Tadeusz Trzaskalik

Sylwia Zawadzka

AHP APPLICATION TO RAW MATERIALS STOCK MANAGEMENT

Abstract

In the paper the problem of choosing logistics methods for control the level of stock is considered. The aim of the paper is to show how the AHP method can be applied for each sort of raw material stock management. For numerical illustration we use numerical data from a ceramic factory.

Keywords

Raw materials, stock management, analytic hierarchy process (AHP).

INTRODUCTION

One of the key problems for production firms is raw material stock management. In many small and medium-size Polish firms the problem of raw materials storage occurs. Firms very often apply former experience and signed agreements with suppliers. Logistic methods are used to determine the time of and quantity of ordering [2; 7; 8].

The problem of choosing the logistic method to control the optimal level of stock for each sort of raw material separately is multicriterial. It can be formulated as the problem of choosing the best alternative which can be solved by means of AHP method. Application of such methods seems to be attractive for decision makers [5; 6; 1].

The aim of this paper is to show how the AHP method can be applied for each sort of raw material stock management. For numerical illustration we use numerical data from a ceramic factory.

The paper consists of five chapters. In Chapter 2 logistics of raw materials is discussed. In Chapter 3 raw material stock management in a ceramic factory is shown. In Chapter 4 an application of AHP method for raw material stock management in the ceramic factory is proposed. The summary is given in Chapter 5.

1. LOGISTICS OF RAW MATERIAL STOCK

The logistic system in a firm can be divided into three parts:
- delivery logistics,
- production logistics,
- sale logistics.

Raw material stock management is an integral part of delivery logistics. The ability of keeping a low level of raw material stock is an important factor determining the competitiveness of the firm.

Raw materials are delivered by suppliers and do not require any technological operations. They are the basic materials bought for the production purposes. In a ceramic factory important raw materials are clay, chalk and sand.

There are several reasons to keep the raw materials stock in a firm:
- necessity to compensate for differences in intensity flows,
- protection against the uncertainty. Forecasts of demand and supply can be inexact. Raw materials stock protects the company against such forecasts and random disturbances as well,
- protection against an increase of demand,
- covering the shortages caused by delay in delivery,
- discounts connected with greater orders.

ABC classification can be applied for rational raw material stock management [2]. Raw materials utilized by a firm can be classified into class A, class B and class C.

<u>Class A</u>

The most important raw materials in production process. They influence the production output very much, thus they should be efficiently ordered and stored. They comprise 5-10% of the total quantity and 75-80% of the row materials total value.

<u>Class B</u>

Raw materials with stabilized characteristics. They comprise about 20% of the total quantity of row materials.

<u>Class C</u>

Mass raw materials. Their value is not significant.

Storing raw materials involves lock-up capital. Raw materials should be thus purchased in quantities needed for production only. It is important with respect to ordering the materials from suppliers and determining the rate of using them. It can be noticed that there are raw materials regularly used, raw materials used at changeable rate, and raw materials rarely used. It is important for the decision maker to know the characteristics mentioned above for all the raw materials used in the production process.

If raw materials are used regularly, the synchronization of the demand and orders is required. In the case of raw materials used with random deviation, storing them is the best solution. If raw materials are used rarely, the determination of supplies and storing should be done on individual basis.

The appropriate raw materials stock management policy depends mainly on the rapidity of using them. The following questions should be answered before making a decision about storing raw materials:

1. Which materials should be stored in the storehouse?
2. What is the size of an optimal order?
3. When should the order be placed?
4. Which raw materials stock control system should be applied?

We will consider five most frequently applied raw materials stock management models [3; 8].

Model M1

This is a model of stock level determining the time of ordering. The company that uses this model defines the alarm stock level *w* that indicates the time of supply. The size of this supply should be fixed at the level Q^*, which is an optimal size of supply that depends on the average level of using raw materials, storing costs and fixed costs of supplies. The optimal size of supply ensures the minimal total cost (the original formula of the total costs includes stock creation costs and stock maintaining costs) (see Fig.1).

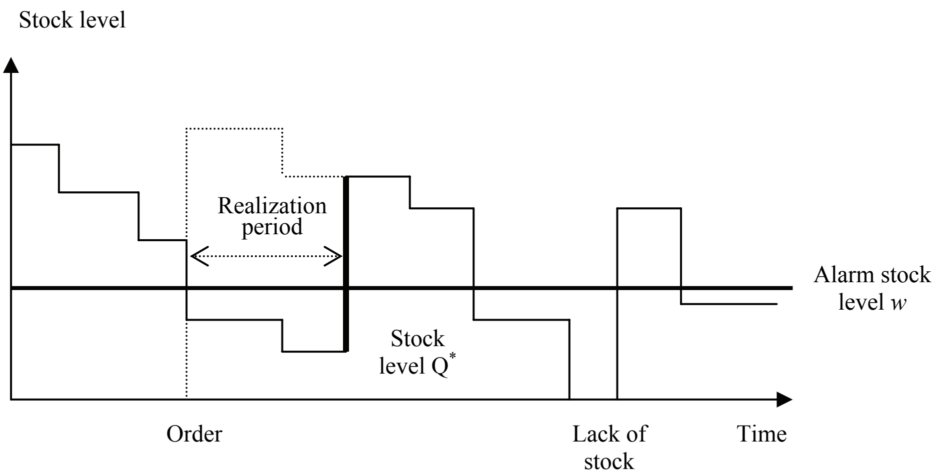

Fig. 1. Model M1

Model M2

This is a model of regular cycle of ordering. It takes into consideration the regularity of supplies and controls the stock at fixed and regular intervals. The main factor considered by the model is the size of order that increases the stock up to the fixed level *W*. The size of order is the result of subtraction of the current level of stock from the fixed level *W*. The supply is bigger if the current level of stock is low and it is smaller if the current level of stock is high. This method requires the determination of two factors: the level of resources *W* and the ordering cycle (see Fig. 2).

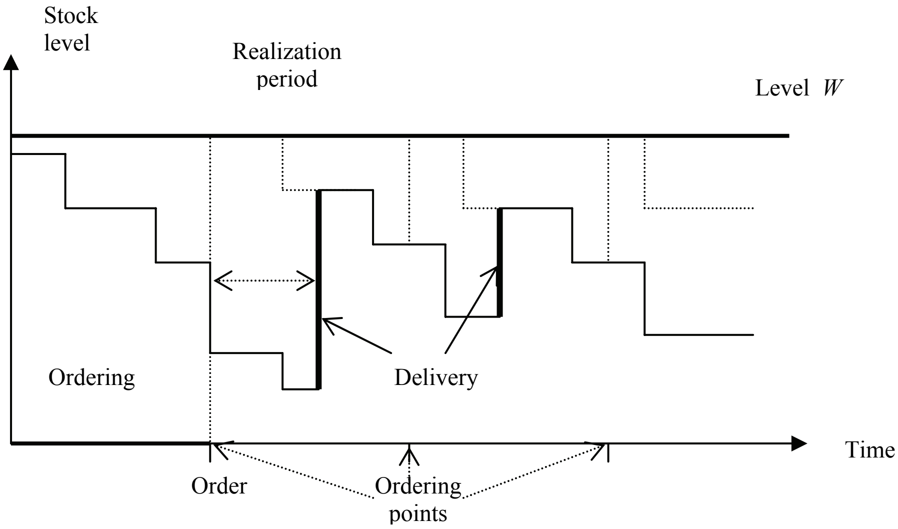

Fig. 2. Model M2

Model M3

This model determines the time of ordering in regular cycles. It is assumed that the stock level of a considered raw material is checked at fixed and regular periods. An optimal cycle of ordering *C*, which determines the time of checking the stock level, is identified. The order is placed when the current level of resources is lower than or equal to the ordering level *w* at the time of checking. This model is similar to the model M1, but does not require regular stock level checking. All the parameters are calculated in the same way as in the model M1 (see Fig. 3).

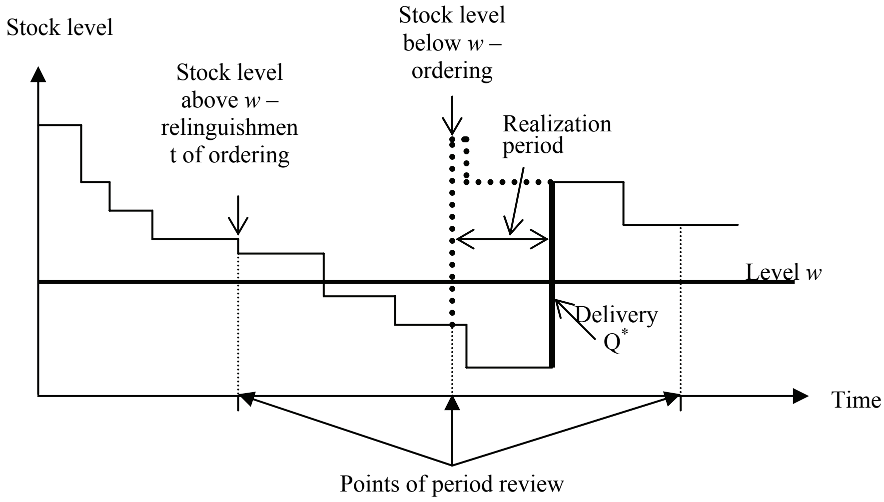

Fig. 3. Model M3

Model M4

This model is called a minimum-maximum model ("w,W"). Periodical monitoring of stock level is required. Orders are placed when the stock level is lower than the alarm level *w*. The size of order is the result of subtraction of the current stock level from the maximum level *W*. The additional factor *w*, called the alarm level ($w<W$) is determined. The order is not placed when the current level is between *w* and *W* (see Fig. 4).

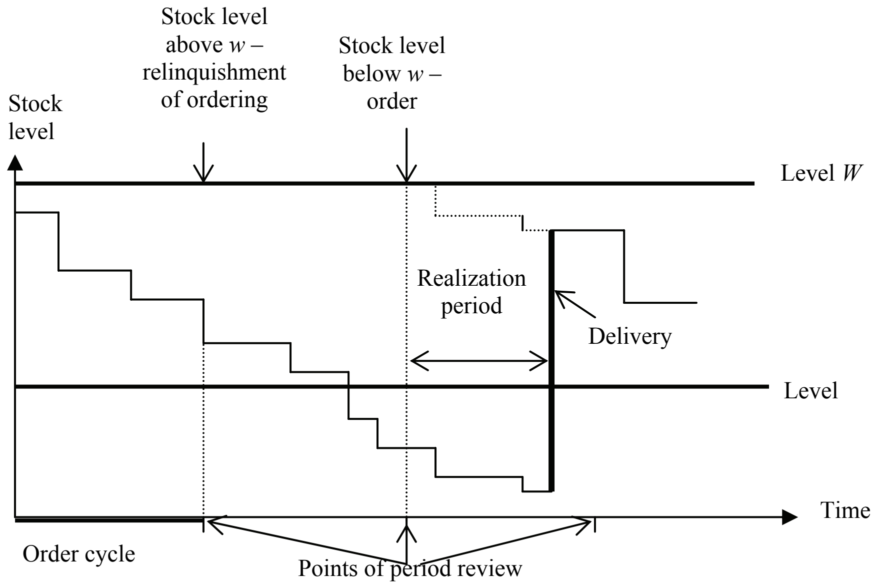

Fig. 4. Model M4

Model 5

In this model the time of ordering and the regular cycle of ordering are determined. There is a double protection against the stock shortage. The order that increases the stock up to the level *W* is placed if the current level drops below the alarm level *w* or in fixed periods. The scale of order is the result of subtraction of the current level of stock from the level *W* (see Fig. 5).

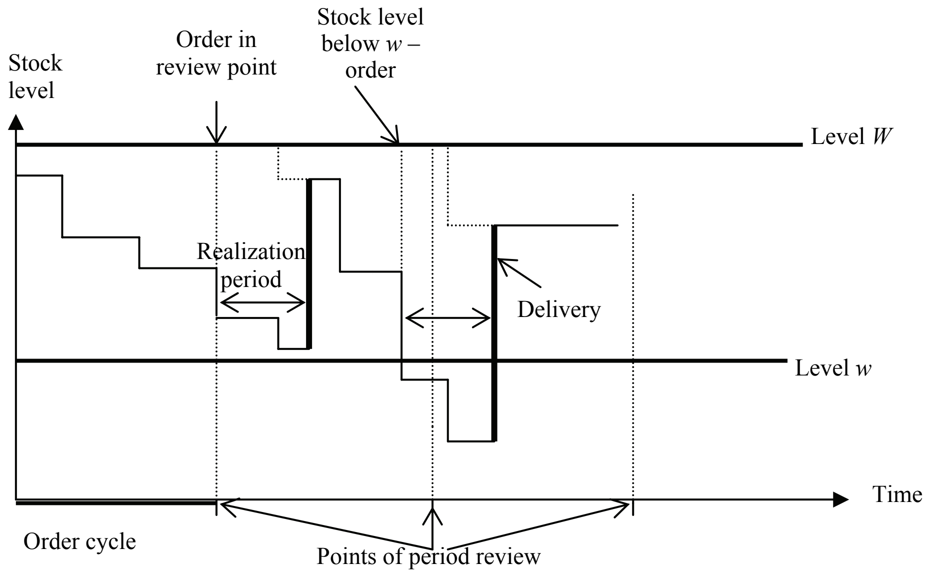

Fig. 5. Model M5

3. RAW MATERIALS STOCK MANAGEMENT MODELS IN A CERAMIC FACTORY

The production process in a ceramic factory can be divided into four stages:

1. Dry mass production – the grinding of the raw materials and mass liquidation.
2. Forming of products.
3. Baking.
4. Decorating – hand- or machine-made.

The dry mass production is the basic part of the production process because dry mass is the main component of every single product. The list of raw materials is given in Table 1. The quantities of raw materials given above are sufficient to produce two tones of dry mass.

Table 1

Raw materials for dry mass

No	Raw material	Symbol	Quantity [kg]	%
1	Clay TC1W	S1	300	12,7
2	Kaolinite Grudzeń	S2	1200	50,6
3	Clay Bełchatów	S3	180	7,6
4	Waste mass	S4	210	8,9
5	Sand	S5	130	5,5
6	Chalk	S6	150	6,3
7	Talc	S7	25	1,1
8	Glass capsules	S8	125	5,3
9	Feldspar	S9	50	2,1

Source: Database in considered ceramic factory

We will apply ABC classification method in our ceramic factory. The results are given in Table 2.

Table 2

ABC classification of raw materials used for dry mass production

Raw material	Value	Cumulated value	%	ABC Classification, A=75%,B=90%
S2	6507600,00	6507600,00	33,60	A
S1	4291650,00	10799250,00	55,77	A
S3	4256307,00	15055557,00	77,74	B
S6	1609368,75	16664925,75	86,06	B
S9	1028654,00	17693579,75	91,37	C
S4	883575,00	18577154,75	95,93	C
S8	584410,00	19161564,75	98,95	C
S5	201135,00	19362699,75	99,99	C
S7	2710,69	19365410,44	100,00	C
Sum	19365410,44			

Source: Databese in considered ceramic factory

The percentage share of raw materials in subsequent classes in total value of raw materials is given in Table 3.

Table 3

ABC Classification

Class	Number of raw materials	Quantity %	Value %
A	2	22,22	55,77
B	2	22,22	30,29
C	5	55,56	13,94
Sum	9		

In further considerations we will analyze raw materials of classes A and B.

Information about daily stock levels of raw materials of classes A and B and details of the production process in the period under consideration (July-September 2001) made it possible to conduct simulations by means of the models M1-M5.

The results of managing the level of stock of raw material S2 under application of the model M1 are given in Table 4. In the example shown below we apply daily utilization of kaolinite (S2), starting from the initial level of 20 000 kg. The days of placing the order are identified. The length of the arrow in Table 4 corresponds to the period of the order realization.

Table 4

Model M1 for kaolinite Grudzeń (S2)

No	**S2**	Model M1									
0		**No**	**S2**	**No**	**S2**	**No**	**S2**	**No**	**S2**	**No**	**S2**
1	18800	14	20364	27	1164	**40**	**19891**	53	291	66	54
2	17600	15	19164	28	18327	41	18691	54	18054	67	17818
3	16400	16	17564	29	17127	42	17491	55	16854	68	16618
4	14600	17	15964	30	15927	43	16291	56	15654	69	15418
5	12800	18	14364	31	14727	44	15091	57	14454	70	14218
6	11000	19	12764	32	13527	45	13491	58	13254	71	13018
7	9800	20	11164	33	12327	46	11891	59	12054	72	11818
8	8600	21	9564	34	10527	47	10291	60	10854	73	10618
9	7400	22	8364	35	8727	48	8691	61	9054	74	9018
10	6200	23	7164	36	6927	49	7091	62	7254	75	7418
11	**5000**	24	5964	**37**	**5327**	50	5491	63	5454	76	5818
12	3800	**25**	**4764**	38	3727	**51**	**3691**	**64**	**3654**	**77**	**4218**
13	2600	26	2964	39	2127	52	1891	65	1854	78	2618

The results of applying the other models for material S2 are given in Tables 5-8. In a similar way the remaining raw materials from classes A and B are considered.

Table 5

Model M2 for kaolinit Grudzeń (S2)

No	S2	Model M2									
0	**20000**	**No**	**S2**	**No**	**S2**	**No**	**S2**	**No**	**S2**	**No**	**S2**
1	18800	14	1400	27	3902	40	3302	53	3502	66	3102
2	17600	15	200	28	2102	41	2102	54	1902	67	1902
3	16400	16	20302	29	19502	42	20702	55	19902	68	20102
4	14600	17	18702	30	18302	43	19502	56	18702	69	18902
5	12800	18	17102	31	17102	44	18302	57	17502	70	17702
6	11000	19	15502	32	15902	45	16702	58	16302	71	16502
7	9800	20	13902	33	14702	46	15102	59	15102	72	15302
8	8600	21	12302	34	12902	47	13502	60	13902	73	14102
9	7400	22	11102	35	11102	48	11902	61	12102	74	12502
10	6200	23	9902	36	9302	49	10302	62	10302	75	10902
11	5000	24	8702	37	7702	50	8702	63	8502	76	9302
12	3800	25	7502	38	6102	51	6902	64	6702	77	7702
13	***2600***	***26***	***5702***	***39***	***4502***	***52***	***5102***	***65***	***4902***	***78***	***6102***

Tabela 6

Model M3 for kaolinite Grudzeń (S2)

No	S2	Model M2									
0	**20000**	**No**	**S2**	**No**	**S2**	**No**	**S2**	**No**	**S2**	**No**	**S2**
1	18800	14	1400	27	1164	40	927	53	291	66	54
2	17600	15	19164	28	-636	41	18691	54	-909	67	17818
3	16400	16	17564	29	17127	42	17491	55	16854	68	16618
4	14600	17	15964	30	15927	43	16291	56	15654	69	15418
5	12800	18	14364	31	14727	44	15091	57	14454	70	14218
6	11000	19	12764	32	13527	45	13491	58	13254	71	13018
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9	7400	22	8364	35	8727	48	8691	61	9054	74	9018
10	6200	23	7164	36	6927	49	7091	62	7254	75	7418
11	5000	24	5964	37	5327	50	5491	63	5454	76	5818
12	3800	25	4764	38	3727	51	3691	64	3654	77	4218
13	***2600***	***26***	***2964***	***39***	***2127***	***52***	***1891***	***65***	***1854***	***78***	***2618***

Table 7

Model M4 for kaolinite Grudzeń (S2)

No	S2	Model M4									
0	**20000**	**No**	**S2**	**No**	**S2**	**No**	**S2**	**No**	**S2**	**No**	**S2**
1	18800	*14*	*1400*	27	2702	***40***	***3302***	53	4702	*66*	*6302*
2	*17600*	15	20702	*28*	*902*	41	2102	***54***	***3502***	67	5102
3	16400	*16*	*19102*	29	19502	*42*	*902*	55	2302	***68***	***3902***
4	*14600*	17	17502	*30*	*18302*	43	20702	*56*	*1102*	69	2702
5	12800	*18*	*15902*	31	17102	*44*	*19502*	57	20702	*70*	*1502*
6	*11000*	19	14302	*32*	*15902*	45	17902	*58*	*19502*	71	20702
7	9800	*20*	*12702*	33	14702	*46*	*16302*	59	18302	*72*	*19502*
8	*8600*	21	11102	*34*	*12902*	47	14702	*60*	*17102*	73	18302
9	7400	*22*	*9902*	35	11102	*48*	*13102*	61	15302	*74*	*16702*
10	*6200*	23	8702	*36*	*9302*	49	11502	*62*	*13502*	75	15102
11	5000	*24*	*7502*	37	7702	*50*	*9902*	63	11702	*76*	*13502*
12	***3800***	25	6302	*38*	*6102*	51	8102	*64*	*9902*	77	11902
13	2600	***26***	***4502***	39	4502	*52*	*6302*	65	8102	*78*	*10302*

Table 8

Model M5 for kaolinite Grudzeń (S2)

No	S2	Model M5									
0	**20000**	**No**	**S2**	**No**	**S2**	**No**	**S2**	**No**	**S2**	**No**	**S2**
1	18800	14	20702	27	1502	40	1502	53	1902	66	1702
2	17600	15	19502	28	18902	41	20302	54	19702	67	19502
3	16400	16	17902	29	17702	42	19102	55	18502	68	18302
4	14600	17	16302	30	16502	43	17902	56	17302	69	17102
5	12800	18	14702	31	15302	44	16702	57	16102	70	15902
6	11000	19	13102	32	14102	45	15102	58	14902	71	14702
7	9800	20	11502	33	12902	46	13502	59	13702	72	13502
8	8600	21	9902	34	11102	47	11902	60	12502	73	12302
9	7400	22	8702	35	9302	48	10302	61	10702	74	10702
10	6200	23	7502	36	7502	49	8702	62	8902	75	9102
11	**5000**	24	6302	37	5902	50	7102	63	7102	76	7502
12	3800	**25**	**5102**	**38**	**4302**	**51**	**5302**	**64**	**5302**	77	5902
13	*2600*	*26*	*3302*	*39*	*2702*	*52*	*3502*	*65*	*3502*	***78***	***4302***

3. APPLICATION OF AHP METHOD TO MODEL SELECTION

We assume that the decision maker wants to choose the best model for raw material stock level management. We will consider each sort of raw materials of classes A and B separately. The decision alternatives are as follows:

M1 – the model of stock level determining the time of ordering,
M2 – the model of constant cycle of order,
M3 – the model of stock level determining time of order in regular cycle of ordering,
M4 – the model minimum-maximum “w-W”,
M5 – the model in which time of ordering and regular cycle of ordering are determined.

It seems reasonable to consider the following four criteria:
K1 – total cost of placing orders in the considered period,
K2 – total number of inspections,
K3 – unit price of order,
K4 – scale of the shortage (if applicable).

A hierarchical model created according to AHP rules is given in Fig. 6.

Applying AHP method for the kaolinite Grudzen (S2) raw material we obtain the ranking presented in Table 9.

Table 9

Priorities for S2

No	Model	Priority %
1	M4	31,90
2	M2	25,23
3	M5	19,37
4	M1	17,37
5	M3	6,12

A hierarchical model created according to AHP rules is given in Fig. 6.

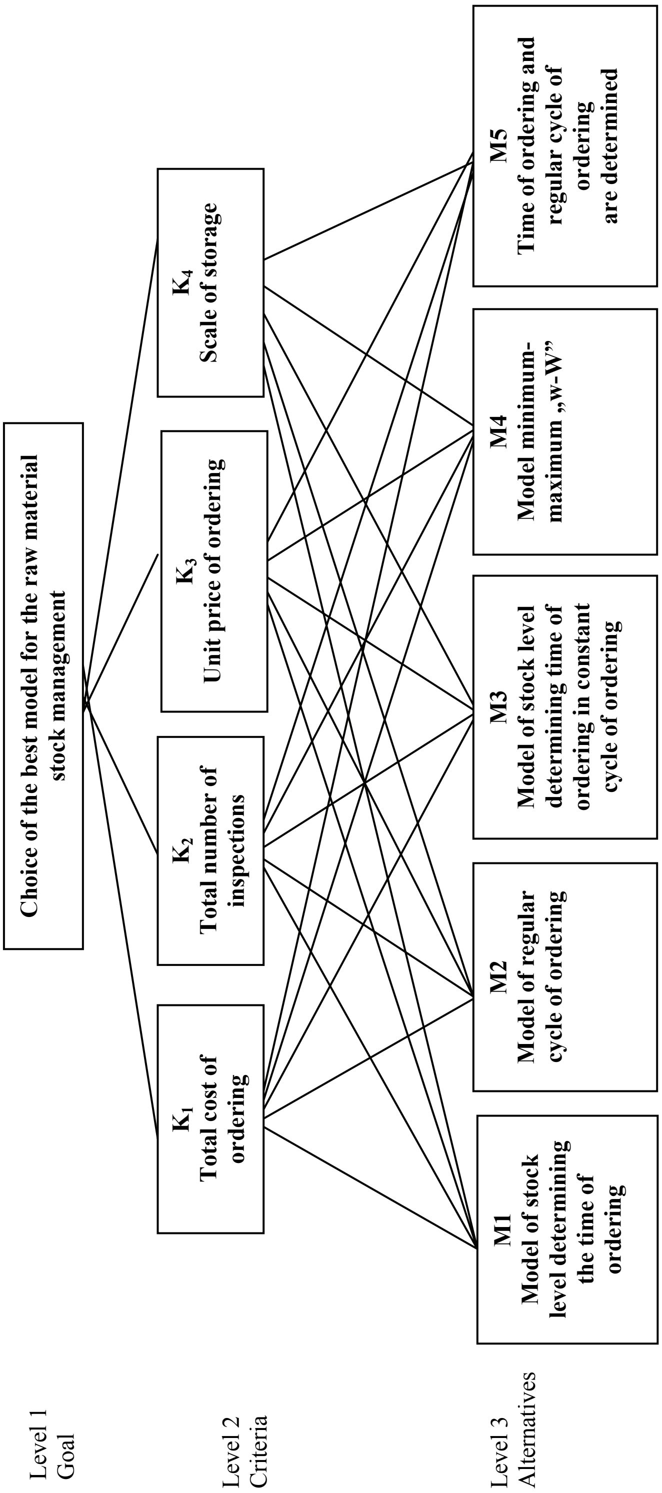

Fig. 6. AHP hierarchical model

The results show that the model M4 should be applied for stock level management of the kaolinite Grudzeń (S2) raw material. The local preferences show that the most important factor was the unit price of order. Tables 10 – 12 show the results obtained for the remaining materials.

Table 10

Priorities for S1

No	Model	Priorities %
1	M3	25,63
2	M1	24,58
3	M5	17,99
4	M2	16,67
5	M4	15,13

Table 11

Priorities for S3

No	Model	Priority %
1	M2	25,71
2	M1	25,61
3	M4	19,21
4	M5	18,24
5	M3	11,24

Table 12

Priorities for S6

No	Model	Priority %
1	M1	23,64
2	M4	22,72
3	M2	20,38
4	M5	17,67
5	M3	15,59

CONCLUSION

For the most important kaolinite Grudzen (S2) raw material the model M4 was determined by AHP method to be the most profitable one. For the clay TC1W (S1) raw material the model M3 is a little more favorable than the model

M1. Both these models can be thus applied to S1 raw material management. For the clay Bełchatów (S3) raw material the models M2 and M1 appear to be equally good. The less important chalk raw material (S6) can be managed best by the models M1 and M4.

The results of applying AHP method obtained for the presented example show that it can be successfully applied for real-world resources management problems in production companies.

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