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# OPTIMISATION OF INVENTORY MANAGEMENT IN FOUNDRY IN TERMS OF AN ECONOMIC ORDER QUANTITY

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Recording of inventory and constant monitoring have a huge impact on the cost level of enterprises operating in the metallurgical sector. The article presents methods to optimise the inventory management in terms of a size of orders. This applies to the assumed cost of storage, procurement, expenditure in time unit and unit prices calculated for a range of castings. As an optimisation tool, functions and modules supplied with the MS Excel spreadsheet have been used.

*Key words:* computer-aided foundry production, logistics, order quantity

**Optimatizacija upravljanja zalihama u ljevaonicama u pogledu ekonomičnog naručivanja količina.** Snimanje zaliha i stalno praćenje ulaznih materijala imaju ogroman utjecaj na razinu cijene kod poduzeća koja posluju u metalurškom sektoru. U članku su prikazane metode za optimizaciju upravljanja zalihama u smislu veličine narudžbe. To podrazumijeva i procjenu troška skladištenja, nabave, potrošnju u jedinici vremena i jedinične cijene izračunate za različite odljevke. Kao alat za optimizaciju korištene su proračunske tablice MS Excel sa funkcijama za različite module.

*Ključne riječi:* računalno potpomognuta proizvodnja u ljevaonicama, logistika, količina naručivanja

## INTRODUCTION

The main objective of logistics in metallurgical plants is skilful warehouse management, remembering that the well-run warehouse and efficient stock control enable smooth running of production and trouble-free circulation of goods. In [1,2] it was noted that proper operation of the warehouse has a significant effect on costs generated by the company. The correct interpretation of the warehouse data is one of the key factors that decide about the financial results of the company. Inaccurate analysis of total inventory can lead us to a false conclusion that we have high inventory levels, characterised by small deviations, while in reality more detailed analysis carried out for individual items will unmistakably show low levels with large deviations, or even the zero status of goods.

## DESCRIPTION OF PROBLEM

Using a spreadsheet, one can effectively monitors the inventory, also in the case when different raw materials (products) are stored in the warehouse. This is possible by keeping a database in the spreadsheet and updating it at the end of settlement day by introducing the current values of both revenues and expenditures. In this simple way, at any time, we can have ready detailed information about the specific inventory items and the system of logistics. The basic rule for running any warehouse: first, determine the current status of each article separately, and second, introduce changes, if any. To get the final status add the value of the income to the initial status, or – in the case of expenditure - subtract its value from the status. Any change in the status of raw materials in the warehouse should be dated, and then the final status at the end of the selected reporting period (one day) will make the initial status at the beginning of the next reporting period (day) [3,4].

## METHOD OF RESEARCH

The first step is to create a spreadsheet to control the raw material stock necessary to produce castings, where the raw material is designated by an identifier K3-456-Z and the spreadsheet is called STATUS_K3-456-Z. The first line of this spreadsheet should be completed by inserting appropriate data in the fields named: IDENTIFIER, DATE, STATUS, INCOME, EXPENDITURE AND REMINDER. Then, in block of cells H2: J6 of the sheet, for the raw material K3-456-Z enter the following data: PRICE/ PIECE; e.g. 8 PLN, DELIVERY DATE, e.g. 3 days, DELIVERY READINESS, which is the probability of delivery estimated from orders placed during previous periods of cooperation with the supplier, and which can amount to e.g. 95 %, STORAGE COSTS, which include, among others, the rent paid, preparation of storage sites and other means of storage, etc., and which can amount

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to e.g. 18 %, ORDER OR CONTRACT COSTS, which are related with the contract itself (e.g. telephone charges, delivery costs, etc.) and can amount to e.g. 45 PLN. First, it is necessary to specify the values that will be optimised at the subsequent stages of the study, i.e. MINIMUM RESERVE of raw material K3-456-Z in stock, e.g. 1 000 pieces, ORDER QUANTITY, e.g. 3 000 pieces. Enter in the next line the data linked with the relevant fields: IDENTIFIER of raw material, STARTING DATE of registration of the raw material income and expenditure (e.g. the date 2008-03-01), marking first the column of cells B and formatting it with category DATE to yy-mm -dd. To cell C2, which defines the stock available in warehouse – introduce a formula compatible with equation (1), which means that when the INITIAL STATUS of raw material K3-456-Z is 2 500 pieces, this formula should run as follows: = 2 500+D2-E2, and to cell E2 – insert the value of the first expenditure in pieces (e.g. 50). Then to cell F2 enter the formula=IF(C2<$I$8;"PLEASEORDER!";"), so as to get under the heading REMINDER the message PLEASE ORDER! displayed. Using function = IF (...) this will happen when the current inventory status in the current record (the value in cell C2) is lower than that defined in cell I8. At the next stage, copy to cell A3 the contents of cell A2 (IDENTIFIER of raw material) and to cell B3 enter another date. In cell C3 enter formula computing the stock currently available in the warehouse: INITIAL STATUS + INCOME - EXPENDITURE = (C2+D3-E3), and in cell E3 enter current Expenditure, e.g. 60 pieces. Copy also the formula in cell F2 to cell F3. In this way, a database on the warehouse management of raw material K3-456-Z has been made. It has two data records (the second and the third row of spreadsheet STATUS_K3-456-Z). To enter other data records on the storage management of raw material K3-456-Z, a tool very useful in the creation of databases, called FORM, can be applied. To do this, select and mark block of cellsA1: F3 and choose command FORM in the DATA menu. To determine the anticipated ANNUAL EXPENDITURE of raw material K3-456-Z, in the next step create a spreadsheet called RR_K3-456-Z, where in cells B1 and B2 enter the lowest (FIRST DAY) and highest (LAST DAY) date using data collected in the spreadsheet STATUS _K3-456-Z. The starting date of reporting period can be calculated either by simple procedure of copying the date of the first operation (i.e. the date shown in cell B2 of the spreadsheet STATUS_K3-456-Z) or by a more versatile procedure which consists in determining from formula =MIN ('STATUS _K3-456-Z'!B:B) the minimum date in column B. The date of the last entry of the stored item can be obtained using function = MAX(...). Of course, before copying format these CELLS with category DATE. Then, in cell B3, by simple subtracting calculate the DIFFERENCE IN DAYS, i.e. the difference between the first and last entry (Figure 1).

To this difference (amounting to 106 days) add one (i.e. one day), because in reality the number of the reporting days was 107. TOTAL EXPENDITURE of raw ma-

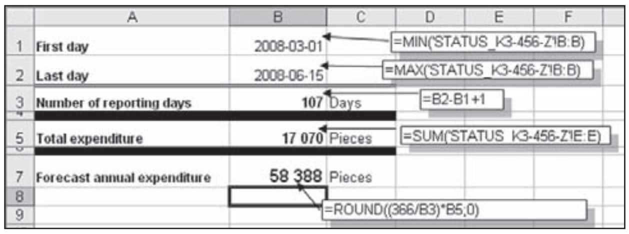


**Figure 1** Fragment of spreadsheet RR_K3-456-Z

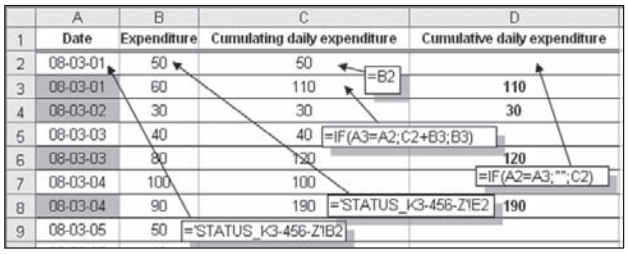


**Figure 2** Cumulative daily expenditure calculated in spreadsheet RD_K3-456-Z

terial K3-456-Z within the adopted reporting period is obtained by summing up all the values of the expenditures contained in the spreadsheet STATUS_ K3-456-Z. ESTIMATED ANNUAL EXPENDITURE is calculated dividing the number of days in a given year (366) by the number of reporting days and multiplying the result by TOTAL EXPENDITURE. The obtained value should be rounded to the nearest integer, using e.g. function = ROUND (...).The next step involves the determination of daily expenditure of raw material K3-456-Z. For this purpose, in a new spreadsheet called RD_K3-456-Z format column *A* with category *Date*, and then, after giving appropriate names to the data columns, copy to columns A and B the values of dates and expenditures, respectively, from the spreadsheet STATUS_K3-456-Z (Figure 2).

To calculate total expenditure in a workday of the warehouse, i.e. the so-called cumulative daily expenditure, enter to cell C2 the formula = B2, which copies the value of the first expenditure on the first workday of the warehouse, while to cell C3 enter the formula = IF (A3=A2C2+B3, B3), which, depending on the change of the date (by comparing the contents of cell A3 with cell A2), either calculates the total value of expenditures (by summing up the contents of cells B3 and C2) or copies the value of expenditure from column B (i.e. the contents of cell B3). In column D selected data from column C are obtained, and (strictly speaking) the cumulative daily expenditure falling to each day of the warehouse operation (CUMULATIVE DAILY EXPENDITURE), calculated by entering in cell D2 the formula = IF(A2=A3;";C2) which, depending on the change of the subsequent reporting date (comparing the contents of cells A2 and A3), will either return an empty string (if the date has not been changed, that is, A2=A3) or the contents of cell C2 (cumulative expenditure - if the date has been changed). Copy this FORMULA to cell D3, and then copy block of cells C3:D3 to other cells in columns C and D (i.e. to block of cells D4:C195). At the next stage determine the structure of CUMULATIVE

DAILY EXPENDITURES, i.e. process those expenditures to the form of an interval stem plot. To this end, divide CUMULATIVE DAILY EXPENDITURES contained in block of cells D2: D195 into classes (intervals) and determine for the examined EXPENDITURE the frequency of occurrence: ABSOLUTE, RELATIVE AND CUMULATIVE, i.e. calculate the number of cases corresponding to a defined class of the CUMULATIVE DAILY EXPENDITURE. It has been assumed that the stem plot will consist of 40 classes (intervals). To create a series of this type, in column G, from cell G3 to cell G42, create a sequence of values from 2,5 % to 100 % at a step of every 2,5 % (as 100 % divided by 40 equals 2,5 %). To fill block of cells G3:G42 with values from 2,5 % to 100 %, enter to cell G2 the value of 2,5 %, and to cell G3 the value of 5 %, then select block of cells G2:G3, set the mouse cursor in the left bottom corner of the selected area, where the cursor should take the shape of a cross, and drag next this item (holding the left mouse button pressed down) to cell G42, in which the value obtained should be 100 %. Put the value 0 in cell H3 (which makes the lower limit of the first interval). In cell I3, to determine the upper limit of the first interval, use formula: = ROUND (F3*MAX($D$2:$D$165);0), since it is the rounded 2.5% value of the maximum daily expenditure. Copy this formula to cell I4, and to cell H4 copy the value of the upper limit of the first interval using formula = I3, where the said upper limit of the first interval will also make the lower limit of the second interval. Copy next the contents of the block of cells H4:I4 to block of cells H5:I42. To determine absolute frequency of occurrence of the cumulative daily expenditure in a given class, having selected block of cells I3:I42, enter to cell I3 the table function =FREQUENCY(D:D;I3:I42), which shows the frequency distribution in a vertical array. As a first argument in this function (TABLE DATA) give address of the block that contains the data for which we want to calculate the frequency (this is column D), while the second argument (TABLE-INTERVALS) should give address of the intervals in which will be grouped the values from the first array (TABLE_DATA). Upon entering this function with arguments, place cursor in the field of the formula pressing simultaneously the key combination [Shift] [Ctrl] and [ENTER]. Observe that table function = FREQUENCY(...) has been completed with braces. The relative (percent) frequency of occurrence of daily expenditures in the first class (cell J3) can be calculated dividing the absolute frequency (in cell I3) by the total number of all daily expenditures (i.e. 107), inserting in cell K3 the formula =I3/SUM ($I$3:$I$42), which should be next copied to block of cells J4: J42. To calculate the relative cumulative frequency of the daily expenditure, copy to the first cell in block of cells K3:K42 the contents of cell J3, inserting in this cell the formula = K3 and in cell L4 the formula = K3+J4, which is next copied to block of cells L5:L42. Then, format block of cells K3:L42 with CATEGORY-

| M | N | O |
|---|---|---|
| Average cumulative daily expenditure: | 160 | =ROUND(AVG(D:D);0) |
| Median daily expenditure: | 130 | =MEDIAN(D:D) |
| Minimum daily expenditure: | 10 | =MIN(D:D) |
| Maximum daily expenditure: | 520 | =MAX(D:D) |
| 25% quartile of daily expenditure: | 70 | =QUARTILE(D:D;1) |
| 75% quartile of daily expenditure: | 215 | =QUARTILE(D:D;3) |
| Standard deviation: | 113,3 | =STDS(D:D) |

**Figure 3** Calculation of selected characteristics for cumulative daily expenditures

PERCENT to zero decimal places. To end the operations related with the cumulative daily expenditure, calculate basic characteristics of the descriptive statistics for this parameter (Figure 3).

In the next step, a new spreadsheet called STATUS_MIN_K3-456-Z estimates the minimum order quantity for the stated number of days until the delivery completion and for the required delivery readiness. To this end, to cell B2 copy (by pointing) the contents of cell I3 from the spreadsheet STATUS_K3-456-Z, while to cell G1 copy the value of DELIVERY READINESS from cell I4 in the spreadsheet STATUS__K3-456-Z, and to cell A3 copy from the spreadsheet R_D_K3-456-Z (from cell K3) the relative cumulative frequency for the first class of the daily expenditure. In cell B3 calculate the relative cumulative frequency for the specified delivery date according to formula: = 1-(1-A3)^$B$2, calculated from formula: 100 % - (100 % - Cumulative _ frequency _ given%) DATE_DELIVERY. To estimate the minimum status in cell G2 use function = VLOOKUP ((1G1)+B3,B3:D42,3)*B2+(B2/2)*'RD_K3-456-Z'!N1, which checks if the extreme left column in TABLE (the second argument B3:D42) contains certain value called REFERENCE (the first argument, i.e. cell 1-G1, i.e. 5 %), and returns the value in the indicated cell of the third column of the TABLE block (because the third argument of this function bears number 3). This value (which is 26 in cell D4) is multiplied by the number of days till the delivery date (i.e. the contents of cell B2), and to thus obtained value is added a half of the average expenditure multiplied by the number of days till the delivery date. Transfer the estimated value of the minimum status to cell I8 in spreadsheet STATUS_K3-456-Z (Figure 4).

| | H | I | J |
|---|---|---|---|
| 1 | | | |
| 2 | Price/piece | 8,00 | zł |
| 3 | Delivery date | 3 | days |
| 4 | Delivery readiness | 95,0% | |
| 5 | Storage costs | 18% | |
| 6 | Order costs | 45,00 | zł |
| 7 | | | |
| 8 | Minimum inventory | 318 | pieces |
| 9 | Order quantity | 3000 | pieces |
| 10 | | | |
| 11 | Estimated value of | | |
| 12 | minimum status | | |

**Figure 4** Estimated value of the minimum status moved to spreadsheet STATUS_K3-456-Z'

The last stage in the inventory management optimising is calculating OPTIMUM BATCH SIZE OF ORDERED GOODS. To this end, copy to the newly created spreadsheet W_Z_K3-456-Z from spreadsheet STATUS_K3-456-Z the following data: PRICE/PCS., STORAGE COSTS, ORDER COSTS and from spreadsheet RR_K3-456-Z-ANNUAL EXPENDITURE. Calculation of the economic batch size of the raw material (product) Q (i.e. the economic order quantity) is done with the formula [5]:

$$Q = \sqrt{\frac{2 \cdot \textit{Annual demand} \cdot \textit{Order costs}}{\textit{Price / piece} \cdot \textit{storage costs \%}}}$$

To calculate this quantity use formula ROUND (SQRT ((2*B4*B3)/(B1*B2)) ;0), which makes the obtained value rounded to an integer. In cell F2, this amount can be rounded to the number of tens. So the optimum order quantity (in terms of cost minimising) will be 2 000 pieces. Copy this value to cell I9 in spreadsheet STATUS_K3 I9-456-Z. To optimise the warehouse operating costs there is no need to order 3 000 pieces, but only 2 000 pieces of the raw material K3-456-Z. To collect data for a graphic representation of the cost development, insert in block of cells A8:G8 appropriate row headers and define in the first column in cells A9:A27 examples of the coefficient values (e.g. from 0,2 at every 0,1 up to 20), for which the cost components have been calculated together with overheads. To calculate ORDER QUANTITY (in *cell* B9) for given multiplier (equal to 0,2), multiply it by, rounded to the nearest hundred, ROUNDED ORDER QUANTITY, i. e. by = A9*$F$2. The NUMBER OF NECESSARY SUPPLIES is calculated in cell C9 by rounding the quotient of ANNUAL EXPENDITURE / ORDER QUANTITY, i.e. = ROUND ($B$4/B9;0). The value of ORDER COSTS was obtained multiplying the previously calculated NUMBER OF ORDERS by COST OF INDIVIDUAL ORDER, i.e. = C9*$B$3, while AVERAGE WAREHOUSE INVENTORY was calculated dividing BATCH SIZE by two, i.e. = B9/2. Overall STORAGE COSTS were obtained in cell F9 multiplying AVERAGE WAREHOUSE INVENTORY by PRICE/PIECE and STORAGE COSTS indicated as an interest, i.e. = E9* $B$1* $B$2/OVERALL STORAGE COSTS were obtained in cell G9 summing up ORDER COSTS and STORAGE COSTS, i.e. = D9+F9. The formulae from block of cells B9:G9 were copied to block of cells B10:G29 thus obtaining data to a chart COST STRUCTURE, from which the value of an optimum ordered batch size was read out. Thus obtained data are useful in plotting a chart of the cost structure, which accounts for OVERHEAD COSTS series (G9:G29), STORAGE COSTS series (G9:G29) and ORDER COSTS series (D9:D29). This chart was plotted in a new spreadsheet called STRUCTURE_COST. The intersection of lines STORAGE COSTS and ORDER COSTS gives on the x-axis (which is the ORDERED PRODUCT (RAW MATERIAL) BATCH SIZE)) the optimum ordered batch size. For this point, the line of OVERHEAD COSTS gets closest to the abscissa.

## CONCLUSIONS

In calculating the optimum status of order, it is necessary to consider not only the average value of expenditures from the warehouse during the reporting period, but also their distribution and structure. In this discussion should also take into account the assumption (in most cases true) that the values collected during the reporting period will be valid in the future forecast, too. This assumptions is the basis for forecasting in general [5,6]. Based on the three and a half month (from March 31 to June 15) observations of the warehouse operation, that the minimum stock to guarantee the lowest warehouse operating costs of approximately 2740 PLN (including also other parameters, i.e. PRICE/PIECE, DELIVERY DATE, DELIVERY READINESS, STORAGE COSTS, ORDER COSTS) should be kept at a level of about 318 pieces of the raw material K3-456-Z, while the minimum batch size of this raw material delivered to the warehouse should be kept at a level of about 2 000 units.

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**Note**: The responsible translator for English language is K. Kowalska-Bany, Katowice, Poland.