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ANALYSIS OF THE PROBLEM OF OPTIMIZED MATERIAL PROCUREMENT IN ERP SYSTEMS

Andrzej Jardzioch, Mariusz Wojtalik

S u m m a r y

The paper is concerned with a specific element of an ERP-class system – the Technical Production Preparation module (TPP) used by a company producing metal components. The module is responsible, inter alia, for determining the amount of material required to complete a specific order. The authors have presented a problem encountered by ERP system users while working with the Technical Production Preparation module.

Keywords: ERP system, Technical Production Preparation module, material limit

Analiza problemu optymalnego zamawiana materiałów w systemach klasy ERP

S t r e s z c z e n i e

W pracy prowadzono analizę wybranego fragmentu systemu ERP – modułu Technicznego Przygotowania Produkcji w firmie wytwarzającej wyroby metalowe. Moduł odpowiedzialny jest między innymi za określenie zapotrzebowania na materiał niezbędny do produkcji wyrobu zleconego. Przedstawiono problemy użytkowników systemu ERP w trakcie pracy z modułem Technicznego Przygotowania Produkcji.

Słowa kluczowe: system ERP, moduł Technicznego Przygotowania Produkcji, zapotrzebowanie materiałowe

1. Introduction

ERP-class computer systems are currently widely used in small and medium enterprises alike. Implementation of ERP systems enables businesses to integrate all production processes within a single, coherent solution, thus offering a significant competitive advantage. The most frequently used ERP modules include the following: technical production preparation, finance and accounting, sales, warehouse management, logistics, production, HR and payroll [1].

A number of scientific publications deal with the problem of correct selection of ERP-class software. A view is common that the choice of the ERP system

Address: Andrzej JARDZIOCH, DSc Eng. West Pomeranian University of Technology, Faculty of Mechanical Engineering and Mechatronics, 19 Piastów Av., 70-310 Szczecin, e-mail: Andrzej.Jardzioch@zut.edu.pl; Mariusz WOJTALIK, PhD Eng. University of Applied Sciences in Wałcz, 50 Bydgoska St., 78-600 Wałcz, e-mail: mariusz.wojtalik@pwsz.eu

should take into consideration, in each case, the specific character of a given company. It is also equally common for those publications to state that a detailed model of a specific company, as well as of the production processes it relies upon, needs to be drawn up. The scientific publications deal also with a different problem - namely proper implementation of the ERP system [2-5].

Analysis of ERP systems implemented at various industrial plants shows that flexibility and the ability to adjust a specific solution to the requirements of a given business, operating in any sector of the market, is one of the greatest advantages of this type of tools. ERP-class systems are implemented both by mass-production plants and by companies offering low-volume or customized products alike.

The structure of an ERP system is based on database mechanisms (Fig. 1). In simplified terms, each ERP-class system is made up of two databases: a static database and a dynamic database [3, 6].

The former database is used for storing information on machinery and equipment, structure of the products made, production technologies used, subcontractors and business partners. One may say that information contained in this database relates to the production experience of the company and to its know-how. The other data base is of the dynamic variety and contains information relevant for current production (list of orders accepted for completion, order completion deadlines, volume of production in progress, current inventory levels). Specialized ERP system modules cooperate with the aforementioned databases, collecting, processing and saving information stored therein.

The Technical Production Preparation module is one of the most important components of an ERP-class system [7, 8]. It is responsible for processing production-related information, for determining the amount of material that is required to perform a specific order, and to enter production data into the ERP system's static database (Fig. 1). The following are crucial types of data entered into the static database:

- information on finished and semi-finished products, i.e.: product structure, process flows, material allowances;
- material index lists;
- information on production stations, machinery and tools;
- production processes within the company;
- planned product cost calculations based on the duration of production processes and expected material consumption.

The article presents the problem of determining, in a correct fashion, the amount of material required to manufacture a specific product. The amount of material required to manufacture a product is referred to, in ERP systems, as the "material allowance". The following are distinguished: net material allowance and gross material allowance. The net material allowance is the amount of material required to manufacture a product, without waste and leftovers taken into consideration. The gross material allowance is the amount of material with the waste created during the manufacture process, as well as processing-related surplus added.

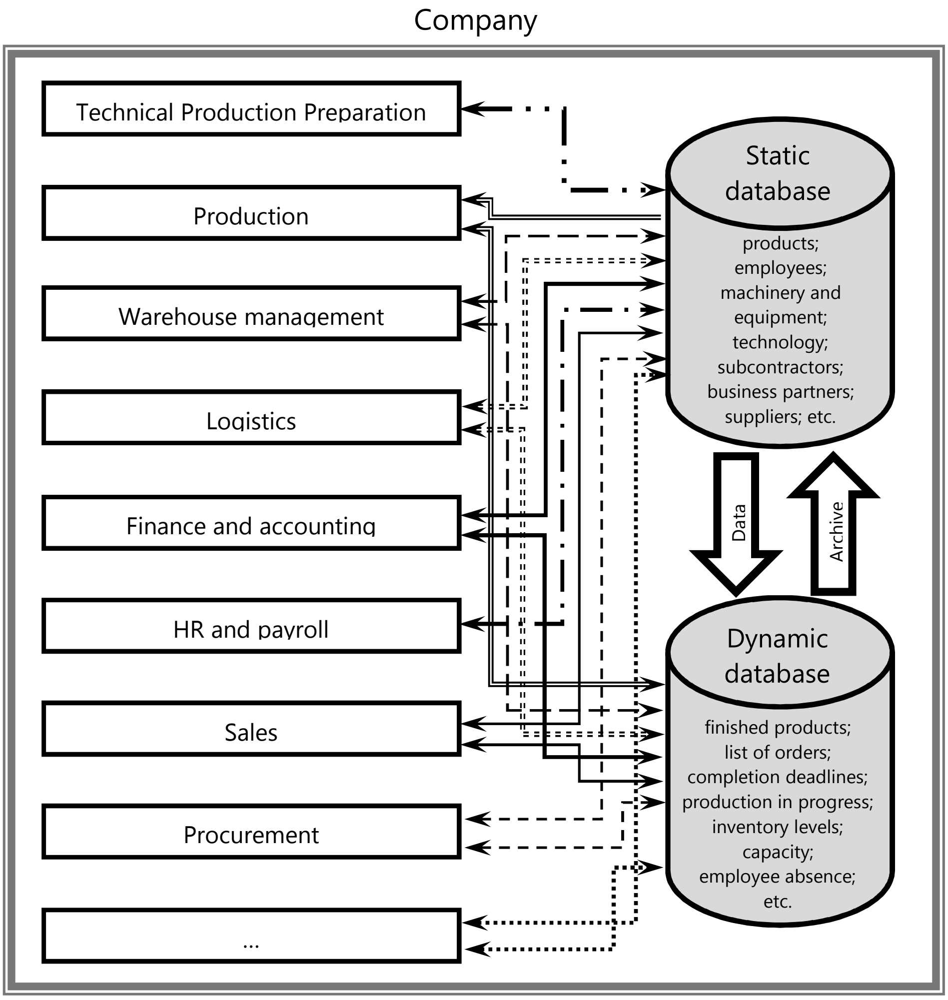

Fig. 1. Flow of information between databases and individual ERP-class system modules

Determination of the gross material allowance is by no means an easy task. One may use the process of establishing the gross material allowance for hot-rolled steel products as an example here. Popular RP70x50x2 closed profiles are only available commercially in two lengths: 6 m and 12 m. If a given product requires that two elements (5 m and 3.5 m long) be used, the net material allowance equals 8.5 m. However, in order to determine the gross material allowance, one has to take into consideration the commercially available lengths of the profiles required. In order to manufacture a specific product, a single 12 m profile may be ordered (with two elements, measuring 5 m and 3.5 m respectively, cut out of it). Alternatively, two 6 m profiles may be ordered (with one used to cut the 5 m element, and to other to cut the 3.5 m element). In this case, the gross material allowance equals 12 m. The problem gets more complicated when the order requires that 10 products be manufactured, each one comprising the same profiles (5 m and 3.5 m). The net material allowance equals 85 m. The gross material allowance, in turn, will depend on the blanking method adopted. In order to perform the order, 20 profiles, each of them measuring 6 meters in length, may be ordered. The first 10 profiles will be used to cut elements that are 5 m long, while the next 10 profiles will be used to cut elements that are 3.5 m long. In this case, the gross material allowance will equal 120 m. However, it is possible to order 5 profiles that are 12 m long (used for cutting 10 elements that are 3.5 m long and 5 elements that are 5 m long), and 5 profiles that are 6 m long (used for cutting 5 elements that are 5 m long). In this case, the gross material allowance will equal 90 m only.

The example presented below aims to indicate that the gross material allowance depends on the method used to plan the production process and exerts a direct impact on the quantity of the material ordered. It also needs to be mentioned that in the case of actual production processes in which the product is made up of different elements, it is not possible to rely on simple algorithms to plan the blanking shapes. One may assume that in the case of complex products, determination of the gross material allowance is a complicated issue and depends on the standardization strategy adopted by a given business.

2. Determination of the gross material allowance and material procurement in the ERP system

The following example may be used to depict the problem of determining the correct gross material allowance.

A complex product A (Fig. 2) comprises 4 elements made of the RP70x50x2 closed structural profile. The following amounts of material are required to produce each of those elements:

- part number C-001 – length 1250 mm, weight 4.45 kg;
- part number C-002 – length 540 mm, weight 1.92 kg;
- part number C-003 – length 2480 mm, weight 8.82 kg;
- part number C-004 – length 1320 mm, weight 4.70 kg.

In order to enter relevant product data into the ERP system, an index for “RP70x50x2 closed profiles” needs to be created. The following numbers have been assigned to indexes corresponding to the individual elements: C-001, C-002, C-003 and C-004.

Item	Q'ty	Name	Designation	Length	Drawing No.	Material	Remarks
1	1	Profil	70x50x2	1250	C-001	1.0038 (S235JRG2)	
2	1	Profil	70x50x2	540	C-002	1.0038 (S235JRG2)	
3	1	Profil	70x50x2	2480	C-003	1.0038 (S235JRG2)	
4	1	Profil	70x50x2	1320	C-004	1.0038 (S235JRG2)	

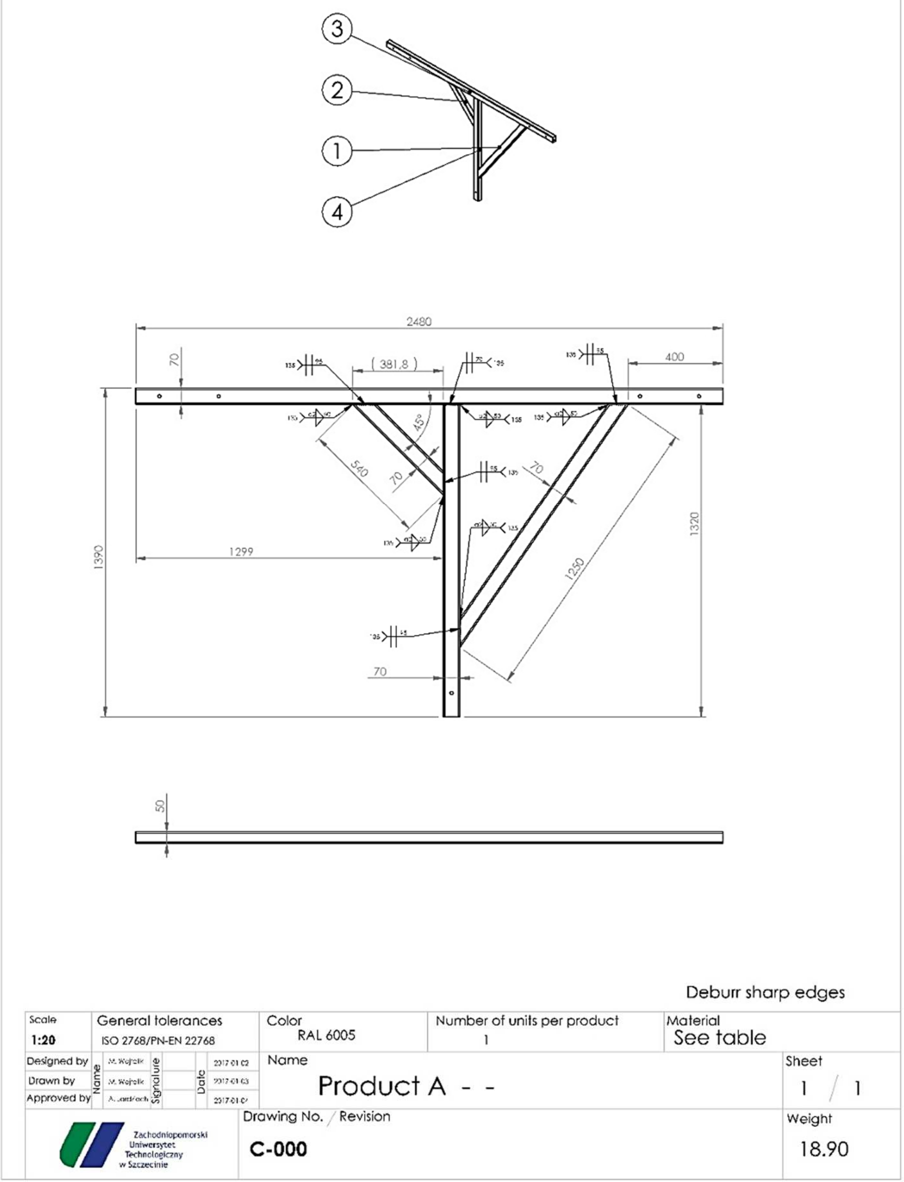

Fig. 2. Structure of product A with individual element indexes

The processes required to produce each component have also been entered into the ERP system, as have been the processing times assigned to the specific operations. For instance, three operations have been defined for element C-004: saw cutting – 2 minutes; scribing – 3 minutes; drilling – 2 minutes. Then, the gross material allowance has been determined, as required to produce each component.

The C-000 product index is assigned to product A. Then, technical processes required to manufacture product A are identified. Five operations have been defined: joining – 5 min.; welding – 10 min.; cleaning – 5 min.; bead blasting – 5 min.; painting – 10 min. Then, the gross material allowance has been determined, as required to manufacture the product. The gross material allowance states what components a given product is made up of. In the case in question, the following need to be used to manufacture one piece of the complex product A: 1 piece of C-001 profile, 1 piece of C-002 profile, 1 piece of C-003 profile and 1 piece of C-004 profile.

Once the technical documentation of the complex product has been drawn up, the manufacturing process may commence. However, depending on the strategy adopted, the amount of material required to manufacture a specific product may differ. The said amount depends also on the number of items produced (lot size) and on the strategy adopted to determine the allowances of material required for production. Four strategies used for determining material allowances may be distinguished: a simplified strategy, a strategy with surplus material included, a commercial lengths strategy and a process-based strategy.

Below is a description of the individual strategies applied to produce a single piece of the product.

Simplified strategy for 1 piece of product A

It is assumed that in the case of a single piece, the gross value equals the net value. The process engineer states the amount of material required to produce the individual components, based on the values from the technical drawing. Once all material-related data has been entered into the system, the material-related parameters of the individual elements are added. The ERP system informs the procurement department about the amounts of material required: “RP70x50x2 rectangular, closed structural profile, order volume: 5590 mm, weight: 19.90 kg”. Due to the lengths available commercially, the procurement department cannot order the dimension of 5590 mm – – it “rounds up” the amount to the next dimension that is available commercially and orders a profile that is 6000 mm long and that weighs 21.36 kg.

Strategy with surplus material included, for 1 piece of product A

It is assumed that the gross value equals the net value plus the surplus required for cutting (e.g. 5 mm) for a single piece. The process engineer identifies the amount of material required to produce a given part, increased by the surplus required for cutting: e.g. for part C-001 – length of 1255 mm, weight of

4.68 kg. Once the data has been entered into the system, the procurement department receives the following information: “RP70x50x2 rectangular, closed structural profile, order volume: 5610 mm, i.e.: 19.97 kg”. Due to the lengths available commercially, the procurement department “rounds up” the amount to the next dimension that is available commercially and orders a profile that is 6000 mm long and that weighs 21.36 kg.

Commercial length strategy, for 1 piece of product A.

A gross value is adopted, selected in such a way as to be a multitude of the lengths available commercially. The process engineer states the amount of material required to produce each element:

- part no. C-001 - length 1250 mm, weight of 4.45 kg, a profile that is 6000 mm long may be used to make 4.8 parts (1). This value is rounded down to a full number (4 pieces). The above means that for each piece, a profile that is 1500mm long (2) and weighs 5.34 kg is required;

Formula applied to calculate the number of full-length sections:

$$\frac{w_h}{l_n} = i \tag{1}$$

Formula applied to calculate the gross length of a section

$$\frac{w_h}{i} = l_b \tag{2}$$

where: w_h – length available commercially, l_n – element length, l_b – gross element length, i – number of full-length sections.

Example of calculations for part C-001:

$$\frac{6000\ \text{mm}}{1250\ \text{mm}} = 4.8, \quad \frac{6000\ \text{mm}}{4} = 1500\ \text{mm}$$

- part number C-002 – length 540 mm, weight 1.92 kg, assume length 545.45 mm, weight 1.94 kg;
- part number C-003 – length 2480 mm, weight 8.82 kg, assume length 3000 mm, weight 10.68 kg;
- part number C-004 – length 1320 mm, weight 4.70 kg, assume length 1500 mm, weight 5.34 kg.

Once the data has been entered into the system, the procurement department receives the following information: “RP70x50x2 rectangular, closed structural profile, order volume: 6546 mm, i.e.: 23.3 kg”. The procurement department "rounds up" the amount to the next dimension that is available commercially and orders the following amounts of profiles: 2 x 6000 mm in length, weight of 42.72 kg, or 1 x 12000 mm in length, weight of 42.72 kg.

Process analysis strategy for 1 piece of product A

The process engineer analyzes product A and groups the elements based on the steelworks products required (in this particular case, only one steelworks product is used). Gross values are adopted and "adjusted" to make sure that the sum of all gross values equals the full commercial lengths of the material ordered. The process engineer groups all elements by type of material required for their manufacture. In this particular case: rectangular, closed structural profile RP70x50x2 – used for making parts C-001; C-002; C-003 and C-004, total length (1250 + 540 + 2480 + 1320) is 5590 mm. Knowing the commercially available lengths, the process engineer states that 6000 mm are required to produce all elements. The amount of material required to produce each element needs to be entered into the ERP system. In this case, we are dealing with 4 elements, and the difference between the commercially available length of the RP70x50x2 profile and the sum of lengths of all elements equals (6000-5590) 410 [mm]. The process engineer chooses the surplus to make sure that the sum of lengths of all elements equals the commercially available length. The surplus may be defined proportionally to the lengths, for instance:

- part No. C-001 length 1250 mm, weight 4.45 kg, data fed to the system – length 1250 + 100 = 1350 mm, weight 4.81 kg;
- part number C-002 – length 540 mm, weight 1.92 kg, data fed to the system – length 540 + 50 = 590 mm, weight 2.11 kg;
- part number C-003 – length 2480 mm, weight 8.82 kg, data fed to the system – length 2480 + 160 = 2640 mm, weight 9.39 kg;
- part number C-004 – length 1320 mm, weight 4.70 kg, data fed to the system – length 1320 + 100 = 1420 mm, weight 5.05 kg.

Once the data has been entered into the system, the procurement department receives the following information: "rectangular, closed structural profile, order volume: 6000 mm, i.e.: 21.36 kg".

All strategies referred to above allow to order the correct amount of material required to produce one piece of the complex product A. However, application of the commercial length strategy will result in purchasing a higher amount of material, which means that the costs borne will be higher (table 1).

If an order for 45 pieces of product A has been received, the way in which the strategies described above work will be slightly different. Below is a description of all those strategies if 45 pieces of product A are to be produced.

Simplified strategy for 45 pieces of product A

It is assumed that in the case of a single piece, the gross value equals the net value. When producing 45 pieces of the product, the procurement department receives the following information: “RP70x50x2 rectangular, closed structural profile, order volume: 251 550 mm, i.e.: 895.50 kg”. The procurement department “rounds up” the amount to the next dimension that is available commercially and orders the following amounts of profiles: 42 x 6000 mm in length, weight of 897.12 kg.

Strategy with surplus material included, for 45 pieces of product A

It is assumed that the gross value equals the net value plus the surplus required for cutting (e.g. 5 mm) for a single piece. When producing 45 pieces of the product, the procurement department receives the following information: “RP70x50x2 rectangular, closed structural profile, order volume: 252 450 mm, i.e.: 898.7 kg”. The procurement department “rounds up” the amount to the next dimension that is available commercially and orders the following amounts of profiles: 43 x 6000 mm in length, weight of 918.5 kg.

Commercial length strategy, for 45 pieces of product A

A gross value is adopted, selected in such a way as to be a multitude of the lengths available commercially. When producing 45 pieces of the product, the procurement department receives the following information: “RP70x50x2 rectangular, closed structural profile, order volume: 294 546 mm, i.e.: 1048.58 kg”. The procurement department orders the following amounts of profiles: 50 x 6000 mm in length, weight of 1068 kg.

Process analysis strategy for 45 piece of product A

The operator analyzes product A and groups the elements based on the steelworks products required (in this particular case, only one steelworks product is used). Gross values are adopted and “adjusted” to make sure that the sum of all gross values equals the full commercial lengths of the material ordered. When producing 45 pieces of the product, the procurement department receives the following information: “RP70x50x2 rectangular, closed structural profile, order volume: 270 000 mm, i.e.: 961.2 kg”.

Table 1 contains a summary of the results that are obtained while applying the individual strategies to produce a single piece as well as 45 pieces of product A. The simplified strategy and the strategy with surplus material included have turned out to be incorrect. They have resulted in the amount of material supplied being insufficient to produce 45 pieces of product A. The commercial length strategy has resulted in the amount supplied exceeding the amount required to produce 45 pieces of product A. The process analysis strategy, in turn, has turned out to be a very good solution. It has enabled the company to order the smallest amount of material required to perform the complete order.

Table 1. Material requirement depending on the strategy adopted

Material	**Simplified strategy, mm**		**Strategy with surplus material included, mm**		**Commercial length strategy, mm**		**Process analysis strategy, mm**	
Requirement for 1 unit of product A	6000	✓	6000	✓	2 x 6000	×	6000	✓
Requirement for 45 units of product A	42 x 6000	×	43 x 6000	×	50 x 6000	×	45 x 6000	✓

3. Conclusion

The problem the present paper is concerned with, i.e. estimation of the amount of the gross material allowance, is less or more complicated to solve, depending on the specific character of the product at hand. In companies in which production lots are of the same size, material allowances may be corrected after the first lot has been completed. If different products and different lot sizes are produced, no such solution is available. Furthermore, the individual elements may be used in different products. For instance, part C-002 may be used in products B and C as well. In such situations, the process analysis strategy is recommended. It is time-consuming and requires the operator to analyze the structure of the product after each change of the production lot size, but offers considerable savings as far as the amounts of materials ordered are concerned.

Analysis of the example provided shows that it is necessary to modify the manner in which material allowances are worked out by ERP-class systems. Such a system should rely on an algorithm determining the amount of material required depending on the size of the order and on the structure of the product made. The authors' further efforts will focus on developing such an algorithm based on artificial intelligence methods.

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