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MULTI- CRITERIA DECISION BASED APPROACH TO SELECTING THE TYPE OF INDUSTRIAL HALLS USED IN FOOD INDUSTRY

Ozrislava Milinković[1], Branislav Jakić[2], Slobodan Vuksanović[3],Dragana Macura[4], Milica Šelmić[5]

Abstract

Design of production facility in food industry covers all stages of its development, from concept and selection of technological processes to the construction and putting facility in to operation. The objectives pursued in the selection and construction of multipurpose industrial facility is reducing costs as well as the negative impact that the building has on the environment. In other words objectives are connecting engineering theory and practice, in order to achieve savings in the use of resources necessary for the construction, reducing costs of maintenance and usage of the facility from the perspective of the whole life cycle. Introducing the concept of sustainability in food industry must start from choosing sustainable plant where food is processed, packed and stored. This is important because in a polluted environment is not possible to produce high-quality food. Applying multi-criteria decision methods is enabling us to objectively evaluate the impact that industrial buildings used in the food industry have on the environment, as well as their ability to meet production and environmental criteria. The paper is devoted to an analysis of commonly used industrial halls in food industry and building systems in terms of environmental protection and sustainable development.

1 Ozrislava Milinković Ph.D., University Business Academy Novi Sad, Faculty for Applied Management Economic and Finance, Nemanjina 4, 11000 Belgrade, Serbia +381 11 2643390, E-mail: ozradjurovic@yahoo.com

2 Branislav Jakić Ph.D., Full Professor, University Business Academy Novi Sad, Faculty for Applied Management Economic and Finance, Nemanjina 4, 11000 Belgrade, Serbia+381 11 2643390,E-mail: branislav.jakic@mef.edu.rs

3 Slobodan Vuksanović Ph.D., Assistant Professor,University Business Academy Novi Sad, Faculty for Applied Management Economic and Finance, Nemanjina 4, 11000 Belgrade, Serbia +381 11 2643390,E-mail: jassnna@yahoo.com

4 Dragana Macura Ph.D., Assistant Professor, Belgrade University, Faculty of Transport and Traffic Engineering, Vojvode Stepe 305, 11000 Belgrade, Serbia,+381 11 3091286, E-mail: d.macura@sf.bg.ac.rs

5 Milica Šelmić Ph.D., Assistant Professor, Belgrade University, Faculty of Transport and Traffic Engineering, Vojvode Stepe 305,11000 Belgrade, Serbia,+381 11 3091286, E-mail: m. selmic@sf.bg.ac.rs

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JEL*: L74, Q01, Q40, Q50*

Introduction

The Industrial Revolution and the development of mass production led to an increase in living standards and to progress in almost all aspects of human life. Development of the industry led to urbanization, economic and social prosperity, mass food production and increase in population. Development of new technologies has strongly reflected in the agriculture and food industry .Use of pesticides and fertilizers has enabled the creation of more abundant food supply while chemists and chemical engineers contributed food to be higher in quality and testier. However, human progress has come at the great price to environment. Increase in population inevitably led to increased exploitation of resources, deforestation, and emission of carbon dioxide, pollution of water, air and waste generation. Depletion of resources and growing environmental pollution triggered the reaction of experts to review the relationship between people and nature and to introduce the concept of "sustainability" in all aspects of human activity.

Methodology

In the paper relevant literature was used and the realistic data regarding initial cost of building construction, speed of construction, cost of maintenance for the period of 60 years, thermal losses, energy used for manufacturing construction material, mechanical resistance and stability of the building, noise protection, lifespan of the building, possibility of recycling, emission of harmful substances and radiation from materials and fire resistance. Analysis of the data was performed using multi-criteria decision-making method Analytic Hierarchy Process (AHP), with purpose of selecting the type of multipurpose industrial facility (hall) used in the food industry which will be cost effective while respecting environmental criteria.

Problem of selecting type of industrial hall used in the food industry

Selecting the type of industrial hall is a complex process because the selection criteria are often contradictory as well as interests of participants in decision-making process. Criterions that are most commonly conflicted are the initial price of the construction and impact on the environment. It is not uncommon that objects that have a low or lower initial construction costs have very high cost of maintenance and exploitation that can exceed the initial cost of construction several times as well as being environmentally unfriendly, over-consuming natural resources and therefore are not sustainable. In practice the main selection criteria of investment is the initial cost of construction without considering the cost of maintenance, cost of exploitation the exploitation and environmental impacts through the entire life cycle of the object.

Multi-criteria decisions making processes is applied to the important strategic decisions when there are a large number of criteria needed to be taken in to account as well as a large number of stakeholders (decision makers) with conflicted value systems. Multi-criteria decisions making processes and its methods can greatly improve the decision-making process and contribute to a more detailed and more accurate comparative analysis of infrastructure facilities by various criteria, such as economic and ecological. The proposed "best solution" has a good chance to be accepted as a good compromise between the various conflicting interests of participants in decision making process. Such methodological approach can lead to significant financial savings, reduced environmental pollution, resource consumption and faster integration into the European standards.

Belgrade region has a significant land potential of about 221 thousand hectares of agricultural land, which makes 68% of the total territory of Belgrade (Belgrade chamber of industry and commerce, 2015). Available land has significant capacity for the cultivation and processing of basic agricultural products, which is a good basis for the development of food industry. Development of food industry requires the construction of industrial facilities for the processing, storage, packaging and distribution of agricultural products. To assess the impact of industrial facilities on the environment and human health it is necessary to consider all phases of construction including the use of natural raw materials for the manufacture of building products of the construction method, the use of object-hall and eventually demolition and recycling. The construction is considered to be an activity that consumes the greatest amount of natural resources, requires high energy consumption during construction of multipurpose industrial buildings, as well as the operation of facilities (heating, cooling, and lighting) which is directly related to the emission of carbon dioxide and greenhouse gases.

In order to select the most sustainable industrial building-hall, analysis was conducted on the four most frequently built industrial halls used in the food industry:

- A1 - steel hall with sandwich panels,
- A2 - classic brick hall with a steel roof,
- A3 - prefabricated halls of reinforced concrete elements and
- A4 - prefabricated halls of ferrocement sandwich elements.

For the assessment of the sustainability and profitability of multifunctional industrial halls the following criteria has been taken in consideration: initial cost of building construction, speed of construction, cost of maintenance for the period of 60 years, thermal losses, energy used for manufacturing construction material, mechanical resistance and stability of the building, noise protection, lifespan of the building, possibility of recycling, emission of harmful substances and radiation from materials and fire resistance.

Based on realistic data from the practice properties of materials used and construction of buildings following calculations have been made:

X1 – Initial cost of building construction. The value of construction objects can be expressed through the total cost and over the unit of measurement of the constructed object. In Serbia it is common practice that m^2 is used as unit of measurement of built space. Cost calculations include only construction without finishing works and furnishing of the object. Values are defined according to the current offers of contractors.

Table 1. Average price of industrial halls € / m^2

Type of hall	Average price € / m^2
Steel hall with "sandwich" panel	210
Hall made of bricks with steel roof	320
Prefabricated hall made from reinforced concrete (AB)	380
Prefabricated ferrocement (FC)	290

Source: Authors' research

X2 - The speed of construction. It is measured with the number of days required to build facility. Speed of construction depends largely on the construction technology. Construction technology can be classified into: a traditional construction, improved traditional construction, industrialized construction and prefabrication.

Table 2. Speed of construction measured in working days

Type of hall	Speed of construction measured in working days
Steel hall with "sandwich" panel	60
Hall made of bricks with steel roof	120
Prefabricated hall made from reinforced concrete (AB)	45
Prefabricated ferrocement (FC)	45

Source: Authors' research

X3 - Maintenance costs for a period of 60 years. Maintenance is a process which ensures that a building or its parts are functional to use. Maintenance ensures safety, functionality and maintains the value of the property and its quality. In The Law on Planning and Construction of the Republic of Serbia are given two types of maintenance: investment and ongoing maintenance. Investment maintenance is performing construction or other works, depending on the type of object in order to improve condition during exploitation of the facility (Law on planning and construction article 2-36).

The current (regular) maintenance is performing the in order to prevent any damage caused by the use of the object or with the purpose of eliminating such damage and its consisting of inspection, repairs and taking preventive and protective measures, and all other works which provides a satisfactory level of usability (Law on planning and construction article 2-36a).

Table 3. Steel hall with "sandwich panels" - Maintenance cost calculated in Euros

No.	**Steel hall**	Unit	Qt. /No. work	Period	Times in 60 years	Pack	Price pack. / no. Days	Spending / hours days	Price unit.	Total
1	**Paint steel**	m^2	742.29	10	5	5l	25	1l/8m^2	0.625	2,319.66
	Work	h	6		5		10	10	2.5	7,500.00
	work patform	h	1		5		10	10	20	10,000.00
2	**The ridge**	m	1,405	15	3	6m	8		1.33	5,620.00
	The sealant	m	1,405	15	3	600ml	10	50ml/m	0.83	3,512.50
	work	h	12		3		10	10	2.5	9,000.00
	work platform	h	1		3		10	10	20	6,000.00
3	**Roof panel**	m^2	672	40	1	pcs			26	17,472.00
	work platform	h	6		5		10	10	3	9,000.00
	crane	h	1		5		10	5	50	12,500.00
4	**gutters**	m	138	25	2	m			4	1,104.00
	work	h	3		2		5	10	3	900.00
	work platform	h	1		2		5	10	20	2,000.00

total for 60 years	**86,928.16**
for/m2 yearly	**1.88**

Source: Authors' research

Table 4. Hall made of bricks with steel roof - Maintenance cost calculated in Euros

No.	**Hall from bricks**	Unit	Qt. /No. work	Period	Times in 60 years	Pack	Price pack. / no. Days	Spending / hours days	Price unit.	Total
1	**Mortar**	m^2	672	50	1				7	4,704.00
2	**Facade and facade paint**	m	672	20	2				4	5,376.00
	work	h								0.00
	work platform	h	1		3		20	8	20	9,600.00
2	**The ridge**	m	663	15	3	6m	8		1.33	2,652.00
	The sealant	m	663	15	3	100m	25	m	0.25	497.25
	work	h	6		5		10	10	2.5	7,500.00
	work platform	h	1		5		10	5	20	5,000.00
3	**Roof panels**	m^2	762	40	1	pcs			8	6,096.00
	work	h	6		5		10	10	3	9,000.00
	crane	h	1		5		10	5	50	12,500.00
4	**gutters**	m	138	25	2	m			4	1,104.00
	work	h	3		2		5	10	3	900.00
	work platform	h	1		2		5	10	20	2,000.00

total for 60 years	**66,929.25**
for/m2 yearly	**1.45**

Source: Authors' research

Table 5. Prefabricated AB hall - Maintenance cost calculated in Euros

No.	AB Hall	Unit	Qt. /No. work	Period	Times in 60 years	Pack	Price pack. / no. Days	Spending / hours days	Price unit.	Total
1	**Color concrete**	m^2	672	15	3	5l	30	1l/4m^2	1.5	3,024.00
	work	h	6		3		10	10	2.5	4,500.00
	work platform	h	1		3		10	10	20	6,000.00
	The sealant	m	1,405	15	3	600ml	10	50ml/m	0.83	3,512.50
	work	h	12		3		10	10	2.5	9,000.00
	work platform	h	1		3		10	10	20	6,000.00
3	**POLY-URETHAN**	m^2	672	15	3	25kg	130	1.5kg/m^2	7.8	15,724.80
	work	h	6		3		6	10	3	3,240.00
4	**gutters**	m	138	25	2	m			4	1,104.00
	work	h	3		2		5	10	3	900.00
	work platform	h	1		2		5	10	20	2,000.00

total for 60 years	**55,005.30**
for m2 yearly	**1.19**

Source: Authors' research

Table 6. Prefabricated FC hall - Maintenance cost calculated in Euros

No.	FC hall	Unit	Qt. /No. work	Period	Times in 60 years	Pack	Price pack. / no. Days	Spending / hours days	Price unit.	Total
1	**Mortar**	m^2	213	50	1				7	1,491.00
2	**Facade and façade color**	m	213	20	2				4	1,704.00
	work platform	h	1		3		8	10	20	4,800.00
3	**POLY-URETHAN**	m^2	1,217	15	3	25kg	130	1.5kg/m^2	7.8	28,477.80

total for 60 years	**36,472.80**
for/m2 yearly	**0.79**

Source: Authors' research

X4 –Energy used for the production of building materials. Construction materials are mainly obtained by processing of raw materials. For the production of building materials it is necessary to spend a certain amount of energy in order to obtain a usable building material from raw materials. Besides greenhouse gas emissions production process often requires a great expenditure of energy (Kreijger, 1979). Production of building materials is responsible for 80% of energy consumption and the construction process itself is responsible for only 13% (Gorkum, 2010).For the selection of building materials in addition to functionality, the impact they have on people's health the total energy balance should be taken into account (Hawken, Lovins, Lovins, 2009).It represents the total energy that some construction materials "consume" during the lifetime.

Table 7. Steel hall with "sandwich panels" - Energy consumption during manufacturing of construction materials

No.	Description of materials	m^3	t	kwh/t	Mwh total
1	Steel and steel plates	5.14	40.06	4,500.00	180.29
2	Mineral wool	148.00	17.76	6,000.00	106.56
					286.85

Source: Authors' research

Table 8. Hall made of bricks with steel roof - Energy consumption during manufacturing of construction

No.	Description of materials	m^3	t	kwh/t	Mwh total
1	Steel and steel plates	3.28	25.57	4,500.00	115.07
2	Clay blocks	156.00	109.20	832.00	90.85
3	AB,MB30	18.00	48.60	1,050.00	51.03
4	Mineral wool	159.58	19.15	6,000.00	114.90
					371.85

Source: Authors' research

Table 9. Prefabricated FC and AB halls - Energy consumption during manufacturing of construction

Description of materials	***Prefabricated FC hall dimensions 48x17***	***Prefabricated AB hall dimensions 48x17***
	Mwh	**Mwh**
Cement and steel	166.79	242.99
Extruded polystyrene	110.84	117.31
TotalMwh	**277.63**	**360.30**

Source: Authors' research

X5 - Thermal losses. Thermal transience also known as the "U" -value, is the rate of heat transfer and is measured in watts through one square meter of the building divided by the difference in temperature across the structure. It is expressed in watts per square meter (W / m^2K). The thermal transience of most of the walls and roofs can be calculated using the ISO 6946 standards; unless there are metal bridges to bridge the insulation in which case can be calculated using the ISO 10211 standards. ISO 6946 is the method of calculating the thermal resistance and thermal conductivity of construction components and building elements, excluding doors windows and other components through which air flows is provided and heat transfer in the ground (ISO 6946:2007).The characteristics of heat transfer depend on each structural element of the thermal conductivity of the material used, the thickness of the various components, geometric structure (straight, curved walls) as well as environmental conditions. The term "heat transfer loss" is a term used to describe the ability of the building envelope to save energy which is very important in assessing the energy efficiency of the building. Construction objects are responsible for 40% of total energy consumption in all European Union member states (Poel, Cruchten, Balaras, 2007).

Table 10. Thermal losses for analyzed halls

Type of hall			Steel hall with "sandwich" panel			Hall made of bricks with steel roof			RC hall			FC hall		
No.	SURFACES	c	m^2	w/m^2K	W	m^2	w/m^2K	W	m^2	w/m^2K	W	m^2	w/m^2K	W
1	Outer window - vertical wall	1	163	3.1	19,201.40	163	3.1	19,201.40	163	3.1	19,201.40	19.2	3.1	2,261.76
2	Outer window - roof	1		3.1			3.1			3.1		42.2	3.1	4,971.16
3	Outer vertical wall	1	672.77	0.39	9,970.51	672.77	0.27	6,902.66	672.77	0.25	6,391.35	213.03	0.26	2,104.78
4	Roof	1	768.84	0.39	11,394.21	768.84	0.39	11,394.21	768.84	0.25	7,303.98	1217	0.29	13,411.33
5	Floor	0.5	768.84	0.29	8,472.62	768.84	0.29	8,472.62	768.84	0.29	8,472.62	768.84	0.29	8,472.62
6	Surface of outer layer	m^2	2,373.45			2,373.45			2,373.45			2,260.27		
7	Volume of the object	m^3	5,190.44			5,190.44			5,190.44			5,190.44		
8	Factor of the specific shape	c	0.46			0.46			0.46			0.44		
9	Transmission loss	W	49,038.73			45,970.88			41,369.35			31,221.65		
10	Specific transmission losses	W/m^3	9.45			8.86			7.97			6.02		

Source: Authors' research

X6 - Total CO_2 emissions during the manufacturing of construction materials. During the manufacturing and processing of building materials, the environment is polluted in several different ways (Cole, 1998). One of the most alarming is through the emission of harmful gases especially carbon dioxide (CO_2). Construction materials are responsible for 75% of the total carbon dioxide emissions during the construction of the facility (Flower, Sanjayan, 2007).Based on values for emission of CO_2 for usual and alternative materials calculation has been made of total CO_2emission during the manufacturing of construction materials for analyzed halls.

Table 11. Steel hall with "sandwich panels" - Total CO_2 emission

No.	**Description of materials**	m^3	t	CO_2 kg/t	CO_2 (t) total
1	Steel and steel plates	5.14	40.06	1,720.00	68.91
2	Mineral wool	148.00	17,76	1,100.00	19.54
					88.45

Source: Authors' research

Table 12. Hall made of bricks with steel roof - Total CO_2 emission

No.	**Description of materials**	m^3	t	CO_2 kg/t	CO_2 (t) total
1	Steel and steel plates	3.28	25.57	1,720.00	43.98
2	Clay blocks	156.00	109.20	114.00	12.45
3	AB,MB30	18.00	48.60	370.00	17.98
4	Mineral wool	159.60	19.15	1,100.00	21.07
					95,47

Source: Authors' research

Table 13. AB and FC halls - Total CO_2 emission

Description of materials	***Prefabricated FC hall dimensions 48x17***	***Prefabricated AB hall dimensions 48x17***
	CO_2 (t)	**CO_2 (t)**
Cement and steel	75.06	103.95
Extruded polystyrene	12.21	12.93
Total emission of CO_2 (t)	**87.28**	**116.88**

Source: Authors' research

X7 - *The emission of harmful substances and radiation from materials*. Emission of harmful substances that are occurring as a result of production, exploitation, and destruction of building materials are negatively affecting both human health and the environment (Costner, 2005). State authorities are continuously studying different types of chemical additives used for creating and improving performance of construction materials. Many are rated as extremely toxic and even carcinogenic. Some of the most commonly used building materials include polyvinyl chloride (PVC), formaldehyde, radon and crystalline silicon.

- Steel hall with sandwich panels - sandwich panels are coated with "PVC" film to ensure water resistance. This coating to a lesser extent emits toxic fumes in the form of gas dioxin. According to the criteria emission of harmful substances and radiation from materials, this hall could be assessed as "average".
- Hall made of bricks with steel roof- In the composition of this hall all natural materials are included such as clay blocks and mortar. Hollow clay blocks are made of bricks which in small quantities are releasing toxic gas radon. According to the criteria of emission of harmful substances and radiation from the material, this hall could be assessed as "average".
- AB Prefabricated halls - In the composition of this hall next to the cement and mineral wool insulation that does not come in contact with the end user, are all natural materials which are not hazardous to human health. According to the criteria of radiation harmful substances from the material, this hall was assessed as "good".
- FC Prefabricated halls - In the composition of this hall next to the cement and steel and polystyrene is included. All this materials are not hazardous to human health. According to the criteria of radiation harmful substances from the material, this hall was assessed as "good".

X8 - Resistance to fire. DIN 4102 is widely accepted and used, German standard which describes the fire resistance properties of materials (DIN 4102-2).For the purpose of testing, materials are exposed to direct flame and then the rate of burning is measured. According to this standard, materials are classified as follows:

Table 14. Fire resistance expressed in minutes

Type of hall	Fire resistance expressed in minutes
Steel hall with “sandwich” panel	30
Hall made of bricks with steel roof	30
Prefabricated hall made from reinforced concrete (AB)	90
Prefabricated ferrocement (FC)	120

Source: Authors' research

X9 - Protection against noise. Environmental noise is unwanted or harmful sound (Law on noise protection in the environment article 3-1). The only obstacle between the people and the noise lies in the construction techniques, materials, and in creating physical barriers which reduces the sound energy to the allowable limit in the relevant areas. Sound protection is realized by choosing suitable design of the facility, performing sound insulation and mitigation measurement, or noise limitations (Law on noise protection in the environment article 3-17). Sound insulation is managed in the facility by implementing architectural - building measures that prevent the transmission of sound from one room to another after broadcasting with aimed to prevent the transmission of sound as much as possible. The goal is to reduce the noise that users of object can hear to the acceptable level. The unit of measurement which expresses the sound level is the decibel. The calculation is based on the properties of exterior walls and materials they are made from and it's carried out by the Faculty of civil engineering. In their work Antalova and Minarovièová (2003) are showing acoustic properties of homogeneous and composite elements. Based on these data following values have been defined:

Table 15. Noise protection values for analyzed halls

Type of hall	Noise protection expressed in dB
Steel hall with “sandwich” panel	32
Hall made of bricks with steel roof	61
Prefabricated hall made from reinforced concrete (AB)	72
Prefabricated ferrocement (FC)	64

Source: Authors' research

X10 - *Mechanical resistance and stability of the building*. The mechanical stability of the object can be static and dynamic. Static stability implies that the structure must be designed in a way that during the process of construction and usage does not crash deform or any other kind of structural damage does not occur. Dynamic stability implies that the structure must be designed so that due to the effect of natural forces such as earthquakes, wind or load due to the snows does not come to collapsing of the object.

Table 16. Mechanical stability and resistance values for analyzed halls

Type of hall	Mechanical stability and resistance expressed in MPa (N/mm^2)
Steel hall with "sandwich" panel	0.07
Hall made of bricks with steel roof	3.5
Prefabricated hall made from reinforced concrete (AB)	10
Prefabricated ferrocement (FC)	30

Source: Authors' research

X11 - *The lifespan of the facility*. The life span of the building structure can be described by:

- Technical lifetime is the period in which the construction element or structure is able to fulfill its intended function.
- Functional lifetime refers to the time period in which the objects fulfill the purpose of its aim and expectations of users in accordance with applicable standards and regulations.
- Economic life of the building structure is the period in which the costs of its operation and maintenance are within the planned cost.

Table 17. Life spam of halls expressed in years

Type of hall	Life spam of halls expressed in years
Steel hall with "sandwich" panel	30
Hall made of bricks with steel roof	Up to 50
Prefabricated hall made from reinforced concrete (AB)	Over 100
Prefabricated ferrocement (FC)	Over 100

Source: Authors' research

X12 - *Possibility of recycling*. Construction industry is responsible for almost 40%–50% of solid waste produced in the European Union yearly (Sterner, 2002). After demolishing a construction object behind it remains building materials such as concrete, wood, glass, metal structures and other. With recycling of these materials their processing and re-use reduces the negative impact of environmental contamination occurring during the production of new material. The recycling reduces the amount of waste and use of natural resources, recycling and reuse of materials reduces the energy and thus emissions of carbon dioxide that is emitted into the air during excavation of raw materials from nature and it's processing (Perez-Lombard, Ortiz, Pout, 2008).

- Steel hall with "sandwich" panels - Steel is material very suitable for recycling while the sandwich panels cannot be recycled due to the filling of mineral wool, which can harm human health. Evaluation of recyclability is "average".
- Hall made of bricks with steel roof- Steel reinforcement and concrete forming part of this hall can be very successfully recycled while facade and insulation materials from mineral wool are not suitable for recycling. Evaluation of recyclability is "average".

- Prefabricated reinforced concrete hall (AB) -Reinforced concrete that majority work became part of this hall can be recycled as insulation material polystyrene. Rating recyclability is “very good.”
- Prefabricated ferrocement halls (FC) Even though the whole building consists of reinforced concrete, reinforcement method is very specific and the armature is difficult to disentangle from concrete which prevents completely recyclable. Insulating filling is polyurethane that can be recycled. Rating recyclability is “very good.”

Multi- criteria decision based approach used - Analytical Hierarchy Process

Multi criteria decision making process represents one of the most important nonmonetary analysis of today (Papadopoulos,Karagiannidis, 2008) and analysis suitable for evaluation of construction projects and their impact on the environment (San-Jose,Cuadrado, 2010). Analytical hierarchy process (AHP) is one of the most used multi-criteria approaches to scenario analysis and decision-making with consistent evaluation of elements criteria and alternative (Saaty, 1980). AHP is a decision support system. A specific tool for the analysis of the hierarchy of the system, which by evaluating system elements in pairs in relation to the elements of the upper-level hierarchy level, is helping decision makers in the decision process.

AHP allows interactive analysis of the sensitivity of the evaluation process. In addition to this advantage, during the evaluation of elements it checks the consistency of reasoning and decision-makers examine the validity of the obtained rankings of alternatives and criteria, as well as their weight values (Saaty, 1986). AHP approach can treat both quantitative and qualitative attributes of alternatives.

AHP has been applied in various fields of strategic management, where decisions have far-reaching significance. Significance and validity of the scientific basis of this approach is confirmed by the numerous scientific papers and dissertations in which this approach is studied in detail and upgraded. Several scientific conferences dedicated only AHP approach, further confirming its quality and timeliness.

The hierarchy consists of a goal, which is at the top, and he is not compared with any other element of the system; then follows the second level - the criteria to be compared to each other in pairs in relation to the target. If there are sub criteria, they are mutually comparable in relation to each criterion, to which they belong. Finally, the alternatives are compared in relation to the criteria. So, at each hierarchical level elements are compared in relation to the elements of the upper-level.

Application of analytical hierarchy process and analysis of results

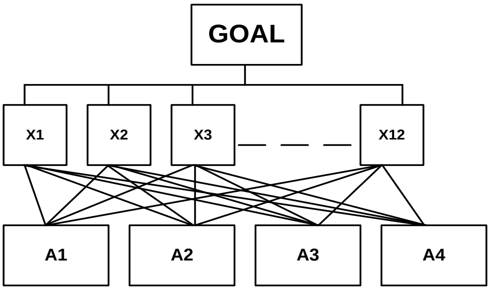
In this paper model was developed to select the type of industrial buildings - halls used in the food industry. The aim of this multi-criteria model is to maximize the profitability of the hall for the entire life cycle of the facility. Total of twelve relevant criterion has been defined, and the four alternatives, as discussed in the previous section. The developed model is graphically represented in the following figure.

Table18. Values of alternatives as per selected criterions

		Initial cost of construction	Speed of construction	Thermal losses	Energy needed for production of construction materials	Cost of maintanance for the period of 60 yrs	Total emission of Co^2 in production of construction materials	Fire resistance	Emission of harmful substances and radiation from materials	Sound protection from air - outside (Rw)	Mechanical stability and resistance	Life span	Recycling
	Description	eur/m^2	work.day	w/m^3	kwh	eur/m^2	t	minutes	5 points desc.	dB	MPa. (N/mm^2)	years	5 points desc
Steel hall with sandwich panels		210	60	9.45	286.85	1.88	88.45	30	average	32	3.5	40	average
Hall made from bricks with steel roof		320	120	8.86	371.85	1.45	95.47	30	average	61	10	50	good
Prefabricated AB hall		380	45	7.97	360.30	1.19	116.88	120	good	72	30	100	very good
Prefabricated FC hall		290	45	6.02	277.63	0.79	87.28	120	good	64	34	100	good

Source: Authors' research

Figure 1. AHP model



Source: Authors' research

In the developed model some criterions are "cost" type such as: initial cost of construction, speed of construction, thermal losses, maintenance costs, energy needed for production of construction materials, total emission of carbon dioxide during the production of construction materials emission of harmful substances and radiation from materials; and some are "benefit" type: fire resistance, possibility of recycling, noise reduction, mechanical stability and resistance, life cycle cost of object. "Cost" type criterions we wish to minimize while "benefit" type criterions we wish to maximize.

To define final rang of alternatives it is necessary to define relative weight of criterions. To the first criterion "initial cost of construction" double values is given compared to the other criterions which are of the same value. The reason behind such defining of a relative weight of criterions and giving priority to the first criterion compared to the others, is the fact that in practice it is price that is breaking factor in selecting type of industrial hall.

Table 19. Weights of criterions

Criterions	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
Relative weights	0.15	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08

Source: Authors' research

Next table represents final rang of halls and relative weights of alternatives. Calculation has been made after implementation of AHP multi-criteria decision support model.

Table 20. Final ranking of calculated results

Alternatives	Relative weight of alternatives	Final ranking of alternatives
Steel hall with "sandwich" panel	0.155	3
Hall made of bricks with steel roof	0.144	4
Prefabricated hall made from reinforced concrete (AB)	0.301	2
Prefabricated ferrocement (FC)	0.401	1

Source: Authors' research

Conclusion

Application of the Analytic Hierarchy Process (AHP) method for decision support enabled the objective decision of selecting the type of multipurpose industrial facility (hall) used in the food industry. We analyzed four types of most commonly built industrial halls used in the food industry: steel hall with sandwich panels, classic brick hall with a steel roof, prefabricated halls of reinforced concrete elements and prefabricated halls of ferrocement sandwich elements.

Analysis was carried out with the aim of reducing costs and respecting relevant environmental criteria. The data used in the analysis are real and calculated on the basis of material properties and structure of the analyzed object. According to the results of analysis, object which is recommended as a good compromise for investors from the aspect of cost reduction and preservation of the environment is prefabricated ferrocement hall. Such a result has justified from following reasons: with selection of prefabricated ferrocement hall financial savings at least 20% financial savings have been made for the investor compared to the other three halls. Also considerable savings are visible in the usage of construction material as 30% less cement and 31% of steel is needed. Additional savings are made in the transportation and assemble phase due to the considerable less weight of the construction (at around 50%). This type of hall can be recycled almost entirely and it provides savings in energy through entire life cycle of object: in the construction faze 30%, exploitation 50%, and recycling 50%.

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VIŠEKRITERIJUMSKI PRISTUP IZBORA TIPA INDUSTRIJSKIH HALA KORIŠĆENIH U PREHRAMBRENOJ INDUSTRIJI

***Ozrislava Milinković*[6], *Branislav Jakić*[7], *Slobodan Vuksanović*[8], *Dragana Macura*[9], *Milica Šelmić*[10]**

Abstrakt

Projektovanje proizvodnog pogona prehrambene industrije uključuje sve faze njegovog razvoja, od ideje i odabira tehnološkog procesa do izgradnje i puštanja u pogon. Ciljevi kojima se teži u odabiru i izgradnji višenamenskog industrijskog objekta su smanjenje troškova ali i negativnog uticaja koji objekat ima na životnu sredinu. Drugim rečima teži se povezivanju inženjerske teorije i prakse radi ostvarivanja uštede u korišćenju resursa potrebnih za izgradnju, smanjivanja troškova upotrebe i održavanja gledano iz ugla celog životnog ciklusa objekta. Uvođenje koncepta održivosti u prehrambenu inudstriju mora početi od odabira održivih postrojenja u kojima se obrađuje, pakuje i sladišti hrana. Ovo je važno jer u zagađenoj životnoj sredini nije moguća proizvodnja kvalitetne hrane. Primenom višekriterijumskih metoda odlučivanja omogućeno je objektivnije sagledavanje uticaja višenamenskih industrijskih objekata korišćenih u prehrambenoj industriji na životnu sredinu kao i njihovu sposobnost da ispune zadate proizvodne i ekološke kriterijume. Rad je posvećen analizi najčešće korišćenih industrijskih objekata-hala namenjenih prehrambenoj industriji i sistemima gradnje sa aspekta zaštite životne sredine i održivog razvoja.

Ključne reči: *višenamenski industrijski objekti -hale, zaštita* ***životne*** *sredine, održivi razvoj, višekriterijumska optimizacija - analitički hijerarhijski proces.*

6 Dr Ozrislava Milinković Univerzitet Privredna Akademija Novi Sad, Fakultet za primenjeni menadžment ekonomiju i finansije, Nemanjina 4, 11000 Beograd, Srbija +381 26 43 390, E-mail: ozradjurovic@yahoo.com

7 Profesor, dr Branislav Jakić, Univerzitet Privredna Akademija Novi Sad, Fakultet za primenjeni menadžment ekonomiju finansije, Nemanjina 4, 11000 Beograd, Srbija +381 26 43 390, E-mail: branislav.jakic@mef.edu.rs

8 Docent, dr Slobodan Vuksanović, Univerzitet Privredna Akademija Novi Sad, Fakultet za primenjeni menadžment ekonomiju i finansije, Nemanjina 4, 11000 Beograd, Srbija +381 26 43 390, E-mail: jassnna@yahoo.com

9 Docent, dr Dragana Macura, Univerzitet u Beogradu, Saobraćajni fakultet Vojvode Stepe 305, 11000 Beograd, Srbija, +381 11 3091286, E-mail: d.macura@sf.bg.ac.rs

10 Docent, dr Milica Šelmić, Univerzitet u Beogradu, Saobraćajni fakultet Vojvode Stepe 305, 11000 Beograd, Srbija, +381 11 3091286, E-mail: m.selmic@sf.bg.ac.rs

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