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PLANNING THE SUPPLIES OF PRODUCTION MATERIAL PURCHASED IN CONSTANT SIZE OF DELIVERY PACKAGE

1. Introduction

Today, if one wishes to manage the company effectively, it is necessary to dedicate much more time and attention to the tools of planning, control and management. A new group of tools is required, providing better clarity of the company's costs and revenues, which in turn means that the results and expenses should be planned and controlled even more carefully than so far.

In many companies, it is easy to notice the need for developing new tools supporting the decision process already on the stage of production planning and supply of materials. In practice, determining the size of production lots, or the material supplies and their schedule are often one of the least appreciated and badly executed planning activities. This fact is mainly caused by the lack of knowledge as to the possibilities, conditions and consequences of applying the methods selected.

This study is totally devoted to the issue of material supply planning in relation to the production requirements of the company. This work is an attempt to search for a methodological approach assisting the decision process. The assumption is that the proposed procedure should be simple enough to avoid any significant cost while putting it into practice.

2. Planning the supply of production materials– decision process

The fundamental purpose of planning material procurement is to assure the continuity of production. In other words, planning is aimed at meeting the requirements of production regarding the kind of materials, their size and terms of delivery. Such decisions also have to be economically justified.

Literature gives many methods supporting this decision process, however, in practice they are not applied in Polish companies to a larger extend or they are not used at all. The reason for this state of things most often lies in the lack of abilities to adapt certain methods to the operating conditions of a given company. However, each person responsible for the control of production materials supplies, sometimes even unconsciously, creates some repeatable outline of the procedure. Therefore, a question arises automatically, whether it is possible to design a general method, which would at the same time be flexible enough to be used in practice by various companies. Certainly, every general solution still needs to be adjusted to the specific activity of any given company. The following work is an attempt to find such a method.

In the beginning, it is necessary to point out that this procedure refers to the selection of the optimal (according to the criterion accepted) delivery plan of a single material.

The proposed method of making decisions consists of the two consecutive stages. The role of the first one is to generate all feasible variants of the material delivery plan. In the next stage, based on a subjective criterion, the choice of the optimal solution is being made. The cost criterion is the one most often applied. In other words, the company tries to determine the quantities and dates of material deliveries in such a way that production needs are satisfied in 100%, while at the same time incurring the lowest expenses related to the flow of this material.

3. Stage 1 – generating the set of acceptable decisions

On the first stage of the proposed procedure, a set of alternative, acceptable decisions related to the quantities and dates of deliveries of a given material in a given period of time should be generated. Only those decisions, which cover the production needs in 100%, are considered acceptable. In reality, the feasibility of alternative solutions and their acceptability should also be considered with respect of other criteria specific to a given company, for instance in the context of its storage capacity or financial capabilities. Practice often shows that a constraint of some kind appears in the purchasing process, which in many cases significantly affects the whole purchasing planning procedure. A typical case here could be for example the size of commercial packages in which the given material can be purchased from a certain supplier. Therefore, in the proposed procedure an assumption is made that the material from the particular supplier can only be bought in multiples of the commercial package. For more clarity, it is further assumed that the supplier can offer only one and unchangeable size of the package. Moreover, an infinite availability of the material is also assumed.

In order to enter the first stage of the procedure, it is essential to establish some basic assumptions. This study was based on the general principles applied in formulating the assumptions for dynamic programming [1, pp. 165-167]:

1) the replenishment plan (purchase orders) refers to the procurement of one purchased material only, in one type of commercial packaging of size „S". The quantity of a single purchase must be a multiple of the commercial packaging size;

2) planning is carried out for a finite number of n periods (e.g.: of months). Every period can be identified by the starting and ending point. We are assuming that the period numbered i is determined by the interval $[i-1, i]$ what we read: period i has its beginning at moment $i-1$ and ending at moment i;

3) the supply of the material is being transferred to the warehouse where it is being added to the available stock in the beginning of the period. The available stock at the end of a period is becoming the available supply in the beginning of the next period. Let z_i mean the available stock at the moment i, $i = 0, 1, \ldots, n$. We are interpreting z_0 as the available stock in the beginning of period 1. z_1 means the available stock at the end of the period 1 what is equal to the available stock in the beginning of the period 2;

4) we represent the quantity purchased in period i with x_i, $i = 1, 2, \ldots, n$ (in multiples of a single distribution package „S"). The purchase can be made within the whole period. Based on the priniciple of adding it to the stock available at the beginning of the period, we are deciding that we have the right to make use of it as if it was available in the beginning of the period;

5) we assume that we know the orders for the material in every period. We represent the order in period i, $i = 1, 2, \ldots, n$ with d_i.

In the model:

- size of the order is treated as external data resulting from the real orders or from the forecast,
- we will be treating the available stock of the material as a result figure, calculated on the basis of purchased quantities and consumption resulting from production orders,
- size of a single purchase of the material is a variable decision.

It is possible to find a simple balancing equation between the introduced values:

$$z_i = z_{i-1} + x_i - d_i,\ i = 1, 2, \ldots, n,$$

which we read directly – available stock at the end of the period i is equal to available stock in the beginning of the period increased by the purchase in this period and decreased by the size of the realized production order in this period. We are receiving a set of recursive equations, which show the changes in stock quantities resulting from the purchase decisions and production requirements.

Having determined the basic assumptions of the method, it is possible to start formulating the task of the first stage of the procedure, and then finding the method of its solution:

TASK:

Assuming that the sequence of production orders for the material is known for n periods, and knowing the size of commercial packaging of the material, the task is to determine the quantity purchased in each period in such a way that it will be possible to carry out production orders with the stock available at the warehouse.

SOLUTION TO THE TASK:

1. Determine the total number of purchased distribution packages in the analyzed n periods.

2. Determine feasible variants of the quantity of purchased distribution packages in every period, so that it is possible to carry out production orders using the stock at the warehouse.

We assume that the available stock at the beginning of the first period $z_0 = 0$.

The process of determining legal variants of purchase quantities in periods i, $i = 1, 2, \ldots, n$ will be presented in more detail using the example of planning of supplies of the material „T" in one of production companies.

Example:

Material „T" is being purchased in multiples of constant, 25 kilogram distribution packages.

Planning of supplies of the material „T" will be conducted for twelve consecutive periods (in this case months).

Initial data:

Size of commercial package [kgs]	25

Period	1	2	3	4	5	6	7	8	9	10	11	12
Quantity drawn from stock [kgs]	5	3	4	6	6	5	6	5	6	4	3	4

Auxiliary data:

Total quantity drawn from stock [kgs]	57
Number of commercial packages [pcs]	3

Period	1	2	3	4	5	6	7	8	9	10	11	12
Cumulative quantity drawn from stock [kgs]	5	8	12	18	24	29	35	40	46	50	53	57
Cumulative number of packages [pcs]	1	1	1	1	1	2	2	2	2	2	3	3

Solution:

In the analyzed example of supplies of material „T", the generation of acceptable variants gave the following results:

Table 1. Acceptable variants of supplies of material „T"

Period	1	2	3	4	5	6	7	8	9	10	11	12
Variant 1	3	0	0	0	0	0	0	0	0	0	0	0
Variant 2	2	1	0	0	0	0	0	0	0	0	0	0
Variant 3	2	0	1	0	0	0	0	0	0	0	0	0
Variant 4	2	0	0	1	0	0	0	0	0	0	0	0
Variant 5	2	0	0	0	1	0	0	0	0	0	0	0
Variant 6	2	0	0	0	0	1	0	0	0	0	0	0
Variant 7	2	0	0	0	0	0	1	0	0	0	0	0
Variant 8	2	0	0	0	0	0	0	1	0	0	0	0
Variant 9	2	0	0	0	0	0	0	0	1	0	0	0
Variant 10	2	0	0	0	0	0	0	0	0	1	0	0
Variant 11	2	0	0	0	0	0	0	0	0	0	1	0
Variant 12	1	2	0	0	0	0	0	0	0	0	0	0
Variant 13	1	1	1	0	0	0	0	0	0	0	0	0
Variant 14	1	1	0	1	0	0	0	0	0	0	0	0
Variant 15	1	1	0	0	1	0	0	0	0	0	0	0
Variant 16	1	1	0	0	0	1	0	0	0	0	0	0
Variant 17	1	1	0	0	0	0	1	0	0	0	0	0
Variant 18	1	1	0	0	0	0	0	1	0	0	0	0
Variant 19	1	1	0	0	0	0	0	0	1	0	0	0
Variant 20	1	1	0	0	0	0	0	0	0	1	0	0
Variant 21	1	1	0	0	0	0	0	0	0	0	1	0
Variant 22	1	0	2	0	0	0	0	0	0	0	0	0
Variant 23	1	0	1	1	0	0	0	0	0	0	0	0
Variant 24	1	0	1	0	1	0	0	0	0	0	0	0
Variant 25	1	0	1	0	0	1	0	0	0	0	0	0
Variant 26	1	0	1	0	0	0	1	0	0	0	0	0
Variant 27	1	0	1	0	0	0	0	1	0	0	0	0
Variant 28	1	0	1	0	0	0	0	0	1	0	0	0
Variant 29	1	0	1	0	0	0	0	0	0	1	0	0
Variant 30	1	0	1	0	0	0	0	0	0	0	1	0
Variant 31	1	0	0	2	0	0	0	0	0	0	0	0
Variant 32	1	0	0	1	1	0	0	0	0	0	0	0
Variant 33	1	0	0	1	0	1	0	0	0	0	0	0
Variant 34	1	0	0	1	0	0	1	0	0	0	0	0
Variant 35	1	0	0	1	0	0	0	1	0	0	0	0
Variant 36	1	0	0	1	0	0	0	0	1	0	0	0
Variant 37	1	0	0	1	0	0	0	0	0	1	0	0
Variant 38	1	0	0	1	0	0	0	0	0	0	1	0
Variant 39	1	0	0	0	2	0	0	0	0	0	0	0
Variant 40	1	0	0	0	1	1	0	0	0	0	0	0
Variant 41	1	0	0	0	1	0	1	0	0	0	0	0
Variant 42	1	0	0	0	1	0	0	1	0	0	0	0
Variant 43	1	0	0	0	1	0	0	0	1	0	0	0
Variant 44	1	0	0	0	1	0	0	0	0	1	0	0
Variant 45	1	0	0	0	1	0	0	0	0	0	1	0
Variant 46	1	0	0	0	0	2	0	0	0	0	0	0
Variant 47	1	0	0	0	0	1	1	0	0	0	0	0
Variant 48	1	0	0	0	0	1	0	1	0	0	0	0
Variant 49	1	0	0	0	0	1	0	0	1	0	0	0
Variant 50	1	0	0	0	0	1	0	0	0	1	0	0
Variant 51	1	0	0	0	0	1	0	0	0	0	1	0

Source: own study.

Having determined the set of acceptable decisions – variants of supplies of material „T" in the analyzed period of twelve months – it is possible to initiate the second stage of the procedure, i.e. to the selection of the optimal variant of supplies.

4. Stage 2 – indicating the best variant of material supplies

The aim of the second stage of the proposed procedure is to indicate which solution from the group of previously established acceptable solutions is the optimal one, from the point of view of a criterion approved by a given company. Most often, this type of decisions is made on the basis of cost criteria which are reliable and which were designed especially for the needs of a given company. The proposed procedure was based on cost related components, most often used by companies when planning material supplies. These components were divided into 3 basic groups: material costs, stock creation costs and stock holding costs. Three combined basic groups of costs, in the presented model calculation, comprise a decision cost value called „the calculated supply consumption cost". To make the results clearer and to simplify the procedure of calculating the costs in the presented „model calculation" only these components of the three standard groups were indicated, which in practice play the biggest part during the process of making this type of planning decisions.

5. Calculation of cost for decision purposes – model form

The calculation of expenses of each variant of material supplies is based on the following classification of cost elements in the presented method:

1. Material costs

a) direct materials,

b) buying costs.

The position „direct materials" includes expenses for materials which serve for direct product manufacturing.

The value of direct materials is being established according to the actual purchase prices.

„Buying costs" includes the area of the company's activity related to the purchase of materials for the needs of its production operations. In general, this item includes the costs, not included in the purchase price, of all activities of the company resulting in the receipt of the materials to their first place of storage. Example expenses being acknowledged as costs of this item are shipment costs, services and wages for loading and unloading, costs of packaging necessary to protect the delivery, customs fees, etc.

Costs of the material purchase will be represented in the presented model calculation as „shipment costs".

2. Stock creation costs

They will be represented in the model calculation as a separate cost element. They will be represented as „constant costs of material delivery receipt".

3. Stock maintenance costs

Costs of maintaining the stock of the material in the model calculation will be represented as insurance costs, storage costs and the cost of binding capital in material stocks. In order to calculate the aforementioned costs, a formula of average cost assignment will be used, which is calculated as a fraction of the value of the materials in stock. As a result, there is a need to handle relative ratios of the storage. The amount of these three components will be represented as „relative ratio of the costs of storage".

Recapitulating the accepted pricing criterion – „calculated cost of material consumption" – will consist of 4 main cost elements:

1. Direct materials.
2. Shipment costs.
3. Constant costs of material delivery receipt.
4. Stock maintenance costs.

Example:

In the discussed example of supplies of the material „T", the acceptable variants of size of purchases generated on the first stage, result in considerably diversified values of costs. This variety of obtained results is a consequence of the assumptions accepted previously. In the analyzed example of supplies of the material „T" these assumptions are introduced in the following way:

It is assumed that the company purchases material „T" only from one supplier X.

4. Direct materials

Supplier X made his selling price of material „T" dependent on the size of a single purchase:

Single purchase [kg]	(0; 10>	(10; 20>	(21; 30>	(30; 40>	(40; 50>	(50;80 >
Purchasing price per unit [pln/1kg]	710	680	660	615	585	570

5. Shipment costs

In the proposed method it was assumed in the beginning, that we analyze the procurement of only one material which is being purchased exclusively from a single, constant supplier. In other words, we assume a constant shipping point of the material to our company.

The shipping warehouse of supplier X is located at a distance of 317 km from the company being analyzed. The company receives the material at its own cost,

using the services of one of the forwarding agents available in the market. Settlements with the forwarding agent are being made according to a price list of transportation services specified in the contract – the table of fees. This table is a matrix of transport fees, where individual costs depend on the distance and the weight of the shipment. It is assumed that the volume requirements of the shipment are always satisfied (Table 2).

Table 2. Table of transport fees

		WEIGHT (KG)						
		1-30	31-60	61-100	101-150	151-200	201-250	...
DISTANCE (KM)	1-50	30	33	38	45	51	60	...
	51-100	33	34	39	47	53	62	...
	101-150	41	42	51	58	71	79	...
	151-200	42	44	56	89	108	125	...
	201-250	43	45	60	96	115	132	...
	251-300	44	46	62	101	122	141	...
	301-350	45	47	68	104	128	150	...
	351-400	46	49	70	110	133	158	...
	401-450	47	50	73	113	136	164	...
	451 - 500	48	51	76	115	140	170	...
	...	...	...	...	...	...	...	...

Source: own study.

6. Constant cost of material delivery receipt

In the presented example of supplies of material „T" it was assumed that the constant cost of receiving a single delivery of the material is 300 zlotys.

7. Stock maintenance costs

Monthly rate of the expense of binding the capital	1,67%
Monthly rate of insurance	0,21%
Monthly rate of storage costs	0,63%
Monthly relative ratio of costs of storage	**2,51%**

Solution:

The values of the calculated cost of consumption of material „T", for each of the acceptable variants of deliveries, are presented in table 3.

In the analyzed example, „Variant 11" of planning the supply of materials „T" turned out to be the most profitable variant, according to the accepted criterion, i.e. two deliveries in the analyzed twelve months – first delivery of two packages in the 1st period and the second delivery of one package in the 11th period.

When studying the above results, it is worth noticing that except for the fourth and tenth line, the first twelve lines consist only of the variants presenting various combinations of two supplies in the analyzed period of twelve months – one

Table 3. Calculated cost of material consumption

No.	Variant	Raw materials [pln]	Shipment cost [pln]	Material cost [pln]	Delivery recept cost [pln]	Storage cost [pln]	Calculated cost of material consumption [pln]
1	Variant 11	45 750,00	88,00	45 838,00	600,00	4 305,92	50 743,92
2	Variant 46	45 750,00	88,00	45 838,00	600,00	4 326,29	50 764,29
3	Variant 10	45 750,00	88,00	45 838,00	600,00	4 745,71	51 183,71
4	Variant 1	42 750,00	68,00	42 818,00	300,00	8 136,87	51 254,87
5	Variant 39	45 750,00	88,00	45 838,00	600,00	5 152,77	51 590,77
6	Variant 9	45 750,00	88,00	45 838,00	600,00	5 196,54	51 634,54
7	Variant 8	45 750,00	88,00	45 838,00	600,00	5 658,68	52 096,68
8	Variant 31	45 750,00	88,00	45 838,00	600,00	5 999,99	52 437,99
9	Variant 7	45 750,00	88,00	45 838,00	600,00	6 132,42	52 570,42
10	Variant 51	49 500,00	120,00	49 620,00	900,00	2 534,26	53 054,26
11	Variant 6	45 750,00	88,00	45 838,00	600,00	6 618,05	53 056,05
12	Variant 22	45 750,00	88,00	45 838,00	600,00	6 868,48	53 306,48
13	Variant 50	49 500,00	120,00	49 620,00	900,00	2 974,05	53 494,05
14	Variant 45	49 500,00	120,00	49 620,00	900,00	2 978,43	53 498,43
15	Variant 5	45 750,00	88,00	45 838,00	600,00	7 115,87	53 553,87
16	Variant 44	49 500,00	120,00	49 620,00	900,00	3 418,22	53 938,22
17	Variant 49	49 500,00	120,00	49 620,00	900,00	3 424,87	53 944,87
18	Variant 38	49 500,00	120,00	49 620,00	900,00	3 433,75	53 953,75
19	Variant 4	45 750,00	88,00	45 838,00	600,00	7 626,18	54 064,18
20	Variant 12	45 750,00	88,00	45 838,00	600,00	7 758,77	54 196,77
21	Variant 43	49 500,00	120,00	49 620,00	900,00	3 869,04	54 389,04
22	Variant 37	49 500,00	120,00	49 620,00	900,00	3 873,54	54 393,54
23	Variant 48	49 500,00	120,00	49 620,00	900,00	3 887,01	54 407,01
24	Variant 30	49 500,00	120,00	49 620,00	900,00	3 900,50	54 420,50
25	Variant 3	45 750,00	88,00	45 838,00	600,00	8 149,31	54 587,31
26	Variant 36	49 500,00	120,00	49 620,00	900,00	4 324,36	54 844,36
27	Variant 42	49 500,00	120,00	49 620,00	900,00	4 331,18	54 851,18
28	Variant 29	49 500,00	120,00	49 620,00	900,00	4 340,28	54 860,28
29	Variant 47	49 500,00	120,00	49 620,00	900,00	4 360,76	54 880,76
30	Variant 21	49 500,00	120,00	49 620,00	900,00	4 378,96	54 898,96
31	Variant 2	45 750,00	88,00	45 838,00	600,00	8 685,56	55 123,56
32	Variant 35	49 500,00	120,00	49 620,00	900,00	4 786,50	55 306,50
33	Variant 28	49 500,00	120,00	49 620,00	900,00	4 791,11	55 311,11
34	Variant 41	49 500,00	120,00	49 620,00	900,00	4 804,92	55 324,92
35	Variant 20	49 500,00	120,00	49 620,00	900,00	4 818,74	55 338,74
36	Variant 27	49 500,00	120,00	49 620,00	900,00	5 253,25	55 773,25
37	Variant 34	49 500,00	120,00	49 620,00	900,00	5 260,24	55 780,24
38	Variant 19	49 500,00	120,00	49 620,00	900,00	5 269,57	55 789,57
39	Variant 40	49 500,00	120,00	49 620,00	900,00	5 290,56	55 810,56
40	Variant 26	49 500,00	120,00	49 620,00	900,00	5 726,99	56 246,99
41	Variant 18	49 500,00	120,00	49 620,00	900,00	5 731,71	56 251,71
42	Variant 33	49 500,00	120,00	49 620,00	900,00	5 745,87	56 265,87
43	Variant 17	49 500,00	120,00	49 620,00	900,00	6 205,45	56 725,45
44	Variant 25	49 500,00	120,00	49 620,00	900,00	6 212,62	56 732,62
45	Variant 32	49 500,00	120,00	49 620,00	900,00	6 243,69	56 763,69
46	Variant 16	49 500,00	120,00	49 620,00	900,00	6 691,08	57 211,08
47	Variant 24	49 500,00	120,00	49 620,00	900,00	6 710,44	57 230,44
48	Variant 15	49 500,00	120,00	49 620,00	900,00	7 188,90	57 708,90
49	Variant 23	49 500,00	120,00	49 620,00	900,00	7 220,76	57 740,76
50	Variant 14	49 500,00	120,00	49 620,00	900,00	7 699,22	58 219,22
51	Variant 13	49 500,00	120,00	49 620,00	900,00	8 222,34	58 742,34

Source: own study.

delivery of two packages and one delivery of a single package. The interesting thing is that the fourth and tenth line are occupied by two extreme possibilities of material supplies. Fourth line is taken by „Variant 1", i.e. delivery of all 3 packages already within the 1st period. Despite the lowest material cost of all the variants (the lowest price per unit and the cost of transport), very high maintenance costs (but it is worth underlining that not the highest of all variants), made this variant fall to the fourth position. The second extreme delivery option, consistent under the circumstances with the 'just-in-time' idea, is presented in „Variant 51". In this variant, the two subsequent deliveries appear in the periods, in which at the beginning of the given period, the stock is lower than the planned quantity to be drawn for production. In this example there are four deliveries of a single package. Analyzing the results of this variant, it is easily observed that they are almost exactly in opposition to the results of „Variant 1".

In „Variant 51" there are the highest of all material costs and at the same time the lowest maintenance costs. The total amount of the above costs placed this variant on the tenth position.

6. Findings

It seems that the presented method of calculating may in many cases facilitate decision making process, regarding the size and terms of delivery of particular raw materials for production. This procedure may be especially helpful in comparing the offers of different suppliers of the same material. In practice, very often different suppliers offer the material in various sizes of commercial packages. The significant difference in their offers concerns also the purchasing price and the transport cost, whether it is already included in the price or the customer has to consider the additional cost of receiving the purchased goods. The comparison of all these important elements of the offer, being of key importance for the final choice of the customer, and then determining the delivery dates as well as the sizes of particular purchases, would be quite inconvenient without means of some algorithm. The presented method of calculation could be a helpful suggestion in making such decisions.

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PLANOWANIE DOSTAW MATERIAŁU PRODUKCYJNEGO NABYWANEGO W STAŁYM CO DO WIELKOŚCI OPAKOWANIU DOSTAWCZYM

Streszczenie

Niniejsze opracowanie zostało w całości poświęcone zagadnieniu planowania dostaw materiałowych pod kątem potrzeb produkcyjnych przedsiębiorstwa. Praca ta jest próbą poszukiwania podejścia metodologicznego wspomagającego proces decyzyjny. Z założenia proponowany sposób postępowania ma być na tyle prosty, aby bez konieczności ponoszenia znacznych nakładów był łatwy do zastosowania w praktyce.

Fundamentalnym celem planowania dostaw materiałowych jest zapewnienie ciągłości produkcji. Innymi słowy planowanie to polega na zaspokojeniu wymagań produkcji odnośnie do rodzaju materiałów, wielkości i terminów ich dostaw. Podejmowanie tego typu decyzji musi mieć również swoje ekonomiczne uzasadnienie.

Na wstępie należy zaznaczyć, iż postępowanie to dotyczy wyboru najlepszego (według przyjętego kryterium) planu dostaw pojedynczego materiału.

Proponowany sposób podejmowania decyzji składa się z dwóch kolejno następujących po sobie etapów. Zadaniem pierwszego etapu jest wygnerowanie wszystkich dopuszczalnych wariantów planu dostaw materiału. W kolejnym kroku, na podstawie subiektywnie przyjętego kryterium, dokonuje się wyboru najlepszego rozwiązania. Najczęściej występującym kryterium decyzyjnym jest kryterium kosztowe. Innymi słowy przedsiębiorstwo stara się tak ustalić wielkość i terminy dostaw materiału, aby zabezpieczając w 100% potrzeby produkcji, ponosić jak najniższe koszty związane z przepływem tego materiału.

Wydaje się, że zaprezentowana metoda obliczeniowa może w wielu przypadkach znacznie wspomóc proces podejmowania decyzji odnośnie do ustalania wielkości i terminów dostaw poszczególnych materiałów produkcyjnych. Postępowanie to może okazać się bardzo pomocne, zwłaszcza przy porównywaniu ofert kilku dostawców tego samego materiału.

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