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Predicting Order Lead Times

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Entering on market, companies confront with different problems. But the largest problems of today's time are too long lead times of orders. A client that wants a particular product to be made will select the best bidder considering on delivery time.

To make a bid just on the basis of experience of employees is very risky nowadays. Therefore we propose a procedure by which - on the basis of actual lead times of orders processed in the company's workplaces in the past - expected lead times of planned (and indirectly - production) orders can be predicted. The result of the proposed procedure is an empirical distribution of possible lead times for the new order, and on the basis of this distribution it is possible to predict the most probable lead time of a new order. Using the proposed procedure, the sales department can make a prediction for the customer about delivery time of the planned order.

As an illustration of the procedure for predicting lead times of orders, a case study is presented: lead time of order for the "tool for manufacturing the filter housing" was predicted; the tool is manufactured in the Slovenian company ETI Ltd.

Keywords: lead times, prediction, operation order, empirical distribution

0 INTRODUCTION

Companies on the global market offer similar or the same products at comparable price and quality. The main difference between these companies is in the predicted order development time and in observance of the deadlines for delivery time.

Before making a bid, the sales department has to provide data on operations that will have to be carried out for a particular order, data on the time required for performing these operations, and data on requested delivery time. Currently, the data at times of realization of operations are obtained from experienced company employees, while the customer specifies delivery time. However, estimates based on personal experience can be rather misleading. Consequently, the bids may be based on wrong delivery time which can couse that the company does not receive the order.

Development of ICT – which are important resources for improving and maintaining the competitive advantages of the company on the market [1] – made radical changes as ICT simplifies many business-related tasks. Every company that wants to be competitive on the global market needs a suitable enterprise resource planning system – ERP system. There are several ERP systems available on the market [2] and it is the task of each company to select the optimum system [3].

The paper will present how the data stored in the ERP system can be used for calculation of lead times of orders (and indirectly: lead times of manufacturing orders) on the basis of theory developed at the IFA Hannover [4] and [5]. Furthermore, the calculation of percentage of manufacturing order lead times will be shown, which allows the calculation of the confidence interval. The purpose of this paper is therefore to propose a procedure for predicting lead times of manufacturing orders on the basis of past gathered data on actual lead times.

In our research we have not found an approach for predicting lead times as described in this paper, so we assume that it is a new approach which uses already known and developed theory of IFA Hannover, and adds a new method for predicting order lead times.

1 METHOD FOR PREDICTING MANUFACTURING ORDER LEAD TIMES

When talking about "an order", it is necessary to distinguish between operational, manufacturing, assembly and production order [4], as presented in Figure 1.

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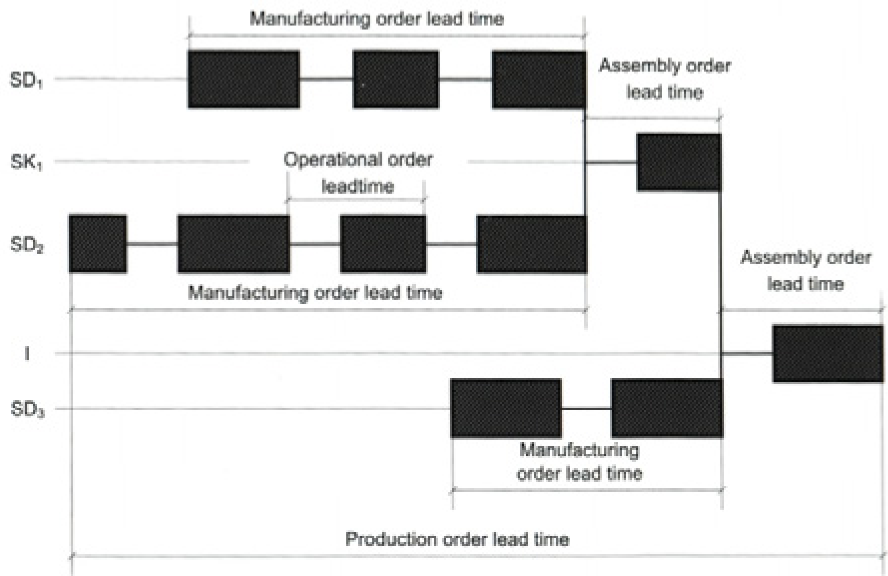

Fig. 1. *Order lead times [4]*

When designing a procedure for predicting manufacturing order lead times, it will be assumed that the company uses an ERP system, whose database contains data about past operational and assembly orders in company workplaces. Any ERP system should therefore provide data on:

- production-order code,
- assembly-order code,
- manufacturing-order code,
- operational-order code,
- type and sequence of operations on manufacturing and assembly orders,
- IDs of workplaces where operational orders have been carried out,
- actual execution times of operational orders,
- date of completing a particular operational or assembly order in the previous workplace,
- date of finishing a particular operational or assembly order in the observed workplace.

ERP system output data should be available in Microsoft Excel format (xls).

Based on previous research on problems of determination of lead times let us to the conclusion, that the proposed procedure for predicting order lead times consists of the following steps:

Step 1: Determining actual lead times of already processed operational orders in the company's workplaces

H. P. Wiendahl [4] says that the lead time of the *i*-th operational order N_i $(1 \leq i \leq n)$ which has been executed in the *j*-th workplace DM_j $(1 \leq j \leq m)$ is defined as an interval, calculated from the time when the *i*-th operational order has been completed in the previous, i.e. *(j-1)*-th workplace, till the time when the *i*-th operational order has been completed in the observed, i.e. *j*-th workplace (Fig. 2).

Lead time of an operational order is therefore:

$$TO_{i,j} = tK_{i,j} - tK_{i,(j-1)} \qquad (1),$$

$TO_{i,j}$ – lead time of the *i*-th operational order in the *j*-th workplace

$tK_{i,j}$ – completion time of the *i*-th operational order in the *j*-th workplace

$tK_{i,(j-1)}$ – completion time of the *i*-th operational order in the previous *(j-1)*-th workplace

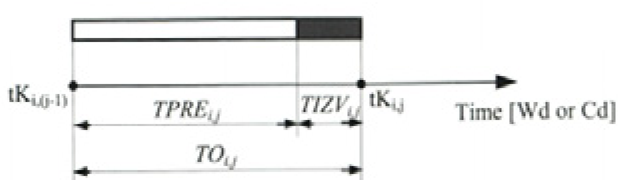

Fig. 2. *Lead time of operational order [4]*

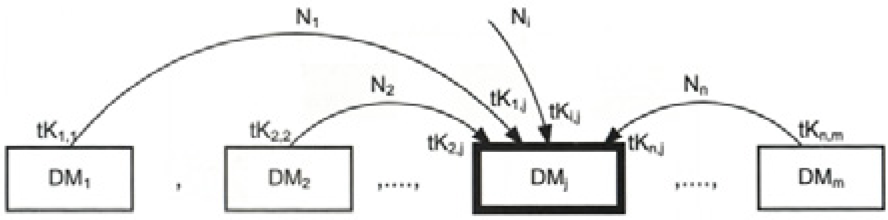

Fig. 3. *Flow of operational orders through the DM_j workplace [4]*

i – operational order number
j – workplace number

On the basis of the ERP system output data it is possible to calculate (for any j-th workplace $\boldsymbol{DM_j}$) the actual lead times of previously executed operational orders, i.e. orders that have been processed in the $\boldsymbol{j}$-th workplace in the observed time interval P (Fig. 3).

The actual lead times of operational orders, executed in the $\boldsymbol{j}$-th workplace in the observed time interval are therefore:

$$\begin{aligned} TO_{1,j} &= tK_{1,j} - tK_{1,(j-1)} \\ TO_{2,j} &= tK_{2,j} - tK_{2,(j-1)} \\ &\dots \\ TO_{i,j} &= tK_{i,j} - tK_{i,(j-1)} \\ &\dots \\ TO_{n,j} &= tK_{n,j} - tK_{n,(j-1)} \end{aligned} \qquad (2)$$

n – number of processed operational orders in the past on i-th workplace
m – number of workplaces

Vectors of actual lead times of operational orders, executed in the past in all company workplaces (table 1), will present the basis for predicting expected lead times of the planned new production orders.

Step 2: Forming assembly structure of the planned production order and technology routings for parts and components of planed order

The assembly structure and technology routings of realization of component parts and assemblies of manufacturing orders are made on the basis of available documentation of the planned production order. Figure 4 presents the principle of building the assembly structure.

Table 1. *Vectors of lead times of operational orders*

	Workplace					
	DM 1	DM 2		DM j		DM m
Vectors of lead times	$\begin{bmatrix} TO_{1,1} \\ TO_{2,1} \\ \vdots \\ TO_{n,1} \end{bmatrix}$	$\begin{bmatrix} TO_{1,2} \\ TO_{2,2} \\ \vdots \\ TO_{n,2} \end{bmatrix}$	...	$\begin{bmatrix} TO_{1,j} \\ TO_{2,j} \\ \vdots \\ TO_{n,j} \end{bmatrix}$	...	$\begin{bmatrix} TO_{1,m} \\ TO_{2,m} \\ \vdots \\ TO_{n,m} \end{bmatrix}$

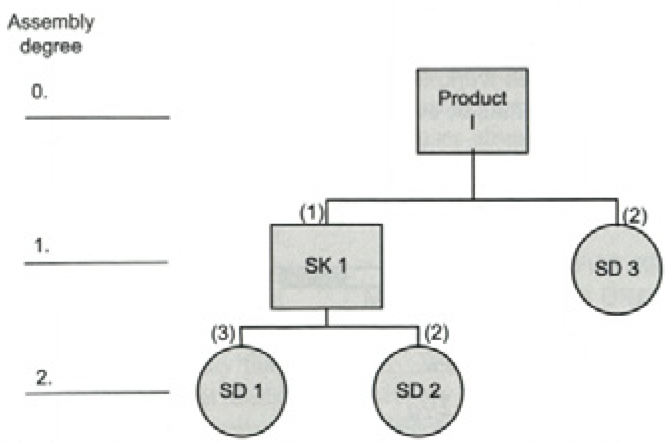

Fig. 4. *Principle of construction of assembly structure of production order I*

Legend:
I – product
SK – mark of asembly
SD – mark of component part
(x) – number of built ins of component parts and assemblies in assembly of higher degree

Figure 5, presents technology and assembly routings for manufacturing parts and components of the production order I.

Step 3: Random sampling and summing of vector element values of actual lead times of operational orders of individual manufacturing or assembly order

Figure 6 presents the principle of random sampling and summing of vector element values of operational order actual lead times in the past of planned manufacturing and assembly orders.

$TO_{SD1,1}$ – lead time of component part SD_1, got after first iteration

$TO_{SK1,1}$ – lead time of assembly SK_1, got after first iteration

$TO_{I,1}$ – lead time of product I, got after first iteration

Figure 6 shows a schematic presentation of random sampling and addition of lead times values achieved in the past from workplace vectors, defined by technology and assembly routings for manufacturing parts and assembly of

Part / component	Prescribed sequence of operations			
SD 1	Turning DM1	Milling DM3	Grinding DM4	
SD 2	Turning DM1	Milling DM3	Planing DM2	Grinding DM4
SD 3	Planing DM2	Grinding DM4		
SK 1	Assembling DM5			
I	Assembling DM5	Control DM6		

Fig. 5. *Technology and assembly routings of parts and components of production order I*

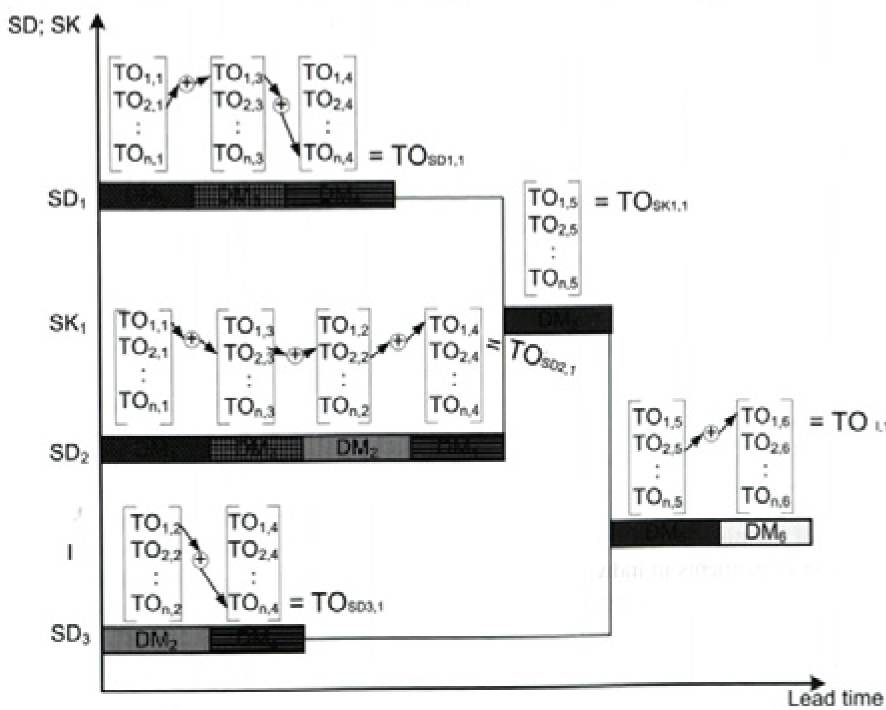

Fig. 6. *Random sampling and summing of vector element values of actual operational order lead times achieved in the past*

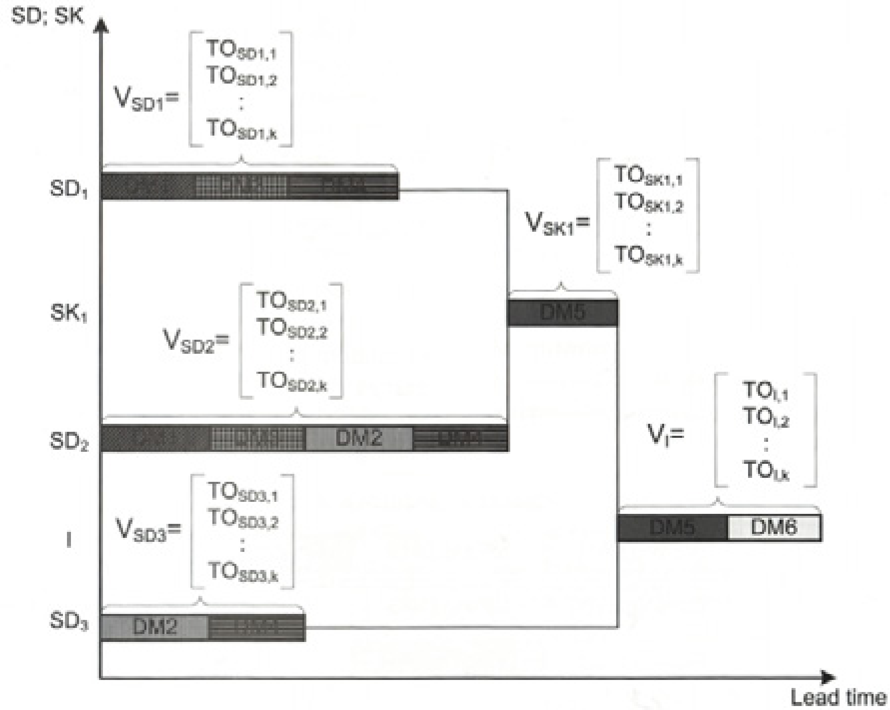

Fig. 7. *Setting up vectors of expected lead times of planned manufacturing and assembly orders*

components.

It is necessary to select the number of iterations for random sampling of lead times of manufacturing and assembly orders of planned production order (computer supported). The number of iterations is affected by the order type – by increasing its complexity, the number of iterations should be increased, too.

Step 4: Setting up vectors of expected lead times of manufacturing and assembly orders of planned order

Results of step 3 allow setup of vectors of the expected lead times of the manufacturing and assembly orders of planned production order, as presented in Figure 7.

$TO_{SD1,k}$ – lead time of component part SD_1, got after k - th iteration

V_{SD1} – lead time vector of assembly SD_1

k – number of iteration

The number of elements in individual vector depends on the number of performed iterations k. The number of required iterations can be established on the basis of tests, as it is necessary to assure a stable process, which cannot be achieved by a small number of iterations. A criterion for an adequate number of iterations is that multiple use of the procedure must yield comparable results, by which the stability (convergence) of the procedure is achieved.

Step 5: Definition of vector of expected lead times of the planned order

In order to define the vector of expected lead times of the planned production order V_I, it is necessary to transform the Gantt chart of production order (Fig. 7) into an activity network diagram of order and enter into it the vectors of expected lead times of manufacturing and assembly orders of planned order (Fig. 8).

Initial data of activity network diagram of planned order are:

- date of starting the execution of the virtual order $\boldsymbol{SD_0}$:

$$TZ_{SD_0} = 0 \qquad (4),$$

- vector of the virtual manufacturing and assembly order $\boldsymbol{V_{SD0}}$ is:

$$V_{SD_0} = \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix} \qquad (5),$$

- vectors of expected lead times of manufacturing and assembly orders of the planned order are:

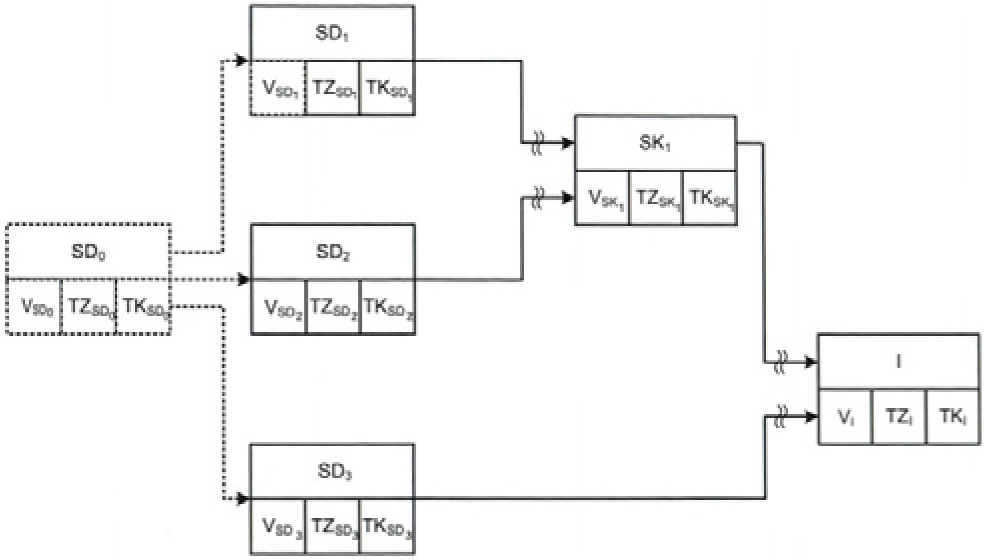

Fig. 8. *Activity network diagram of the planned (new) order*

$$V_{SD_1}, V_{SD_2}, \ldots, V_{SK_1}, V_I$$

For a virtual order SD_0, which has no predecessors in activity network diagram, it is assumed that the date of starting the execution of order is (for the first iteration):

$$TZ_{SD_{0,1}} = 0 \qquad (6),$$

and the date of finishing the execution of order is

$$TK_{SD_{0,1}} = TZ_{SD_{0,1}} + TO_{SD_{0,1}} = 0 + 0 = 0 \qquad (7).$$

For other manufacturing or assembly orders, which have one or more predecessors (Fig. 9) is the date of starting the execution of orders then:

$$TZ_{SD_{b,1}} = \max_{k \in P^*} \{ TZ_{SD_{a,1}} + TO_{SD_{a,1}} \} \qquad (8)$$

P* – predecessors of the observed order N_j
and the date of finishing the execution of orders

$$TK_{SD_{b,1}} = TZ_{SD_{b,1}} + TO_{SD_{b,1}} \qquad (9).$$

Date of completing the last manufacturing or assembly order **I** is equivalent to the expected lead time of the planned order *TO* in the activity network diagram:

$$TK_I = TO \qquad (10).$$

Figure 8 shows the calculation for one vector element of expected lead time of the planned order. Such a calculation must be done for a selected number of iterations of randomly sampled values from vectors of individual component partsand assemblies of planned order. The calculation is carried out as follows:

- For sequential operations, individual randomly sampled lead times from vectors of sequentially listed workplaces are summed up. The result of each iteration is stored into a new vector, which represents the sum for one component or part.
- For parallel operations it is necessary to collect randomly sampled lead times from vectors of parallel workplaces, and then find a maximum lead time for each parallel path. Thus obtained results in each iteration should be stored in the common vector of maximum times of parallel paths, as the critical path in the activity network diagram is always the path with the longest required lead time for realization the manufacturing order.

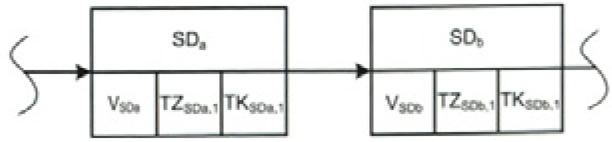

Fig. 9. *Basic element of activity network diagram*

Calculation has to be repeated for the selected number of iterations.

Thus obtained expected lead times of the planned order will represent empirical distribution of lead times of the planned order.

Step 6: Predicting delivery time of the planned order

Step 5 in predicting order lead time has lead to the vector of expected lead times of order, i.e. to a certain distribution of lead times.

In real life, however, an exact value of lead time for delivery of order is required.

The most probable delivery lead time for the planned order can be estimated by using median, which means that there is a 50% probability that the actual delivery time will be shorter, and 50% probability that it will be longer than stated. As the 50% risk is usually unacceptable for the client, so the estimated value should be stated for a wider confidence interval.

For instance, 90% confidence interval is defined as 90% probability that the order will be delivered before the stated time. Therefore, maximum delivery time that can be guaranteed to the customer with 90% reliability, corresponds to the 90th percentage of empirical distribution of prediction of the planned order.

Percentage [6] and [7] provides the value of Y, which is larger than P% of the values in the X set. In other words, e.g. 90[th] percentage gives the value, which is larger than 90% of all values (sorted from smallest to largest) in the X set (Fig. 10).

In order to obtain the P-th percentage of X sorted values, it is necessary to calculate the R rank [8]:

$$R = P(X+1)/100 \qquad (11),$$

which is rounded to the first integer and then the value from the X set is selected, which corresponds to this rank.

R – percentage rank
P – percentage
X – number of sorted set elements

Based on the above explanation and our tests, we propose that the 90th percentage be used as a standard. In this way it is possible to state with 90% confidence that the order will be completed within the expected time.

If the company wants to achieve even higher reliability, it can use an even higher percentile (for example 99th) – and thus minimize the risk.

Naturally, the choice of the percentage may depend on importance of the order and the customer – the more important the customer, or the more important the order, the higher is the interest of the company to get a particular order.

In the proposed procedure for predicting manufacturing order lead times, in addition to MS Excel, the MATLAB software will be used [6], which allows execution of mathematical operations and graphical presentation of results.

2 TESTING THE PROCEDURE FOR PREDICTING ORDER LEAD TIMES

The procedure for predicting order lead times was tested in the tool shop of ETI Ltd. company from Izlake, Slovenia. It produces tools for transforming and cutting, tools for injection moulding of thermoplastic and duroplastic materials, jet and press machines for duroplastic

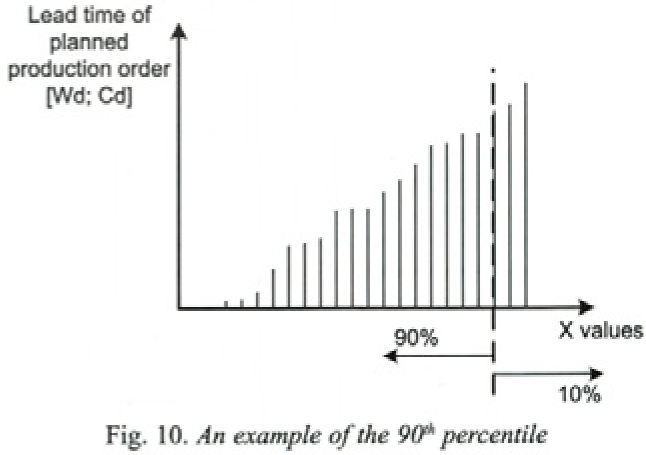

Fig. 10. *An example of the 90[th] percentile*

materials, press machines for ceramic materials, and automated assembly appliances.

This tool shop speciality is design and manufacturing of high-quality tools for injection moulding of thermoplastic and duroplastic materials. Thanks to its many years of experience in making tools for ETI company, the tool shop started producing tools and appliances for external customers in the following fields: automotive industry, household appliances, medical technology, electrical engineering, electronics and illumination.

Tool shop uses Largo ERP system, developed by Perftech Ltd. company from Bled [9], Slovenia. Because of their way of production (tools are made for known customers and each tool is unique) it is very difficult to precisely predict duration of production – but this is essential data for making bids and winning orders.

Company management decided to test the suitability of the proposed procedure for predicting lead times of orders in a case study of determining lead time of order for the "tool for manufacturing filter housing # 705429" (Fig. 11).

Steps of the procedure for predicting manufacturing order lead time for the "tool for manufacturing filter housing # 705429":

Step 1: Determining actual lead times of operational orders finished in the past in the company's workplaces

For the experiment, the Largo ERP system data were used in the period from December 12, 2002 till August 22, 2005.

First it was necessary to export data from Largo ERP system to MS Excel format. The following data were exported from the database: order number, arrival date, departure date, manufacturing time, and sequence of operational orders.

Largo ERP system uses calendar dates and does not take into account the company's labour-days calendar. Therefore the data which are not adapted to the company's labour days are useful mainly for predicting the duration of production from the sales department's point of view and not that much for manufacturing planning – for this purpose it would be necessary to take into account the company's labour-days.

In agreement with the tool shop management it was decided that for determining actual lead times of operational orders finished in the past, the data from the ERP system would be used from December 12, 2002 till August 22, 2005. During that time, 22,850 manufacturing orders were processed in the production, with 57,951 operational orders in 35 workplaces (Table 2).

It can be seen that during the observed time a rather varying number of operational orders passed across workplaces (minimum of 2 orders over workplace 44321 and maximum of 7307 orders over workplace 44253).

Actual lead times of individual operational orders were calculated on the basis of the data obtained from the ERP system. The calculation was made in MS Excel on the basis of Equation (1). Figure 12 presents a part of the calculation of actual lead times of operational orders in Excel table.

The results have shown that majority of actual lead times shorter then 1 Cd or 1 Cd, exceptions to the rule are some extreme cases, e.g. 464 Cd.

Fig. 11. Filter housing made by tool # 705429

Table 2. *Number of operational orders finished on workplaces in the tool shop*

Code:	Workplace name:	Number of finished orders in three years:
44000	Cooperation – service	21
44141	Design of devices	151
44142	Machine electronics	130
44143	Design of tools	2288
44211	Slitting	1420
44221	Turning	3706
44222	CNC turning	1052
44231	CNC programming	371
44232	CNC Milling Micron	2660
44241	CNC programming	668
44242	CNC Milling Picomax 60	4153
44243	CNC programming	9
44244	CNC Milling Deckel Maho	1400
44251	CNC Milling Picomax 54	2018
44252	Milling	235
44253	Rough milling	7307
44261	Plane grinding	1972
44262	Plane/profile grinding	4225
44263	Round grinding	2894
44264	Tools sharpening	159
44265	CNC coordinate grinding	7
44271	CNC programming of wire erosion	1126
44272	Wire erosion	1927
44273	Wire erosion -Makino	3161
44281	Dip erosion - AGIE	439
44282	Dip erosion - Charmilles	1565
44283	Dip erosion - Sinitron	513
44286	Omega punching	745
44291	Heat treatment	5172
44311	Manual machining	4288
44312	Assembly of tools	812
44313	Assembly of machines and devices	197
44321	Sampling	2
44331	Measurement	885
44332	DEA Omicron measurement	273
	Three years production:	57951

Step 2: Using or forming assembly structure of the planned order and technology routings of parts and components of order – for tool # 705429

In this step known assembly structure is formed (Fig. 13), as well as known type and sequence of operations (Fig. 14) for the tool under discussion - tool # 705429.

It can be seen from Figure 13 that the tool consists of two parts: ejecting and feeding part. The tool consists of bought parts and of parts/components made in the tool shop. There is just one assembly operation at the end, which is followed by testing.

For tool parts and components that are manufactured in the tool shop it was necessary to gather data on type and sequence of required operations, which

	B	C	D	E	F	G	H	I	J
1	Order Nr.	Nr.working order	Workplace	Sequence	Workplace name	Production time [Eh]	Arrival date	Departure date	Lead time [Cd]
2	6229	700609	44232	30	CNC Milling Micron	4	22.5.2003	22.5.2003	0
3	6229	700609	44311	20	Manual machining	1,5	15.5.2003	2.6.2003	18
4	6231	700609	44253	10	Rough milling	3,5	13.5.2003	15.5.2003	2
5	6231	700609	44262	30	Plane/profile grinding	2	17.5.2003	30.5.2003	13
6	6231	700609	44242	20	CNC Milling Picomax 60	3	15.5.2003	17.5.2003	2
7	6231	700609	44272	40	Wire erosion	6	30.5.2003	3.6.2003	4
8	6232	700609	44253	10	Rough milling	3	14.5.2003	14.5.2003	0
9	6232	700609	44253	20	Rough milling	3,5	14.5.2003	16.5.2003	2
10	6232	700609	44262	50	Plane/profile grinding	7	19.5.2003	28.5.2003	9
11	6232	700609	44242	30	CNC Milling Picomax 60	9	16.5.2003	17.5.2003	1
12	6232	700609	44242	60	CNC Milling Picomax 60	9	28.5.2003	2.6.2003	5
13	6232	700609	44311	40	Manual machining	3	17.5.2003	19.5.2003	2
14	6233	700609	44253	10	Rough milling	1	16.5.2003	16.5.2003	0
15	6233	700609	44232	20	CNC Milling Micron	2	16.5.2003	19.5.2003	3
16	6233	700609	44311	30	Manual machining	1,5	19.5.2003	2.6.2003	14
17	6234	700609	44253	10	Rough milling	3,75	14.5.2003	15.5.2003	1
18	6234	700609	44262	30	Plane/profile grinding	1,5	19.5.2003	30.5.2003	11
19	6234	700609	44232	20	CNC Milling Micron	4,5	15.5.2003	19.5.2003	4
20	6235	700609	44253	10	Rough milling	9	19.5.2003	19.5.2003	0
21	6235	700609	44232	20	CNC Milling Micron	6	19.5.2003	20.5.2003	1
22	6235	700609	44311	30	Manual machining	2,5	20.5.2003	2.6.2003	13
23	6236	700609	44253	10	Rough milling	4	16.5.2003	16.5.2003	0
24	6236	700609	44232	20	CNC Milling Micron	5	16.5.2003	19.5.2003	3
25	6236	700609	44311	30	Manual machining	2,5	19.5.2003	2.6.2003	14
26	6237	700609	44253	10	Rough milling	2,5	12.5.2003	12.5.2003	0
27	6237	700609	44261	30	Plane grinding	1	17.5.2003	3.6.2003	17
28	6237	700609	44232	20	CNC Milling Micron	3,5	12.5.2003	17.5.2003	5

Fig. 12. *Calculation of actual lead times of finished operational orders in interval from December 12, 2002 till August 22, 2005*

provide quality parts and components. For the tool # 705429 some of these data are presented in Figure 14.

In tool shop in ETI Ltd. they do an conglomeration of operations named preparing on manufacturing, which for this order contains: machine electronics (44142), design of tools (44143) and slitting (44211). This is actually not a real part of the tool, which can be shown in Figure 14, but it consumes time, so it is necessary to count it in by the sequence of operations.

Steps 3 and 4: Random sampling and summing of vector element values of actual operational order lead times of individual manufacturing or assembly order of the planned order, and setup of vectors of expected lead times of manufacturing and assembly orders of the planned order for the tool # 705429

On the basis of defined sequence of machining on parts and components for the tool # 705429 made by MATLAB software, the vectors of expected lead

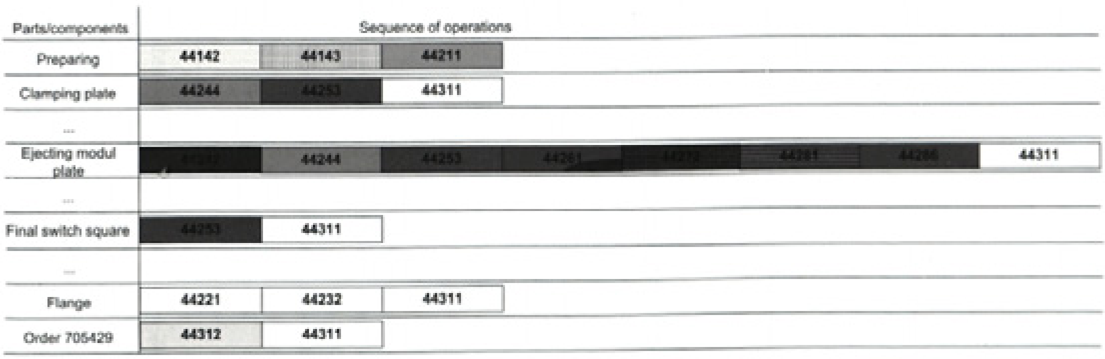

Fig. 14. *Type and sequence of operations required for manufacturing parts and components of the tool # 705429*

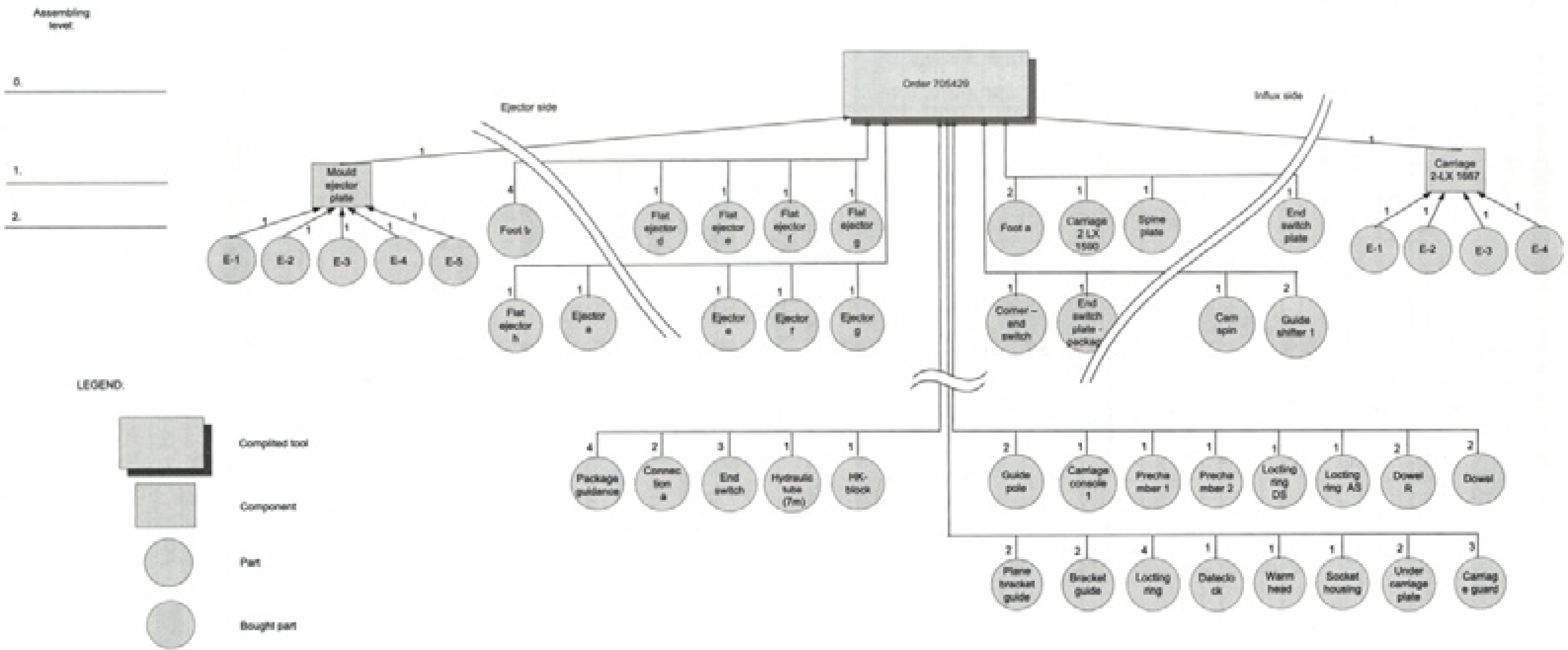

Fig. 13. *Part of assembly structure of the tool # 705429*

Note: All component parts made in this tool shop, have the first treatment named preparing, which for this order contains: Machine electronics (44142), Design of tools (44143) and Slitting (44211).

times of manufacturing and assembly orders have been set up, as described in the theoretical part of this paper.

On the basis of tests with 500, 1000, 5000, 10,000, 20,000 and 50,000 iterations we concluded that the prediction process stabilizes at approximately 10,000 iterations. If much fewer iterations are used, predictions are unstable, as insufficient data are used. If many more than 10,000 iterations are selected, the data used are repeated, so the result is not any better, while the processing time increases. We therefore used 10,000 iterations during a random selection of lead times.

On the basis of these 10,000 iterations of random selection of order operation lead times, the vectors of expected lead times of manufacturing and assembly orders have been obtained - tool # 705429 (Fig. 15).

Step 5: Definition of vector of expected lead times of the planned manufacturing order for the tool # 705429

10,000 iterations were made for the calculation of expected lead time vector of the planned order for the tool # 705429. A sample calculation of lead time for one iteration is presented in Figure 16. Expected lead time of the planned order is calculated as the sum of time of preparing, maximum time of parallel manufacturing orders, and assembly order, which in our case amounts to 16 + 28 + 9 = 53 Cd.

After 10,000 iterations the final vector of expected order lead time for the planned order for the tool # 705429 with distribution presented in Figure 17 was obtained.

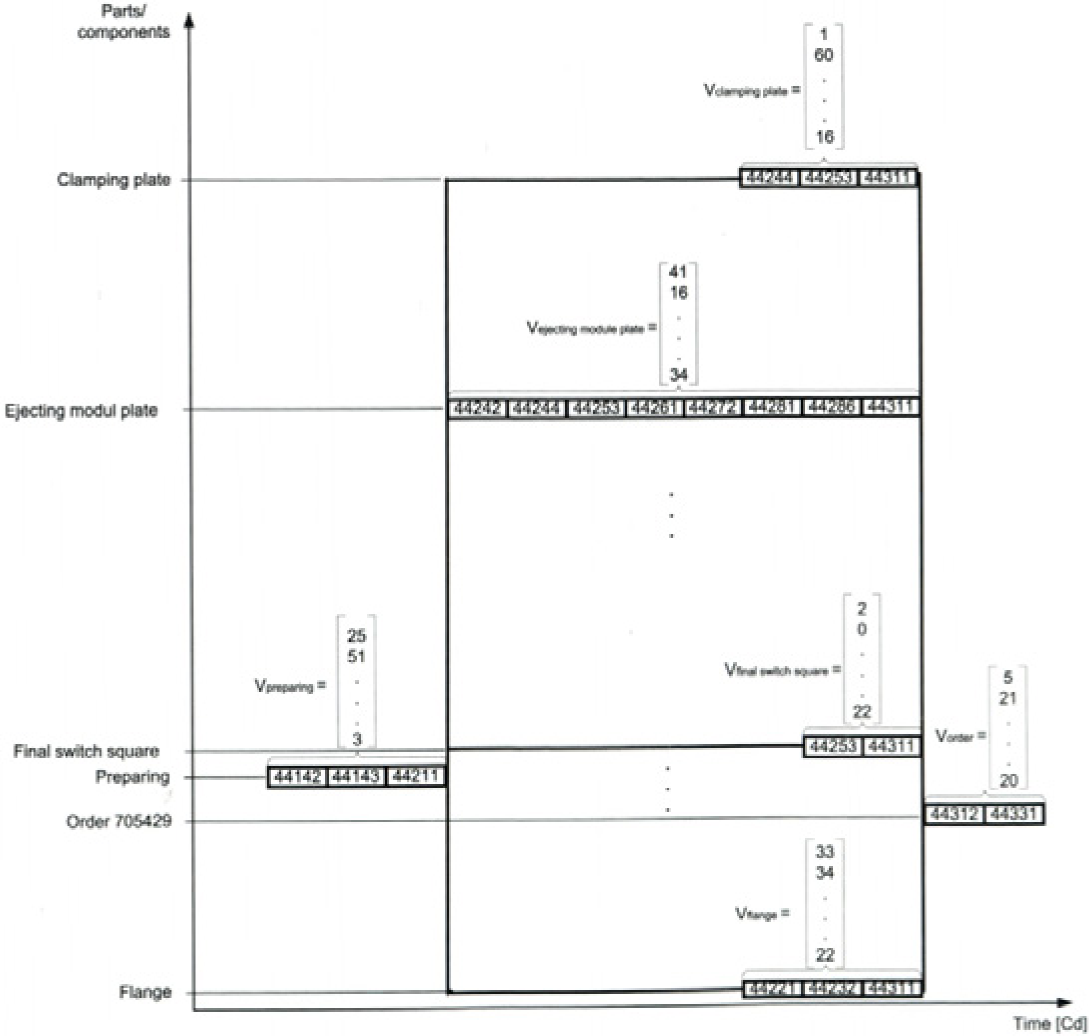

Fig. 15. *Setup of vectors of expected lead times of manufacturing and assembly orders*

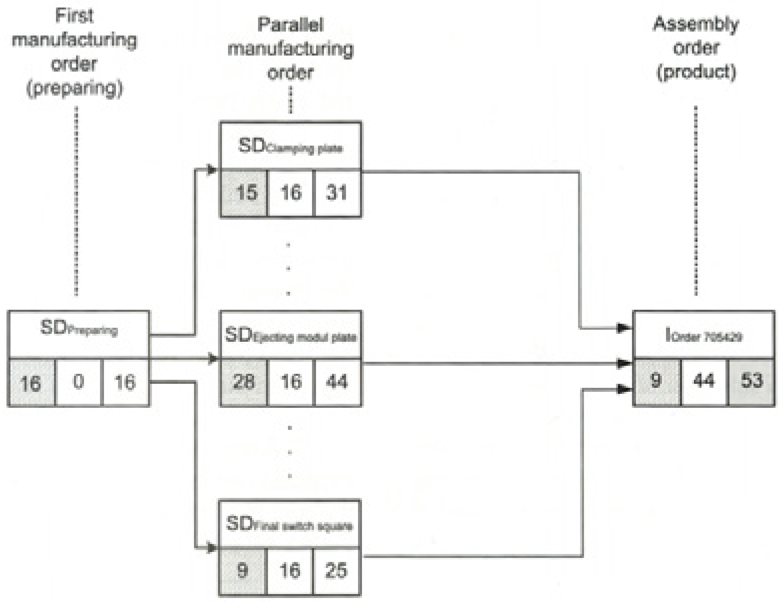

Fig. 16. *Activity network diagram of one iteration of the order # 705429*

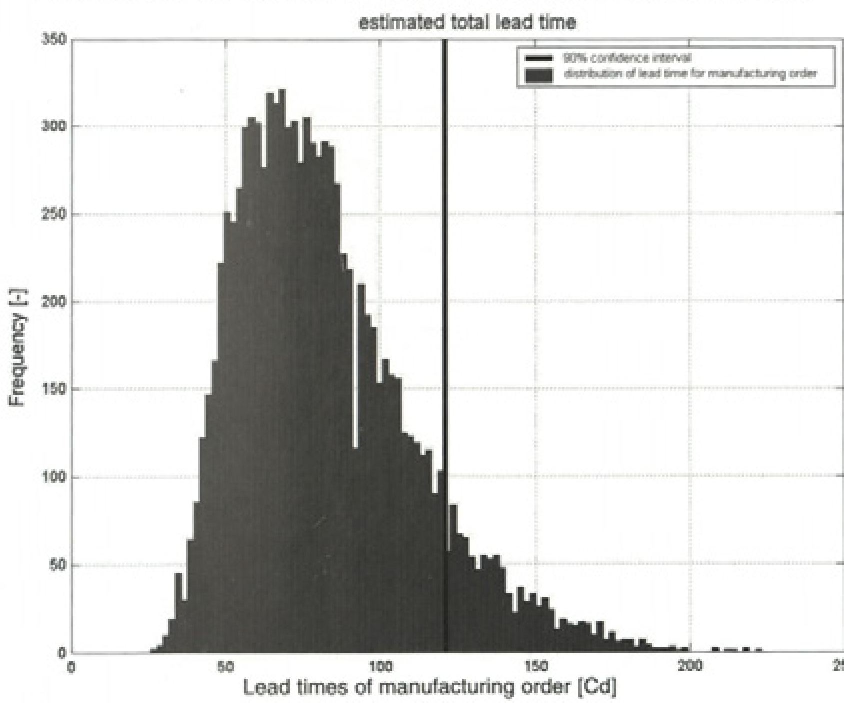

Fig. 17. Distribution of lead times for manufacturing order # 705429

Step 6: Predicting delivery time of the planned tool production order # 705429

In the fifth step the vector of lead time of the planned order (i.e. distribution of lead times of order) was set. However, no customer is interested in a lead-time vector (or distribution of lead times), so as the first approximate delivery time value, the median of this vector is used; for this order it is:

$$TO_{med} = 77 \text{ Cd}$$

TO_{med} – median lead time of the tool production order # 705429

Expected lead time therefore equals to the 50th percentage of the vector of expected lead times.

Confidence intervals are defined according to the selected confidence levels.

If a very high confidence level is required, the 90th percentage is used. So, for the order # 705429 it can be stated with 90% confidence level that this order will be produced within

$$TO_{90\%} = 120 \text{ Cd}$$

$TO_{90\%}$ – lead time at 90th percentage

The company has to decide itself, which risk level it is ready to accept when signing the contract with the customer.

3 CONCLUSION

Due to ever fiercer competition of companies on domestic and foreign markets, and due to transition from the market of sellers to the market of customers, the companies have to continuously reduce delivery times of the order.

The paper proposes a procedure for predicting manufacturing order lead times on the basis of past actual lead times of operational orders. The use of the proposed procedure allows:

- prediction of lead time needed for delivery of any new order,
- variation of delivery-time calculations on the basis of acceptable risk level by selecting the confidence interval.

The basis for calculation of delivery time is median, while 90th percentage may represent the upper (safe) limit, which can be offered to the customer as the latest delivery lead time. On the basis of its experience and its willingness to risk, the company can choose different confidence interval.

The procedure for predicting order lead times has been tested in a case study of predicting lead times for producing a tool for manufacturing a filter casing in the tool shop of the ETI Ltd. Case study was performed on the basis of data, defined in calendar days collected in three years in the data base of ERP system Largo.

By using this procedure of predicting manufacturing order lead times, sales department can make a well-defined bid for the customer in a short time without the sales person needing many years of experience – (s)he only needs well-defined technology routings, while the company management provides the confidence interval.

In the future it is planned that the proposed procedure will be improved by taking into account the sequence of operations required to complete an order, the influence of the number of operations per order, the influence of manufacturing time, etc.

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