3rd Conference on Production Systems and Logistics

Generation of a Data Model For Quotation Costing Of Make To Order Manufacturers From Case Studies

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Abstract

For contract or make to order manufacturers, quotation costing is a complex process that is mainly performed based on experience. Due to the high diversity of the product range of these mostly small or medium-sized companies (SMEs) and the poor data situation at the time of quotation preparation, the quality of the calculation is subject to strong variations and uncertainties. The gap between the initial quotation costing and the actual costs to be spent (pre- and post-calculation) is crucial to the existence of SMEs. Digitalization in general can help companies to get a better understanding of processes and to generate data. For improving these processes, an understanding of the important data for that specific process is crucial. Accurate quotation costing for customized products is time-consuming and resource-intensive, as there is a lack of an overview of data to be used within the process. This paper therefore derives a data model for supporting quotation costing in the company, based on literature-based costing procedures and recorded case studies for quotation and calculation. Based on the results, SMEs will have a first overview of the needed data for quotation costing to optimize their calculation process.

Keywords

Calculation costing; pre- and post-calculation; data model; make to order manufacturer

1. Introduction

As stated above, the quotation costing is a very manual and time-consuming process with often inaccurate results for make to order manufacturers. The general digitalization trend can help these companies to improve the results by using valid and extensive data. As a first step to do so, companies must know, which data are important for the calculation process. The data can be shown in a data model derived from case studies of different make to order manufacturers to learn, how equal or different they use data for the quotation costing process.

Today, companies in all industries are faced with the major challenge of digitizing their processes and using IT systems so that business processes can be carried out more automatically and efficiently. IT is assuming the role as an enabler of digitization in this process. [1] With the trend of digitalization in companies, the value of data has also been recognized. [2] The availability of information, and thus the ability to generate knowledge from data, significantly determines the competitiveness of a company. [3] IT systems in use require and generate data, which in turn can be used to optimize business processes and act more economically. However, there are some processes that still require a lot of manual work and personal experience. One of these is the process for quotation calculation in companies that produce individual products for customers (make to order manufacturers). To improve that complex and time-consuming process, an understanding of the actual data used and a generation of a data model with all needed data is

DOI: https://doi.org/10.15488/12160 publish-Ing.

* *The paper successfully passed the peer review process but was not presented at a conference.*

the first step to reach a data-based calculation. This paper deals with identifying the used data for quotation calculation from case studies and deriving a data model to optimize that process.

2. Theoretical background

In the following, the general problem statement and the theoretical foundations are described as well as the state of the art in the field of quotation costing for SMEs.

2.1 Problem statement and theoretical foundations

Calculation costing determines the costs for the production of a product or service unit. While direct costs can be allocated to an individual product or order, the allocation of overhead costs according to their cause is a major challenge for contract manufacturers. [4] [5] Quotation costing is the calculation for the first quotation for the customer. The challenge in quotation costing for contract manufacturers is that the quotation should be customer-oriented on the one hand, by determining the customer's upper price limits, and cost-oriented on the other hand, by determining the cost-covering lower price limit. [6] Companies with a high degree of complexity, such as contract manufacturers, require a much more detailed cost accounting system in order to be able to compete in the market than companies with a lower degree of complexity. However, a study shows that this is not implemented in practice, resulting in mostly inaccurate cost statements. [7]

Make to order manufacturers use different methods for quotation costing (kilo-cost method, material cost method, division costing, similarity costing, equivalence number costing, surcharge costing, target pricing), which, however, are all characterized by a lack of precision due to the large proportion of estimated and empirical values. [8] A study on quotation costing shows that overhead costing is by far the most frequently used costing method. [7] However, this highly simplified method only allows a limited allocation of cost by its causes. The specific procedure for identifying the prime cost for the quotation calculation differs in the practical application in different companies, the theoretical goal however is always to find the exact costs that are spent to produce a good.

A fast and precise quotation calculation represents an important competitive factor in industrial sectors, due to the fierce competition, the result must already have a very high quality. [9] To be able to allocate costs according to causes would therefore mean an enormous gain regarding the quality of the quotation costing. Activity-based costing aims to allocate costs according to their cause and can thus reveal inefficiencies. But this type of cost accounting is only suitable for repetitive tasks and thus cannot be implemented in a meaningful way as a costing methodology for make to order manufacturers. [10] With increasing product variety and differences in the number of units, the allocation of costs within the company according to their cause becomes increasingly complex and difficult to implement economically. [11] For the calculation of a quotation this means that in contradiction to the great uncertainty of cost statements at the beginning of a project, there is the requirement of exact cost target setting. [11]

2.2 State of the Art

With the help of the repeatability of calculation results, it is possible to assess the calculation results in terms of their quality. The degree of standardization of methods correlates positively with the repeatability. A study shows that while 90% of respondents attach high or very high importance to repeatability, less than a third of companies are able to achieve this goal. Consequently, repeatability and the degree of standardization are considered significant by companies, but they are only partially able to meet this goal. [7]

Based on an automatic analysis of CAD models of a work piece without detailed work and production planning, KNOBLACH has developed a system for a fast quotation calculation for flexible processes of sheet metal part production and for production with progressive dies. [12] This procedure finds an application

exclusively for sheet metal parts with specific process and manufacturing peculiarities (consideration of procedures of the shearing and laser cutting). All in all, the approach becomes very company-specific, since the respective company-specific cost structure must be represented in the calculation scheme. Another possibility is the approach of HAUSCHILD, who dealt with dynamic quotation costing for contract manufacturers. The aim of his work is to improve the internal coordination of the departments involved in costing (production, sales, purchasing). In addition, he has taken into account the time variability of the input variables used in his approach in order to increase the meaningfulness of the quotation costing. [13] In this approach a strong focus is put on the temporal factors of the in- and out payments and the data needed and available for a quotation costing is rather neglected. Due to the only sporadic use of corporate IT at the time of both publications, the data available in times of a variety of production systems are not taken into account, which leads overall to a non-transferable approach.

With the help of special costing procedures, the costs for geometrically similar parts can be identified by providing geometrically based cost forecasts. [14] [15] In the application, an IT-supported, database-based costing model for project-accompanying costing has been developed, which consists of a coupling of methods for processing technical and business information and product costing. The procedure is based on feature descriptions of the production parts and uses the procedure of Case Based Reasoning. [16] However, the approach is not suitable for evaluating different components or for comparing different manufacturing processes. Furthermore, the approach focuses on product-accompanying costing and not on the process of quoting before manufacturing starts.

In addition, there are also approaches that use artificial intelligence algorithms to approach the topic of manufacturing costs. However, these refer to other areas of application that can be calculated with simpler rules than make to order manufacturing (e.g. additive manufacturing, mass customization). [17] [18]

WESTEKEMPER has looked into the methodology of quotation pricing for contract manufacturers. Initial costing procedures can also be found here, but the research focus is on pricing procedures, which addresses a completely different focus. The costing procedures he stated do not go beyond the state of the art. [19]

A final look at the existing software landscape in the area of quotation costing shows that the existing software supporting this process either focuses on a specific industry (mainly automotive), or does not contain its own data model for the relevant data to be used, but transfers the previously manually calculated criteria into a software environment. This, in turn, is to be seen more as a digitization step and does not improve the general process.

In conclusion, it is clear from the state of the art that there are a variety of approaches for supporting quotation calculation for contract manufacturers. What is lacking so far, is a data-driven approach that supports a direct improvement of the general calculation process as well as the calculation result through an easy application.

3. Methodological approach

In order to develop a data-supported or data-based quotation calculation, the data and criteria used by different companies within the quotation process are recorded in the methodical procedure by means of case studies. These different data are merged in a data model, which enables a later application in an IT system and thus represents a first step towards an actual data-based quotation costing. The research question can be formulated as follows:

"What data is used in the quotation costing process of different make to order manufacturers and how does a data model look like based on these information?"

Research Procedure

First, case studies have been conducted in semi-structured interviews. The companies for the case studies were selected according to the following criteria: customer-specific production, complex product structure, make to order manufacturer (one-time or small batch production), small or medium-sized companies. In addition, a focus was placed on the diversity of the different companies (degree of digitization, company size, products, etc.) in order to obtain the most comprehensive result possible for the data model. During the interviews, after a brief theoretical introduction, the quotation costing process of the specific company was presented and discussed in detail. In each case, particular focus was placed on the data and associated IT systems used in individual process steps. At the end of the interview, the main challenges for the company in quotation costing and the information needed for optimizing the process were discussed. As a result, the case studies revealed the data used for quotation costing with the respective source (personal knowledge, Excel, ERP system, etc.) and further information and data needed for improving the quality of the quotation costing result. Based on these results, a data model was derived for each case study. Subsequently, these data models have been extended and combined into a common data model for quotation costing.

Background Data Model

A data model is a *"model of the data to be described and processed in an application area and their relationships to each other"*. [20] Data models have emerged from the desire to organize existing data. As the use of IT systems increases, so does the volume of existing data and the demands on the quality of this data. With the help of ordering criteria and distinguishing features, data models structure relevant data. [21] With the help of this approach, the transparency of organizational structures is increased and potential for improving processes in the company is revealed, making data models an aid for solving organizational issues. [3] The logical data model is a data model for representing and explaining the statistical and database elements of a business unit or the requirements for its procedures and techniques in a logical and theoretical way that eventually leads to their application in a database. [22]

Unified modelling language (UML) is a standardized representation or notation that allows object-oriented models to be represented in a uniform manner. Class diagrams can be used to represent classes and objects, their attributes and methods, and the relationships (so-called associations) between them. Classes and objects are represented as boxes. As shown in Figure 1, a class always contains a class name at the top. In the second section of the class, in the middle area, attributes are listed that can be assigned to the class. Behind a ":" likewise the data type (string, int, boolean...) is indicated. [23] Beneath this the methods are listed. Objects, which are specific examples of a class, possess a name, which is underlined in order to be able to differentiate an object quickly and transparently from a class. [24]

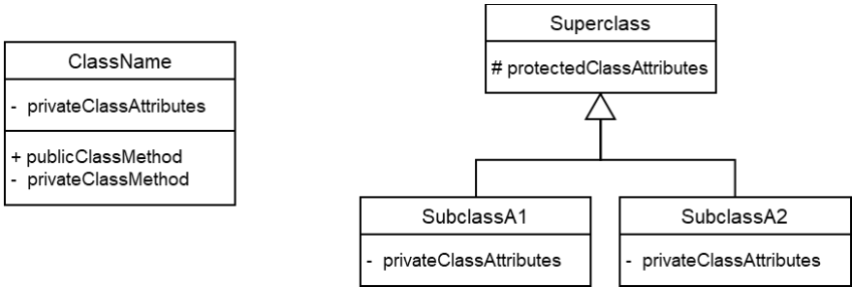

Figure 1: Example of UML Class Diagram

The visibility of attributes or methods of a class can also be mapped in UML. If an element of a class is public, this means that the corresponding element is also visible outside the class. Accordingly, if the attribute or method is prefixed with a "+". A "-" is used if the element should only be visible within its own class (private). Finally, the property protected can be listed, which describes that an element is only visible within the class in which it is described and in all subclasses. [24] The relationships that exist between the classes and/or objects are represented with the help of lines. Here, three different types of relationships are distinguished, associations, whole/part relationships and general/specialization relationships. [24]

4. Case studies

Different companies were interviewed in order to identify relevant and used data from SMEs for quotation costing. These companies have in common, that they all are contract manufacturers, which means that they face challenges for complex products with small batch sizes. On the other hand, these companies can be classified as small or medium-sized enterprises for which the quality of the quotation costing plays an important role. In order to also reflect the diversity within this group of companies, the companies differ in the type and scope of their service provision (products, services, interaction with customers, degree of digitization, etc.). The aim of the interviews were to get an understanding of the process of cost calculation in the context of quotation costing. In particular, it was asked, which criteria are considered to be cost-relevant variables and which decision-making criteria are used to determine the level of costs. First and foremost, experience is a highly relevant aspect when estimating costs at an early stage, even before the customer actually places an order. Therefore, an attempt was made to list criteria that are relevant for decision-making when using experience-based, manual adjustments.

Company 1 – Interview conducted with the General Manager

The company was founded in 1969. It is a DIN ISO 9001 certified company that manufactures prototypes, individual parts and small series. The company specializes in particular in the machining of components, some of which are large. In addition to machining, they also offer their own design department (machine and plant construction) as well as steel construction work including welding technology.

The costing process at Company 1 begins with a customer inquiry, which in turn triggers an internal feasibility analysis. The product specifications (e.g. component dimensions, necessary production processes and number of pieces) are used. On the one hand, this enables a check to be made as to whether the technological constraints for manufacturing the components can be met within the company and whether all the relevant information for a complete production order is available. It is also checked on the basis of the current production capacity utilization, which is derived from the Enterprise Resource Planning System (ERP system), whether sufficient capacities are available in production to accept the order. After a successful check, a corresponding production order is created, whereby a work schedule and the associated bill of materials are generated. This information is now used to calculate the cost of goods sold as part of a preliminary costing. The cost of goods sold is made up of four components. These include the machine hourly rate calculation, the calculation of material costs, the consideration of external costs and other costs.

First, the production costs are calculated with the help of a spreadsheet calculation in Excel. Here, the work schedule is used and the planned machine utilization is offset against the corresponding machine hourly rates. The machine hourly rates are based on the usual variables of the hourly rate calculation (investment costs, depreciation, maintenance costs, etc.), but in this case also on an overhead surcharge and the production wages. As a result, this cost module can be used to calculate all costs incurred during production on the corresponding machines.

For the calculation of the material costs, the bill of material is used. The required raw materials are selected on the basis of dimensioning, material selection and quality and the corresponding quantity is offset against the current material prices. This then results in the material costs. It was emphasized at this point that the increasing volatility of material prices plays a significant role in this cost module. As a rule, shipping costs are not incurred, as customers often prefer to collect the goods themselves. However, if the customer requests delivery, a shipping surcharge is calculated based on the transport volume and the distance to the customer. The level of these costs is also influenced by whether long-term customer relationships already exist.

After adding up the cost areas described above, the cost price for the requested component is calculated. A profit markup and any cash discount are added to these cost prices to obtain the net quotation price. In addition to this, the earliest possible delivery date is also specified and sent to the customer within a quotation. This completes the quotation process.

Mainly used criteria for quotation costing: Product specifications, production capacity check, work schedule, bill of material, machine hourly rate, material costs out of current material prices

Company 2 – Interview conducted with the Production Controller

As a subsidiary of a larger technology group Company 2 is a producer of banknotes and security papers. The company was founded in 1964 and today supplies banknotes to the European Central Bank.

The request to the company includes the product specifications, which include the desired paper/substrate type and the number of pieces. Once all the relevant information are available, a production order is created, which includes the work schedule and bill of materials. The quotation calculation then follows using a spreadsheet containing current market prices for the required material, the annually updated planned values, and cost curves based on post-calculations of sold products. The product specifications are entered into the calculation tool and the cost curve provides information on the expected production costs depending on the batch size. The material costs are also derived accordingly from the spreadsheet. A profit markup is added in the end. Numbers may be corrected again manually. This is done on the basis of findings from variance analyses, which are carried out monthly. An attempt is made to identify and understand deviations in past customer orders.

Mainly used criteria for quotation costing: Product specifications, work schedule, bill of material, current market prices, cost curve from post-calculation of sold products

Company 3 – Interview conducted with the Sales Representative

Company 3 was founded in Cologne in 1896 and offers a wide range of printed products for commercial purposes. In addition to the product steps of image processing and advertising technology, the company offers in particular digital and screen printing as well as offset printing.

The process of quotation calculation at Company 3 starts with the customer inquiry, which includes product specifications such as the product type (e.g. advertising banner), the motif and the number of pieces. If the necessary information is complete, a production order with a corresponding work schedule is derived from it. The calculation consists of the direct production costs, the material costs and the additional overhead costs. The work schedule and the resulting machine assignment serve as the basis for the direct production costs. The machine hourly rate associated with the respective machines is then multiplied by the corresponding forecast production time per machine to calculate the direct production costs. Here, production times are based to a large extent on the experience knowledge of the calculator. Important factors are the printing speed, which is strongly dependent on the selected motif, and estimates of the production employee. The material unit costs result from the production order or the customer's inquiry. A material selection is made, whereby the material quantity in turn depends on the work schedule. This is because, depending on the machine selection and the associated offcuts, as well as the material scrap during setup of the machine, there is an additional requirement for raw material. Consequently, the total material requirement is determined by the calculator and offset against the material prices. The material prices are again stored in the system and are based on price agreements requested on a quarterly basis. Finally, the total direct material costs are calculated.

Together with a fixed surcharge for administration and sales, which is independent of the order volume, this results in the quotation cost. A profit markup, a cash discount and any commissions are then added to these to obtain the net quotation price.

Mainly used criteria for quotation costing: Product specifications, work schedule, material cost, overhead cost, machine hourly rate, machines used, forecast of production time, material prices for production material

Company 4 – Interview conducted with the Operations Planning Representative

Company 4 was founded in 1996 and specializes in the manufacturing and repair of rolls. In addition to manufacturing, disassembly and repair, the company also offers surface treatment and coating of rolls and specialized technical consulting.

After the process starts with a customer inquiry, the product specifications of the inquiry are analyzed. These include in particular the technical drawing of the product to be manufactured, where the component dimensions and the required manufacturing processes can be derived from. A corresponding production order is created, from which a work schedule can be taken. The quotation calculation then follows in the sense of a differentiated markup calculation. A distinction is made between the cost items direct production costs, direct material costs, special direct sales costs, administrative overheads and production overheads. Comparable orders are considered in the calculation and individual numerical values are estimated. The actual work schedule of the products already manufactured are exported from the accounting system.

First, the direct production costs are determined. For this, the machine hourly rates and production wages are taken as a basis and multiplied by the respective forecast production times. The work schedule is used as a basis to map the machine selection. The manual input of the production times is of great importance in order to ensure a high degree of accuracy in the cost calculation. The times of comparable orders stored in the booking system are initially used as the basis for estimating the production time. Based on this, empirical values are used to increase precision. The calculator takes into account which employee is listed as a machine operator in the booking system. For example, the experience of long-serving employees can be an indicator that the production job already completed was completed particularly quickly. A more conservative estimation of the production time by adding a corresponding markup could therefore be recommended. Also the posting date in connection with the considered machine tool is used as criterion for the estimation of the production times. If a machine is newly acquired, it can be expected during commissioning that the employee is still untrained in its operation. Delays caused by technical problems that the machine operator is not able to eliminate as quickly as expected in normal operation are also conceivable. The transferability of the production times could therefore be accompanied by a certain lack of precision when this information is taken into account. A manual correction is therefore necessary.

Another criterion is parallel jobs that may have been performed on the same machine without this being recorded in the booking system by the employee. This circumstance is not directly apparent, but can be checked by looking at other jobs that were logged in the booking system on the same day.

In addition, the work schedule of the historical data under consideration can provide information about problems that the machine operator had to rectify. If incidents were documented, the calculator can make an appropriate correction to the production times on this basis. Material errors or setup times are conceivable incidents that delay further processing and can thus greatly distort the production time booked in the system. Once the direct production costs have been calculated by multiplying the respective hourly machine rates (or the equivalent of production wages) by the forecast production times, the direct material costs are determined. The necessary raw materials can be taken from the bill of materials of the production order. However, the design drawing also provides information on the selection of raw materials. The tolerances required by the customer and the mechanical boundary conditions are used and compared with the raw materials or standard parts actually available. A correction of the parts list is often necessary. Multiplying the material selection by the corresponding material prices finally yields the material unit costs. The material prices are determined on the basis of quarterly price agreements. In this calculation, it should be noted that purchased parts are not yet taken into account. These are declared as special direct costs of the sales department and result either from concrete offers from suppliers, are estimated as a lump-sum markup or

can also be taken from post-calculations of past orders. The calculated costs are then added together and a variable administrative and production overhead rate is applied. The result is the cost of goods sold of the costing object. After taking into account the profit markup and a cash discount, the result is the net quoted price.

Mainly used criteria for quotation costing: Product specifications (technical drawing of product), work schedule, comparable orders, machine hourly rate, production wages, forecasted production time (from work schedule of historical comparable orders), machine operator for historical orders, experience of machine operators, machine tool, check of parallel jobs of historical common orders, incidents documented in the work schedule

5. Data model for quotation costing

For the generation of the data model for quotation costing, the results from the interviews are summarized and explained briefly in the following.

The expert interviews show that the criteria used for the quotation and the cost calculation is highly agreed upon by the interviewees. A production order is first created on the basis of the customer inquiry, which consists of the bill of material and the work schedule. This is then followed by the calculation of the cost. Here, a rough distinction can be made between production costs, material costs and other overheads.

The production costs consist of those costs which arise from the machine assignment in the production. The basis for this is the work schedule, it specifies the sequence and allocation in which the raw parts are produced on the respective machines and tools. This can be used for a machine hourly rate calculation, the cost rates for the machines are fixed. A decisive variable for the cost determination is the production time. This is determined by the calculator as stated in the case studies on the basis of various factors. A correct estimation of the production time is a decisive success criterion for the precision of the forecast cost calculation. The interviews show that in business practice, empirical values are of great importance. Production times are estimated in conjunction with discussions with production employees and on the basis of (manually filtered) historical data. These are then multiplied by the corresponding machine hourly rates to produce the production costs.

A preliminary calculation of the expected material costs is based merely on the evaluation of the bill of materials. It provides information on which raw parts and purchased parts are required for the production order. In addition to the dimensioning, type and number of pieces, it also shows which material specifications exist in order to be able to make an appropriate material selection. Depending on the industry and product spectrum, corrections may have to be made here because the requested components do not correspond to the dimensions of unfinished parts. This process, which is also based on personal experience, takes place with the help of feedback from the customer. Once the bill of material is finalized, costs are calculated and totaled based on price agreements, lump sums, or specific quotes from suppliers to determine the total material costs. The production costs are added to the material costs to give the expected production costs. In order to include those costs in the quotation that are not directly attributed to the criteria stated above, an overhead markup is added to the production costs. This is usually a fixed cost rate that is calculated based on an overhead calculation. In particular, administrative and selling expenses are included. All these information are summarized and outlined in the following UML Diagram (Figure 2).

Description of the UML Diagram

The class model “Prime Costs” is used to calculate the cost of goods and the UML notation makes it possible to quickly obtain a general understanding of the basic structure of the data model. The prime cost class is at the end of the calculation. This class is used to calculate the quotation cost for the customer on the basis of

direct and overhead costs. The latter are determined on the basis of a stored overhead rate on the direct costs. The direct costs in turn consist of the material and production costs.

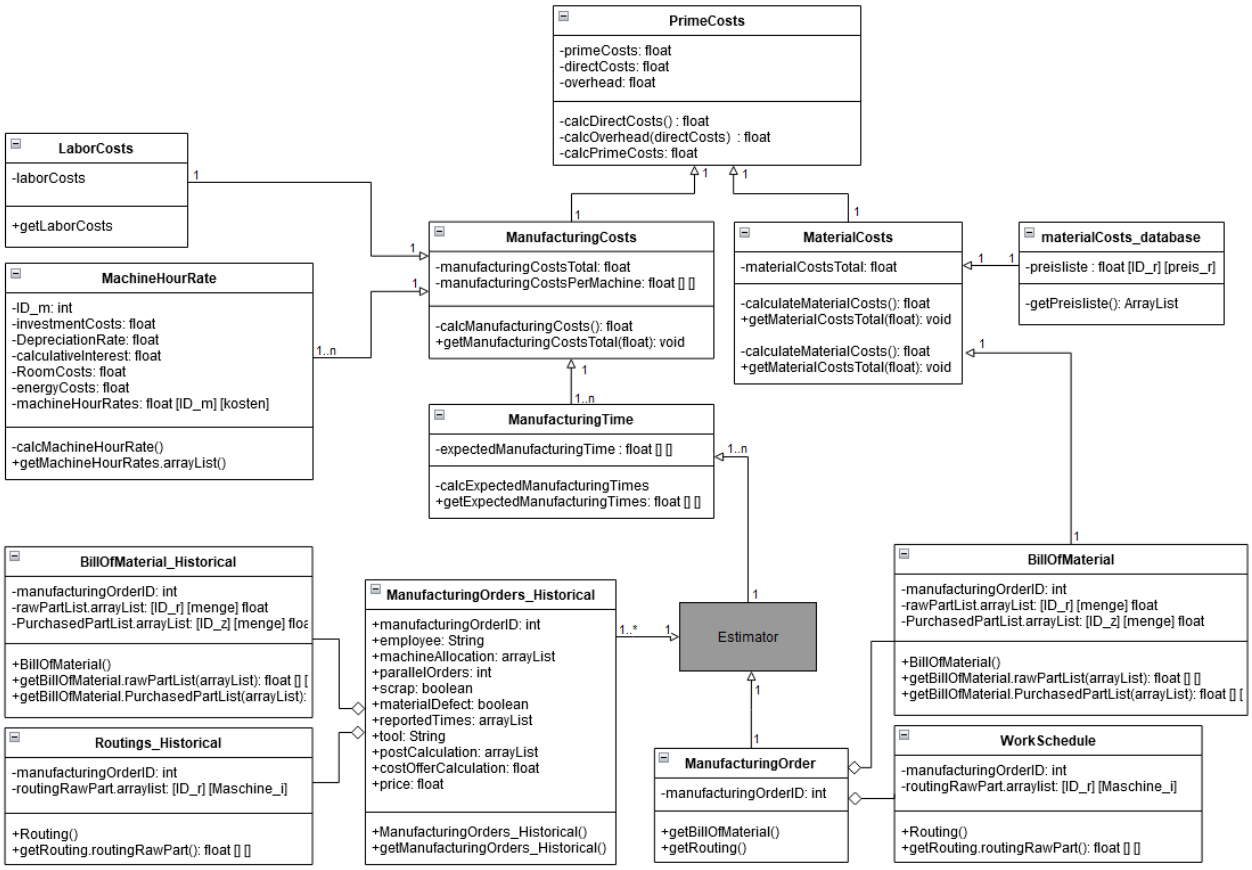

Figure 2: Data Model for Quotation Costing in SMEs

In the class material costs, the information from the bill of materials (BoM) is related to the costs for the corresponding raw parts and purchased parts. After creating an array list that associates the items from the BoM with the corresponding material prices from the Material Database class, the total material costs can be returned using a simple multiplication. This value is stored in the materialCostsTotal attribute and can be retrieved by a corresponding getter method in the cost price class.

The production costs are calculated in the corresponding class with the help of machine hourly rates, the wage costs and the predicted production times. The machine hourly rates are also initialized as a separate class. This has all the relevant attributes of each machine that is actually used within the production operation. In addition to the machine-specific ID, the class stores all relevant values for the complete calculation of the machine hour rates. The result is stored in an array list containing the machine ID and the machine costs for one hour for all machines. The labor costs in turn are set as attribute laborCosts. A corresponding method in the production costs class can retrieve the values. The production time is also stored in a separate class. Since the values refer to the corresponding machines, it is also stored in an array list. The first value is the machine ID, the second value is the production time. The values, which are assumed for the production time, are initialized with the help of a manual input of the calculator.

As stated in the expert interviews described above, the production times are estimates based on experience. At this point, the class diagram illustrates which information is used by the calculator to provide an estimation for the times. In addition to the current production order, past production orders are also included in the decision-making process. A list of the work steps and stations and thus the necessary machine assignment can be taken from the work schedule from the production order. Comparable historical orders

are then available to the calculator, in which the actual, but also the previously assumed production times can be taken. The associated class ManufacturingOrders_Historical also contains further attributes that can be useful for evaluating the historical data. For example, the employee of the work step, which is stored in the booking system, can be a decision criterion. The attribute machineAllocation provides information about the sequence in which the production took place. Depending on the layout of the production hall, this can provide information about transport routes and associated distortions of the production times in the booking system. The parallelOrders attribute stores the number of orders produced at the same time. A low capacity utilization, for example, is an indication that the production time could have been shorter. In addition to other influencing factors, a deviation between planned and actual values can also be used to improve the expected accuracy of the occupancy times of current production orders. The array list stored as postCalculation as well as the postOfferCalculation is used for this purpose. Intelligent processing of the above-mentioned attributes and influencing factors makes it possible to estimate production costs as precisely as possible.

6. Summary and Outlook

Above all, it becomes clear that the process of quotation costing is currently highly dependent on people and is based in many places on estimations and personal experience. In order to transform quotation costing as a data-supported process, all necessary information and data must be available in used IT system(s). As stated in the very beginning, the interviews also underlined, how many different tools, databases or files are currently used in this process and how time consuming the generation of the prime costs are. To make such an effort for a quotation, not knowing whether the customer will accept it or not, is highly inefficient and risky.

The different criteria used for quotation costing in the case studies are explained and summarized in the data model. Thanks to the UML notation, this data model can be transferred in Business Software or other IT systems to build up a data-bases quotation costing process.

The first finding of the research was, which exact data are needed for the quotation. With the generated results SMEs can check the data model to get an overview, which data they might need to add to their calculation to improve the process and their results. Moreover, the model also shows, which data must be available and can lead companies to the transparency, which process they really need to digitize to get access to data-related information beside the personal experience they mostly rely on so far.

A huge impact for the optimization of the quotation quality is the factor of personal experience and the estimation processes. Especially for important information that are crucial to the quality of the final result the case studies show, that they mainly rely on estimated information. Further research should be conducted here to detail the “Estimator”- Class in the UML diagram, to receive a data-supported estimation. In this area, artificial intelligence applications are particularly conceivable in order to identify similar orders and to draw corresponding conclusions about the current quotation.

References

[1] Abolhassan, F. (Ed.), 2016. Was treibt die Digitalisierung?: Warum an der Cloud kein Weg vorbeiführt. Springer Gabler, Wiesbaden, 138 pp.

[2] Fischer, J., 2019. Datenmanagement: Datenbanken und betriebliche Datenmodellierung. Walter de Gruyter GmbH & Co KG.

[3] Hars, A., 2013. Referenzdatenmodelle: Grundlagen effizienter Datenmodellierung: Schriften zur EDV-orientierten Betriebswirtschaft. Springer-Verlag.

[4] Coenenberg, A.G., Fischer, T.M., Günther, T. (Eds.), 2016. Kostenrechnung und Kostenanalyse. Schäffer Poeschel, Stuttgart.

[5] Albrecht, T., Ulbricht, G., 1931. Die Vorkalkulation Im Kessel- und Apparatebau. Springer, Berlin, Heidelberg.

[6] Kleinaltenkamp, M., Saab, S., 2009. Technischer Vertrieb: Eine praxisorientierte Einführung in das Business-toBusiness-Marketing. Springer, Berlin.

[7] FACTON GmbH, TMG Consultants GmbH, 2015. Herausforderung Angebotskalkulation: Aktuelle Marktumfrage zu Methoden, Organisation, Tools und Handlungsfeldern in Unternehmen der produzierenden Industrie, 56 pp. Accessed 5 January 2020.

[8] Schuh, G., Schmidt, C., 2014. Produktionsmanagement. Springer Berlin Heidelberg, Berlin, Heidelberg, 387 pp.

[9] Obermaier, R., 2017. Industrie 4.0 als unternehmerische Gestaltungsaufgabe. Springer Fachmedien Wiesbaden, Wiesbaden, 320 pp.

[10] Plinke, W., Rese, M., Utzig, B.P., 2015. Industrielle Kostenrechnung. Springer Berlin Heidelberg, Berlin, Heidelberg, 360 pp.

[11] Ehrlenspiel, K., Kiewert, A., Lindemann, U., Mörtl, M., 2014. Kostengünstig Entwickeln und Konstruieren. Springer Berlin Heidelberg, Berlin, Heidelberg, 618 pp.

[12] Knoblach, J., 1999. Beitrag zur rechnerunterstützten verursachungsgerechten Angebotskalkulation von Blechteilen mit Hilfe wissensbasierter Methoden. Dissertation, Bamberg, 178 pp.

[13] Georg Hauschild, 1994. Einwicklung eines Verfahrens zur dynamischen Angebotskalkulation für Unternehmen der Einzel- und Kleinserienfertigung. Dissertation, Aachen.

[14] Denkena, B., Lorenzen, L.-E., Schürmeyer, J., 2009. Rule-based quotation costing of pressure die casting moulds. Prod. Eng. Res. Devel. 3 (1), 87–94.

[15] Liu, W., Yang, C., Zhou, X., 2018. A network quotation framework for customised parts through rough requests. International Journal of Computer Integrated Manufacturing 31 (12), 1220–1234.

[16] Konarsky, M., Leidich, E., Götze, U., 2011. Projektbegleitende Kalkulation komplexer Produkte der Auftragsfertigung. DFX 2011: Proceedings of the 22nd Symposium Design for X, Tutzing nr. Munich, Germany, 11.-12.10.2011 (2), 195–206.

[17] Kadir, A.Z.A., Yusof, Y., Wahab, M.S., 2020. Additive manufacturing cost estimation models—a classification review. Int J Adv Manuf Technol 107 (9-10), 4033–4053.

[18] Ning, F., Shi, Y., Cai, M., Xu, W., Zhang, X., 2020. Manufacturing cost estimation based on a deep-learning method. Journal of Manufacturing Systems 54, 186–195.

[19] Westekemper, M., 2002. Methodik zur Angebotspreisbildung - am Beispiel des Werkzeug- und Formenbaus. Dissertation, 227 pp.

[20] Siepermann, M., 2018. Datenmodell. https://wirtschaftslexikon.gabler.de/definition/datenmodell-28093/version-251730.

[21] Urlaß, F., 2019. Daten- und Prozessmodellierung für Versicherer. Springer Fachmedien Wiesbaden, Wiesbaden, 490 pp.

[22] Shahbaz, Q., 2015. Data Mapping for Data Warehouse Design: Computer Science Reviews and Trends.

[23] Stevens, P., 2006. Using UML. Software engineering with objects and components: The Addison-Wesley object technology series, Harlow.

[24] Gomaa, H. Software modeling and design. UML, use cases, patterns, and software architectures 2011.

Biography

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