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Technique improvement of supply chain creation: storage service supplier selection

Master's Thesis by the 2nd year student:

Tarabanov Pavel

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Research adviser:

Nikolay A. Zenkevich, Associate Professor

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ЗАЯВЛЕНИЕ О САМОСТОЯТЕЛЬНОМ ХАРАКТЕРЕ ВЫПОЛНЕНИЯ ВЫПУСКНОЙ КВАЛИФИКАЦИОННОЙ РАБОТЫ

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Аннотация

Автор	Павел Тарабанов
Название магистерской диссертации	Совершенствование методики создания цепочки поставок: выбор поставщика складских услуг
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Научный руководитель	Николай Анатольевич Зенкевич, к. ф.-м. н.
Описание цели, задач и основных результатов	**Основная цель**: Совершенствование методики выбора поставщика складских услуг и её применение к кейс-компании **Основные задачи**: • На основе обзора литературы разработать руководства для создания цепи поставок • Определить метод выбора элемента цепочки поставок • Специфицировать метод и усовершенствовать методику выбора поставщика складских услуг • Реализовать методику выбора поставщика складских услуг на примере кейс-компании **Результаты**: • Руководства по созданию цепи поставок были сформулированы на основе обзора литературы • Обосновано, что метод АПИС является наиболее подходящим методом для выбора элемента цепочки поставок • На основе АПИС метода была разработана методика выбора поставщика складских услуг • Разработанная методика применена на выборе поставщика складских услуг для Компании Saint-Gobain
Ключевые слова	Цепочка поставок, Элемент Цепочки Поставок, АПИС Метод, Методика Выбора Элемента, Поставщик Складских Услуг, Экспертная Оценка, Принятие Решений в Условиях Неопределенности.

Abstract

Master Student's name	Pavel Tarabanov
Master Thesis Title	Technique improvement of supply chain creation: storage service supplier selection
Faculty	Graduate School of Management
Main field of study	Master in Management
Year	2016
Academic Advisor's name	Nikolay A. Zenkevich, Associate Professor
Description of the goal, tasks and main results	**Main goal**: Technique improvement of storage service supplier selection and its application to case company **Research tasks**: • On the base of literature review formulate guidelines for the supply chain creation • Define the method for selecting the element of the supply chain • Specify the method and improve technique of storage service supplier selection • Apply the technique to storage service supplier selection for the case company **Research results**: • Guidelines for the supply chain creation were formulated on the base of literature review • It was substantiated that APIS method is the most suitable for the selecting element of the supply chain • On the base of APIS method the technique of storage service supplier selection was created • The technique was applied to storage service supplier selection for Saint-Gobain company.
Keywords	Supply Chain, Supply Chain Element, the APIS Method, Technique of the Element Selection, Storage Service Supplier, Expert Evaluation, Decision-making Under Uncertainty.

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Introduction

The existing level of globalization and economic development can not be achieved without a transport and logistics solutions in the last 10-20 years. During this time, enterprises have switched from solving relatively simple transport problems to complex logistics solutions, including lower operating costs, increase the speed and flexibility of supply, as well as measuring and managing the associated risks. Companies, which are able to find optimal solutions, gain significant competitive advantage and often gain a leading position in the industry. However, creation of supply chain is not an easy task due to the large number of factors: lack of sufficient experience, legal restrictions, conditions of logistics infrastructure and many others. Nowadays in the process of supply chain creation companies should use certain frameworks and follow concrete steps, to do it in the most appropriate way.

Such problem as technique improvement of supply chain creation is one of the most important which companies are facing today because competent decisions in the field of supply chain can reduce delivery times, production costs and increase competitiveness on the market. In the literature nowadays exists several methods of selecting an element in supply chain, even though nothing is written about storage service supplier selection, so a gap was identified successfully.

The main goal of this research is technique improvement of storage service supplier selection and its application to case company.

In order to achieve this goal, the following tasks should be performed:

- On the base of literature review formulate guidelines for the supply chain creation
- Define the method for selecting the element of the supply chain
- Specify the method and improve technique of storage service supplier selection
- Apply the technique to storage service supplier selection for the case company

The current master thesis has the following structure: introduction, four chapters, each unfolding one of the objectives stated above, conclusions, references and appendices. In the first chapter of this paper, theoretical perspective of the problem of supply chain formation is described, with the main focus on supply chain classification, guidelines for creation of supply chain and types of supply chain organization models. Chapter 2 devotes to the identification of methods for selecting an element in supply chain, it describes three methods and more precisely it covers mathematical optimization methods. Nevertheless, in second chapter is mentioned that no concrete model exists in storage service supplier selection and consequently discovered models might be adopted as a selection procedure, since warehouse is assumed to be an element in supply chain. In the Chapter 3, detailed explanation of warehouses business feature is presented together with

existing realities of storage service selection processes. Part 3.3 describes the methodology of particular work and further on in part 3.4 new method specification on storage service supplier selection is presented. Finally, in Chapter 4 a practical implementation of new method of storage service supplier selection is shown. As a case company Saint-Gobain enterprise was chosen, company's managers were involved in assessing characteristics and gaining final result of selecting new warehouse instead of current one.

The following notation system was used for tables, figures and formulas. Every figure, table or formula used in the current master thesis has a double-digit number, where the first number matches to the according Chapter number and the second relates to the counting number of a corresponding figure, table or formula within the chapter.

Chapter 1. Supply Chain Creation

The main objective of this chapter is to provide the literature review dedicated to the supply chain management, in particular to the supply chain creation methods.

1.1. Supply Chain Definition and Classification

Before the analysis of methods of the supply chain creation it is necessary to provide a definition of Supply Chain Management (SCM). Various definitions of SCM have been offered in several past years. The APICS Dictionary describes the supply chain as: the processes from the initial raw materials to the ultimate consumption of the finished product linking across supplier user companies and the functions within and outside a company that enable the value chain to make products and provide services to the customer (Cox, 1995). Also Supply chain management (SCM) is described as the management of a network of interconnected businesses involved in the provision of product and service packages required by the end customers in a supply chain. SCM span all movement and storage of raw materials, work-in-process, and finished goods from point of origin to point of consumption (Harland, 1996). Quinn (1997) defines the supply chain as "all of those activities associated with moving goods from the raw-materials stage through to the end user. This includes sourcing and procurement, production scheduling, order processing, inventory management, transportation, warehousing, and customer service. Importantly, it also embodies the information systems so necessary to monitor all of those activities." Summing up all definitions mentioned above it could be concluded that Supply Chain Management indicates – particular actions which are taking vital part of the value chain and gives additional value to the product. Mainly these actions are: delivering, manufacturing, warehousing, orders management, distribution and information systems, needed for managing this processes. Partners in the chain as suppliers, carriers, third party companies, IT providers, organizations departments are linked by supply chain management. All the managers of supply chain whether they are from one company or not are working together to give competitive advantage to their supply chain. It is important to mention that companies run their businesses in highly competitive environment and thus have to make their supply chain efficient through the economic point of view.

For the purpose of the following research terms supply chain modelling and supply chain creation will be closely related to each other. It can be claimed for that supply chain creation plays a vital role at the start point of the businesses of every company.

There is a significance of supply chain modelling and creation and it lies in two aspects: firstly, in order to manage the supply chain effectively, it should be properly created, secondly, processes which are integrated and coordinated needed to be modelled (Vernadat, 1996).

According to the definition of supply chain of (Mentzer, 2001) "a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer" which is defined as a most comprehensive and suitable for exact work, three levels of supply chain complexity could be identified: direct supply chain, extended supply chain and ultimate supply chain, Fig. 1.1. A company, customer and a supplier, which are involved in the upstream and downstream flows of products, services, finances and information, form direct supply chain (Fig. 1 a. Direct Supply Chain). Suppliers of the direct supplier, customers of the direct customer, all involved in the upstream and downstream flows of products, services, finances and (or) information, form an extended supply chain (Fig. 1b. Extended Supply Chain). Ultimate supply chain includes all the organizations involved in all the upstream and downstream flows of products, services, finances and information from the ultimate supplier to the ultimate customer (Fig. 1.1c Ultimate Supply Chain).

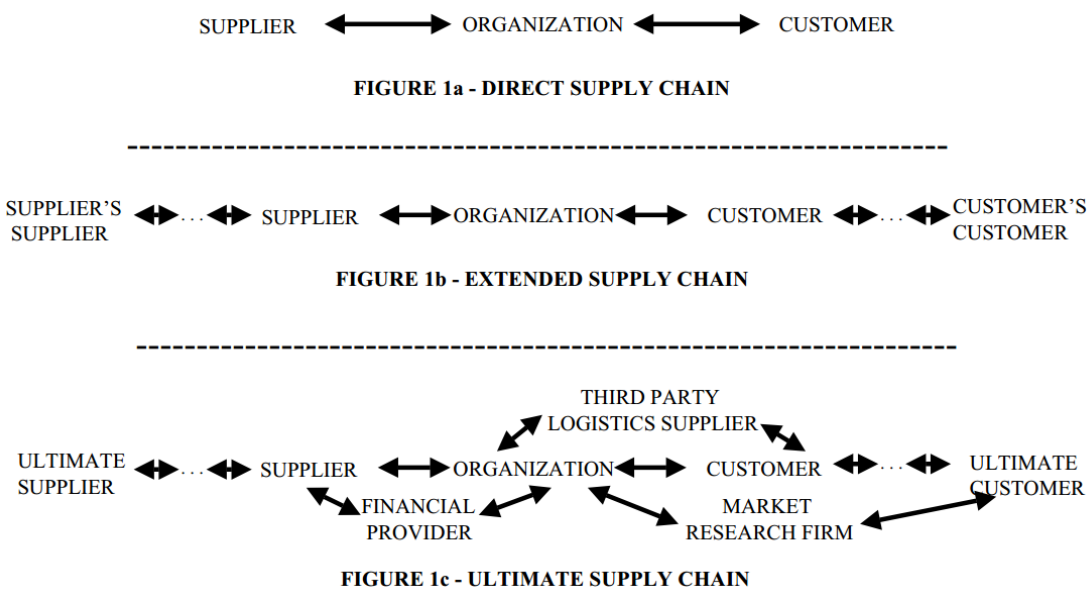

Figure 1. 1 Types of channel relationships.

(Mentzer, 2001)

A supply chain is a complex inter-firm network with multi-participants and processes, and every participant is an autonomous or semi-autonomous.

Also (Campbell, 2002) identified three types of relationship strategies between buyer and suppler.

- Competitive- relations between both sides are independent and a competitive market forces determine the price. Mainly enterprises follow competitive strategy, when goods are highly standardized, when it is not the core product and also exists big variety of alternatives for supplier to choose.

- Cooperative-relations between both sides are independent as well. Competitive strategy of relationships also means that companies cooperate to increase the profit. The cooperation accompanied by positive transaction cost, usually in form of specific investments. Companies invest in some area, for example, IT system, and thus reduce time of delivery and so on. So in other words cooperative strategy require investments in the majority of situations.
- Command-relationships between both parties are dependent, one party has a stronger position.

Buyer and supplier could implement strategies at the same time; all possible interactions are shown in the Tabl. 1.1.

Table 1. 1 Relationship strategies and recommendations (Campbell, 2002)

Relationship strategies and recommendations				
Strategy of buyer	**Strategy of seller**	**Match Title**	**Recommendation for buyer**	**Recommendation for seller**
Competitive	Competitive	Perfect market	Standardize requirements	Obtain lower costs
Competitive	Command	Sellers's market	Exchange information with other buyers Encourage competitors	Form a cartel Legitimize Standardize the product
Command	Competitive	Buyer's market	Put out trends	Competitive bidding Obtain lower costs or differentiate
Cooperative	Cooperative	Domesticated market	Adapt, cooperate, work together	Customize, specialize, differentiate, innovate
Cooperative	Command	Captive market	Learn from the supplier	Educate the buyer
Command	Cooperative	Subcontract market	Educate the supplier	Learn from the buyer

1.2. Guidelines for Supply Chain Creation

A number of supply chain creation methods and management methodologies describes the supply chain from different aspects, such as process, structure and decision mechanism, but none of them gives the proper and complete answer to the question "How to create supply chain in right way?" and what is more there is no unique methodology for supply chain creation which might suit every situation (condition), nevertheless there is one idea that exists in each method, supply chain creation absolutely depends on the particular condition where it is created. There are plenty of them, for example: business model of the company, market where it operates, relationship between customer and supplier and so on. Consequently, each supply chain is created under special needs and followed by particular guidelines. In the next part of this chapter the existing guidelines

will be covered.

1.2.1 Incoterms. First of all, in the process of supply chain creation, manager has to understand clearly who will be responsible for the goods at the concrete point of delivery. These relationships are regulated by special rules, also called International Commercial Terms (Incoterms) commercial terms published by the International Chamber of Commerce (ICC). They are commonly used in the international commercial transactions or procurement processes. First they were published in 1936, and currently 2014-year edition is used.

Main incoterms principles:

- Distribution between seller and buyer of transport costs for delivery of goods, determine which costs and for how long the seller and buyer bears.
- The moment of transition from the seller to the buyer the risk of damage, loss or accidental destruction of the goods.
- The date of delivery of the goods. Determination of the actual transfer of the goods by the seller to the buyer or his representative. For example, the transport company.

There are eleven incoterms, Fig. 1.2, seven of them are used for any kind of transport (International Chamber of Commerce, 2010):

1. EXW – Ex Works - goods are taken by the buyer from the warehouse of the seller, payment of export duties is obliged to the buyer.
2. FCA – Free Carrier- the goods are delivered to the transport company of the customer, directly to the departure terminal which is specified in the contract, the seller shall pay export duties.
3. CPT – Carriage Paid To- goods are delivered to the main carrier of the customer, the main transportation to the terminal indicated in the contract is paid by the seller, the cost of insurance pays the buyer, import customs clearance and delivery to the arrival terminal of the main carrier provides the buyer.
4. CIP – Carriage and Insurance Paid- goods are delivered to the main carrier of the customer, the main transportation to the terminal indicated in the contract is paid by the seller, the cost of insurance pays the seller, import customs clearance and delivery to the arrival terminal of the main carrier provides the buyer
5. DAT – Delivered at Terminal- delivery to the specified in the contract customs terminal, export payments and transportation, including insurance paid by the seller
6. DAP – Delivered at Place- delivery to the destination specified in the agreement, import duties and local taxes paid by the buyer

7. DDP – Delivered Duty Paid- the goods are delivered to the customer at the destination specified in the contract, without customs duties and risks.

And 4 are used only for sea and inland waterway transport (International Chamber of Commerce, 2010):

1. FAS – Free Alongside Ship- the goods are delivered to the buyer's ship, the contract indicates the port of loading, handling and loading burden.
2. FOB – Free on Board- goods are shipped at buyer's ship transhipment paid by the seller.
3. CFR – Cost and Freight- the goods are delivered to the specified in the contract buyer's destination port, the main transportation insurance, unloading and transhipment paid by the buyer
4. CIF – Cost, Insurance & Freight- the goods are delivered to the specified in the contract buyer's destination port, the main transportation insurance is paid by seller, unloading and transhipment paid by the buyer

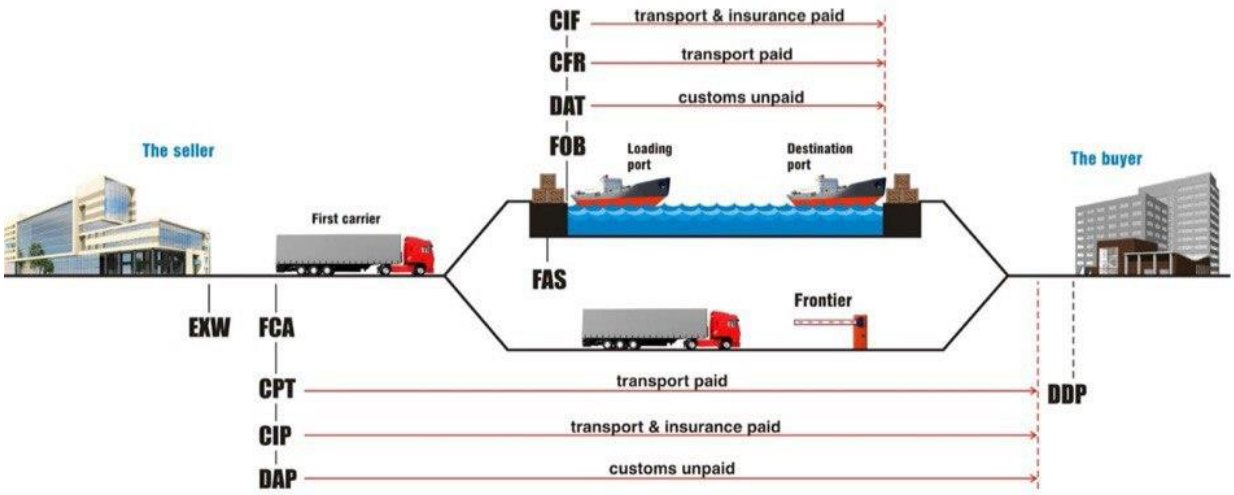

Figure 1. 2 Graphical representation of incoterms

(Ghana Shipping Guide, 2014)

So for supply chain creation it is important to identify proper incoterm, taking into account the way of transportation and who will be responsible for the goods at the exact moment and also pay taxes, insurance and other additional fees.

1.2.2 Party logistics providers. Second important step for supply chain creation, which manager has to take into consideration, is role of party logistics provider. Since each supply chain is build around transportation and movement of the goods, it is important to understand the definition of this term. Transportation is in general a physical movement of people and goods from one place to another. Transport is one of the major activities within logistics, where a creation of time and place utility is performed (Coyle, 1996). For choosing right logistics provider, manager

has to understand the nature of the goods, time limits for the transportation, final destination and frequency of the transportation.

The level of different providers differs enormously – by the range of services and a technological level. According to the adopted in the logistics classification today allocates 5 levels of logistical service (PL- Party Logistics).

1PL provider - the first level. This provider is usually called the owner of the goods (e.g. retailer). All operations of receipt and delivery of cargo perform a firm-owner of the cargo itself. In view of globalization, outsourcing and off-shoring of production, the complexity of distribution services, 1PL leaves in the past, shifting an increasing amount of work to providers who by working with a number of shippers have discounts and provide a better service to customers.

2PL provider - a contracting company that provides transport services only on some specific area of the supply chain. In fact, it's just a transport company, which hired the cargo owner, and does not want to buy their own cars, railway wagons. In this case, if the 1PL is actively trying to move away from their own “fleet”, the 2PL, at least in Russia, it is very relevant.

3PL provider – is a specialized company, which obtains the outsourcing of all or most of the logistics operations. In general, third-party logistics (3PLs) providers introduce efficiency and effectiveness into a company’s logistics operations, allowing shippers to control costs, and better utilize their resources, while helping them provide higher customer services (Partridge, 2008). For the first time this term was used in the early 1970s to describe intermodal marketing companies (IMC) in contracts for cargo transportation. Prior to this, in such treaties featured only two parties - shipper and carrier. When the IMC entered - mediators, who took the goods from the shipper and the carrier - they became intermediaries, “third party” or 3PL contract. Nowadays it applies to any company that provides logistics services to any size. Basically, it is a range of service, which include transportation of goods, warehousing, cross docking, maintenance inventory management, packaging, and freight forwarding. 3PL providers are freight forwarders, courier and other companies offering contract logistics services and transportation. In other words, 3PL provider is an independent economic entity that creates value for its client.

4PL provider - a contractor or a joint venture with the cargo owner, acts as an intermediary between the producer and one or more of its partners. 4PL provider has a high degree of involvement in the client's business processes; it acts as a single connecting link between the client (for example, the manufacturer) and the various providers of logistics services, manages all the processes of the customer supply chain, including courier, freight forwarding and warehousing services. 4PL provider will manage the 3PL providers and those providing services to its clients. Many 4PL providers offer even specialized software as a single interface for working with various companies in the customer's supply chain. In a strategic role, the 4PL serves as the integrator that

brings together the needs of the client and the resources available through the 3PL providers, the IT providers, and the elements of business process management.

5 PL provider - logistics outsourcing company, provides a full range of services through the use of global information and technology space. A sort of "virtual" logistic partner in whose hands all the information about the logistics capabilities of market participants and a high-tech IT-product that allows you to build the most optimal supply chain. A typical example is Amazon.com.

In the Fig. 1.3 all five logistics service providers are shown in the hierarchical way. It could be seen the tendency of increasing added value and key competences and decreasing resource intensity.

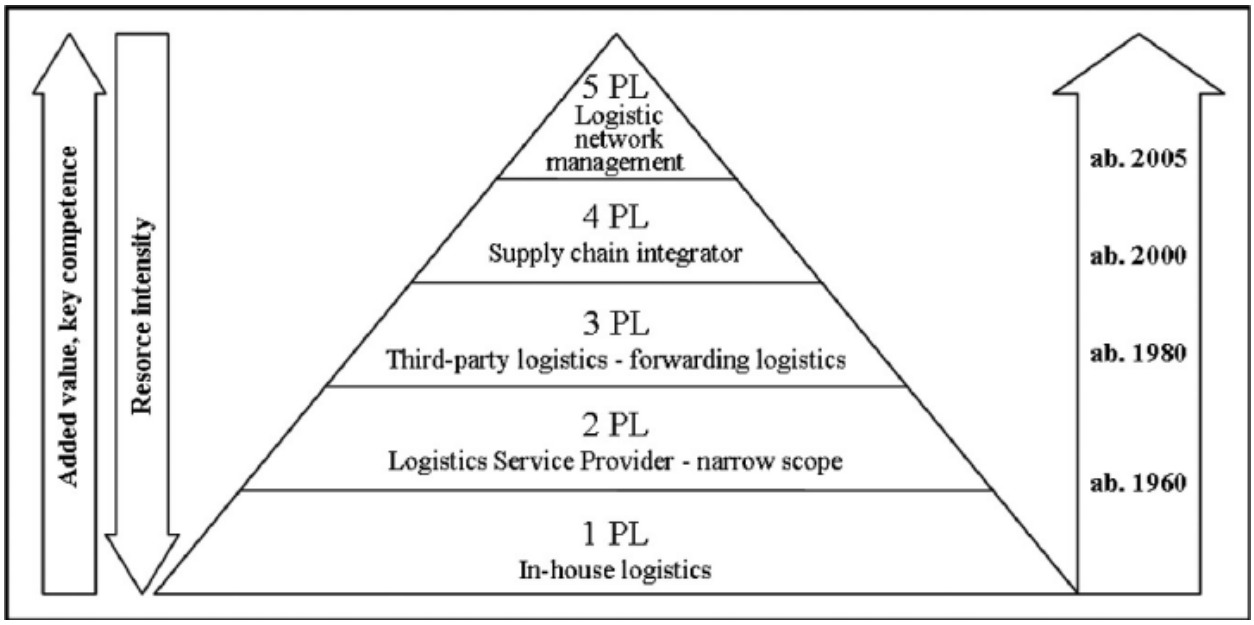

Figure 1. 3 Service providers for supply chain management

(Kozlak, 2009)

1.2.3 Lean and agile supply chains. The final step which manager has to considerate is identification of supply chain strategy. Regarding definition of Hugo, Badenhorst-Weiss and Van Biljon of supply chain strategy, particular definition is invented. Supply chain strategy is a part of overall strategy, it does not go aside from company's strategy of marketing and the product segmentation strategy, has to meet customers needs and take into account competitors supply chain strategy.

In supply chain management exists two generic strategies, they are called "Lean" and "Agile", but also exists a combination of this two terms called "Legile".

Lean is a supply chain term defined as the enhancement of value by the elimination of waste' (Womack & Jones, 2009). Summarizing authors opinion exact definition is created: Lean supply chain strategy - the concept of supply chain management, which is based on TPS (Toyota

Production System), the theory of lean production with the main aim of continuous improvement through the elimination of any action which is not bringing value-added product. In other words, it is based on cost reduction.

Lean supply chain includes seven basic principles:

1. Make all looses equal to zero
2. Make the process of acquiring the goods understandable to all members of the supply chain
3. Assess the possibility of reducing order cycle
4. To achieve uniformity of the materials flow and information flow
5. Increase the speed of turnover and reduce the range of products
6. To make work of all participants in the supply chain coordinated
7. Focus on the total costs in the supply chain

Many firms have implemented this strategy and reached success and advantages over competitors, but this strategy is low human integrated and also characterized like repetitive manufacturing.

Agility is a comprehensive response to the business challenges of profiting from rapidly changing, continually fragmenting global markets for high-quality, high-performance, customer-configured goods and services (Iskanius, 2009). Agile supply chain strategy is more adaptive to different demand fluctuations, it can react quickly on changes in customers needs. As El-Tawy & Gallea, (2011) said agility main objectives are based on business practice, competition, strategic response, building defences against competitors and innovation. Agile strategy is essential while company is operating a lot with individual customer orders, because using this strategy customer would be satisfied faster.

Leagile supply chain strategy is a combination of agile and lean strategies.

This system can be defined as ‘a system in which the advantages of leanness and agility are combined (Krishnamurthy & Yauch, 2009). In this strategy “Lean” minimizes costs, reduce operations and makes work of all participants coordinated whereas “Agility” responds to complexity that might be brought by unexpected changes. Achieving this strategy is complicated process since the real focus of supply chain is to achieve proper combination of two supply chain strategies.

1.3. Types of Supply Chain Creation Models

In general, well-done supply chain creation could be one of the major key success factors for the whole supply chain or particular company in it. Basically, in supply chain management

creation some problems appear which might be solved using centralized and decentralized creation models. These two models are basics in forming supply chain of any company in any sector.

Centralized creation model: in organizations with centralized supply chain, a corporate-level department provides all decisions and has control over purchasing throughout the organization. Also centralized organizations have an ability to influence process and technology decisions, leverage corporate spend and drive standard sourcing, and that lead to economy of scale, that improve operational efficiency. Centralized model suits enterprises with very similar business units where most of the requirements are common across business units (Chang, 2000).

In decentralized model, business units and sites are empowered with autonomy and control over supply, process, and technology decisions. In this structure appears lack of bureaucracy because it improves satisfaction at the site- and business-unit level. Such model suits multiple function enterprises that work independently with a high autonomy degree (Chen, 2005).

Plenty of supply chains could be created depending on the structure, purpose, industry and goods, consequently all of them have different peculiarities. In the current work supply chain of the following structure would be described, Fig. 1.4.

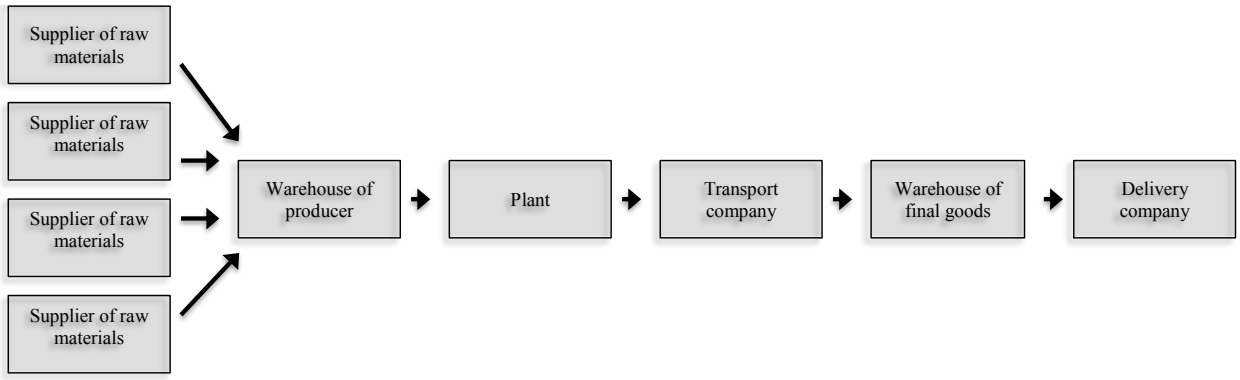

Figure 1. 4 Considered Supply Chain

(Author, 2016)

In the current supply chain producer of final goods has plenty suppliers of raw materials, since it produces different kind of products. All raw materials are stored in the warehouse of supplier, which is situated near by plant. Next element of the supply chain is a transport company, which is responsible for moving final goods to the warehouse, situated in a chosen region. Further step is unloading and storage service that is covered by company who owns warehouse. And finally, a delivery company is obliged to transport goods to the customer or to the store where everything could be sold.

Chapter 2. Methods of Element's Selection for Supply Chain

The following section starts with brief literature review of methods used for selecting an element in supply chain. What is important to mention, nowadays in literature does not exist a concrete well structured and detailed method of storage service supplier selection. There are only methods which describes how to select warehouse location. Deciding the location of warehouse is a highly critical task as it is accompanied by important investments, characterized by a high degree of irreversibility, and determines the prerequisites for processes such as transportation, handling and warehousing for several years (Goetschalckx & Fleischmann, 2010). In warehouse selection, traditionally, the aim is to identify the best location(s) with respect to cost and performance considerations (Terouhid, Ries & Fard, 2012). Classic distribution location decisions are often based on quantitative models such as mathematical programming (Harris, Mumford & Naim, 2009; Ramudhin, 2008). Nowadays there is a huge number of precise mathematical models which can provide solutions in choosing criteria's and thus calculate the best location of the warehouse. In current work, location of warehouse would probably be one of the criteria, which has to be mentioned and assessed in the method of warehouse selection.

Current overview would be based on the methods of the selection of an element in supply chain. As a primer source of information, various databases were used, where articles were selected from ABS journals. So concerning to literature review three basic and well-known principal categories of supplier selection were identified.

2.1 Elimination Method.

This method of supplier selection in supply chain is rather simple then the others and is very fast to apply. On each step of elimination process, manager eliminates from the list of suppliers, that one which does not satisfy selection rule (existed characteristics). With a "conjuctive" rule (Crow, 1980), that supplier which mark with a respect to criteria is lower than the minimal required is eliminated. Finally, the suppliers which satisfies minimum level of criteria goes to the final round and manager is choosing the one, which on his personal opinion suits the best. Also exists, "lexicographic" rule (Wright, 1975), where the most significant criteria to the manager's opinion is chosen, and all the suppliers are measured by exact criteria. If one round is not enough the procedure repeats, but according to the choice of the second important characteristic (Benyoucef, 2003).

2.2 Optimization Methods.

Exact method is based on the mathematical modelling procedures, which are increasing day to day, the purpose is to optimize an objective function, which can be presented by a single criterion of number of criteria. In a single case there is one criterion which retains the cost as the most significant. If that criterion is cost, then all costs are computed, the winner is the supplier which have is the lowest price (Timmerman, 1986).

Multi-criteria optimization is more difficult to apply and model as well. There are different mathematical models which helps to solve the problem of choosing the best supplier. There is no particular need to explain in details all existing modelling programs so the followed logic would be described further. In a multi-criteria situation each criterion is provided with a weight. That weights shows how important is the criterion. Weights are usually provided by programing software of by experts. Finally, the the supplier which has the best mark compared to the total of the weight criteria wins.

AHP (Analytical Hierarchic Process) approach is the basic and crucial in optimization methods (Saaty, 1980), the weight of each criterion is determined by a binary comparison method. Each supplier's mark is calculated by comparing suppliers with respect to each criterion. Detailed explanation of current method is provided.

Analytical Hierarchic Process - mathematical tool systemic approach to complex decision-making problems. AHP does not prescribe to the decision maker (DM), any "right" decisions and allows him to interactively find such an option (alternative), which is well in line with his understanding of the nature of the problem and the requirements for its decision. Analysis of the problem of decision-making in the AHP begins with the construction of a hierarchical structure, which includes the goal, criteria, alternatives, and other factors considered influencing the choice. Every element of the hierarchy can represent different aspects of the problem, and in the account can be taken tangible and intangible factors, measured by quantitative parameters and qualitative characteristics, objective data and subjective expert assessments. The next step in the analysis is to define the priorities that represent the relative importance or preference elements of hierarchical structure, using paired comparisons procedure. Stretch priorities allow reasonably compare diverse factors, which is a distinctive feature of the AHP. At the final stage of the analysis the synthesis of (linear convolution) is carried out on a hierarchy of priorities. As a result, the priorities of alternatives are calculated relative to the main goal. The best alternative is considered to be the maximum priority value.

To drive AHP approach managerial judgments have to be used, which are done in pair-wise comparison of items on an exact level with respect to the impact on the other level. Pair-wise

shows the importance of one item among another. There are plenty of scales which might be used for quantifying managerial judgments, example is given on the Tabl. 2.1.

Table 2. 1 Characteristics Measurement Scale (Ahmetov, 2001)

The range of the relative importance	**Factors**
1	Equal importance
3	Moderate superiority of one over the other
5	A significant or strong superiority
7	Very strong superiority
9	Perfection
2,4,6,8	The intermediate solution between two adjacent judgments
Inverse the value of the following numbers	While comparing one activity to another to get one of the above numbers (e.g., 3), the comparison of the second type of activity with the first obtain reciprocal (e.g., 1/3)

The choice of the scale determined by the following requirements:

- The scale should enable to capture the difference in the feelings of the people, when they carry out the comparison, to distinguish between shades of feelings as much as possible, that people have.
- The examiner should be assured in all the gradations of their judgments at the same time.

As T. Saaty noted current scale is most appropriate to use and its minor modification is better than all other scales. It could be added that the current method of paired comparisons and this scale is extremely well adapted to the peculiarities of human information processing.

In current modification, as in the classic version of the method of paired comparisons, compares the studied factors together. Moreover, in this method, the factors are compared in pairs with respect to their effects ("weight", or "intensity") for a total for their characterization. Suppose that a particular problem is necessary to determine the composition of an object. And let A1, A2, ... , An, are the main factors determining the composition of an object. Any element in the pairwise comparison matrix above a_{ij} is a positive number, which shows at how many time weight of an object A_i is bigger than A_j. Then, to determine the structure of the object is filled with a matrix of pairwise comparisons, Tabl. 2.2.

Table 2. 2 Pairwise Comparison (Ahmetov, 2001)

	A1	A2	…	An
A1	1	a_{12}	…	a_{1n}
A2	a_{21}	1	…	a_{2n}
…	…	…	…	…
An	a_{n1}	a_{n2}	…	1

Meanwhile, exists a flexible interactive decision support system (DSS) APIS (APIS – Aggregated Preference Indices System) which is a software for decision-making under uncertainty (Hovanov, 1998). DSS APIS is a universal flexible effective tool for multi-criteria decision-making under uncertainty with the use of nonnumeric, inexact, and incomplete information.

The structure of Aggregated Preference Indices method (which is realized in DSS APIS) is a special case of general structure of Aggregated Indices Method and consists in four successive steps (stages). Such sequence of operations (steps) for constructing of general estimations of alternatives' preference is named APIS Project. The steps of a APIS Project are special cases of above-stated general case, and may be interpreted in a analogous manner: (0) alternatives, attributes, and attributes values fixation; (1) monotone single preference indices construction; (2) additive aggregative function selection; (3) weight-coefficients estimation by uncertain information. The final step of getting of output data of an APIS Project may be marked out: (4) Calculation of aggregated preference estimations for alternatives (Hovanov, 2005) .

The main advantage of DSS APIS over another well known decision support systems just consists in its ability to take into account different types of uncertain information on weight-coefficients. Namely, APIS works with the next types of uncertain information (Hovanov, 2005).

- Non-numeric information on weights
- Non-exact information on weights
- NNN-information on weights (non-numeric, non-exact (inexact), and non- complete (incomplete) information)
- indirect uncertain information on weight-coefficients
- Non-numeric information on aggregated preference estimations
- Non-exact information on aggregated preference estimations
- NNN-information on aggregated preference estimations – (non-numeric, non-exact (inexact), and non- complete (incomplete) information)

There are many different variants to exploit the potentialities of DSS APIS, but the next three

typical applications modes may be recommended as use-proven tools for simple decision of complex practical problems in multilateral decision-making under uncertainty.

- Synthesis of aggregated preference estimations
- Analysis of aggregated preference estimations
- Joint analysis and synthesis of aggregated preference indices

2.3 Probabilistic Method.

Decision in supplier selection problem usually is handled in a relatively routine fashion, because of a probability of customer's making an error, however there is a high probability that relatively inappropriate supplier will be selected, thus it will directly affect customer. Also there is a high probability that selected supplier is appropriate for the original purchase order, but not for the modified contract.

With respect to the method called "Payoff Matrix" (Soukup, 1987) a certain number of future scenarios could be defined. All scenarios consist of marked suppliers with a respect to the criteria. Then an overall mark of each supplier is computed, and for example a supplier with a stable mark is chosen, according to the various scenarios Tabl. 2.3.

According to (Soukup, 1987) there are three categories of supplier selection decisions:

- All suppliers are similar under all foreseeable circumstances, with small differences in performance, decision is handled routinely.
- All supplier differs significantly; one supplier is superior under all conditions.
- Supplier under one circumstances will not be the best under another circumstances. So all suppliers differ significantly.

Table 2. 3 Classification of supplier selection decisions (Soukup,1987)

Condition	Probability of error	Consequences of error	Decision mode
Suppliers are similar under all conditions	High	Very small	Routine
Suppliers differ significantly, one supplier superior under all conditions	Low	High	Routine
Suppliers differ significantly, best supplier depends on future conditions.	High	Unknown: may be very high	Complex: requires thorough analysis

To sum up, there are three methods of a supplier selections and each of them have their advantages and disadvantages. Since warehouse is a supplier of storage service in supply chain, in current work it would be assumed that existing selection methods might be applied. Nevertheless, storage service supplier selection is extremely tight and complicated procedure, with a lot of different characteristics and steps included. Thereby Aggregated Preference Indices System (APIS) method seems to be most appropriate for storage service supplier selection, as it can provide accurate information with a high level of uncertainty.

Chapter 3. APIS Technique Improvement for Storage Service Supplier's Selection.

3.1 Storage Service Definition and Classification

Warehouse is one of the most important element of logistics system, although not every company management spend a lot of effort on the its selection. In current work, both terms storage service supplier and warehouse assumed to have the similar meaning. At all stages of product flow, starting from the primary source of raw materials and ending with the end user, there is an objective need for a specially equipped areas for holding stocks. This explains the presence of a large number of various types of warehouses. The movement of products through the warehouse increases the cost of goods, due to the associated costs.

In practice, the warehouse can be an open area, where such feedstock as coal, ore or vegetables stored in piles and also some modern facilities to ensure the necessary conditions for storage, for example, frozen foods.

Experts use several different terms for warehouses, often called them as distribution centres and logistics centres. Distribution centre - is a place of finished products storage on the way to the end consumers, while logistics centres store a wide range of products and may be at different place in the supply chain. Warehouse - is any place where the materials are stored, prepared for consumption and supply during the passage through the supply chain. Warehouse should be considered as an integrated component of the supply chain, because its characteristics directly affect the efficiency of the transport and distribution activities, determine inventory management and others. The main purpose of the warehouse - the concentration of stocks, their storage and business continuity and rhythmic execution of customer orders. But in addition to storage, many organizations are using storage as a convenient place to perform other types of work.

Warehouse aims:

- Goods secure storage in the required conditions and with minimal damage
- Ensuring a high level of customer service
- Minimizing costs and high quality of operations
- Effective control of the movement of materials
- Rapid implementation of warehouse operations
- The ability to store the entire range of necessary materials

3.1.1 Role of warehouses in Supply Chains. Warehouses plays vital role in the supply chain, consequently they have different roles and types of usage Fig. 3.1. *Raw material and*

component warehouses. Often that kind of warehouses holds raw materials and situated close to production plant. *Work in process warehouse*. Holds partly assembled products or goods at various points along production line. *Finished goods warehouse*. Hold inventory used to balance and buffer the variation between production schedules and demand. For this purpose, the warehouse is usually located near the point of manufacture and is often characterized by the flow of full pallets in and out. A warehouse serving only this function may have demands ranging from monthly to quarterly replenishment of stock to the next level of distribution. *Distribution warehouses and distribution centres*. Consolidate and accumulate goods from different points of producer, or various firms to combine transfer to common customers. Regularly such warehouse locates central to the production plant and customer. Warehouse is responding to week or month orders. *Fulfilment warehouse and fulfilment centres*. Receive, pick and transfer small orders for individual customers. *Local warehouses*. Distributed in a film in order to shorten transportation distances to permit rapid response to customer demand. Often one piece is picked and at the same day is transferred to the customer.

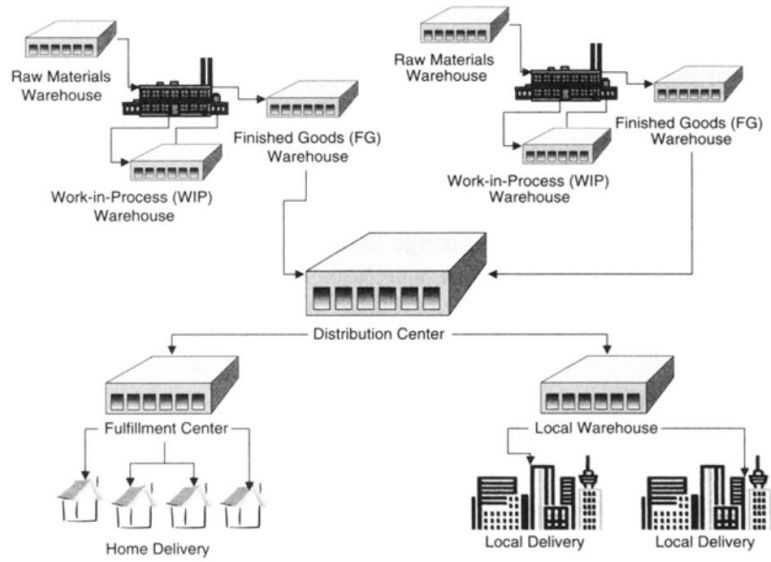

Figure 3. 1 Roles of Warehouses in Supply Chain Management

(McGraw Hill, 2002)

Warehouses are characterized by:

1. By size, from small rooms to giant warehouses covering an area of hundreds of thousands of square meters.

2. By a height of storage: some cargo is stored not above human growth, other requires special devices that can lift and precisely put the goods in a cell at a height of 24 m and more.
3. Design: placed in separate rooms (closed), have only the roof or the roof and one, two or three walls (semi-closed). Some loads are stored even outdoors in designated areas in the so-called open warehouses.
4. By necessity: create and maintain a special mode, for example, temperature, humidity.
5. By the number of users: the warehouse is intended for storage of the goods of one enterprise (individual use), and collective use.
6. According to the degree of mechanization of warehouse operations: non-motorized, mechanized, complex-mechanized and automated.
7. According to the possibility of delivery and export cargo via rail or water transport: near-station or port warehouses (located on the territory of the railway station, or port), a railroad (with decal railway line for supplying and cleaning cars) and in-depth. In order to deliver the cargo to the in-depth station, you must use the road or other mode of transportation.
8. According to the latitude range of the stored goods: specialized warehouses, mixed or variable.

All in all, according to CAN Logistics, three main types of warehouses exist. *Public Warehousing*: Space is leased month-to-month for a fixed fee per square foot. The advantage of public warehousing is that there are no long-term commitments. The disadvantage is that this option is often the most expensive per square foot. *Contract Warehousing*: Space is leased for a fixed term, usually six months or longer. The cost per square foot is generally better than for public warehousing, and the space often comes with features such as racking, forklifts, dedicated docks and 24-hour security. *Private Warehousing*: Space is owned and managed by the business. The main advantage to owning the space is the potential for total control of all aspects of the operation, including leasing out unused space. The biggest downside to private warehousing is the capital needed to acquire the space and the cash flow to manage it.

3.1.2 The main functions of a warehouse. *Conversion* of the products from producer to the products specialized to the consumer, in accordance with demand. Some producer's products are needed to be shaped, packed and etc. The required range of stock contributes to the efficient implementation of customer orders and the implementation of more frequent deliveries and to the extent that you want to the client. Warehousing and storage allows to *align the timing* difference between the output of production and consumption and makes it possible to carry out continuous production and supply on the basis of created inventory. *Transformation of products*. Any storage processes, at least three kinds of products: input, output and internal. In stock there is the

dismantling of some consignments or cargo units and other formation, unpacking of goods, formation of new cargo units, their packaging and bagging. *Reduce the cost of transportation*. Many consumers bought from the stores of the party "less than wagon" or "less than the trailer", which greatly increases the costs associated with the delivery of such goods. In order to reduce transport costs warehouse can perform unitization, i.e. association of small shipments to multiple customers to a full vehicle load. Another form of association is the case when the customer needed the product from different suppliers (Fig. 3.2). The opposite operation - split wholesale - also allows you to reduce cargo transportation costs from one source to multiple customers in a specific territory (Fig. 3.3). *Provision of services*. An obvious aspect of this feature is to provide customers a variety of services, providing the company a high level of customer service, for example:

- Preparation of goods for sale (packaging products, container filling, unpacking, etc.)
- Test instrumentation and operation of the equipment, installation
- Giving the product presentation, pre-processing (e.g., wood);
- Execution of works related to the reduction of commercial risk
- Finishing products to the desired condition, labelling, packaging, preparing products for retailers, so that they can immediately put it on sale
- Forwarding services

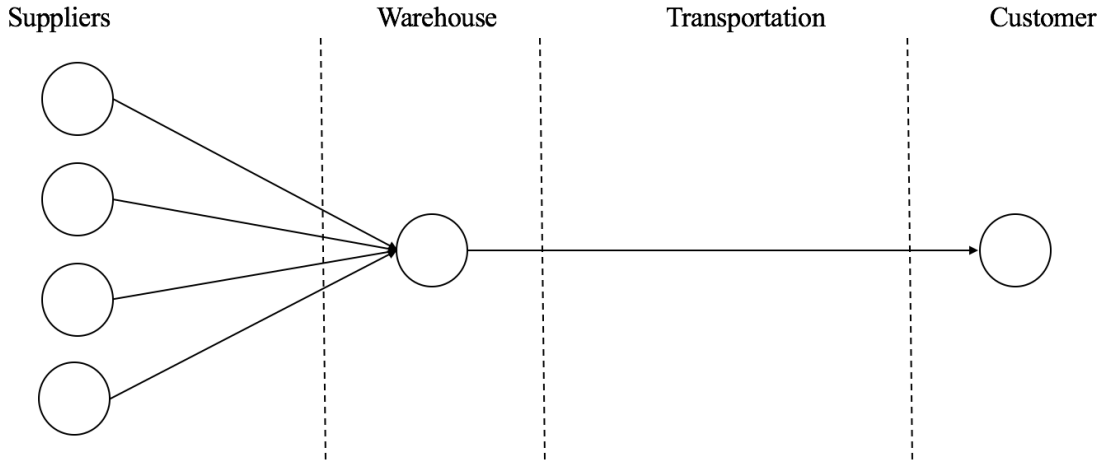

Figure 3. 2 Warehouse Usage for Reduction of Transportation Costs. Unification Process

(Lankina, 2006)

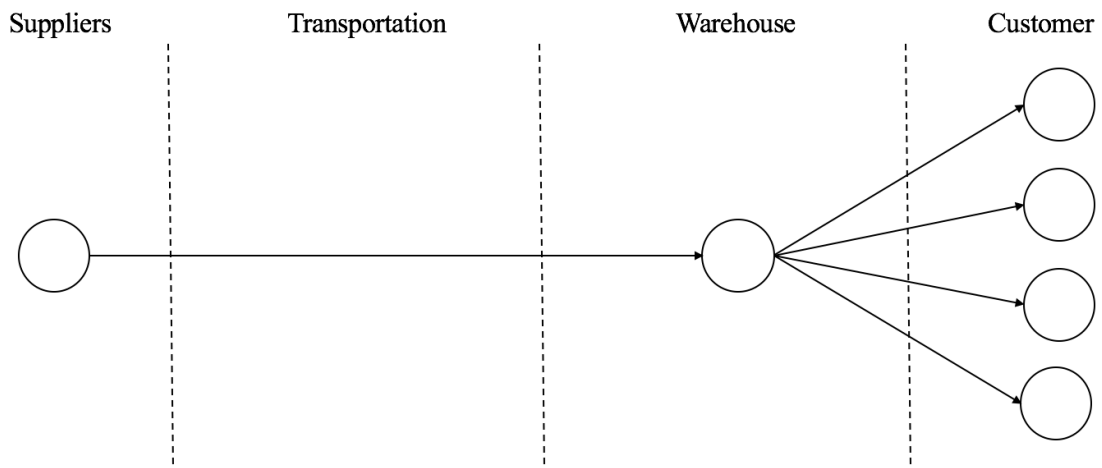

Figure 3. 3 Warehouse Usage for Reduction of Transportation Costs. Wholesale Split

(Lankina, 2006)

3.1.3 Warehouses classification. Warehouses may vary in size, design, degree of mechanization of warehouse operations for warehousing mind on a functional purpose. Warehouse may be a link in the chain of movement of products of industrial purpose (raw material stocks, finished goods, specialized stores, etc.), or be in the area of movement of consumer goods (warehouses). The most popular is the classification based on the technical parameters of the areas of infrastructure development, including utilities. Now there are 4 types of warehouses named by classes «A», «B», «C», «D». Nowadays exists two classifications of warehouses made by Knight Frank (presented in Tabl. 3.1) and Swiss Realty Group.

Knight Frank - one of the leading companies in the field of real estate consulting. Headquartered in London, it has more than 370 offices around the world, including Europe, Asia, America, Russia, Africa, Middle East, etc.

Swiss Realty Group - Swedish investment company engaged in marketing, evaluation, construction and reconstruction of real estate services in the field of architectural design and comprehensive market research, advice on rental and sale of office, retail, warehouse, industrial real estate, land, residential and suburban real estate

Table 3. 1 Knight Frank Classification (Knight Frank Official Web-Page)

Characteristics	Classification					
	A+	A	B+	B	C	D
New one floor warehouse building constructed from light metal panels preferably a rectangular shape and the distance between the spans not less than 24 meters.	+	+				
Single storey warehouse building, preferably rectangular newly built or reconstructed			+	+		
Capital Industrial building or insulated hangar					+	
Basements, unheated production facilities or hangars						+
A smooth concrete floor with anti-dust coating, with a load of not less than 5 tons / sq. .	+	+	+			
The high of ceilings is not less than 13 meters, allowing to install multilevel racking (6-7 tiers).	+					
The high of ceilings is not less than 10 meters		+				
The high of ceilings is not less than 8 meters			+			
The high of ceilings is not less than 6 meters				+		
The high of ceilings is not less than 4 meters					+	+
Climate control inside the warehouse	+	+	+			
Central heating				+	+	
Availability of a fire alarm system and automatic fire extinguishing system.	+	+	+	+	+	*
Availability of of the ventilation system.	+	+	+	+	*	*
Availability of security alarm system and CCTV system.	+	+	+		*	*
Autonomous electric substation and heating module.	+	+	+		*	*
Availability of a sufficient number of dock shelters with dock Levels (not less than 1 per 500 square meters).	+	+	+	+		
Availability of parking for huge vehicles	+	+	+	+		
Availability for manoeuvring for huge vehicles	+	+	+	+		
Presence of the office space at the warehouse	+	+	+	+		
Availability of ancillary facilities (toilets, showers, auxiliary facilities, lockers for the staff).	+	+	+	+		
Availability of accounting systems and personnel access control	+	+	+	+		
Fenced and guarded illuminated landscaped area 24/7	+	+	+	+		
Located close to the highway	+	+	*	*		
Professional and experienced management team	+	*	*	*		
Railway connection to the warehouse	*	*	*	*		

Swiss Realty Group Classification

The first “A” class consists of buildings designed as a storage. It is very important that the equipment, decoration, proximity automobile road network, redevelopment under any kind of load, high speed operations with cargoes and reliability of storage must comply with the principles of modern warehouse logistics. Next classification is carried out in the absence of any parameters that correspond to the class “A”.

In the second class “A” consists of 20-30 summer reconstructed buildings or premises. They are similar to the “A” class premises characteristics, but differ in their location.

Class “B +” consist of buildings constructed in the 90s, but did not have a few parameters which own the class “A”. Due to the fact that, chaotic growth of investments appears in the construction of warehouses, such facilities are presented in the Russian market in large quantities.

Class “B” consist of buildings constructed in the 70-80's. Such buildings usually require some repair works and financial investment. It may be necessary to install a modern security alarm, replace or repair the floors and more.

Fifth class - a class “C”. It includes areas that are not planned and are not used as warehouses. These include taxi parking stations, vehicle maintenance stations and similar manufacturing facilities. These buildings require substantial upgrading, technically and in the construction plans.

Class Six – “C”. These include old buildings built in 30-60 years. This may be the former premises of grocery distribution centres and vegetable storage. Such buildings do not meet current operating requirements.

Class “D” are not intended for use in storage order and space. Such buildings from an economic point of view are easier to demolish than to repair.

Classes “A”, “A+” and “B+” in both classifications are relevant for the current work, since only that kind of warehouses provide proper service and have standards which are required for the majority of big and successful productive companies with a well organized supply chain.

3.2 Practice of Storage Service Supplier Selection

Mainly there are four general steps in choosing warehouse (Kenneth, 1997).

- Learning of the source of supply
- Evaluating alternatives
- Final selection process
- Monitoring decision results

That steps are basic and more detailed information about operations is provided further in the work. Searching for a third party warehouse and the overall process of contract warehouse selection is pretty difficult process, where all details are important and everything should be considered. The provider company should be experienced in the industry of warehouse logistics, and also should specialize only on that business, and not an add to their main business, for example shipping. Exactly that kind of provider would help customer to build sustainable and effective supply chain. Making a bad choice in selecting warehouse provider could badly affect company supply chain.

Purpose Identification. First of all, top-management of a company and logistic warehouse manager have to understand whether it is reasonable to rent a third party warehouse. They are analyzing decision from economic, strategic and social points of view. In some situation it could be more efficient to transport goods from the nearest warehouse, instead of renting a new one. So prediction of demand is analyzed as well.

Information Gathering. Once company has decided to rent a contract warehouse and not to build their own, company is collecting information about potential providers on the market and creates a scope of work they would like to be performed by warehouse provider. Also company is getting information answering certain list of questions, it helps them to understand further needs and details:

- What are risks of spoilage, breakage, or theft?
- How is the product packaged?
- How is the product received?
- What are the planned shipping and receiving volumes, fluctuation peaks and valleys?
- How will orders be transmitted to the warehouse?
- What is the average order size, average lines per order, units per line?
- Are any specialized receiving or shipping services required?
- Approximate costs

- How often will the warehouse receive shipments?
- How often will the goods stored be accessed?
- Does the business require specialized services such as ultraclean storage, cold storage, a communications system, the ability to generate documentation?
- How long will goods be housed?
- Will goods enter once and remain for an extended period (storage), or will there be many shipments received and sent from the warehouse?
- Is this need temporary or permanent?
- Does the warehouse need to be close to a transportation corridor such as a rail line or a port? Or does it make more sense to have a warehouse located near a primary customer or the company office?
- As fuel costs continue to rise, the location of warehousing is not just a matter of convenience, but is strategic to the profitability of the enterprise

Narrow the Field. Finding a third party warehouse provider takes lot of time. Usually companies are using "Request for Information query process" (standard business process which aim is to collect written information about the capabilities of various suppliers) and thus narrow the field to three or five candidates. Company is looking for experienced providers, which are handling similar products, it does not have to be exactly similar goods but at least from the same industry. Infrequently companies are sheering their personal opinion and experience of their warehouse logistics provider, in other words advertising it. That kinds of recommendations plays huge role on this market. It is often in Europe, that companies are using consulting service, to solve problem of selecting third party provider.

Develop a Request for Proposal (RFP). As soon as company clarify steps above they are creating RFP document, where they clearly describe the scope of work and requirements for both physical volumes and service. That requirements are driving final decision. Next stage is sending RFP to the providers, usually it takes from two to four weeks to receive a respond. That process might be done by direct contact or through the tenders.

Evaluate Responses. Final step is evaluation of potential warehouse providers. Team responsible for selection process is reviewing the written proposals received from suppliers, then ideally should hear their oral presentation about warehouse and finally visit appropriate provider. Important point in this step is that primary level of quality is privileged on the price. Team is paying a lot of attention to the information system interfaces of warehouse provider. While evaluating critical importance has several factors:

- coverage (national, regional or local)
- inventory management and control

- order acceptance and processing
- pick and pack operations
- order fulfillment
- assembly/packaging/value-added activities
- in voicing, credit and collection
- presort capabilities
- returns handling
- manifesting
- operational management structure
- organization and strategic direction
- financial stability

All regular steps of warehouse selection process in details were described above, further in the work would be covered Russian practices of warehouse selection, to realize what are the difference.

3.2.1 Russian market practices of selecting warehouses. In the current passage would be described the existing ways of warehouse selection process in the field of construction materials, in Russia. All information for that part was covered by personal interview of a logistics managers in leading Russian companies.

First of all, company get a clear understanding that there is a particular need for a new warehouse. It could happen because of several reasons: expansion to the new regions, running out of agreement with current warehouse, spoiled relationships with current provider, current provider has a bad service (as determined by the results of the visits, audits, inventories of number of complaints from customers, carriers, employees from related departments) and claims to the exact storeroom (failure to comply with terms of the contract, the problems with the construction of legitimacy, lack of space, geographical disadvantages, in accordance with business requirements), force majeure (flood, caught fire, theft). According to the all details which are needed all process is organized in 8 steps (Ivanov, 2006).

1. Collection of initial data on goods needed to be transported, the storage volume, operating performance and standards.
2. Make logistical calculation for the needs of storage capacity, zoning, shelving and equipment needed.
3. Prepare and send out “technical requirement” (TR) for the selection of a warehouses for rent.

4. Visit potential warehouse to check everything. (What is important that warehouse is not only inside equipment and storage place, but also outside area, which customer is probably paying attention on.)
5. Count on each option needs of shelving, technology and materials for handling equipment.
6. Calculate rent budget expecting specific and absolute rent figures.
7. Select the option on the basis of integrating logistics and economics indicators.
8. Sign a contract of renting a warehouse on a certain amount of time.

Following paragraph is clarifying term "technical requirement" (TR), it is a special document for choosing warehouse which is based on the basis of current needs and volumes, taking into account possible changes in business needs and market requirements, production planning, sales and a product of a storage. Usually TR includes concreate area in square meters, required floor, internal temperature, central heating, appropriate liquidity, height of ceiling (not less than…), light, all security conditions, license of firefighters, parking, adopted for trucks, size of a gate and so on.

In the above paragraphs all steps of choosing warehouse were described in details, but nothing was mentioned about the service on the warehouse itself. To get deeper into the problem, an in depth interview with general warehouse logistic manager of company Saint-Gobain was conducted.

During the interview were discovered that, service operations in the warehouse are incredibly important and it is long procedure to agree on it with warehouse service provider. Since suitability of technical requirements of warehouse is not affecting the supply chain so intense as it could make the service provided. Advanced providers could make client's supply chain stronger and more competitive on the market, whereas low quality service would gain additional costs to the client. It happens very often because of the time delays of loading and unloading trucks, not efficient location of the goods in the storage place and extremely long service because workers are not able to find and transport goods rapidly. To solve this problem customer should create an additional contract, specified on the exact situation and specification. Particular contract should standardize all the conditions of service provided on the warehouse. It would include fees, penalties and other responsibilities for both sides, customer and warehouse service provider. In current work it is supposed that warehouse and storage service provider is the same company. Existing problem is supposed to be solved in the following parts.

3.3 Research Methodology

Current research is designed to achieve several tasks:

- to identify relevant characteristics in the process of storage service supplier selection according to in-depth interview
- to assess the importance of different characteristics in the process of storage service supplier selection according to expert opinion
- to identify most important characteristics in the process of storage service provider selection
- to create a method for storage service provider selection

3.3.1 Research design and sample profile. A mixed-model research was used in this work, which combines quantitative and qualitative data collection techniques and analysis procedures as well as combining quantitative and qualitative approaches at other phases of the research. (Saunders, 2009). On the first stage of research and data collection, an in-depth interviews were conducted with the logistics managers of various companies to identify which characteristics are relevant for the process of store service supplier selection. Interview covered narrow group of logistics managers which were found appropriate for current research. On the second stage, an expert estimation survey was conducted to analyze the importance of factors, in the process of selecting storage service provider. Questionnaire was send directly to the logistics managers of different companies of constructing materials industry. The sample included warehouse logistics managers, who are responsible for choosing warehouses in their enterprises, the main purpose of survey was to get understanding of the importance of the chosen factors. The survey lasted for three weeks, during which 12 responses were collected, which is enough for an expert estimation. Questionnaire was done in English and Russian languages, so foreign respondents were offered with English version. The questionnaire consisted of nine comparison-base questions and twenty-seven characteristics. All characteristics were combined by 4 major groups. The respondents were supposed to express their opinion about comparative importance of each characteristic using a 5-point Likert scale. 5 points means that the characteristic plays a vital role in decision making; 3 points means that the characteristics affects the decision making; 1-point means that characteristic has no evident role in decision making.

After collecting information from the sample of my interviews, an excel table with the importance of characteristics were constructed, Appendix 1. On the next stage three representative warehouses were chosen and assessed with the quantitate information (price characteristic) and qualitative information (experience on the market) using the scale from 1 to 7 because it provides more detailed information, where 1 point- means that quality is non acceptable; 3 points- means

that quality is low; 5 points- means that quality is good; 7 points- means that level of quality can be assessed as excellent, Tabl. 3.6. On the final step all collected information was used in the special decision supporting system called Aggregated Preference Indices System (APIS), which is used for multi-criteria estimation and decision making under uncertainty. Exact tool was used first of all because it can measure accurately weights of all criteria used and secondly it can calculate consolidated indicator with qualitative and quantitative characteristics.

3.3.2 APIS description. APIS is based on a method of aggregates (SMEs), the essence of which is to "convolution" many evaluations of a complex object into a single assessment, which is a composite indicator that synthesizes the individual indicators which characterize the quality (efficiency, reliability, safety, profitability, utility, preference etc.) of all multiparameter objects; complex technical systems; variants of administrative, organizational and investment decisions; consumer goods and services; financial and economic projects; individual experts opinions and so on.

A simplified scheme of the construction of a composite indicator of the object can be represented as a sequence of the following steps. A certain vector $x=(x_1,...,x_m)$ of baseline characteristics is formed, each of which is necessary, and all of them together - sufficient for a complete, comprehensive evaluation of a certain quality of the objects (Hovanov, 2005).

1. A certain vector $q=(q_1,...,q_m)$ of individual indicators is formed ,which seems to be a function $q_i = q(x_i;i)$, $i=1,...,m$ of corresponding initial characteristics of the object under study and evaluate, using m various criteria.
2. The form synthesizing function is selected $Q(q)$, associated with a vector of individual indicators $q=(q_1,...,q_m)$ aggregated estimation (combined figure) $Q=Q(q)$, which characterizes the object under study at all.
3. The value of the parameter vector is defined $w=(w_1,...,w_m)$, interpreted as the weights indicators ("weight"), which defines the degree of influence of individual indicators $q_1,...,q_m$ on the summary evaluation Q.

Thus, assuming that the researcher has made a selection of baseline characteristics evaluated object, the method described in the consolidated indicators (SMEs) should pay attention on the following three stages of formation of the composite index:

1) forming a vector selected indicators $q=(q_1,...,q_m)$;
2) the selection of the synthesis function $Q=Q(q)=Q(q;w)$;
3) determination of the weight vector $w=(w_1,...,w_m)$.

The choice of weighting coefficients is the most responsible and difficult stage of construction of the composite indicator because, usually, the researcher does not know the exact numerical values of the weights. In such situations, APIS allows to work with non-numerical, inexact and incomplete weight information.

It should be noted that non-numeric (ordinal) and imprecise (interval) weight information and summary metrics can be, incomplete, not all the weights or all aggregates are included in the non-trivial equality and inequality, components of the system, showing the information available to the researcher (Hovanov, 2005).

The systems implemented with the help of APIS, calculating estimates $\overline{w}_i(I)$ and their accuracy $s_i(I)$ and reliability $p(i, j; I)$ of the pairwise dominance are displayed by the so-called APIS-chart for weighting factors.

For the formation of a specific decision-making process under uncertainty in the APIS user uses the following types of "input" information:

- information about the values $x_i^{(j)}, i = 1,...,m$, $j = 1,...,k$, m baseline characteristics of x_i for the k objects described thus vectors baseline characteristics $x^{(j)} = (x_1^{(j)},...,x_m^{(j)})$, $j = 1,...,k$
- information about the choice of increasing and decreasing functions $q_i = q_i(x_i)$ and their parameters (MIN_i, MAX_i, P_i) to generate values for $x_i^{(j)}$ baseline characteristics $x_1,...,x_m$, values $q_i^{(j)}, i = 1,...,m$, $j = 1,...,k$ and individual indicators $q_1,...,q_m$ for all objects;
- non-numeric (ordinal), inaccurate (interval) and incomplete weight information and summary metrics.

After the insertion of all the above information APIS is calculating "output" information of the following types:

- Information about values $\overline{w}_i(I)$ of the weights about their accuracy $s_i(I), i = 1,...,m$ and reliability $p(i, j; I), i, j = 1,...,m$.
- Information of values $\overline{Q}_j(I)$ of aggregates, their accuracy $S_j(I)$, $j = 1,...,k$ and reliability $P(j,l;I)$, $j,l = 1,...,k$.

The main advantage of DSS APIS over another well known decision support systems just consists in its ability to take into account different types of uncertain information on weight-coefficients.

3.4 APIS Technique Specification for the Storage Service Supplier Selection

There is no need in detailed explanation of all steps of warehouse selection, since the main difference are at the most important, so all preparation steps and data collection steps as well as final step of contract signing will not be mentioned. Consequently, all focus will be based only at

three main steps, which are: Elimination by Technical Requirement, Elimination by Service Contract and APIS method selection.

As a first important step of elimination, company has to create a Technical Requirement, based on the goods needed to be stored and send it to the potential storage service providers. Also it could be done through the tender procedure, since it is more clear and reliable process. As a result of Technical Requirement elimination, several companies will leave the sample of potential providers.

On the second stage company has a smaller sample of potential storage service suppliers and second elimination procedure has to be applied. Elimination by Service Contract is vital for the identification of most appropriate supplier, since company has to be confident that level of storage service provider would not be weak and consequently affect the final customer. Contract has to consist of all requirements which company is expecting to receive from storage service supplier, also penalties has to be mentioned if service is done in a wrong way.

Finally, when the potential candidates are selected, last round of selection has to be applied. It consists of APIS software implementation, and measurement of the warehouse characteristics. A detailed description of the method is presented further.

First of all, company has to identify characteristics which are taken into consideration in decision-making process of warehouse selection, they are highly dependent on the industry where company operates. In particular work characteristics were chosen from in-depth interview with logistics managers. All respondents were from companies which operates in construction materials industry, thus all selected characteristics are primary adoptable to the construction sector companies. In the further step, selected characteristics has to be weighted, APIS software can calculate them, but only with respect to their measures and importance. So, primary company managers have to rank characteristics by importance, in current work the importance of characteristics were received with the help of questionnaire, where managers of logistic company were measuring them. That information would help APIS to calculate aggregated indicator more accurately. Secondary, company managers have to assess all selected characteristics of candidates left, qualitative are assessed by 1 to 7 scale and quantitative are measured by their nature, mainly price per quantity. In particular work, three representative warehouses were chosen, and assessed by the author. Finally, company managers will receive one aggregated indicator for each storage service provider and according to it would make a decision. What is more company managers can choose service provider according to the group of characteristics, APIS is providing this information as well. In concrete work, there are four groups of characteristics and four groups of sub-characteristics, which could be seen at Fig. 3.5.

For clarification of the APIS software implementation a concrete example is provided, (Appendix 2, Fig. 3.6,); (Appendix 3, Fig. 3.7,); (Appendix 4, Fig. 3.8,); (Appendix 5, Fig. 3.9)

Four warehouses were chosen and assessed by author, Tabl. 3.6. First of all, four groups of sub-characteristics were estimated by APIS software and exact aggregated preference indices were created, Tabl. 3.2.

Table 3. 2 Aggregated Preference Estimations (Appendix 14)

	Price of services	Safety	Accessibility	Experience
Warehouse A	**0.741**	0.540	**0.820**	0.169
Warehouse B	0.364	**0.680**	0.284	**0.831**
Warehouse C	0.609	0.296	0.750	0.388
Warehouse D	0.255	0.281	0.575	0.419

It can be noticed that Warehouse A is leading in terms of service and accessibility, whether Warehouse B is better in by Safety and Experience characteristics.

As a next step, remaining characteristics of each group were estimated by APIS software, information for assessment were taken from Tabl. 3.2 and Tabl. 3.6, and certain aggregated preference indices of each group were created, Tabl. 3.3.

Table 3. 3 Aggregated Preference Estimations (Appendix 14)

	Financial Characteristics	Internal Characteristics	External Characteristics	Customer-orientated Approach
Warehouse A	0.571	0.586	0.775	0.327
Warehouse B	0.127	**0.894**	0.113	**0.824**
Warehouse C	**0.778**	0.091	**0.899**	0.269
Warehouse D	0.636	0.225	0.477	0.648

From the table above it can be identified that Warehouse B has advantages in internal characteristics and customer-orientated approach, although Warehouse C is a leader by Financial Characteristics and External Characteristics. To sum up, there is no clear solution which warehouse has to be chosen, that's why the final round of APIS estimation was conducted. Where all warehouses are compared to each other with their indicators and importance of characteristics, results are shown in Tabl. 3.4.

Table 3. 4 Aggregated Preference Estimations (Appendix 11)

	Aggregated Indicator	Rank
Warehouse A	0.665	2
Warehouse B	0.259	4
Warehouse C	**0.741**	1
Warehouse D	0.592	3

On the APIS-diagram we can see short and long intercepts of a straight line; an abscissa of a midpoint of a short interval shows an average estimation of a correspondent object, while the interval's length is equal to the doubled standard deviation of the constructed aggregated preference index; an abscissa of a long interval's right end shows the reliability for dominance relation between neighbouring aggregated estimations. Finally, Aggregated Preference Indices System, shows that Warehouse C has to be chosen as a most preferable storage service supplier. Fig. 3.4.

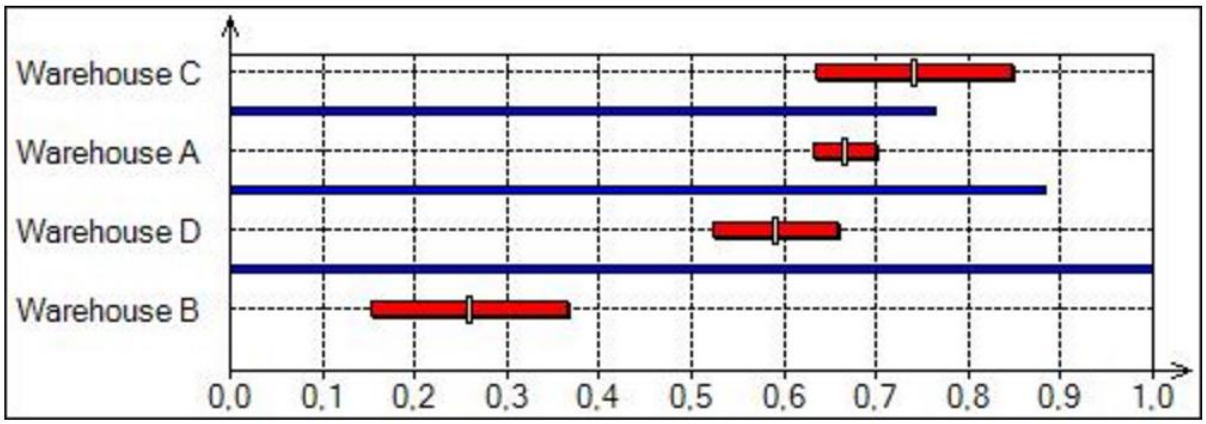

Figure 3. 4 Visualization of Aggregated Preference Indices

(Appendix 11)

Tabl. 3.4 shows that Warehouse C has the highest aggregated preference index which equals to 0.741, on the second place is Warehouse A with indicator 0.665, which is relatively close Warehouse C. Due to information on Fig. 3.4, Warehouse C has wide standard deviation (0,1046), in comparison with Warehouse A (0,0338), Tabl. 3.5.

Table 3.5 Statistics of Alternatives Aggregated Preference Estimations (Appendix 11)

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(Warehouse A)	0,5902	0,7104	0,6650	0,0338	2
Q(Warehouse B)	0,0500	0,4500	0,2588	0,1046	4
Q(Warehouse C)	0,5500	0,9500	0,7412	0,1046	1
Q(Warehouse D)	0,4968	0,7352	0,5917	0,0670	3

In conclusion, it can be stated that, in respect with standard deviation and aggregated preference index, Warehouse C still has to be selected, because standard deviation of Warehouse A is covered by deviation of Warehouse A, consequently both warehouses have the same risk.

Table 3. 6 Estimated Grades of Characteristics (Author, 2016)

Financial Characteristics	Provider 1	Provider 2	Provider 3	Provider 4
Price of rented area	1 m sq. 430 Rur	1 m sq. 550 Rur	1 m sq. 350 Rur	1 m sq. 290 Rur
Financial warranty of warehouse	3	6	7	3
Price of services:				
Storage price	9.90 Rur per Pal/place per day	13 Rur Pal/place per day	11 Rur Pal/place per day	12 Rur Pal/place per day
Loading/Unloading price	110 Rur per Pal	75 Rur per Pal	90 Rur per Pal	120 Rur per Pal
Screening of defective items	5 Rur per product	6 Rur per product	4 Rur per product	5 Rur per product
Internal Characteristics				
Warehouse service machines	3	5	4	7
Area and Height of storehouse	6	7	3	4
Warehouse IT system	5	2	7	4
Safety:				
Access control system	3	7	5	3
Security level	3	7	4	5
Firefighting level	5	5	5	6
CCTV	7	6	5	4
External Characteristics				
Warehouse location	3	5	7	4
Accessibility:				
Ease of access to the warehouse	7	7	7	4
Distance to the nearest highways	6	4	6	7
Distance from the nearest airports, train stations, ports	7	5	7	5
Parking for trucks and other huge vehicles	7	3	5	4
Customer-oriented approach				
Warehouse potential	3	2	7	2
Responsiveness to the client's requirements	5	6	4	6
Client's reviews	6	2	7	2
Experience:				
With the same type of product	5	3	2	6
Experience on the market	3	7	5	4

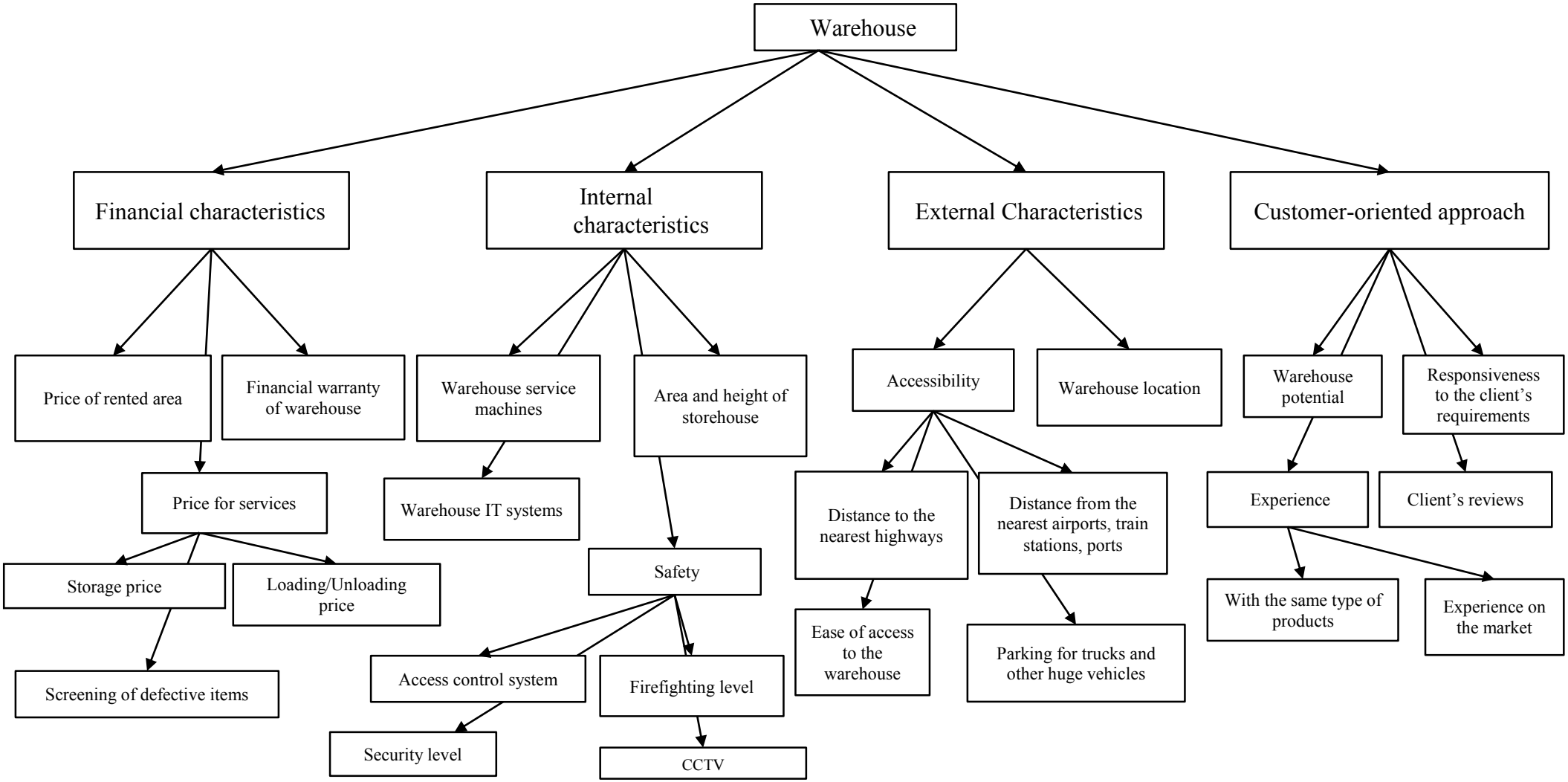

Figure 3. 5 Characteristics of Storage Service Provider

(Author, 2016)

Chapter 4. Storage Service Supplier Selection for Saint-Gobain Company Case

4.1 Saint-Gobain Business and Construction Materials Industry

The case and subject of current research is Saint-Gobain company, the world leader in the habitat and construction markets, designs, manufactures and distributes building and high-performance materials, providing innovative solutions to the challenges of growth, energy efficiency and environmental protection. Saint-Gobain exists on the international market for more than 350 years.

Since there are lack or researches about storage service supplier selection worldwide and none in the industry of construction materials the case of Saint-Gobain was selected. Secondly, Saint-Gobain was chosen because of international perspective, company is presented in 66 countries. All in all, Company owns important roles in the sector of constructing materials, has 7 plants in Moscow and other regions and is continuously expanding to the Russian market.

The company "Saint-Gobain" was founded in 1665 in France by order of Louis XIV as a royal mirror manufactory. "Saint-Gobain" - a world leader in the manufacture and sale of construction products. Nowadays Company headquarter is in Paris, France. President and CEO is Pierre-André de Chalendar. Turnover of "Saint-Gobain" by the results in 2014 exceeded 52 billion euros. This concern owns 1,400 companies, and currently around two hundred thousand employees work for Saint-Gobain worldwide. (Saint-Gobain Company website, 2016).

There are three angels of Saint-Gobain Businesses:

1. Innovative Materials. Comprising the Flat Glass and High-Performance Materials Activities, the Innovative Materials Sector offers a unique portfolio of materials and processes for the habitat and industrial markets.
2. Construction products. The Construction Products Sector offers interior and exterior products to enhance the comfort of buildings and homes, including plaster, acoustic and thermal insulation, wall facings, roofing and pipe systems.
3. Building distribution. The Building Distribution Sector brings to the Group a thorough understanding of customers' needs, whether they are building professionals, private project owners or large companies. It serves the new building, renovation and home improvement markets.

In Russia Saint-Gobain has several offices, they are located in Saint-Petersburg, Moscow, Nizhniy Novgorod, Kazan, Samara, Ekaterinburg, Rostov on Don and Novosibirsk. Company has 7 own warehouse located near the plants. Also company has 4 outsourced warehouses located in,

Novosibirsk, Egorievsk and Saint-Petersburg. Saint-Gobain representation in Russia is located in Business Center PREO 8, 19th floor, 8 Preobrazhenskaya ploschad, Moscow, 107061, Russia. The key clients of the Company are from (D.I.Y) "Do It Yourself" industry, especially stores several stores: Lerya Merlen, Petrovich, OBI and etc.

In the Russian market of construction materials operates huge number of participants, thus a variety of products is enormous, consequently in such circumstances a high competition exists. On the Fig. 4.1, three consumer groups of construction service market are shown, the biggest part takes construction companies which have 60%, then repair companies and private consumers with 15% and 25% respectively. Saint-Gobain is operating with each of the group, the major part in private consumers' sector is Do It Yourself (D.I.Y.) shops, which need it be supplied more rapidly in comparison with other groups of consumers.

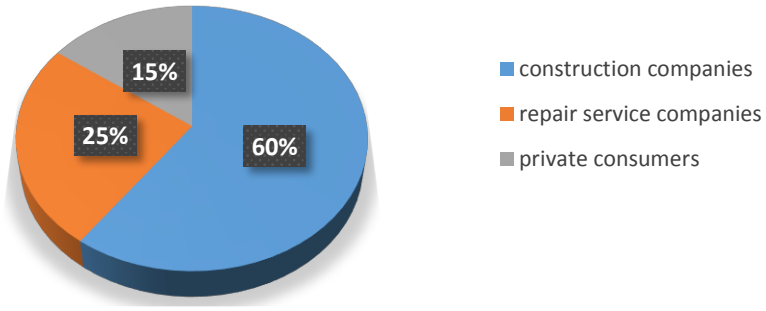

Figure 4. 1 Market Share of Construction Market

(KIT estimation, 2015)

4.1.1 Existing problem in the particular industry. Warehouse - a key part of the business. This is one of the most important component of the business process for any production company, regardless of whether it uses its own warehouse, whether it leases or uses the services of specialized operators. It is obvious that without effective warehouse management business activity is doomed to failure. Meanwhile, warehouse is a key element in company's supply chain, which provides major part in sustainability of supply chain in general. Construction materials industry can not operate without well designed warehouse, thus warehouse selection process is critically important decision making process, which should be assessed from all perspectives and takes into consideration all the parameters and characteristics, which will continue to contribute to the effective storage of goods. On the regular basis companies are selecting warehouse, assessing as a primary importance only price characteristics, consequently falling into trap of cheap storehouse but non efficient services. This behaviour, quite often, have major impact on the supply chain and influence customer service. As an example, would be taken construction material

industry and exactly the situation of loading truck, when warehouse service company is late to serve truck with goods, then truck is late to deliver goods for distributor, finally company has additional costs, that exists but could be easily reduced by creating more detailed contract, which includes penalties and also it means that company made a wrong choice of storage service provider. However, there is a practical solution which is presented in part 4.3 how to choose storage service provider in an accurate way, lower the risk of fail and avoid spending extra money.

4.2 APIS Technique for Saint-Gobain Company Case

All information which would be provided in the part 4.3 is confidential, thus storage service providers names would be changed from the original to the non-existing one.

Saint-Gobain company is not satisfied with its current storage service provider, "Provider X", because of several reasons. Company currently is thinking to change warehouse and is searching for a new one. At the moment, potential candidates have passed through Technical Requirement stage of selection and Elimination by Service Contract, so for the final stage have left only four potential suppliers. Information by four potential suppliers is presented in the Tabl. 4.2. All scores were provided by logistics manager of Saint-Gobain company. Further APIS software implementation is shown, (Appendix 6, Fig. 4.3); (Appendix 7, Fig. 4.4,); (Appendix 8, Fig. 4.5); (Appendix 9, Fig. 4.6).

First of all, four groups of sub-characteristics were estimated by APIS software and exact aggregated preference indices were created, Tabl. 4.1.

Table 4. 1 Aggregated Preference Estimations (Appendix 13)

	Price of services	Safety	Accessibility	Experience
SnP	0.723	0.320	0.216	0.517
YZGLP	0.218	**0.929**	0.432	0.258
SL	**0.868**	0.320	0.682	**0.955**
RSPT	0.732	0.500	**0.824**	0.225

It can be noticed that provider SL is leading in terms of service and experience, whether provider YZGLP is better in by Safety and provider RSPT is leading in accessibility characteristic.

As a next step, remaining characteristics of each group were estimated by APIS software, information for assessment were taken from Tabl. 4.1 and Tabl. 4.4, and certain aggregated preference indices of each group were created, Tabl. 4.2.

Table 4. 2 Aggregated Preference Estimations (Appendix 13)

	Financial Characteristics	Internal Characteristics	External Characteristics	Customer-oriented Approach
SnP	0.549	0.046	0.225	0.527
YZGLP	0.086	**0.988**	0.275	**0.707**
SL	0.762	0.036	0.744	0.450
RSPT	**0.899**	0.372	**0.925**	0.550

From the table above it can be identified that provider YZGLP has advantages in internal characteristics and customer-oriented approach, although provider RSPT is a leader by Financial Characteristics and External Characteristics. To sum up, there is no clear solution which provider has to be chosen, that's why the final round of APIS estimation was conducted. Where all providers are compared to each other with their indicators and importance of characteristics, results are shown in Tabl. 4.3.

Table 4. 3 Aggregated Preference Estimations (Appendix 12)

	Aggregated Indicator	Rank
SnP	0.330	3
YZGLP	0.273	4
SL	0.599	2
RSPT	**0.835**	1

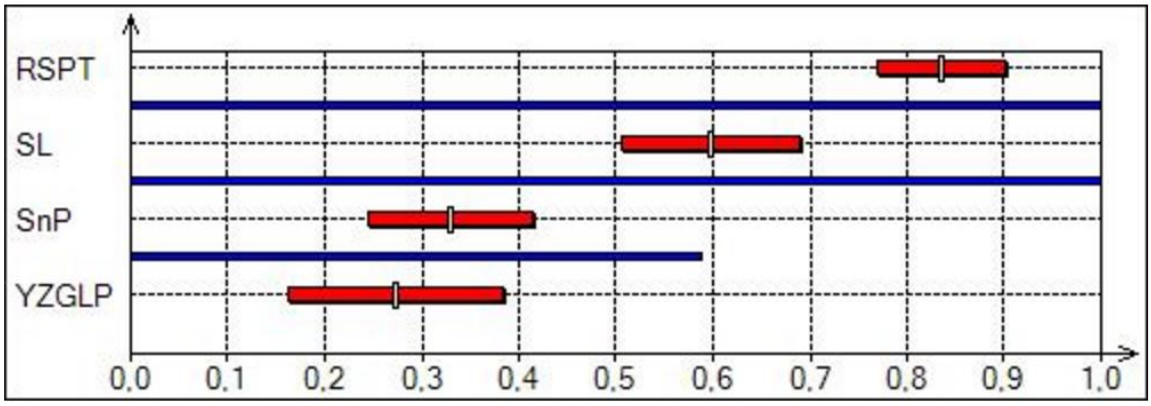

Figure 4. 2 Visualization of Aggregated Preference Indices

(Appendix 12)

On the APIS-diagram we can see short and long intercepts of a straight line; an abscissa of a midpoint of a short interval shows an average estimation of a correspondent object, while the interval's length is equal to the doubled standard deviation of the constructed aggregated

preference index; an abscissa of a long interval's right end shows the reliability for dominance relation between neighbouring aggregated estimations. Finally, in respect with standard deviation and aggregated preference index, provider RSPT has to selected, Fig. 4.2.

Table 4. 4 Estimated Grades of Characteristics (Author, 2016)

Financial Characteristics	SnP	YZGLP	SL	RSPT
Price of rented area	1 m sq. 400 rur	1 m sq. 510 rur	1 m sq. 350 rur	1 m sq. 300 rur
Financial warranty of warehouse	5	3	5	4
Price of services:				
Storage price (1,51-1,88m)	9.60 rur per Pal/place per day	12.80 rur Pal/place per day	9.83 rur Pal/place per day	10.60 rur Pal/place per day
Loading/Unloading price (height less than 1,85; weight less than 1000 kg)	90 rur per Pal	79.90 rur per Pal	70.83 rur per Pal	74.59 rur per Pal
Screening of defective items	4.80 rur per product	5 rur per product	6 rur per product	5 rur per product
Internal Characteristics				
Warehouse service machines	5	7	4	5
Area and Height of storehouse	5	7	5	6
Warehouse IT system	3	5	6	5
Safety:				
Access control system	4	4	4	3
Security level	6	5	6	2
Firefighting level	6	7	6	7
CCTV	4	7	4	6
External Characteristics				
Warehouse location	6	3	5	5
Accessibility:				
Ease of access to the warehouse	3	5	4	5
Distance to the nearest highways	5	4	7	7
Distance from the nearest airports, train stations, ports	7	4	3	3
Parking for trucks and other huge vehicles	5	7	5	5
Customer-oriented approach				
Warehouse potential	2	4	5	2
Responsiveness to the client's requirements	6	7	4	7
Client's reviews	4	3	5	2
Experience:				
With the same type of product	1	1	5	6
Experience on the market	6	5	7	4

Conclusions

This is the final section of the master thesis, which formulates the main conclusions and results, provides an overview of current work, shows managerial implications and scientific relevance of the topic, states limitations and in conclusion describes future research.

The goal set for the present master thesis was technique improvement of storage service supplier selection and its application to case company. This goal was successfully achieved by introducing **APIS technique** of selecting elements in supply chains and current method was tested on Saint-Gobain, construction leader company. **Results** of the thesis can be summarized as follows:

1. Guidelines for the supply chain creation were formulated on the base of literature review. (Incoterms, Party Logistics Providers, Lean vs. Agile Supply Chains)
2. It was substantiated that APIS method is the most suitable for the selecting element of the supply chain. (As it can provide accurate information with a high level of uncertainty
3. On the base of APIS method the technique of storage service supplier selection was created. Company managers in storage service supplier selection process should follow six steps, which are:
    - Purpose identification
    - Information gathering
    - Narrow the field
    - Elimination by technical requirement
    - Elimination by service contract
    - APIS method implementation
4. The technique was applied to storage service supplier selection for Saint-Gobain company.

After listing results of the work, there is a need in short summary how mentioned achievements can be used in business and what is the theoretical contribution of completed thesis, therefore following paragraph would be related to the two important questions, which are mentioned above.

Following (listed above) steps managers lower the risk of choosing an inappropriate storage service supplier and in addition can assess all factors in decision making with an appropriate to the criteria importance. It is important to mention, that current work is extremely significant from the theoretical and practical points of view. From the management theory side,

particular work will fill the gap of non existence framework of storage service provider selection, and the technique of supply chain creation will be improved as well. From the business and practical side, logistics managers of different companies by using new method of storage service provider could achieve several benefits:

- Avoid paying to broker (consultancy) companies for warehouse selection service
- Take into consideration not only price but also other factors which might have different weights according to the industry
- Minimize expenses which are correlated with the weak service in the warehouse

Nevertheless, in current master thesis under close consideration was taken problem of storage service supplier selection, in the title of the work it is stated "technique improvement of supply chain creation". Thus it is important to say that APIS technique can be used for the selection of any element in supply chain and to make it right exact steps have to be followed:

- Identification of the element
- Identification of characteristics which are taken into consideration in decision-making process of the element selection
- Measurement the importance of selected characteristic
- Assessment of selected characteristics
- APIS software implementation

Nevertheless, some limitations to current thesis have to be adopted, since they are primarily related to the applicability of the developed technique in various conditions. First of all, such limitation as equality of terms warehouse and storage service provider has to be introduced, even though in real business it used to happen that mentioned terms are presented by different companies not connected with each other. So in current work, the ideal situation when warehouse company owner is also a service provider is assumed to be. It was decided by the author since it makes all the steps of storage service provider selection more standardized and appropriate to adopt. Secondly, current method was developed for selecting only an outsourced warehouse(element), since company is following absolutely different steps in constructing its own. What is more, in current work, in details were explained warehouses of construction industry, but APIS technique can be easily used with other various industries.

As a future research, it would be interesting to study the affordability of new storage service supplier selection technique, on the example of other various industries, as construction material industry is highly standardized in the conditions needed for goods and fluctuations of the requirements are really low. Hence, such industry as pharmacy, chemicals or natural products pretend to be extremely interesting in the application of new method. Another direction of the

research, could be a practical analysis of results of modified model after a certain period of time. It would show the direct impact on the company and consequently could be measured.

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Appendices

Appendix 1. Importance of characteristics: questionnaire results

C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
	1	2	3	4	5	6	7	8	9	10	11	12	Sum	Sum/N
Financial Characteristics	35	30	30	40	50	25	40	15	30	25	50	40	**410**	0,341666667
Internal Characteristics	30	20	20	20	15	25	20	30	30	30	30	25	**295**	0,245833333
External Characteristics	25	20	40	30	15	30	20	40	20	10	10	25	**285**	0,2375
Customerorientated approach	10	30	10	10	20	20	20	15	20	35	10	10	**210**	0,175
Price for rented area	5	5	5	5	5	5	5	4	3	4	5	5	**56**	0,370860927
Financial warranty of warehouse	3	2	3	4	3	5	5	3	4	5	4	4	**45**	0,298013245
Price for services	4	5	4	3	5	4	4	3	5	4	4	5	**50**	0,331125828
Storage price	5	5	5	5	5	5	5	4	5	5	5	5	**59**	0,395973154
Screening of defective items	2	5	3	3	2	5	3	2	3	3	5	3	**39**	0,261744966
Loading/Unloading price	4	5	4	3	4	5	4	3	5	5	5	4	**51**	0,342281879
Warehouse service machines	2	5	4	3	3	5	4	4	4	3	4	4	**45**	0,241935484
Warehouse IT system	3	1	1	3	1	5	5	4	4	4	4	4	**39**	0,209677419
Safety	4	5	3	4	4	5	4	5	5	5	4	4	**52**	0,279569892
Area and height of storehouse	4	5	5	2	5	3	4	3	5	4	5	5	**50**	0,268817204
Access control system	3	5	2	2	2	5	5	4	5	4	5	5	**47**	0,236180905
Security level	4	5	4	3	3	4	4	4	4	5	5	4	**49**	0,246231156
CCTV	4	4	5	4	4	5	5	5	5	5	4	5	**55**	0,27638191
Firefighting level	3	3	4	4	5	4	4	5	4	4	4	4	**48**	0,24120603
Accessibility	5	5	5	5	4	5	5	5	5	5	5	5	**59**	0,531531532
Warehouse Location	5	4	4	5	5	5	4	4	3	3	5	5	**52**	0,468468468
Distance to the nearest highways	5	5	5	5	5	5	5	5	5	5	5	5	**60**	0,298507463
Ease of access to the warehouse	4	4	5	4	4	4	5	4	5	3	5	4	**51**	0,253731343
Parking for trucks and other huge vehicles	3	5	4	3	5	4	5	5	4	5	2	4	**49**	0,243781095
Distance to the nearest train station, airports, sea ports	2	4	3	4	3	4	5	3	3	4	1	5	**41**	0,2039801
Warehouse potential	3	5	2	4	2	5	4	4	5	4	5	4	**47**	0,236180905
Experience	4	4	3	3	4	4	5	4	5	4	5	5	**50**	0,251256281
Client's reviews	3	4	4	2	3	4	4	5	4	5	4	5	**47**	0,236180905
Responsiveness to the client's requirements	2	5	5	5	5	5	5	5	4	5	5	4	**55**	0,27638191
Experience with the same types of products	4	1	5	3	5	4	5	5	3	5	4	4	**48**	0,484848485
Experience on the market	3	4	4	4	4	5	5	4	5	4	5	4	**51**	0,515151515

Appendix 2. Warehouse A characteristics

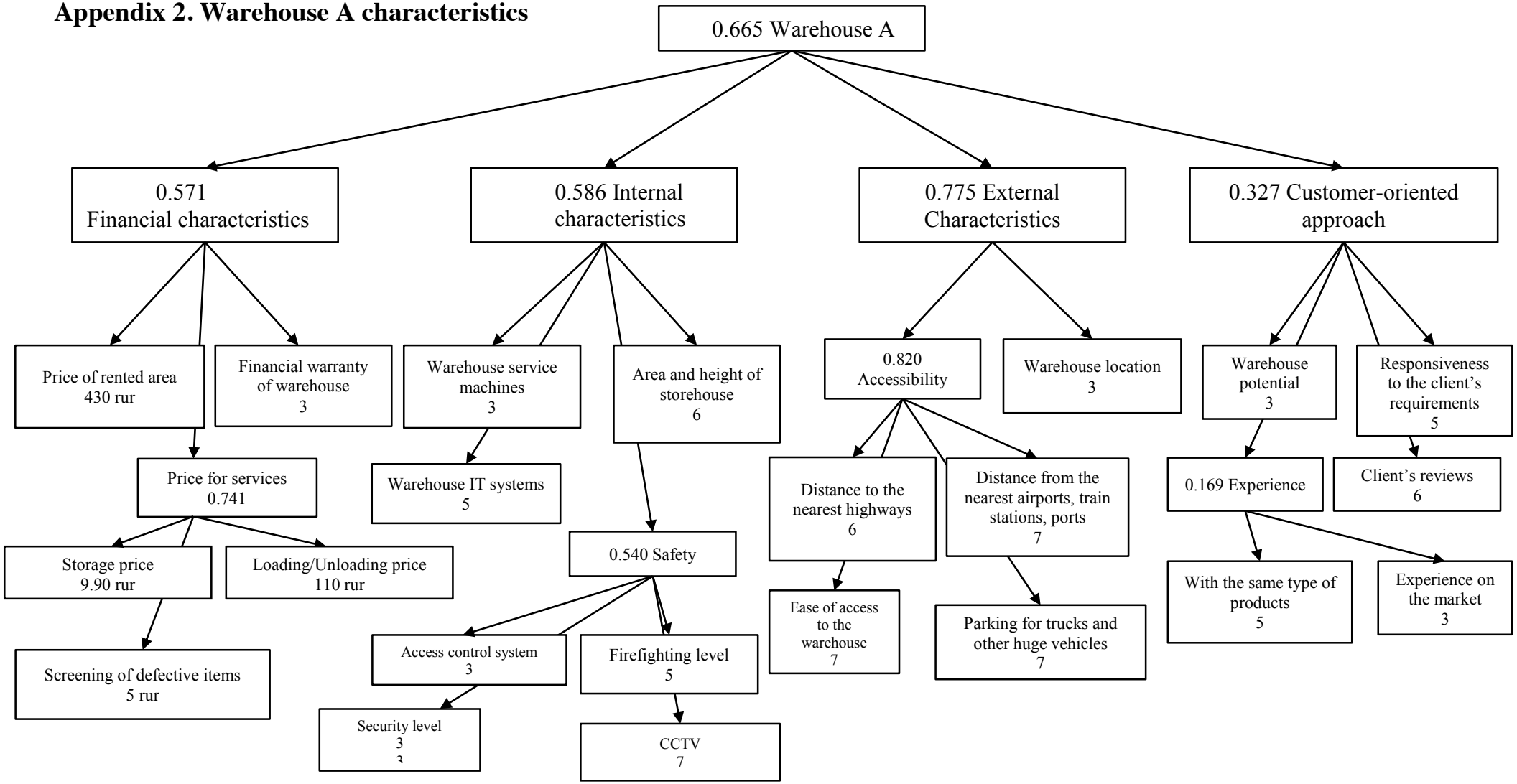


Figure 3. 6 Characteristics of Storage Service Provider

(Author,2016)

Appendix 3. Warehouse B characteristics

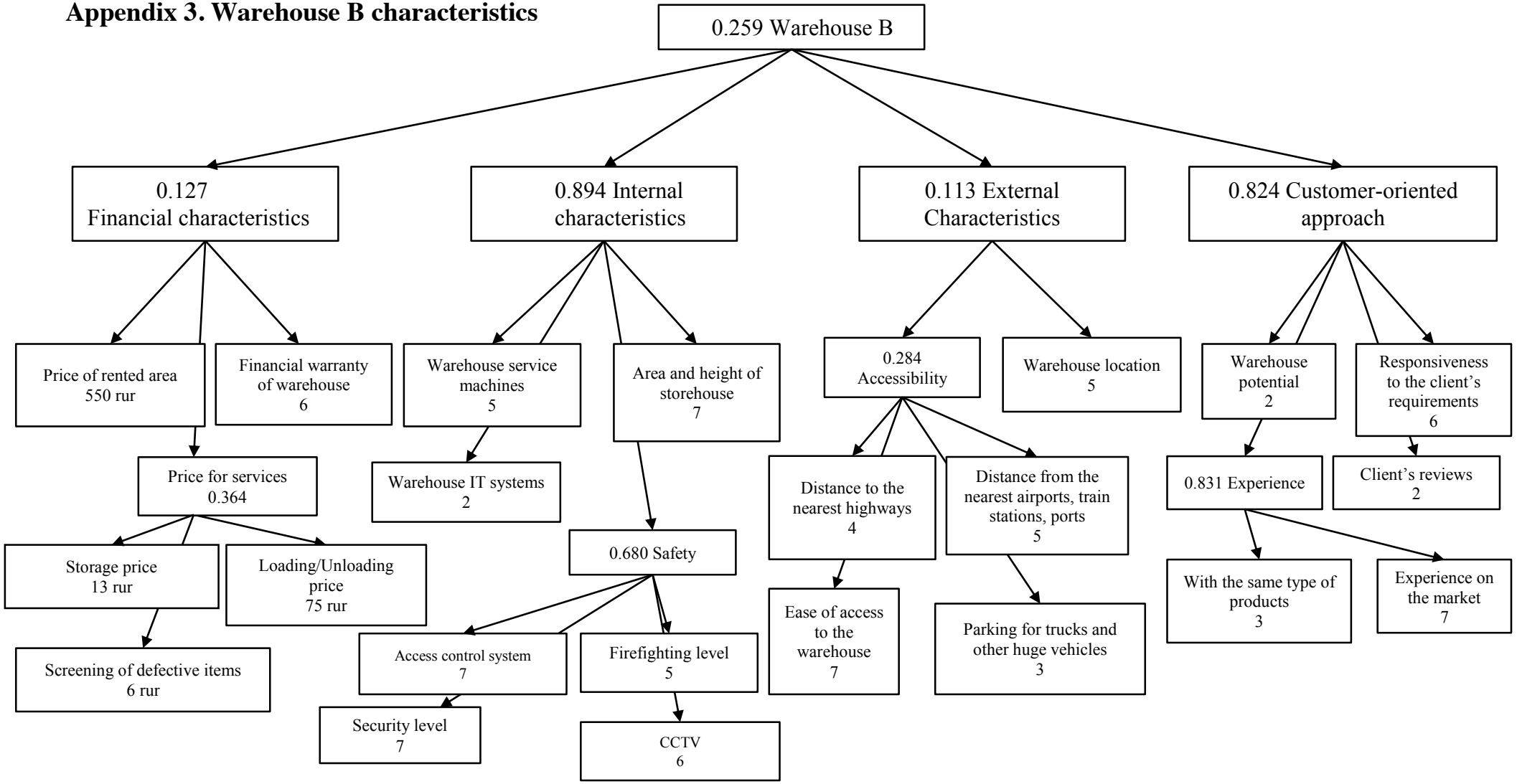


Figure 3. 7 Characteristics of Storage Service Provider

(Author,2016)

Appendix 4. Warehouse C characteristics

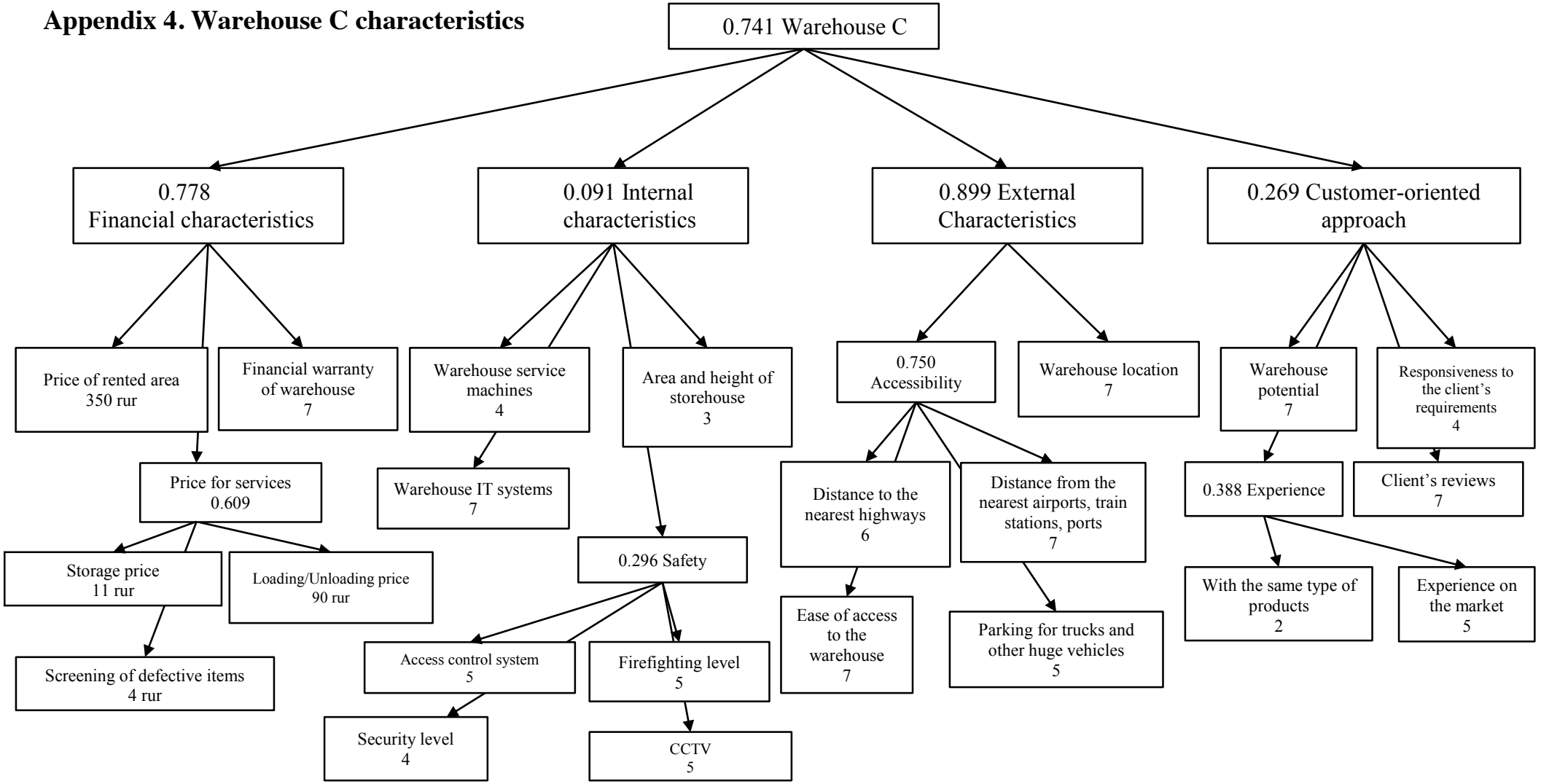


Figure 3. 8 Characteristics of Storage Service Provider

(Author,2016)

Appendix 5. Warehouse D characteristics

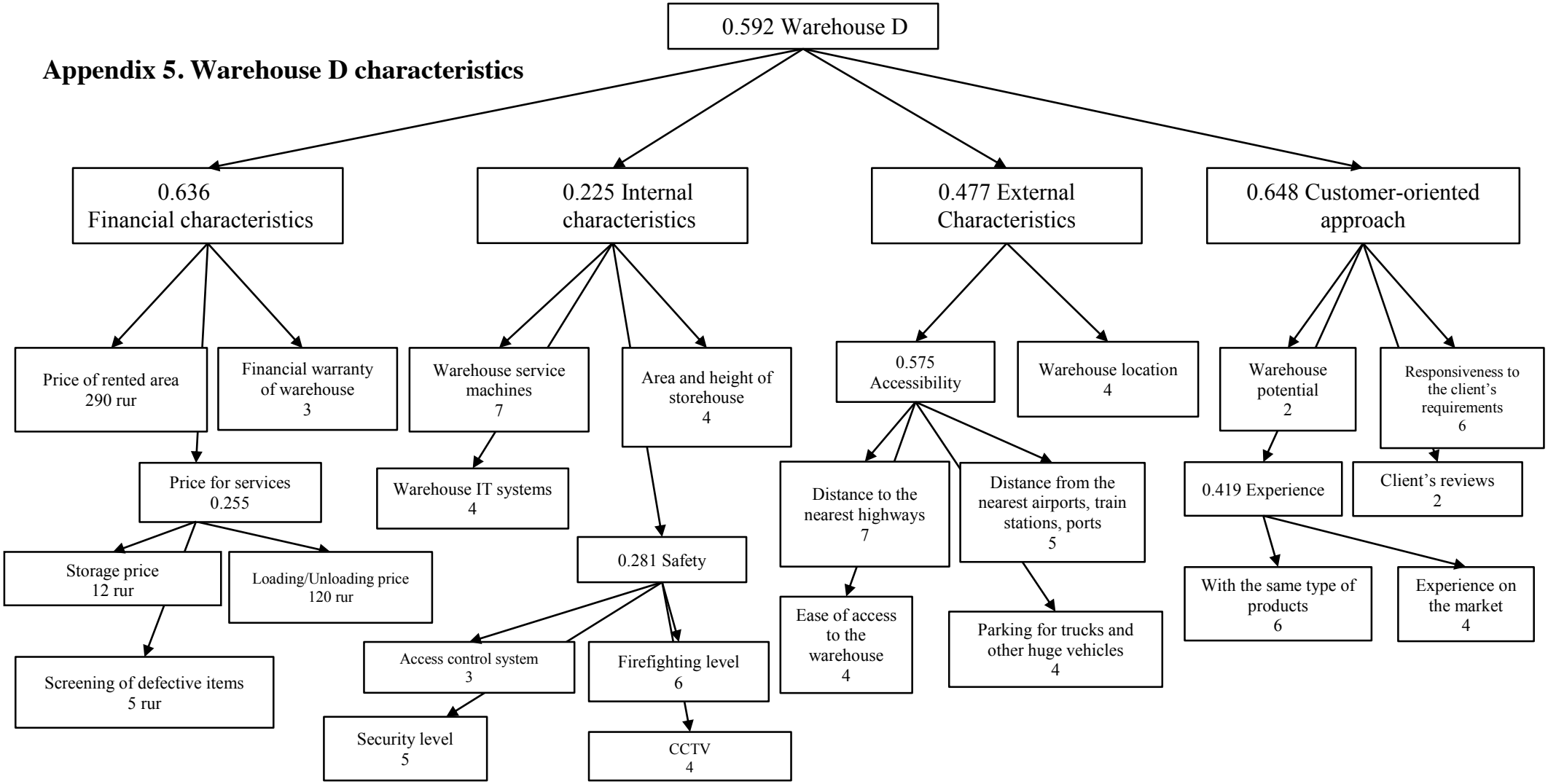


Figure 3. 9 Characteristics of Storage Service Provider

(Author,2016)

Appendix 6. Warehouse SnP characteristics

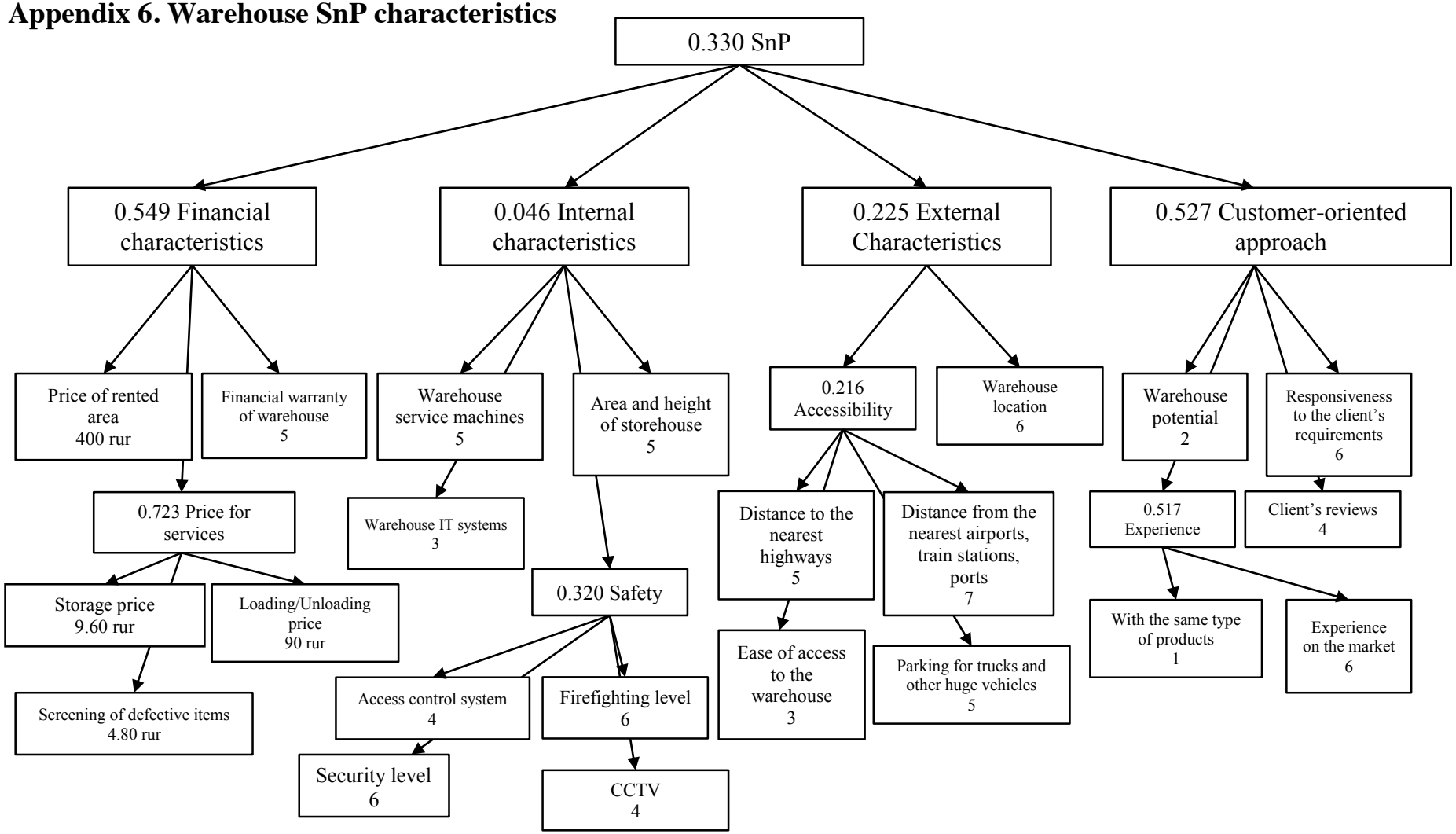


Figure 4. 3 Characteristics of Storage Service Provider

(Author, 2016)

Appendix 7. Warehouse YZGLP characteristics

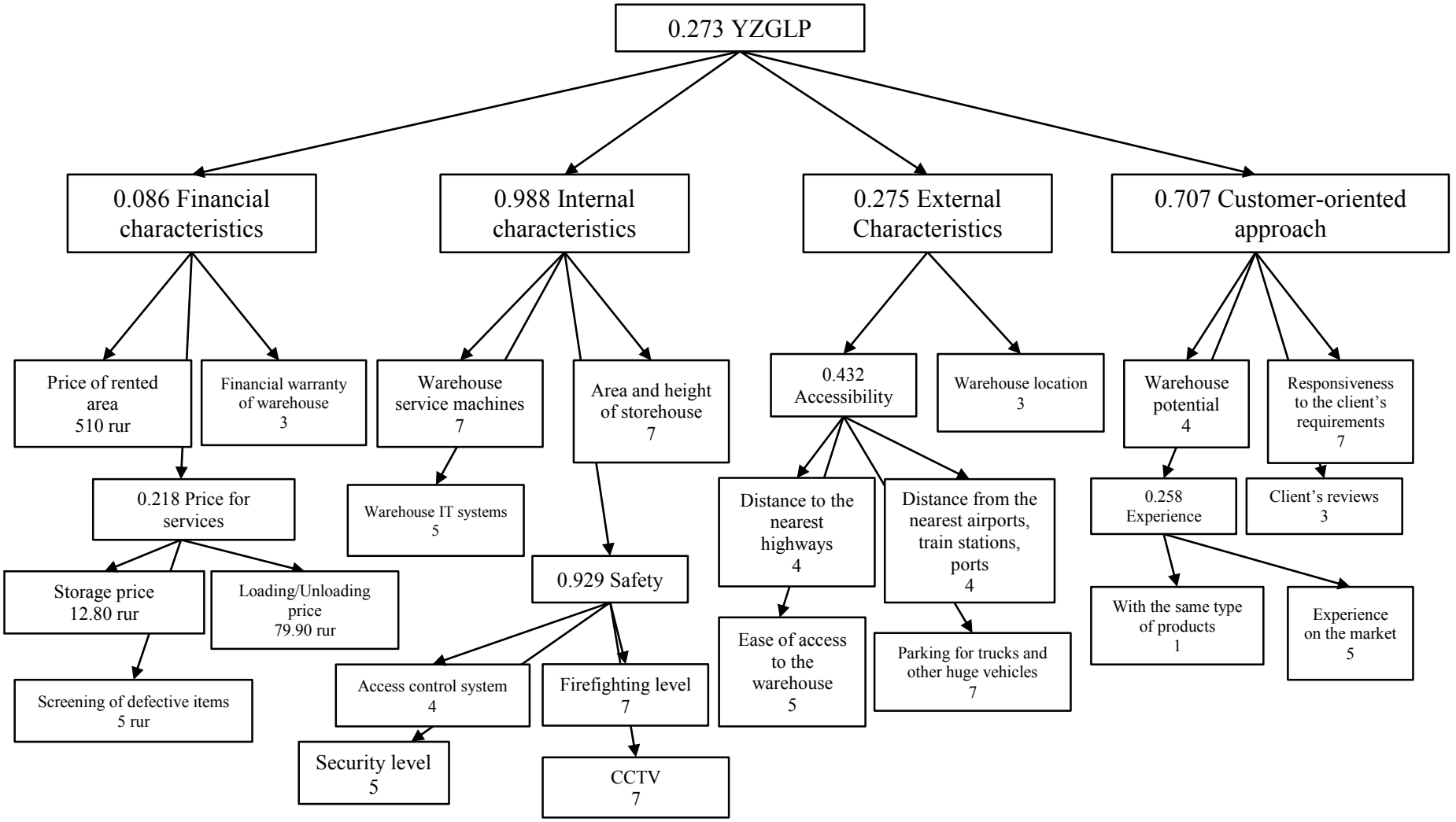


Figure 4. 4 Characteristics of Storage Service Provider

(Author, 2016)

Appendix 8. Warehouse SL characteristics

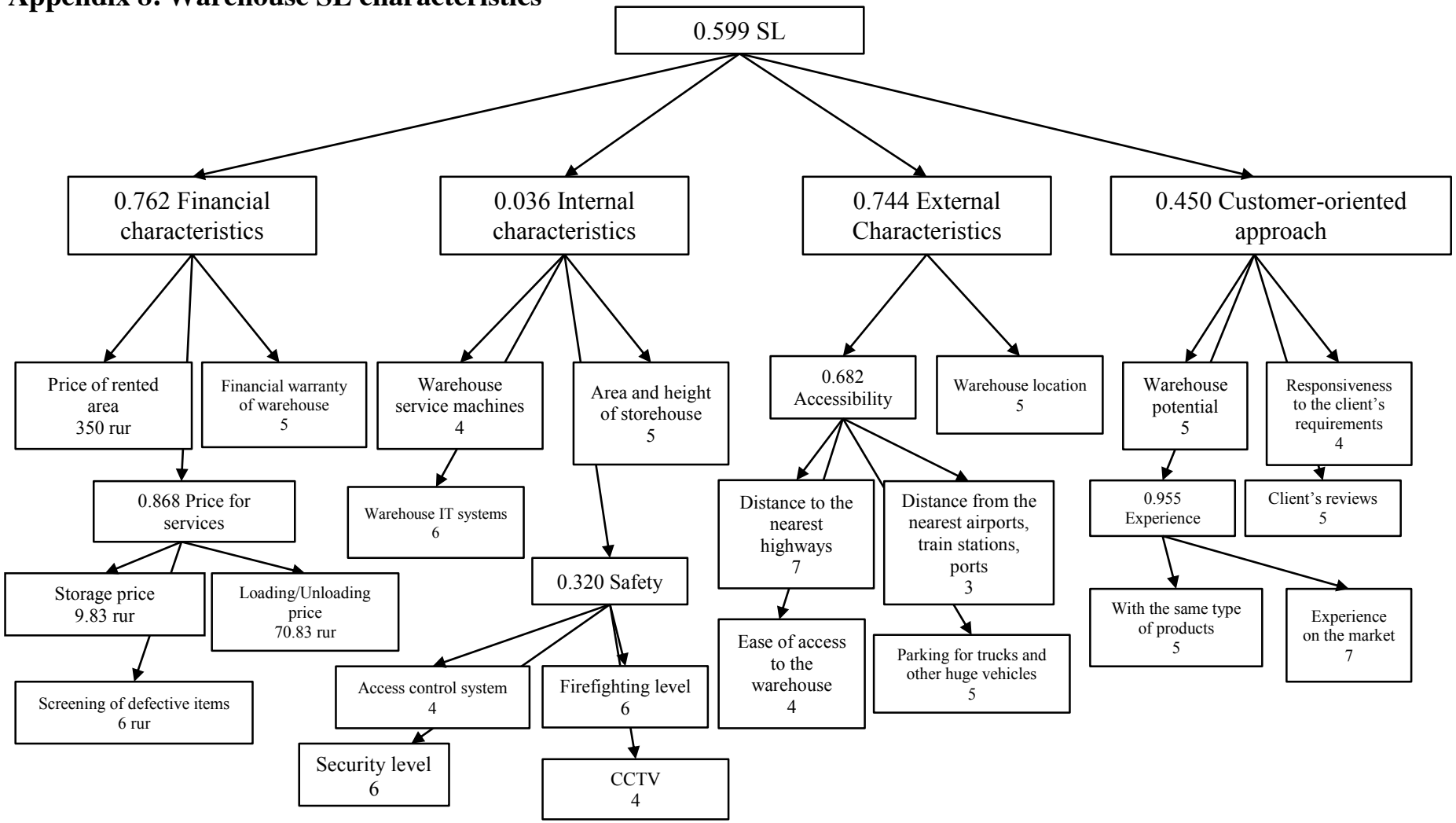


Figure 4. 5 Characteristics of Storage Service Provider

(Author, 2016)

Appendix 9. Warehouse RSPT characteristics

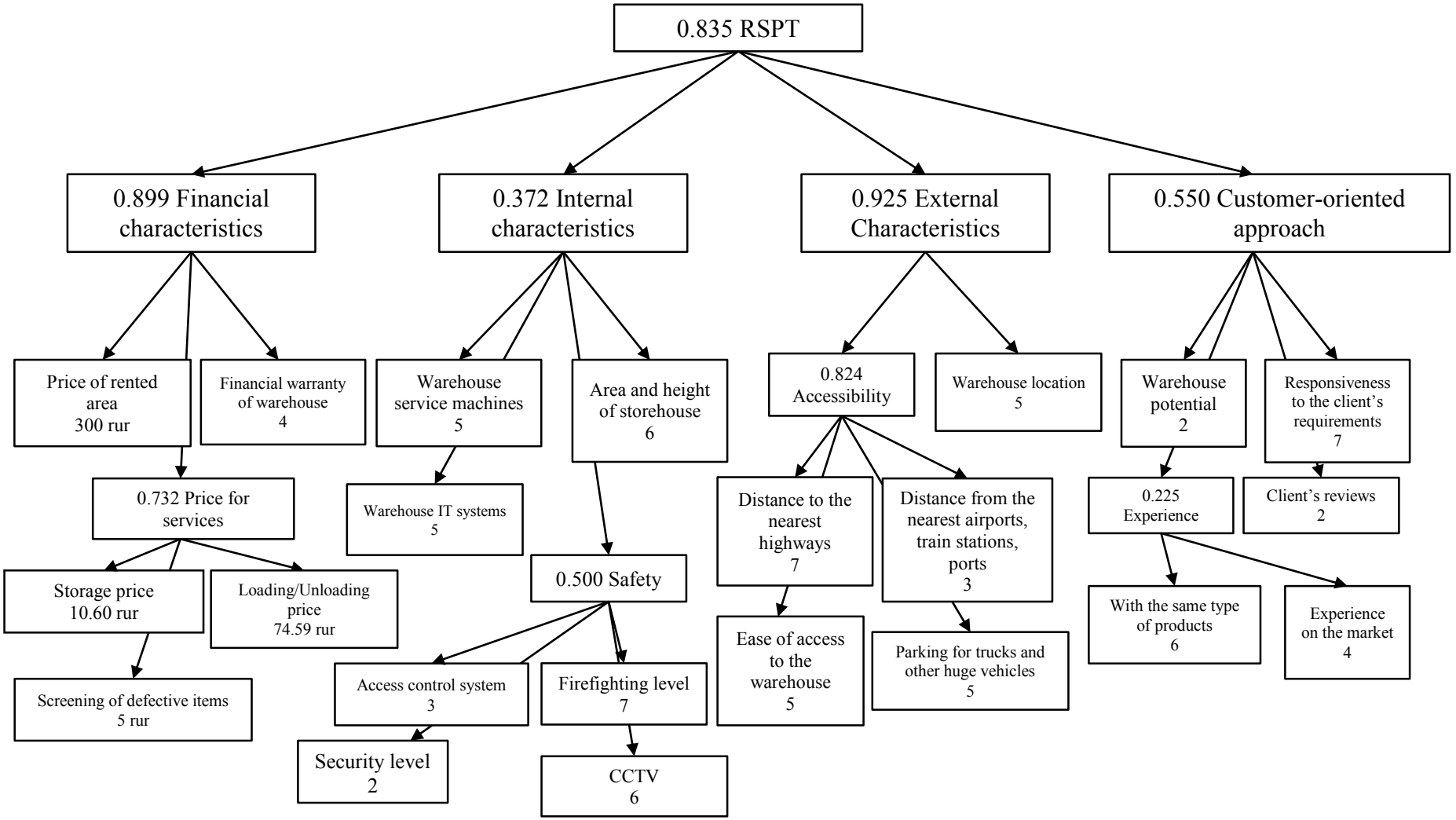


Figure 4. 6 Characteristics of Storage Service Provider

(Author, 2016)

Appendix 10. Questionnaire for criteria importance assessment

Graduate School of Management
St. Petersburg University

Questionnaire for warehouse logistics managers.

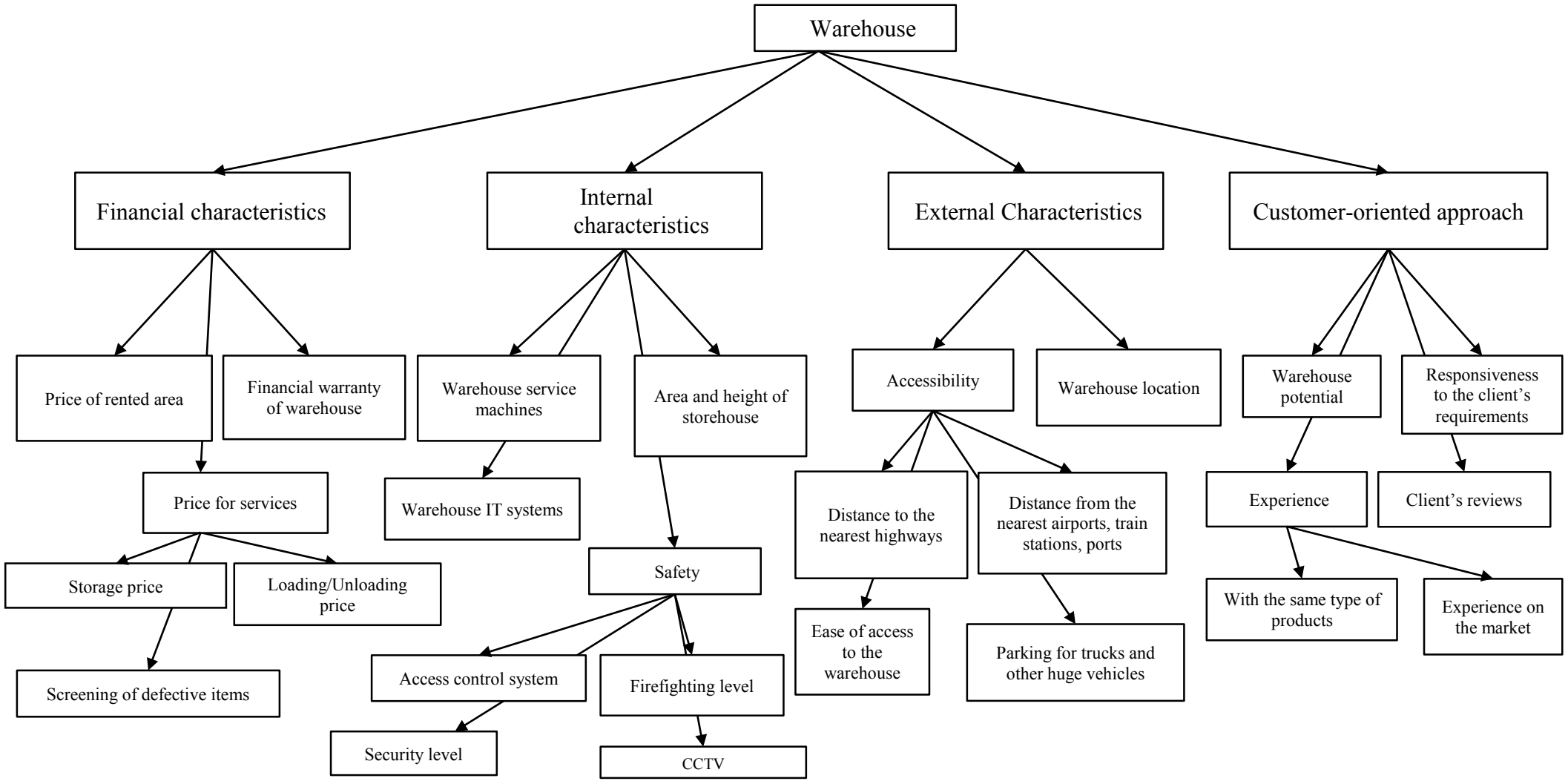
Dear respondent!

This survey is conducted as part of dissertation project carried out by the Graduate School of Management.

The data will be processed by the organizer of the study to develop the method of choice of supplier and warehouse storage services.
The organizer of the study ensures complete confidentiality of the information, the results of the survey will be used only in aggregated form.

The organizer of the study asks you to read instructions carefully and follow them, otherwise your answer can not be accepted for processing because of incorrect or incomplete filling.

Initially, you will see a diagram with the supplier service selection criteria.

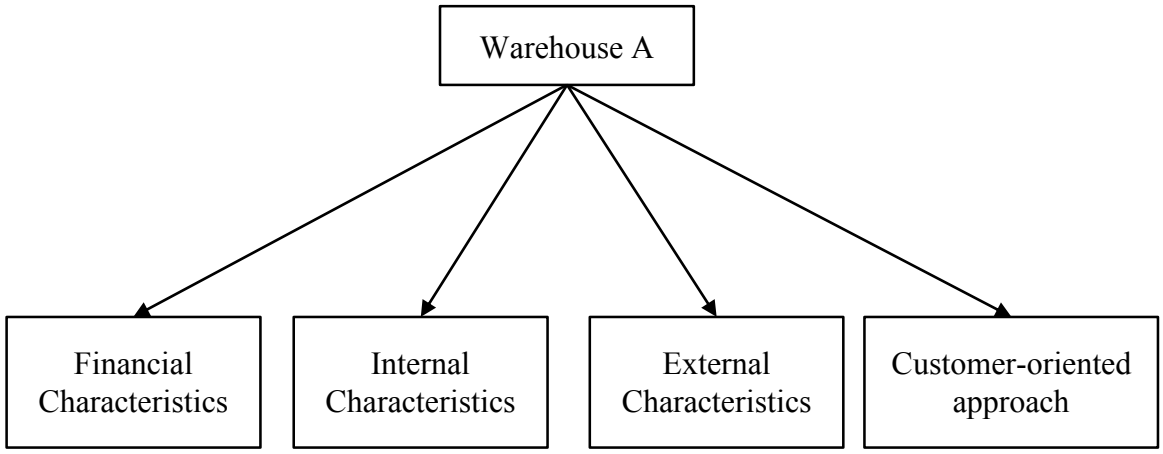

Warehouse
Financial characteristics
Internal characteristics
External Characteristics
Customer-oriented approach
Price of rented area
Financial warranty of warehouse
Price for services
Storage price
Loading/Unloading price
Screening of defective items
Warehouse service machines
Warehouse IT systems
Area and height of storehouse
Safety
Access control system
Security level
Firefighting level
CCTV
Accessibility
Warehouse location
Distance to the nearest highways
Ease of access to the warehouse
Distance from the nearest airports, train stations, ports
Parking for trucks and other huge vehicles
Warehouse potential
Responsiveness to the client's requirements
Experience
Client's reviews
With the same type of products
Experience on the market

Answer, please, following questions:

Each Warehouse is presented by a certain number of characteristics:

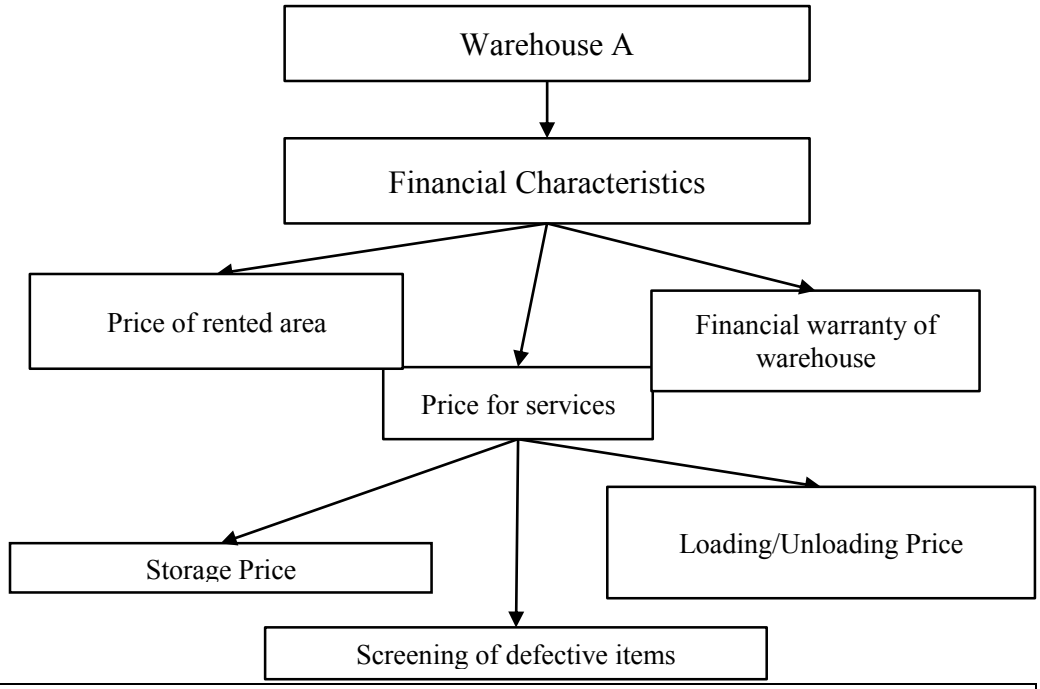
- Financial Characteristics
- Internal Characteristics
- External Characteristics
- Customer-orientated approach

1. Spread 100 points between four characteristics above according to their importance.



Group of Characteristics	Scores
Financial Characteristics	
Internal Characteristics	
External Characteristics	
Customer-oriented approach	

2. Please rate by a 5-point scale the degree of influence of each of the **Financial Characteristics** on the warehouse selection.

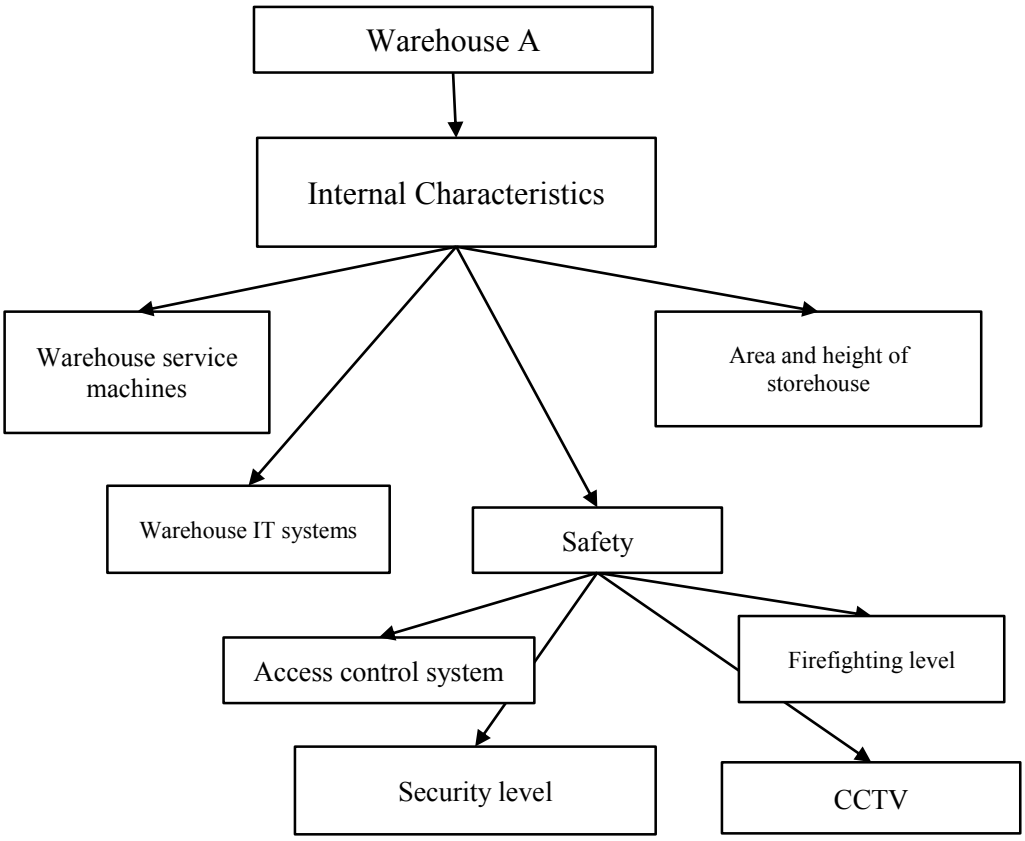


Financial Characteristics					
	1	**2**	**3**	**4**	**5**
Price of rented area					
Financial warranty of warehouse					
Price for services					

Further, please, rate by 5-point scale the degree of importance of the element represented by the characteristics **Price for services**

Price for Service					
	1	**2**	**3**	**4**	**5**
Storage Price					
Screening of Defective Items					
Loading/Unloading Price					

3. Please rate by a 5-point scale the degree of influence of each of the **Internal Characteristics** on the warehouse selection

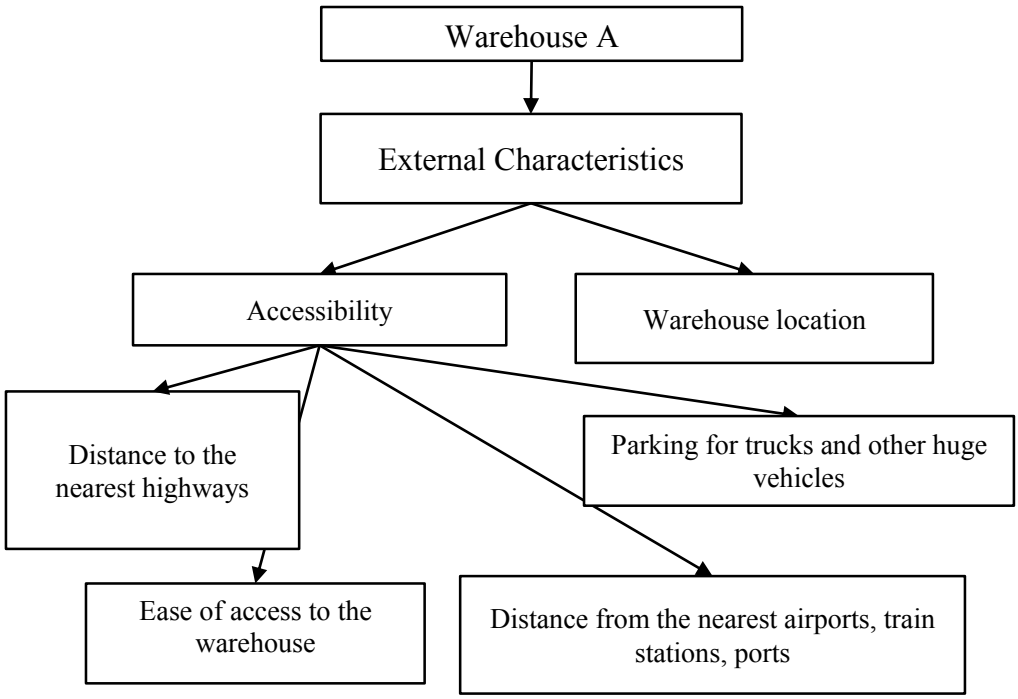


Internal Characteristics					
	1	**2**	**3**	**4**	**5**
Warehouse service machines					
Warehouse IT system					
Safety					
Area and height of storage					

Further, please, rate by 5-point scale the degree of importance of the element represented by the characteristics **Safety**

Safety					
	1	**2**	**3**	**4**	**5**
Access control system					
Security level					
CCTV					
Firefighting system					

4. Please rate by a 5-point scale the degree of influence of each of the **External Characteristics** on the warehouse selection

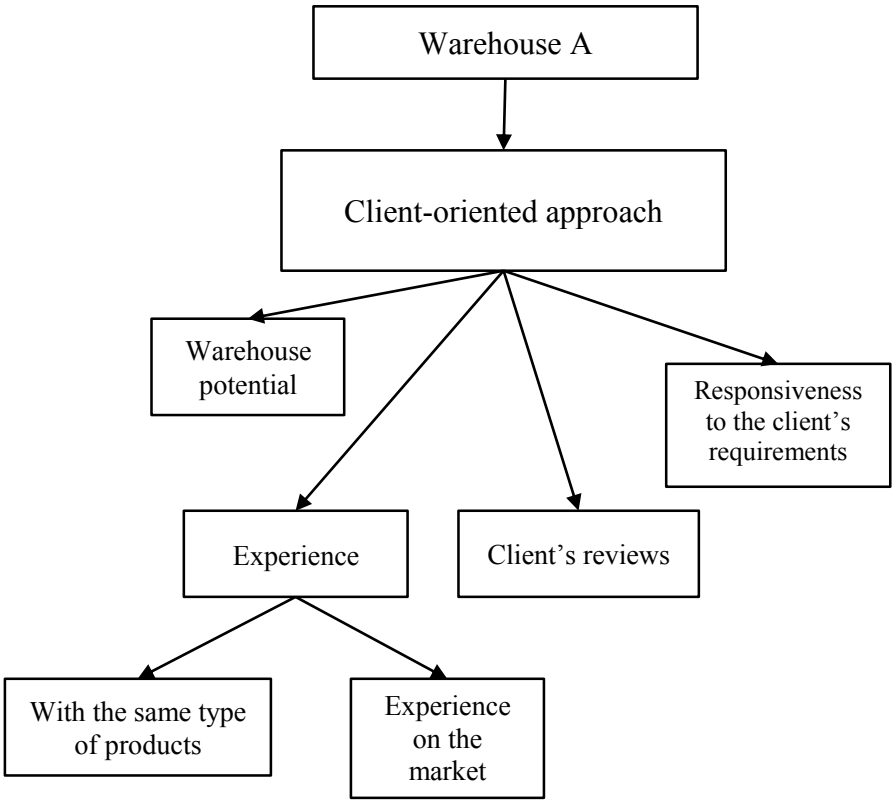


External Characteristics					
	1	**2**	**3**	**4**	**5**
Accessibility					
Warehouse location					

Further, please, rate by 5-point scale the degree of importance of the element represented by the characteristics **Accessibility**

Accessibility					
	1	**2**	**3**	**4**	**5**
Distance to the nearest highways					
Ease of access to the warehouse					
Parking for trucks and other huge vehicles					
Distance from the nearest airports, train stations, ports					

5. Please rate by a 5-point scale the degree of influence of each of the **Client-oriented approach** on the warehouse selection.



Client-oriented approach					
	1	**2**	**3**	**4**	**5**
Warehouse potential					
Experience					
Client's reviews					
Responsiveness to the client's requirements					

Further, please, rate by 5-point scale the degree of importance of the element represented by the characteristics **Experience**

Experience					
	1	**2**	**3**	**4**	**5**
With the same type of products					
Experience on the market					

All your answers are very important for the research.

Contact information:

Pavel Tarabanov
mob: +7-921-792-83-44
e-mail: pavel-tarabanov@mail.ru

Would you be so kind to provide your contact information, in case of necessity to write to you for further details?

- Age

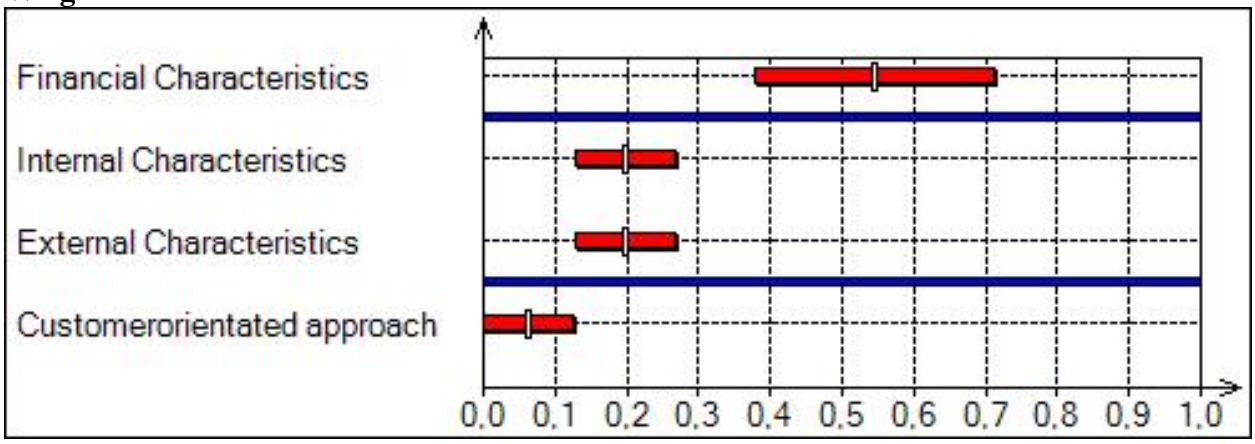
15-20	21-26	27-35	36-50	50-65	More than 65

- Occupation _____
- Name. _____
- Mob. phone: _____
- e-mail: _____

Thank you!

Appendix 11. Output information from APIS Technique for the Storage Service Supplier Selection

Weight-coefficients estimations visualization



Statistics of admissible weight-coefficients values

Weight of index	Min	Max	Mean	StDev	Rank
w(Financial Characteristics)	0,3000	0,9000	0,5441	0,1671	1
w(Internal Characteristics)	0,0500	0,3000	0,1971	0,0696	2
w(External Characteristics)	0,0500	0,3000	0,1971	0,0696	2
w(Customer-oriented approach)	0,0000	0,2000	0,0618	0,0607	3

Weight-coefficients dominance reliability

PW(r,s)	w(Financial Characteristics)	w(Internal Characteristics)	w(External Characteristics)	w(Customerorientated approach)
w(Financial Characteristics)	0,0000	1,0000	1,0000	1,0000
w(Internal Characteristics)	0,0000	0,0000	0,0000	1,0000
w(External Characteristics)	0,0000	0,0000	0,0000	1,0000
w(Customer-oriented approach)	0,0000	0,0000	0,0000	0,0000

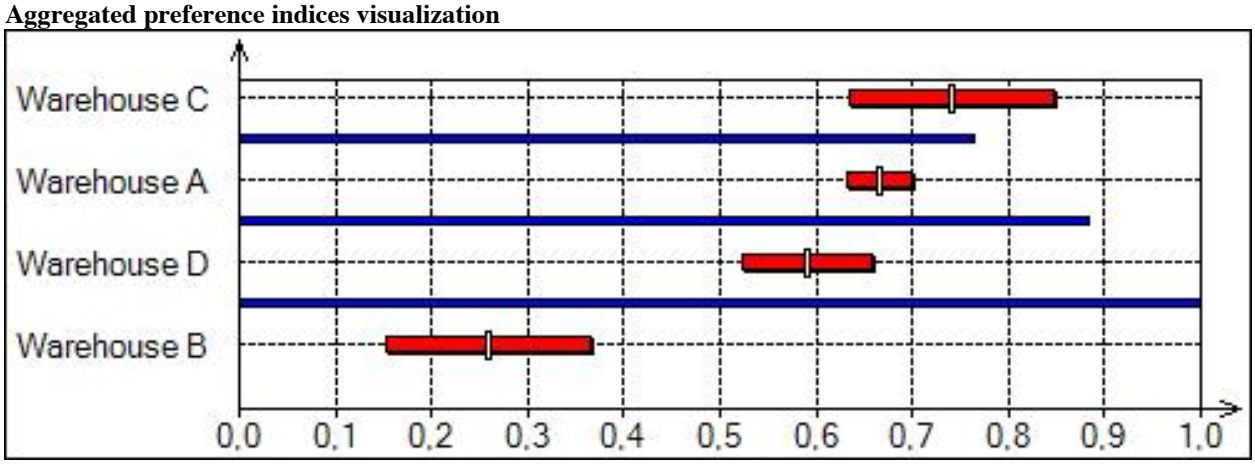
Weight-coefficients covariance

WCOV(r,s)	w(Financial Characteristics)	w(Internal Characteristics)	w(External Characteristics)	w(Customerorientated approach)
w(Financial Characteristics)	0,0279	-0,0109	-0,0109	-0,0061
w(Internal Characteristics)	-0,0109	0,0048	0,0048	0,0012
w(External Characteristics)	-0,0109	0,0048	0,0048	0,0012
w(Customer-oriented approach)	-0,0061	0,0012	0,0012	0,0037

Weight-coefficients correlation

WCORR(r,s)	w(Financial Characteristics)	w(Internal Characteristics)	w(External Characteristics)	w(Customer-oriented approach)
w(Financial Characteristics)	1,0000	-0,9374	-0,9374	-0,6022
w(Internal Characteristics)	-0,9374	1,0000	1,0000	0,2866
w(External Characteristics)	-0,9374	1,0000	1,0000	0,2866
w(Customer-oriented approach)	-0,6022	0,2866	0,2866	1,0000

Aggregated preference indices visualization



Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(Warehouse A)	0,5902	0,7104	0,6650	0,0338	2
Q(Warehouse B)	0,0500	0,4500	0,2588	0,1046	4
Q(Warehouse C)	0,5500	0,9500	0,7412	0,1046	1
Q(Warehouse D)	0,4968	0,7352	0,5917	0,0670	3

Aggregated preference indices dominance reliability

PQ(i,j)	Q(Warehouse A)	Q(Warehouse B)	Q(Warehouse C)	Q(Warehouse D)
Q(Warehouse A)	0,0000	1,0000	0,2353	0,8824
Q(Warehouse B)	0,0000	0,0000	0,0000	0,0000
Q(Warehouse C)	0,7647	1,0000	0,0000	1,0000
Q(Warehouse D)	0,1176	1,0000	0,0000	0,0000

Aggregated preference indices covariance

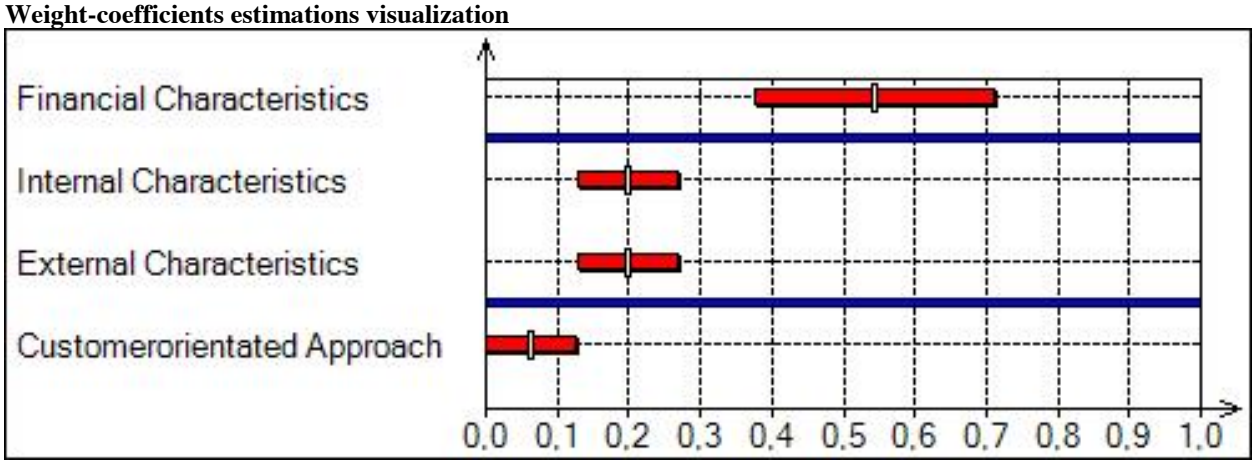
QCOV(i,j)	Q(Warehouse A)	Q(Warehouse B)	Q(Warehouse C)	Q(Warehouse D)
Q(Warehouse A)	0,0011	-0,0023	0,0023	0,0004
Q(Warehouse B)	-0,0023	0,0110	-0,0110	-0,0061
Q(Warehouse C)	0,0023	-0,0110	0,0110	0,0061
Q(Warehouse D)	0,0004	-0,0061	0,0061	0,0045

Aggregated preference indices correlation

QCORR(i,j)	Q(Warehouse A)	Q(Warehouse B)	Q(Warehouse C)	Q(Warehouse D)
Q(Warehouse A)	1,0000	-0,6382	0,6382	0,1878
Q(Warehouse B)	-0,6382	1,0000	-1,0000	-0,8760
Q(Warehouse C)	0,6382	-1,0000	1,0000	0,8760
Q(Warehouse D)	0,1878	-0,8760	0,8760	1,0000

Appendix 12. Output information from APIS Technique for Saint-Gobain Company Case

Weight-coefficients estimations visualization



Statistics of admissible weight-coefficients values

Weight of index	Min	Max	Mean	StDev	Rank
w(Financial Characteristics)	0,3000	0,9000	0,5441	0,1671	1
w(Internal Characteristics)	0,0500	0,3000	0,1971	0,0696	2
w(External Characteristics)	0,0500	0,3000	0,1971	0,0696	2
w(Customer-oriented Approach)	0,0000	0,2000	0,0618	0,0607	3

Weight-coefficients dominance reliability

PW(r,s)	w(Financial Characteristics)	w(Internal Characteristics)	w(External Characteristics)	w(Customerorientated Approach)
w(Financial Characteristics)	0,0000	1,0000	1,0000	1,0000
w(Internal Characteristics)	0,0000	0,0000	0,0000	1,0000
w(External Characteristics)	0,0000	0,0000	0,0000	1,0000
w(Customer-oriented Approach)	0,0000	0,0000	0,0000	0,0000

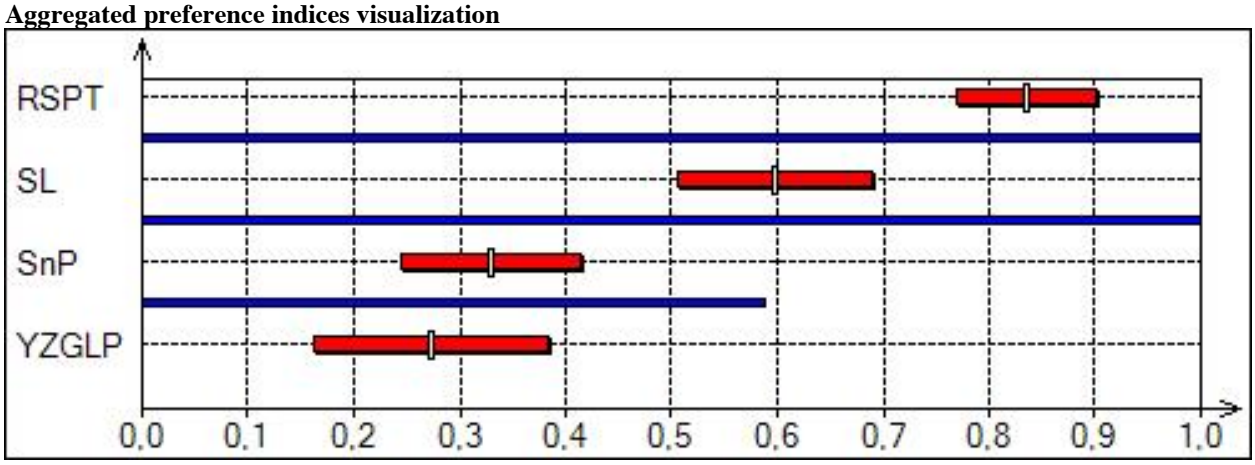
Weight-coefficients covariance

WCOV(r,s)	w(Financial Characteristics)	w(Internal Characteristics)	w(External Characteristics)	w(Customerorientated Approach)
w(Financial Characteristics)	0,0279	-0,0109	-0,0109	-0,0061
w(Internal Characteristics)	-0,0109	0,0048	0,0048	0,0012
w(External Characteristics)	-0,0109	0,0048	0,0048	0,0012
w(Customer-oriented Approach)	-0,0061	0,0012	0,0012	0,0037

Weight-coefficients correlation

WCORR(r,s)	w(Financial Characteristics)	w(Internal Characteristics)	w(External Characteristics)	w(Customerorientated Approach)
w(Financial Characteristics)	1,0000	-0,9374	-0,9374	-0,6022
w(Internal Characteristics)	-0,9374	1,0000	1,0000	0,2866
w(External Characteristics)	-0,9374	1,0000	1,0000	0,2866
w(Customer-oriented Approach)	-0,6022	0,2866	0,2866	1,0000

Aggregated preference indices visualization



Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(SnP)	0,2175	0,5131	0,3304	0,0847	3
Q(YZGLP)	0,0536	0,4679	0,2729	0,1088	4
Q(SL)	0,4348	0,7854	0,5985	0,0923	2
Q(RSPT)	0,7161	0,9676	0,8348	0,0660	1

Aggregated preference indices dominance reliability

PQ(i,j)	Q(SnP)	Q(YZGLP)	Q(SL)	Q(RSPT)
Q(SnP)	0,0000	0,5882	0,0000	0,0000
Q(YZGLP)	0,4118	0,0000	0,0588	0,0000
Q(SL)	1,0000	0,9412	0,0000	0,0000
Q(RSPT)	1,0000	1,0000	1,0000	0,0000

Aggregated preference indices covariance

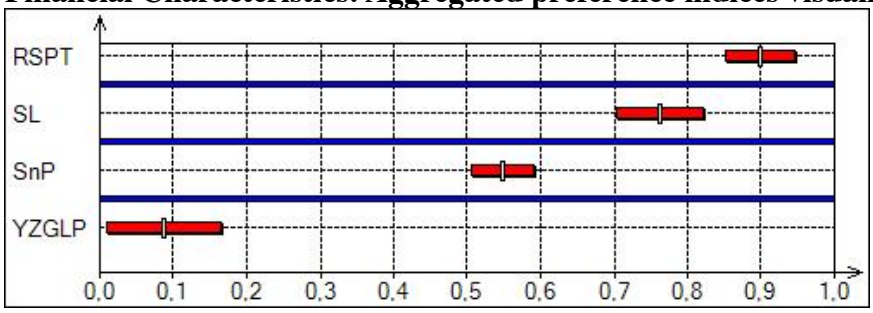
QCOV(i,j)	Q(SnP)	Q(YZGLP)	Q(SL)	Q(RSPT)
Q(SnP)	0,0072	-0,0086	0,0073	0,0052
Q(YZGLP)	-0,0086	0,0118	-0,0100	-0,0072
Q(SL)	0,0073	-0,0100	0,0085	0,0061
Q(RSPT)	0,0052	-0,0072	0,0061	0,0044

Aggregated preference indices correlation

QCORR(i,j)	Q(SnP)	Q(YZGLP)	Q(SL)	Q(RSPT)
Q(SnP)	1,0000	-0,9296	0,9341	0,9281
Q(YZGLP)	-0,9296	1,0000	-0,9999	-1,0000
Q(SL)	0,9341	-0,9999	1,0000	0,9999
Q(RSPT)	0,9281	-1,0000	0,9999	1,0000

Appendix 13. Additional output information from APIS Technique for Saint-Gobain Company Case

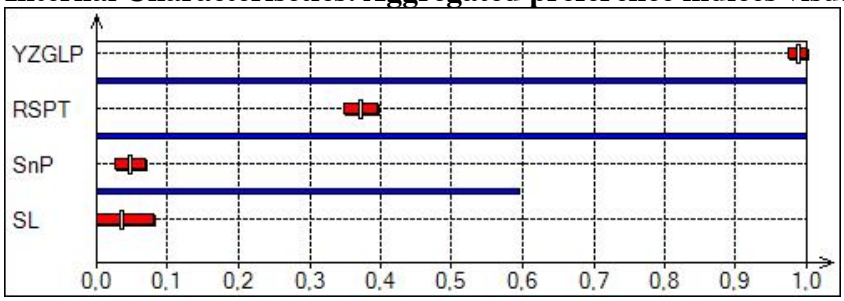
Financial Characteristics. Aggregated preference indices visualization



Financial Characteristics. Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(SnP)	0,4688	0,6377	0,5488	0,0429	3
Q(YZGLP)	0,0000	0,2500	0,0864	0,0762	4
Q(SL)	0,6429	0,8690	0,7621	0,0582	2
Q(RSPT)	0,8018	0,9895	0,8988	0,0473	1

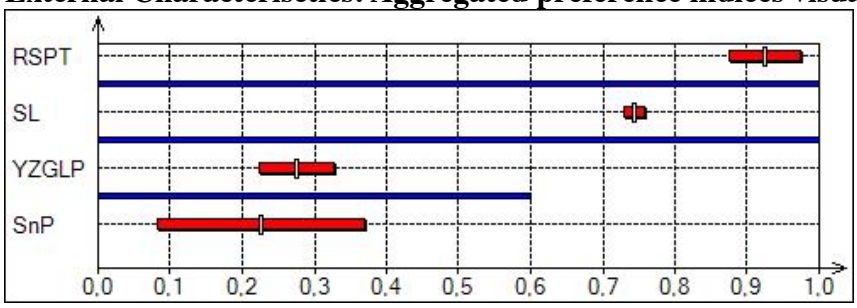
Internal Characterisctics. Aggregated preference indices visualization



Internal Characterisctics. Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(SnP)	0,0167	0,0833	0,0465	0,0200	3
Q(YZGLP)	0,9500	1,0000	0,9879	0,0145	1
Q(SL)	0,0000	0,1500	0,0362	0,0434	4
Q(RSPT)	0,3179	0,4201	0,3723	0,0227	2

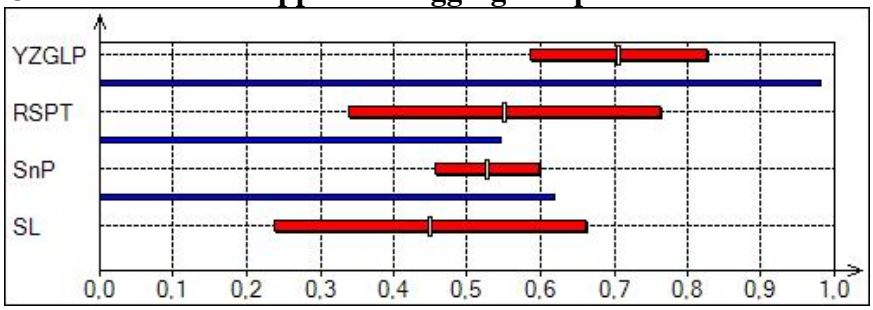
External Characterisctics. Aggregated preference indices visualization



External Characterisctics. Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(SnP)	0,0000	0,4500	0,2250	0,1436	4
Q(YZGLP)	0,1954	0,3553	0,2753	0,0510	3
Q(SL)	0,7215	0,7664	0,7440	0,0143	2
Q(RSPT)	0,8500	1,0000	0,9250	0,0479	1

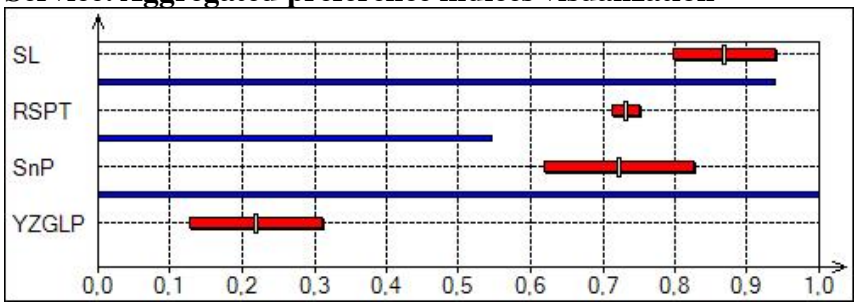
Customer-orieted Approach. Aggregated preference indices visualization



Customer-orieted Approach. Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(SnP)	0,3667	0,6667	0,5267	0,0712	3
Q(YZGLP)	0,5500	1,0000	0,7068	0,1198	1
Q(SL)	0,0000	0,9000	0,4500	0,2121	4
Q(RSPT)	0,1000	1,0000	0,5500	0,2121	2

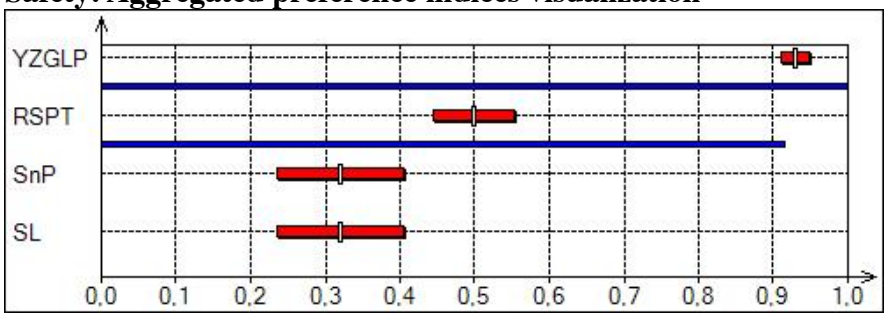
Service. Aggregated preference indices visualization



Service. Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(SnP)	0,5500	0,9500	0,7227	0,1023	3
Q(YZGLP)	0,0263	0,3927	0,2181	0,0912	4
Q(SL)	0,7177	0,9605	0,8679	0,0696	1
Q(RSPT)	0,6933	0,7647	0,7324	0,0179	2

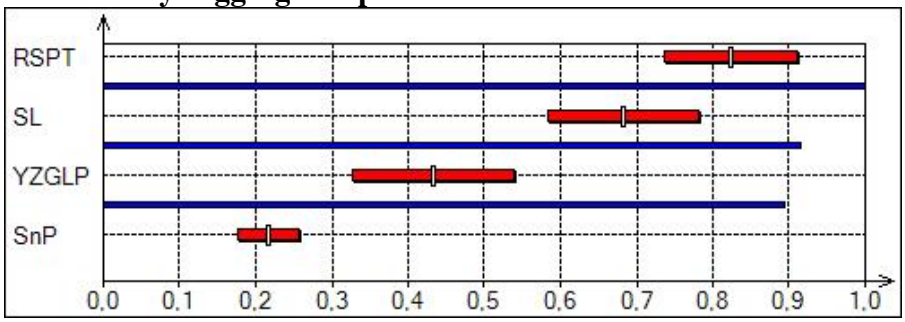
Safety. Aggregated preference indices visualization



Safety. Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(SnP)	0,1000	0,4500	0,3202	0,0848	3
Q(YZGLP)	0,8875	0,9750	0,9290	0,0188	1
Q(SL)	0,1000	0,4500	0,3202	0,0848	3
Q(RSPT)	0,3833	0,6167	0,4996	0,0535	2

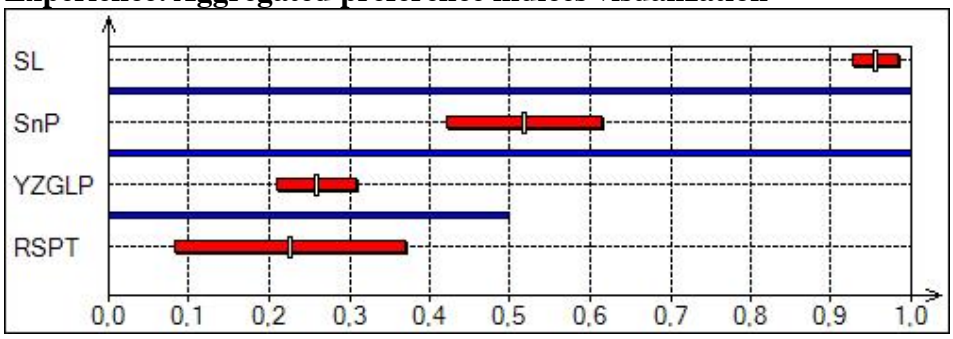
Accessibility. Aggregated preference indices visualization



Accessibility. Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(SnP)	0,1333	0,2833	0,2163	0,0399	4
Q(YZGLP)	0,1500	0,6000	0,4324	0,1048	3
Q(SL)	0,5000	0,9000	0,6824	0,0973	2
Q(RSPT)	0,6500	0,9500	0,8245	0,0874	1

Experience. Aggregated preference indices visualization

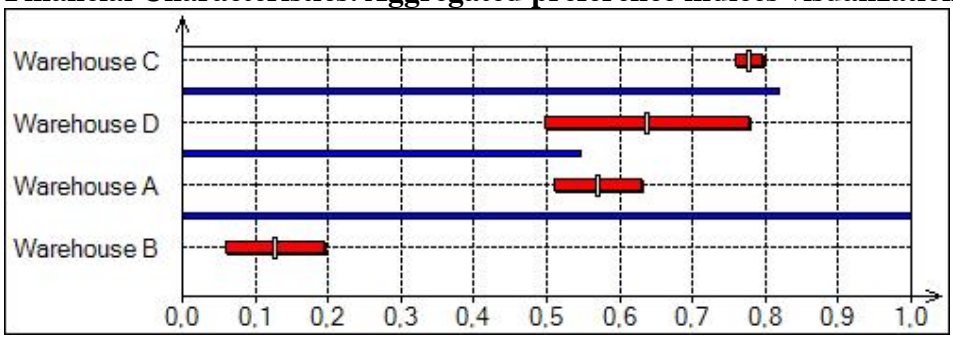


Experience. Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(SnP)	0,3667	0,6667	0,5167	0,0957	2
Q(YZGLP)	0,1833	0,3333	0,2583	0,0479	3
Q(SL)	0,9100	1,0000	0,9550	0,0287	1
Q(RSPT)	0,0000	0,4500	0,2250	0,1436	4

Appendix 14. Additional output information from APIS Technique for the Storage Service Supplier Selection

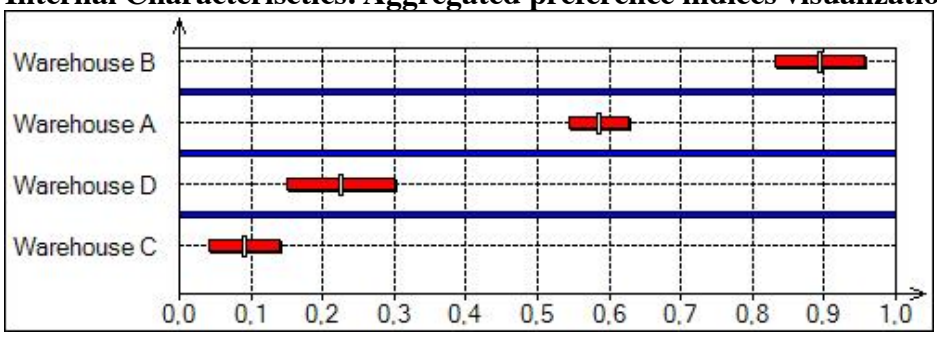
Financial Characteristics. Aggregated preference indices visualization



Financial Characteristics. Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(Warehouse A)	**0,4885**	**0,7038**	**0,5710**	**0,0590**	**3**
Q(Warehouse B)	**0,0112**	**0,2660**	**0,1270**	**0,0657**	**4**
Q(Warehouse C)	**0,7509**	**0,8147**	**0,7778**	**0,0172**	**1**
Q(Warehouse D)	**0,4000**	**0,9500**	**0,6364**	**0,1394**	**2**

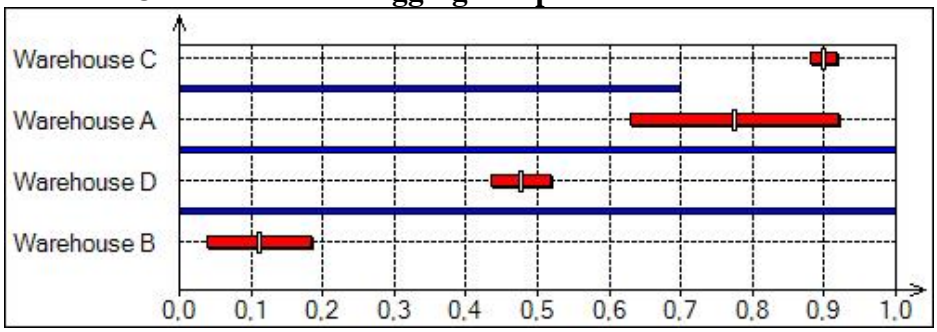
Internal Characterisctics. Aggregated preference indices visualization



Internal Characterisctics. Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(Warehouse A)	0,5122	0,6621	0,5855	0,0397	2
Q(Warehouse B)	0,7500	0,9750	0,8941	0,0621	1
Q(Warehouse C)	0,0313	0,2150	0,0913	0,0486	4
Q(Warehouse D)	0,0750	0,3650	0,2248	0,0733	3

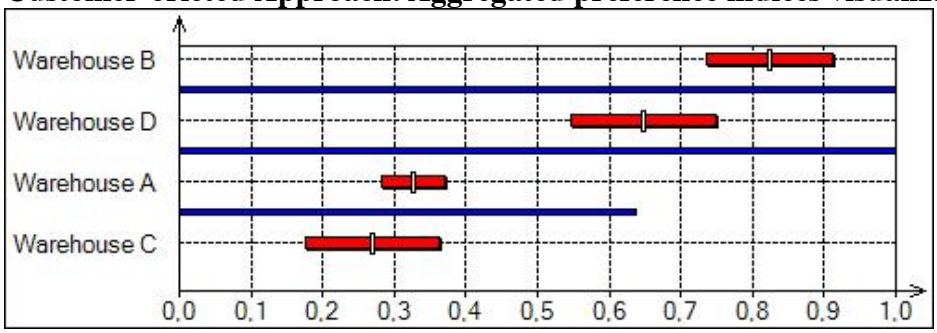
External Characterisctics. Aggregated preference indices visualization



External Characterisctics. Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(Warehouse A)	0,5500	1,0000	0,7750	0,1436	2
Q(Warehouse B)	0,0000	0,2250	0,1125	0,0718	4
Q(Warehouse C)	0,8694	0,9282	0,8988	0,0188	1
Q(Warehouse D)	0,4111	0,5429	0,4770	0,0421	3

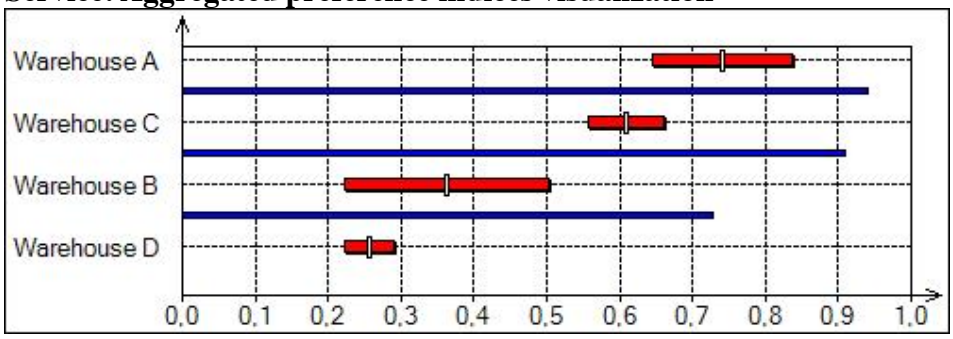
Customer-orieted Approach. Aggregated preference indices visualization



Customer-orieted Approach. Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(Warehouse A)	0,2500	0,4350	0,3270	0,0440	3
Q(Warehouse B)	0,6500	0,9500	0,8245	0,0874	1
Q(Warehouse C)	0,0831	0,4492	0,2695	0,0924	4
Q(Warehouse D)	0,4633	0,8878	0,6477	0,1017	2

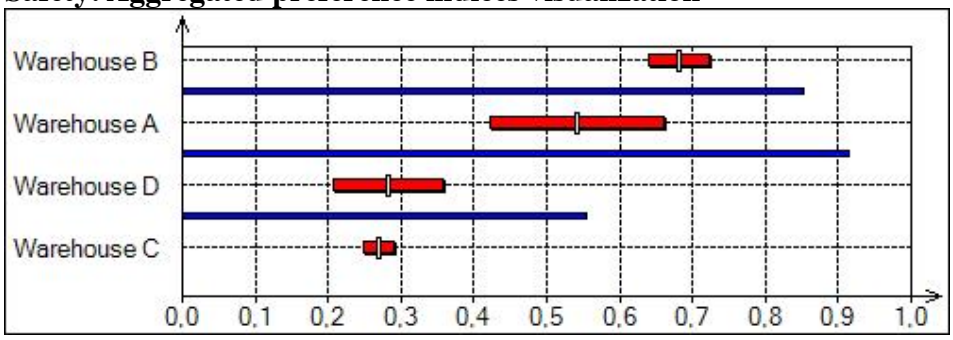
Service. Aggregated preference indices visualization



Service. Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(Warehouse A)	0,6028	0,9611	0,7412	0,0949	1
Q(Warehouse B)	0,0500	0,6000	0,3636	0,1394	3
Q(Warehouse C)	0,5000	0,6667	0,6091	0,0508	2
Q(Warehouse D)	0,1833	0,3167	0,2553	0,0339	4

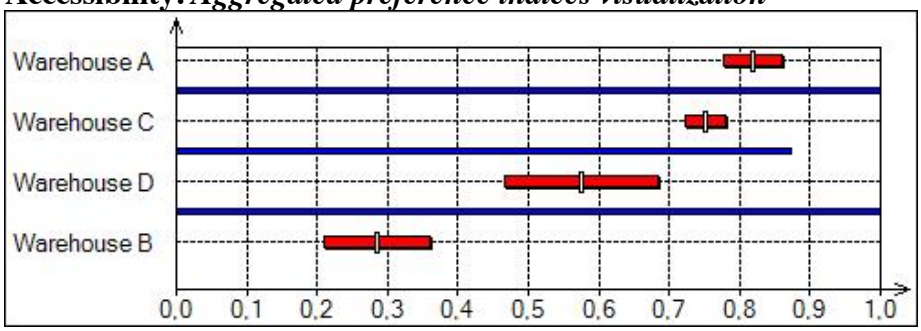
Safety. Aggregated preference indices visualization



Safety. Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(Warehouse A)	0,3500	0,8500	0,5404	0,1188	2
Q(Warehouse B)	0,6000	0,7833	0,6805	0,0409	1
Q(Warehouse C)	0,2208	0,3083	0,2692	0,0202	4
Q(Warehouse D)	0,1000	0,4250	0,2814	0,0748	3

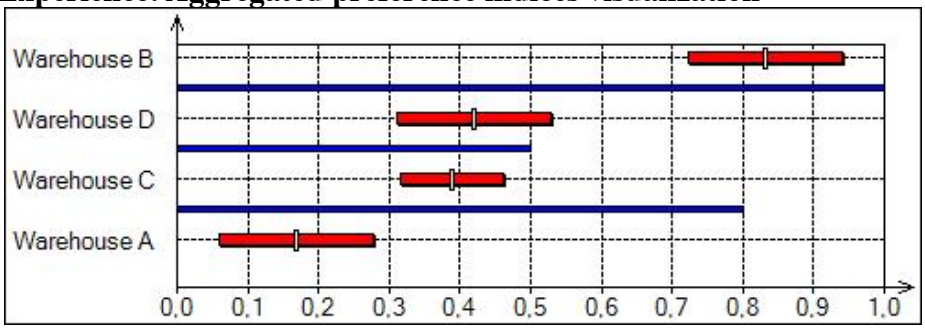
Accessibility. ***Aggregated preference indices visualization***



Accessibility. Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(Warehouse A)	0,7167	0,8833	0,8199	0,0396	1
Q(Warehouse B)	0,1000	0,4500	0,2840	0,0752	4
Q(Warehouse C)	0,6917	0,8083	0,7502	0,0268	2
Q(Warehouse D)	0,4000	0,8625	0,5753	0,1082	3

Experience. Aggregated preference indices visualization



Experience. Statistics of alternatives aggregated preference estimations

Aggregated index of alternative	Min	Max	Mean	StDev	Rank
Q(Warehouse A)	0,0000	0,3375	0,1688	0,1077	4
Q(Warehouse B)	0,6625	1,0000	0,8313	0,1077	1
Q(Warehouse C)	0,2750	0,5000	0,3875	0,0718	3
Q(Warehouse D)	0,2500	0,5875	0,4187	0,1077	2