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Proposal for Cost Calculation of Warehouse Processes and Its Usage for Setting Standards for Performance Evaluation

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***Abstract*—**This paper describes a proposal for cost calculation of warehouse processes and its usage for setting standards for performance evaluation. One of the most common options of monitoring process performance is benchmarking. The typical outcome is whether the monitored object is better or worse than an average or standard. Traditional approaches, however, cannot find any specific opportunities to improve performance or eliminate inefficiencies in processes. Higher process efficiency can be achieved for example by cost reduction assuming that the same output is generated. However, costs can be reduced only if we know their structure and we are able to calculate them accurately. In the warehouse process area it is rather difficult because in most cases we have available only aggregated values with low explanatory ability. The aim of this paper is to create a suitable method for calculating the storage costs. At the end is shown a practical example of process calculation.

***Keywords*—**Calculation, Costs, Performance, Process, Warehouse.

I. Introduction

A wide range of generally accepted benchmarking metrics is used for performance measurement. Generally, there are two different approaches: economic (i.e. revenue related to cost) and technical (i.e. outputs related to inputs). Pure economic performance measurement is somewhat difficult because warehouses typically do not generate revenues. Technical performance measurement uses a wide range of logistics metrics which usually compare one input to one output. An example of a technical metric is the number of picked lines during a given time period. Generally, it is very difficult to measure process performance (or employee performance) if we do not know what to compare. The framework for performance evaluation should be based on the ability of processes (or employees) to meet achievable standards. However, this brings us to a crucial question - what is an achievable standard and how do we get it? In our solution we are looking for possible ways to appropriately establish standards for warehouse process costs. These standards should be achievable and challenging at the same time.

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II. Literature Review

Logistics benchmarking to improve productivity and quality has been used for more than 20 years by more than half of the Fortune 1000 companies [1]. Logistics benchmarking traditionally uses a set of individual factors of productivity which compare one input to one output. This method is often referred as the ratio method [2], [3]. However, the use of various single ratio measures can lead and often leads to distorted results. The problem that came along with single ratios is: how to determine if the warehouse performs well when some metrics are good and others poor [4]? For this reason models were developed which simultaneously include more significant factors. A typical representative of these methods is Data Envelopment Analysis (DEA) [5]. A wide variety of modifications have been developed over the last few years based on the DEA framework in order to make the method more usable for self-reported warehouse data. These studies have in common that they use a large and diverse sample of warehouses; see, [6]-[8]. Furthermore they define a set of warehouse metrics for multi-criteria analysis to determine the best (the most efficient) warehouses in the reference sample. [9] Most of these studies consider costs as one of the factors that enter into the analyzed metrics. None of them, however, focuses on how these costs can be accurately calculated. Costs are usually expressed in aggregated form, thereby explanatory ability is lost [10]-[11]. The goal of this study is to develop a framework for accurate calculation of the warehouse costs that enters performance measurement metrics.

III. Metrics Used to Measure the Performance of Warehouse Processes

The choice of methods for measuring performance is a critical activity for identification of inefficiencies in processes. A suitable set of metrics can be used as a protection against loss of quality or loss of customers. Performance indicators in the warehouse process area can generally be summarized by one of the following:

- Operating costs, such as warehouse costs as a percentage of sales.
- Operating productivity, such as pick-lines, orders, cartons, pallets handled per person per hour.
- Response time, such as order-cycle time (minutes per order).
- Order accuracy, such as fraction of shipments with returns.

Because our solution focuses on operating costs we are looking for Key Performance Indicator (KPI) in this area. The main purpose of monitoring these KPIs is to find opportunities for improving the whole warehouse process. Typical warehouse performance indicators are listed in Table I.

TABLE I
TYPICAL WAREHOUSE PERFORMANCE INDICATORS

Measure	Type	Calculation	Typical value
Cost as % of Sales	min	Total Warehouse Cost / Overall Sales	3.82
Cost per Order	min	Total Warehouse Cost / Total Orders Shipped	5.23
Items per Hour	max	Items Picked (Packed) / Total Warehouse Labour Hrs	120 picked items / hour
Order per Hour	max	Orders Picked (Packed) / Total Warehouse Labour Hrs	5 orders / hour

Table I shows that Cost per Order is calculated from the total warehouse cost. Other metrics are also calculated from total (aggregated) values. If we look at how the warehouse costs are usually monitored in companies we find that they are either not monitored at all or are expressed by one total value, see for example Supply Chain Digest survey [11]. This means that most companies cannot know the structure of warehouse costs or manage them effectively. In other words this means that metrics based on total cost values do not allow us to find opportunities for cost reduction.

IV. PROPOSAL FOR COST CALCULATION OF WAREHOUSE PROCESSES

Usually monitored metrics which include warehouse costs are as follows:

- Cost of receiving per receiving line.
- Cost per put-away line.
- Warehouse cost per item.
- Cost of picking per order line.
- Cost of shipping per order.
- Cost per Order.
- etc.

The exact calculation of the costs listed above by conventional surcharge methods is nearly impossible. It is necessary to use one of the process-oriented methods. In our solution we chose a methodology called Prozesskostenrechnung (PKR) which was developed by Horváth and Mayer in 1989 [12]. PKR methodology (such as Activity Based Costing) is based on allocating costs to activities which are consumed by various products in the production process [13]. The PKR methodology assigns costs to products based on how much of the costs are actually caused by activities associated with these products. The principle of cost allocation is shown in Fig 1.

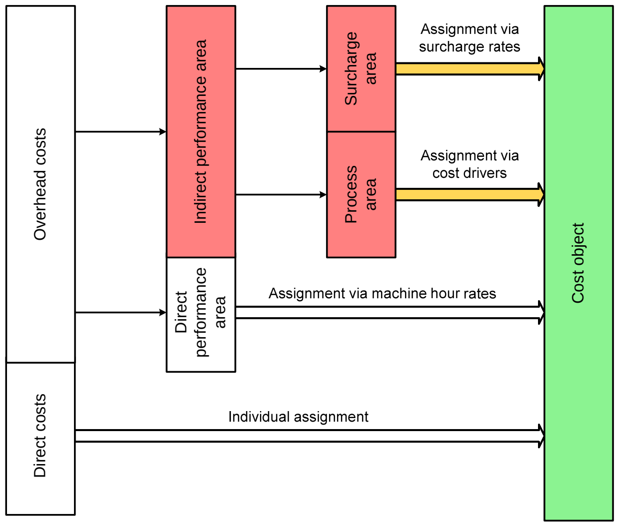

Fig. 1 Principle of costs allocation according the assignment to the cost object - edited according to [12]

Since there are no material transformations performed in the warehouse (and hence there is no direct creation of added value for the customer) warehouse costs belong to overhead costs in the indirect performance area. For each individual warehouse process it is necessary to determine the appropriate method of cost allocation. Basically there are two possible options: process method or surcharge method. In the process method we handle those processes that are stable, standardized and repetitive. All other processes that do not meet these conditions are handled using the surcharge method.

The procedure of process cost allocation is as follows. First, based on the analysis of activities, sub-processes are established in existing costs pools (e.g. purchase department). Cost drivers and process quantities for individual sub-processes are simultaneously defined. The data are obtained from the statistical analysis of repetitive warehouse processes. The next step is summarization of several related sub-processes which exceed cost pools into a few main processes.

Determination of sub-process cost and cost rates is as follows:

1) Selection of allocation basis.
2) Total cost of cost pool is divided into so-called lmi-processes (they are quantity variable and depend on process quantities) and lmn-processes (they are quantity independent). Allocation basis is used as a scale for distribution.
3) Lmi and lmn sub-processes are displayed in the cost pool table.
4) Lmi sub-processes costs are calculated. The total cost of the cost pool is divided between individual sub-processes. Allocation basis is used as a scale.
5) Establishing surcharge. In this step lmn sub-processes costs are assigned to the lmi sub-processes cost.
6) Sub-processes cost rates are established for lmi+lmn sub-processes as a proportion of the cost of sub-processes and corresponding process quantity.

V. Verification of the Proposed Solution for Cost Calculation of Warehouse Processes

The proposed procedure has been numerically verified. Tables II and III show an example of calculation of cost rates for several warehouse sub-processes.

TABLE II
EXAMPLE OF CALCULATING OF WAREHOUSE SUB-PROCESSES COST RATES – RIGHT PART

Number	Sub-process		Cost drivers	Quantity of sub-process	Nr. of employees
1	receiving	lmi	nr. of received pallets	1800	0.5
2	put-away	lmi	nr. of put-awayed pallets	2000	0.3
3	picking	lmi	nr. of picked items	15000	2.0
4	packing	lmi	nr. of packed items	1500	2.0
5	…	…		…	…
Sum					**4.8**
6	control	lmn	-		0.2
Sum (lmi+lmn)					**5.0**

TABLE III
EXAMPLE OF CALCULATING OF WAREHOUSE SUB-PROCESSES COST RATES – LEFT PART

Sub-process costs (EUR)			Sub-process cost rates (EUR)	
lmi	**Surcharge lmn**	**Sum lmi + lmn**	**lmi**	**lmi + lmn**
1000.0	41.7	1041.7	0.56	0.58
600.0	25.0	625.0	0.30	0.31
4000.0	166.7	4166.7	0.27	0.28
4000.0	166.7	4166.7	2.67	2.78
…	…	…	…	…
9600.0	**400.0**	**10000.0**		
400.0				
10000.0				

The calculation procedure described in the previous section is shown at first in general and then numerically for the sub-process called picking. The acronym "SP" in the following formulas means "sub-process". The individual steps of calculation are as follows:

1) Personal capacity is selected as allocation basis. Picking process depends on process quantity; therefore it is an "lmi process".
2) For example we know (from statistical data) that picking process quantity was 15,000 in the previous time period. The total warehouse cost was 10,000 EUR in the same period.
3) Calculation of lmi sub-process cost:

$$\text{SP lmi cost} = \frac{\text{total cost}}{\text{total nr.of employees}} * \text{nr. of employees of SP} \quad (1)$$

$$\text{picking lmi cost} = \frac{10\ 000}{5} * 2 = 4\ 000\ [\text{EUR}]$$

4) Calculation of lmi sub-process cost rate:

$$\text{SP lmi cost rate} = \frac{\text{SP lmi cost}}{\text{amount of SP}} \quad (2)$$

$$\text{picking lmi cost rate} = \frac{4\ 000}{15\ 000} = 0.27\ [\text{EUR}]$$

5) Calculation of lmn surcharge:

$$\text{SP lmn surcharge} = \frac{\text{lmn total cost}}{\sum_{i=1}^{n} \text{SP lmi cost}} * \text{lmi cost of SP} \quad (3)$$

$$\text{picking lmn surcharge} = \frac{400}{9\ 600} * 4\ 000 = 166.7\ [\text{EUR}]$$

6) Calculation of sum lmi+lmn sub-process cost:

$$\text{SP (lmi + lmn) cost} = \text{SP lmi cost} + \text{SP lmn surcharge} \quad (4)$$

$$\text{picking cost} = 4\ 000 + 166.7 = 4\ 166.7\ [\text{EUR}]$$

7) Calculation of lmi+lmn sub-process cost rate:

$$\text{SP (lmi + lmn) cost rate} = \frac{\text{SP (lmi+lmn)cost}}{\text{amount of SP}} \quad (5)$$

$$\text{picking cost rate} = \frac{4\ 166.7}{15\ 000} = 0.28\ [\text{EUR}]$$

The result is that cost of one picking process is 0.28 EUR. Rates for other sub-processes can be calculated analogically.

VI. Conclusion

The use of process-oriented calculation methods (such as PKR) allows us to determine the cost rate for individual warehouse processes with high accuracy. Furthermore, on the basis of cost rates we can set standards for monitoring and measuring the performance of these processes. In comparison to traditional methods metrics which include costs are not calculated from total (aggregated) values. In our solution, the costs are calculated using the process method which also allows us to identify opportunities for future improvements. For example, we can compare the calculated cost of a single picking line with the cost obtained from the total value. And if there is a significant difference we can start looking for reasons why this is so. This means that a process-oriented calculation allows achievable standards to be set for performance measurement of those metrics which include cost. Additional benefits of the process solution include an analysis of processes, identification of bottlenecks or identification of non-value added processes. Implementation of process-oriented calculation leads to increasing transparency of overheads. Traditional calculation uses surcharge which assigns some percentage of costs to products. This percentage may not match the actual consumption. Process-oriented calculation (and thus the PKR methodology) allows allocation of overhead costs according to actual consumption of resources. This effect is especially significant for warehouse processes. In the traditional approach warehouse process costs belong to manufacturing overheads. Thus it is impossible to determine how much of the costs they actually caused. On the other hand process-oriented calculation has one huge disadvantage which lies in its demand for extremely detailed input data. Gathering the necessary data is usually very difficult and time consuming.

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