithstanding

these limitations, the respondents' experiences were deemed valuable in understanding the practical aspects of WMS selection and criteria. However, they had not experienced the practical application of AHP at work and in companies. In future research, it would be beneficial to conduct AHP training sessions using examples from other companies that use this method. This would facilitate a better understanding of the criteria and a more accurate assessment. Furthermore, future studies could involve decision-makers and departmental staff to achieve a more balanced approach, combining practical knowledge with methodological rigour.

3. **Bias of one of the correspondents: project manager of SAP**

Since the results of the pairwise comparison are directly influenced by the personal assessments of the respondents, it is important to evaluate the professional opinion on the subject under study, without taking into account the personal prejudices of the interviewees.

5.2 Conclusion

This research aimed to investigate and accomplish knowledge about the practical use of Analytical Hierarchy Theory in the selection of a Warehouse Management System.

First of all, in this framework, AHP helps to divide complex decision-making processes into more manageable parts, that are easier to comprehend and analyze. It leads to the building of structures, where clearly can be seen the influence of every criterion, such as technical, administrative, cost-vale and their sub-criteria to the final decision of priority of the data in case of choosing the more appropriate WMS.

Second of all, using an AHP increases the credibility of results, as it considers the input information. In this research, data was provided from several departments of company XYZ to analyze it from different sides and get objective opinions on a particular case from experts in the field of supply chain management. As AHP involves pairwise comparison of criteria and alternatives, any minor changes in input can lead to a significant change. Moreover, at the stage of calculations, by applying the theory of eigenvalues and eigenvectors, the large deviations from primary vectors are eliminated and all data

become normalized. Further, that data is used to calculate the consistency ratio, which compares final results with a randomly generated matrix and identifies the level of deviation.

Third of all, the main risk discovered in the course of this work occurs in the selection of respondents, as their opinion as human beings should not be biased and should reflect only objective data from the point of view of the justified as the object of research for further interpretation of the data. This problem can be partially solved in future research on the selected topic by using Fuzzy AHP as a more reliable tool to exclude biased opinions in calculations. Moreover, due to the unpredictability of factors influencing the final decision, AHP as a method cannot position itself as the best possible solution. Abrupt changes in circumstances such as the external environment can significantly impact the final evaluation of the criteria in the long-term perspective. Nevertheless, in the absence of a more accessible method for risk assessment in the field of WMS selection, this method is more objective than random voting in evaluating criteria.

The results of the study demonstrate that the criteria selected for the study, which were based on the literature review and subsequent interpretations of the interviews with respondents, were effectively validated using AHP. This paper successfully applies the methodology of the Analytical Hierarchy Process to identify each criterion weight and key functionalities that are critical to the selection of a WMS.

Ultimately, the hypothesis of this research work has been only partially proved in regards to helping to identify the most objective criteria based on different departments to choose the appropriate WMS and leads to a common agreement between them.

However, the credibility of results, due to the higher-than-acceptable consistency ratio has not been approved and may lead to significant errors during the implementation and integration of the chosen WMS.

Bibliography

Agarwal, P., Sahai, M., Mishra, V., Bag, M., & Singh, V. (2014). Supplier Selection in Dynamic Environment using Analytic Hierarchy Process. *International Journal of Information Engineering & Electronic Business*, *6*(4).

Al-Shakarchy, N. D. K. (2015). Warehouse Management System. *International Journal of Science and Research (IJSR)*, *4*(10), 1253-1260.

Creswell, J. W., & Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approaches. Sage publication.

Efthymiou, I.P. (2014). CASE STUDY ON FAILED IMPLEMENTATION OF ERP SYSTEMS. *University of Piraeus.*

Geometric Mean - definition, formulas, examples and properties. (n.d.) BYJUS. https://byjus.com/maths/geometric-mean/#:~:text=In%20Mathematics%2C%20the%20Geometric%20Mean,total%20number%20of%20data%20values.

Karthikeyan, R., Venkatesan, K. G. S., & Chandrasekar, A. (2016). A comparison of strengths and weaknesses for analytical hierarchy process. *Journal of Chemical and Pharmaceutical Sciences*, *9*(3), 12-15.

Kumar, S., Parashar, N., & Haleem, A. (2009). Analytical hierarchy process applied to vendor selection problem: small scale, medium scale and large scale industries. *Business Intelligence Journal*, *2*(2), 355-362 :

Libretexts. (2024, March 13). *2.6: Geometric mean*. Statistics LibreTexts. https://stats.libretexts.org/Courses/Saint_Mary%27s_College_Notre_Dame/HIT_-_BFE_1201_Statistical_Methods_for_Finance_(Kuter)/02%3A_Descriptive_Statistics/2.06%3A_Geometric_Mean

McAlister, D. (1879). XIII. The law of the geometric mean. *Proceedings of the Royal Society of London*, *29*(196–199), 367–376. https://doi.org/10.1098/rspl.1879.0061

Md. Al Amin, Apurba Das, Sumit Roy, Md. Imran Shikdar. Warehouse Selection Problem Solution by Using Proper MCDM Process. *International Journal of Science and Qualitative Analysis.* Vol. 5, No. 2, 2019, pp. 43-51. doi: 10.11648/j.ijsqa.20190502.13

Minashkina, D., & Happonen, A. (2020, May). A development of the warehouse management system selection framework as academic-industrial collaboration work with sustainability considerations. In *AIP Conference Proceedings* (Vol. 2233, No. 1). AIP Publishing.

Min, H. (2006). The applications of warehouse management systems: an exploratory study. *International Journal of Logistics: Research and Applications*, *9*(2), 111–126. https://doi.org/10.1080/13675560600661870

Min, H. (1992). Selection of software: The Analytic Hierarchy Process. *International Journal of Physical Distribution & Logistics Management*, *22*(1), 42–52. https://doi.org/10.1108/09600039210010388

Muralidharan, C., Anantharaman, N., & Deshmukh, S. G. (2003). Confidence interval approach to consistency ratio rule in the applications of analytic hierarchy process. *West Indian Journal of Engineering*, *26*(1), 17-28.

Oğuztimur, S. (2011). Why fuzzy analytic hierarchy process approach for transport problems?. *European Regional Science Association.*

Olajide, S. E., Lizam, M., & Olajide, E. B. (2016). Understanding the conceptual definitions of cost, price, worth and value. *IOSR Journal of Humanities and Social Science*, *21*(09), 53–57. https://doi.org/10.9790/0837-2109015357

Richards, G. (2018). *Warehouse Management: A complete guide to improving efficiency and minimizing costs in the modern*. Kogan Page.

Roque, R. A. C., Robielos, R. A. C., & Gumasing, M. J. J. (2021). Analysis of Airline Domestic Operations using Linear Programming.

Saaty, T.L. (1988). What is the Analytic Hierarchy Process?. In: Mitra, G., Greenberg, H.J., Lootsma, F.A., Rijkaert, M.J., Zimmermann, H.J. (eds) Mathematical Models for Decision Support. *NATO ASI Series, vol 48.* Springer, Berlin, Heidelberg.

Saaty, T. L. (2008). Decision making with the analytic hierarchy process. *International Journal of Services Sciences*, 1, 1. https://doi.org/10.1504/IJSSCI.2008.017590

Triantaphyllou, E., & Mann, S. H. (1995). Using the analytic hierarchy process for decision making in engineering applications: some challenges. *International journal of industrial engineering: applications and practice, 2*(1), 35-44

Yap, J. Y. L., Ho, C. C., & Ting, C. (2018). Analytic hierarchy process (AHP) for business site selection. *AIP Conference Proceedings.* https://doi.org/10.1063/1.5055553

Appendix

Appendix 1.

Letter of confidentiality for respondents of interview.

Good afternoon!

My name is Aubakirova Zhibek I and my team (Letava Vladislav, Nuktabiyeva Ayana) are students of the 4th year of the university KazGUU (now MNU) and within the framework of research devoted to our thesis we would like to invite you for an interview. Theme of the research: Study of the influence of analytical hierarchical process in the choice of warehouse management system in medium-sized companies and its further effectiveness of its application. As part of this research we would like to invite you as an expert in the field of Supply Chaim Managamant/Accounting/IT to a closed online interview, which will be conducted with each of the three experts individually with full confidentiality. We would like to ask you which criteria in accounting and resource management systems like SAP or 1C are most relevant to you. We assure you that we will not disclose any personal data about you, your position and so on, in the final study you will be mentioned as Specialist/Respondent 1/2/3 from company X. The non-disclosure agreement for this work will be attached below, along with the official seal of the university. It states that we as researchers have no right to disclose personal details of the respondents.

The interview will take place in an online format, at your convenience and will take no more than 15-20 minutes. You can connect without a camera and without specifying your real name. The only thing you need is a working microphone. More details about the study itself we will tell you personally. Please choose an interview date convenient for you and thank you very much for your contribution to the development of scientific activity of young specialists in Kazakhstan!

Appendix 2.

Table 1.

Comparison Matrix of global criteria from Material and Technical Supply Manager.

Tables with main criteria	Technical	Administrative	Cost Value	**Eigenvalue**	**Weight**
Technical	1.000	9.000	9.000	0.973	0.779
Administrative	0.111	1.000	9.000	0.225	0.180
Cost Value	0.111	0.111	1.000	0.052	0.042
				1.250	1.000

Table 1.1.

Comparison matrix of Technical criteria from Material and Technical Supply Manager.

Technical	Integration Process	User Experience	Warehouse Characteristics	**Eigenvalue**	**Weight**
Integration Process	1.000	0.143	0.111	0.057	0.046
User Experience	7.000	1.000	0.111	0.208	0.167
Warehouse Characteristics	9.000	9.000	1.000	0.977	0.787
				1.241	1.000

Table 1.2.

Comparison matrix of Administrative criteria from Material and Technical Supply Manager.

Administrative	Vendor Reputation	Service Level	Training Provided	**Eigenvalue**	**Weight**
Vendor Reputation	1.000	3.000	3.000	0.834	0.552
Service Level	0.333	1.000	7.000	0.532	0.352
Training Provided	0.333	0.143	1.000	0.145	0.096
				1.511	1.000

Table 1.3.

Comparison matrix of Cost criteria from Material and Technical Supply Manager.

Cost	Developme nt Cost	Service Cost	Training Cost	**Eigenvalue**	**Weight**
Development Cost	1.000	3.000	5.000	-0.873	0.581
Service Cost	0.333	1.000	5.000	-0.455	0.303
Training Cost	0.200	0.600	1.000	-0.175	0.116
				-1.503	1.000

Table 2.

Comparison Matrix of Global Criteria from Finance and Accounting Manager.

Tables with main criteria	Technical	Administrative	Cost Value	**Eigenvalue**	**Weight**

Technical	1.000	9.000	5.000	0.970	0.753
Administrative	0.111	1.000	5.000	0.224	0.174
Cost Value	0.200	0.200	1.000	0.093	0.072
				1.288	1.000

Table 2.1.

Comparison matrix of Technical criteria from Finance and Accounting Manager.

Technical	Integration Process	User Experience	Warehouse Characteristics	**Eigenvalue**	**Weight**
Integration Process	1.000	0.143	7.000	0.291	0.219
User Experience	7.000	1.000	5.000	0.953	0.715
Warehouse Characteristics	0.143	0.200	1.000	0.089	0.067
				1.333	1.000

Table 2.2.

Comparison matrix of Administrative criteria from Finance and Accounting Manager.

Administrative	Vendor Reputation	Service Level	Training Provided	**Eigenvalue**	**Weight**
Vendor Reputation	1.000	7.000	5.000	0.960	0.726
Service Level	0.143	1.000	5.000	0.262	0.198

Training Provided	0.200	0.200	1.000	0.100	0.076
				1.322	1.000

Table 2.3.

Comparison matrix of Cost Criteria from Finance and Accounting Manager.

Cost	Development Cost	Service Cost	Training Cost	**Eigenvalue**	**Weight**
Development Cost	1.000	9.000	5.000	0.965	0.744
Service Cost	0.111	1.000	7.000	0.249	0.192
Training Cost	0.200	0.143	1.000	0.083	0.064
				1.297	1.000

Table 3.

Comparison Matrix of Global Criteria from Project Manager.

Tables with main criteria	Technical	Administrative	Cost Value	**Eigenvalue**	**Weight**
Technical	1.000	9.000	9.000	0.973	0.779
Administrative	0.111	1.000	9.000	0.225	0.180
Cost Value	0.111	0.111	1.000	0.052	0.042
				1.250	1.000

Table 3.1.

Comparison matrix of Technical Criteria from Project Manager.

Technical	Integration Process	User Experience	Warehouse Characteristics	**Eigenvalue**	**Weight**
Integration Process	1.000	9.000	7.000	0.968	0.761
User Experience	0.111	1.000	9.000	0.243	0.191
Warehouse Characteristics	0.143	0.111	1.000	0.061	0.048
				1.272	1.000

Table 3.2.

Comparison matrix of administrative criteria from Project Manager.

Administrative	Vendor Reputation	Service Level	Training Provided	**Eigenvalue**	**Weight**
Vendor Reputation	1.000	9.000	9.000	0.973	0.779
Service Level	0.111	1.000	9.000	0.225	0.180
Training Provided	0.111	0.111	1.000	0.052	0.042
				1.250	1.000

Table 3.3.

Comparison matrix of Cost Criteria from Project Manager.

Cost	Developme	Service Cost	Training Cost	**Eigenvalue**	**Weight**

	nt Cost				
Development Cost	1.000	9.000	7.000	0.972	0.769
Service Cost	0.111	1.000	7.000	0.225	0.178
Training Cost	0.143	0.143	1.000	0.067	0.053
				1.264	1.000

Table 4.

Global Criteria weights.

Criteria	**Criteria Weights**	**Sub-Criteria**	**Sub-Criteria Weights**	**Global Weights**
Technical	0.772	Integration Process	0.319	0.246
		User Experience	0.460	0.355
		Warehouse Characteristics	0.221	0.170
Administrative	0.178	Vendor Reputation	0.694	0.124
		Service Level	0.238	0.042
		Training Provided	0.069	0.012
Cost Value	0.050	Development Cost	0.708	0.035
		Service Cost	0.221	0.011
		Training Cost	0.071	0.004
Sum	1.000		3.000	1.000

Table 4.1.

Sorted Global Criteria weights.

Sub-Criteria	**Sub-Criteria Weights**	**Global Weights**
Training Cost	0.071	0.004
Service Cost	0.221	0.011
Training Provided	0.069	0.012
Development Cost	0.708	0.035
Service Level	0.238	0.042
Vendor Reputation	0.694	0.124
Warehouse Characteristics	0.221	0.170
Integration Process	0.319	0.246
User Experience	0.460	0.355
Sum	3.000	1.000

Table 5.

Average Main Criteria Matrix.

Tables with main criteria	Technical	Administrative	Cost Value	**Eigenvalue**	**Weight**
Technical	1.000	9.000	7.399	0.972	0.772
Administrative	0.111	1.000	7.399	0.225	0.178
Cost Value	0.135	0.135	1.000	0.063	0.050
				1.260	1.000

Table 5.1.

Average Technical Criteria Matrix.

Technical	Integration Process	User Experience	Warehouse Characteristics	**Eigenvalue**	**Weight**
Integration Process	1.000	0.568	1.759	-0.530	0.319
User Experience	1.759	1.000	1.710	-0.765	0.460
Warehouse Characteristics	0.568	0.585	1.000	-0.367	0.221
				-1.661	1.000

Table 5.2.

Average Administrative Criteria Matrix.

Administrative	Vendor Reputation	Service Level	Training Provided	**Eigenvalue**	**Weight**
Vendor Reputation	1.000	5.739	5.130	0.942	0.694
Service Level	0.174	1.000	6.804	0.323	0.238
Training Provided	0.195	0.147	1.000	0.093	0.069
				1.358	1.000

Table 5.3.

Average Cost Criteria Matrix.

Cost	Development Cost	Service Cost	Training Cost	**Eigenvalue**	**Weight**
Development Cost	1.000	6.240	5.593	0.950	0.708
Service Cost	0.160	1.000	6.257	0.297	0.221
Training Cost	0.179	0.230	1.000	0.095	0.071
				1.342	1.000

Table 5.

CR Calculation Sum.

Tables with main criteria	Technical	Administrative	Cost Value
Technical	1.000	9.000	7.399
Administrative	0.111	1.000	7.399
Cost Value	0.135	0.135	1.000
Sum	1.25	10.14	15.80

Table 5.1.

CR Calculation with Priority.

Tables with main criteria	Technical	Administrative	Cost Value	Priority (average)
Technical	0.80	0.89	0.47	0.72
Administrative	0.09	0.10	0.47	0.22
Cost Value	0.11	0.01	0.06	0.06

Table 5.2.

CR Calculation with Priority.

Tables with main criteria	Technical	Administrative	Cost Value
Priority (average)	0.72	0.22	0.06
Technical	1.000	9.000	7.399
Administrative	0.111	1.000	7.399
Cost Value	0.135	0.135	1.000

Table 5.3.

CR Calculation with Weighted Sum.

Tables with main criteria	Technical	Administrative	Cost Value	Weighted sum
Technical	0.72	1.97	0.46	3.14
Administrative	0.08	0.22	0.46	0.76
Cost Value	0.10	0.03	0.06	0.19

Table 5.4.

CR Final Table.

Main criteria	**Technical**	**Administrative**	**Cost Value**	**Weighted Sum**	**Priority (average)**	**Lambda Index**	**Eigenvalue**	1.260
Technical	1.000	9.000	7.399	3.14	0.72	4.37	**CI**	0.31
Administrative	0.111	1.000	7.399	0.76	0.22	3.45	**RI**	0.58
Cost Value	0.135	0.135	1.000	0.19	0.06	3.06	**CR**	0.54