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COMPUTER-AIDED MATERIAL DEMAND PLANNING USING ERP SYSTEMS AND BUSINESS INTELLIGENCE TECHNOLOGY

Abstract

Effective decision-making in industry conditions requires access and proper presentation of manufacturing data on the realised manufacturing process. Although the frequently applied ERP systems allow for recording economic events, their potential for decision support is limited. The article presents an original system for reporting manufacturing data based on Business Intelligence technology as a support for junior and middle management. As an example a possibility of utilising data from ERP systems to support decision-making in the field of purchases and logistics in small and medium enterprises.

1. INTRODUCTION

In order for a manufacturing enterprise to function effectively not only must it have an effectively functioning manufacturing system, but also (and above all) efficient information flow as well as fast and correct decision making (George, Schmitz & Storey, 2020; Gola, 2014; Świć & Gola 2013). One of the basic tools for planning and realisation of production utilized in Polish enterprises is ERP class. According to the data by GUS (Central Statistical Office in Poland) for 2019 over 90% of large companies and over 61% middle-sized companies (GUS, 2020) use ERP class software. The major aim of ERP systems is to record economic events – transactions – occurring in the company.

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The functional area of the system may include all aspects of functioning of an enterprise, among others: finance-accounting, fixed assets, human resources, payroll, inventory management, sales, customer relationship management, purchases, production planning and control (Aremu, Shahzad & Hassan, 2019; Sobaszek, Gola & Kozłowski, 2018; Patalas-Maliszewska, 2012).

Since ERP systems play a significant role in ensuring uninterrupted business continuity planning and correct recording of transactions in databases (Huang, Chiu, Chao & Arniati, 2019). The aim of the ERP system is to ensure correct progression of the defined business process and recording all of the economic events (Rodriguez, Molina-Castillo & Svensson, 2020). Information systems may support the decision-making process and fulfil report needs – it is not, however, their major function (Chang, 2020; Cieśla & Gunia, 2019; Alsoub, Alrawashdeh, & Althunibat, 2018). Unfortunately, simply possessing data or basic reports is not sufficient to conduct a more in-depth analysis or answer information needs occurring in organisation and the ERP systems are not a tool SUFFICIENT for effective decision-making in industry conditions (Vargas & Comuzzi, 2020).

This article presents an example of utilizing the data stored in a manufacturing enterprise in ERP system and Business Intelligence technology to fulfil information needs in supply and logistics departments.

2. PLANNING MATERIAL PURCHASES USING ERP CLASS SYSTEMS

A closed control loop MRP system (Fig. 1) is one of the most significant elements of the ERP system in a manufacturing enterprise. The ERP system includes all areas of an enterprise, whereas the MRP area focuses on planning material needs in a closed control loop (Meilin, Xiangwei & Qingyun, 2010).

Contrary to primary Inventory Control systems . the MRP method utilizes the rule of dependent demand. Therefore inventory control (and production capacities) depend on the orders for ready product.

Algorithm for calculating material demand requires the following information:

- bill of material, BOM,
- information on the state of inventory and the cycle of production or purchase from the supplier,
- production schedules indicating when the product is finished (in which quantities too), during production and the date of the product being ready
- information on production orders, time norms and manufacturing routes (order limits).

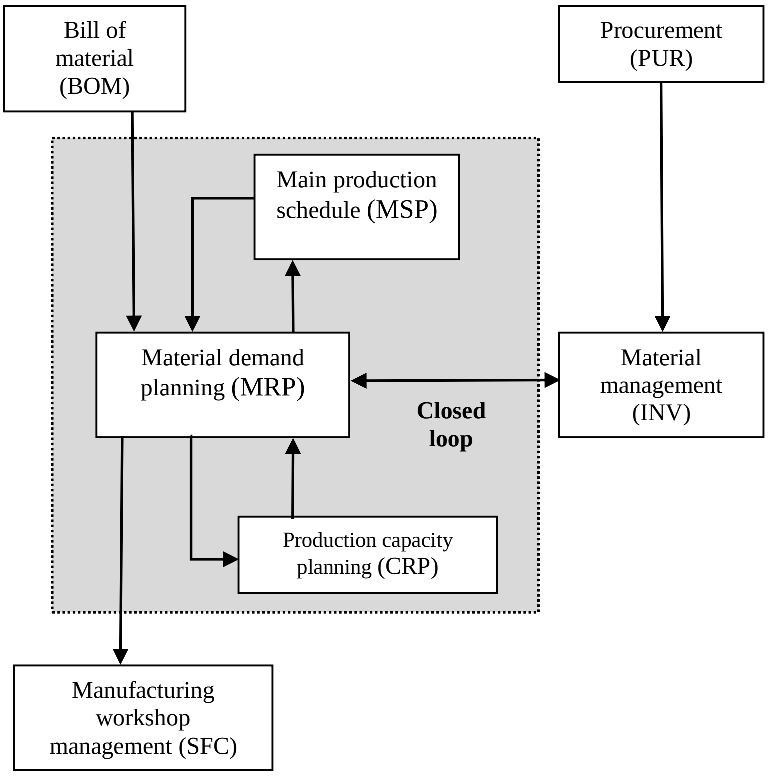


Fig. 1. Model of a closed control MRP loop (Januszewski, 2008)

At the moment of introducing a new order for a finished product and placing it in the schedule the system is able to:

– determine whether the material stock is sufficient to manufacture new product;
– determine when new purchase and delivery of materials ought to be planned in order to finish production at a given date.

The main objective of planning material demand is, based on the data recorded in the system, planning material deliveries at the time they are needed as far as production schedule is concerned as well as delivering the finished product to the customer.

Algorithm for calculating the material demand is as follows (Waters, 1996):

$$ZN = ZB - BB - ZZ, \tag{1}$$

where: ZN – net demand, ZB – gross demand, BB – in stock, ZZ – supply ordered.

Gross demand means all of the materials necessary to manufacture a certain amount of finished product. This information stems from BOM.

“In stock” informs about materials that are currently available in stock and can be immediately used for manufacturing the finished product. It is to be noted that the parts in stock may be in the manufacturing cycle or just in the manufacturing plans.

Supply ordered provides information on materials already ordered, which ought to be delivered to the enterprise at a certain moment. Contrary to the products currently in stock, ordered supply is not yet at the enterprise’s disposal, since the materials are not located in the magazine and the enterprise cannot use it for production. At the moment of delivery and admittance to the magazine the products become “in stock” and can be expended. It is to be noted that delivery dates are planned and it is possible that the materials arrive earlier or, worse yet, later than planned.

On the basis of this data the department of supply and logistics receives an information on which materials and semi-finished products to order. Upon comparing information from schedules and production norms and the information on the time of delivery an important information can be obtained – the last moment to make the order so that it is delivered at the right moment and allows for the order to be made in a timely manner.

The algorithm for calculating the net demand is calculated in certain iterations (e.g. daily at night) for each manufacturing index. It can consider phenomena such as material reservations in the magazine, overseeing storage and logistic minima, including the multidimensional complexity of the product. Moreover, in many cases the information on what and when to purchase may not meet their information needs.

3. BUSINESS INTELLIGENCE SYSTEMS AND OLAP TECHNOLOGY

In the classical sense Business Intelligence (BI) is a user-oriented process of obtaining, exploring, interpreting and analysing data, which leads to expediting and rationalising the decision—making process (De Oliveira & De Almeida, 2019). These systems provide support to the management in the business decision-making process in order to increase the worth of the enterprise (You, Yeung & Jong, 2020).

One of the frequently used technologies in the BI systems is OLAP (*OnLine Analytical Processing*) (Queiroz-Sousa, & Salgado, 2020). It is based on multi-dimensional databases that can be described as cubes. Each dimension of the cube stores data aggregated according to presented criteria (Fig. 2).The dimensions can create hierarches – different levels may occur (e.g time dimension may be divided into years, months, days). OLAP cubes are supplemented by data from transaction systems.

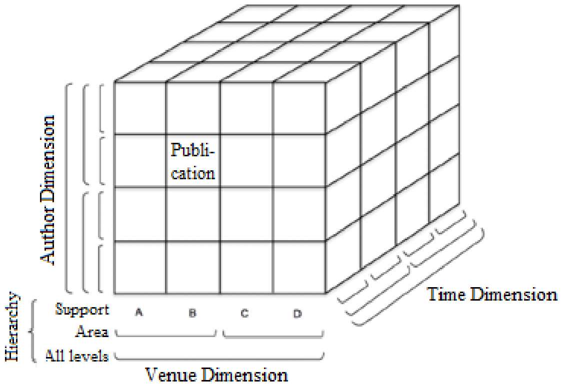


Fig. 2. An example of OLAP cube (Loudcher et al., 2015)

In terms of a multidimensional analysis the following operations may be performed on OLAP cubes (Djiroun, Boukhalfa & Alimazighi, 2019):

- drill down and drill up,
- rotation,
- slicing,
- rating,
- filtration,
- sorting.

Indubitably the data stored in ERP systems is a source of information on the processes occurring within the enterprise (Sobaszek, Gola & Świć, 2020; Zwolińska, Grzybowska & Kubica, 2017; Bocewicz, Nielsen & Banaszak, 2016; Terkaj, Tolio & Urgo, 2015). It is therefore natural to utilize this data as input data for the BI system in order to transform it into information useful business-wise that facilitates the process of analysing and decision-making for the management (Danilczuk, 2019).

4. DECISION-MAKING PROCESS AND THE RANGE OF THE NECESSARY SUPPORT IN THE PROCESS OF MATERIAL REQUIREMENTS PLANNING

One should consider an example of an enterprise with a small-lot production in make-to-order model – MTO. In the enterprise there is an implemented and efficient ERP IMPULS EVO system as well as a closed MRP loop. One of the elements of the system is the module "purchases", which generates purchase suggestions on the basis of the material requirements planning (Fig. 3). The algorithms creating purchase suggestions consider not only basic information stemming from the rules of net demand estimating, but also logistic minimum of orders or the possibility of using replacements. On the basis of purchase suggestions the staff of the logistics department make purchases.

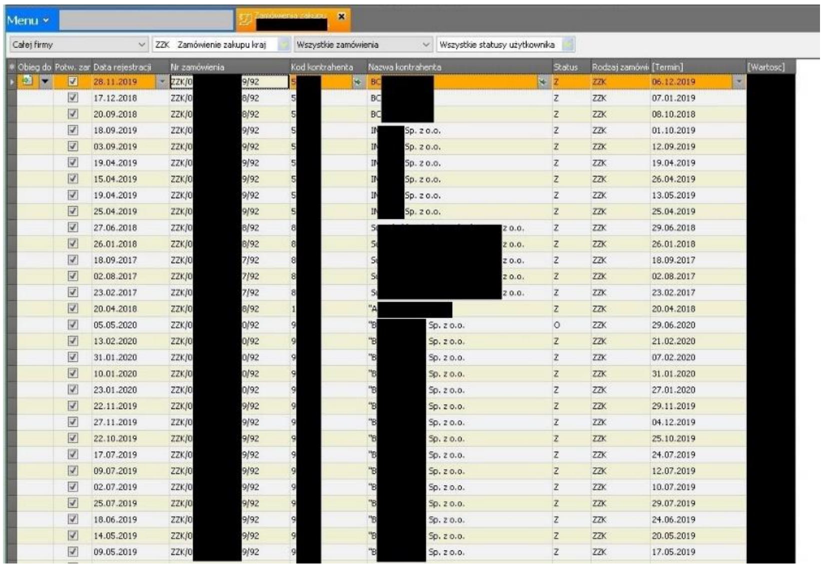


Fig. 3. View of the "Purchases" module in ERP IMPULS EVO

Effectiveness of purchase management is integrated with other areas of the ERP system. Within the purchases module data on orders is recorded (number and name of the order, status of the order, date of execution, time of production). Each order has an assigned status: "shipped", "completed", "partially completed", "cancelled". The first status informs one that the order was shipped to the contractor. Status "completed" informs that all parts of the order were admitted to the ware (instruments of acceptance were issued), partial completion means that at least one part of the order was admitted to the ware. Instruments of acceptance contain an information on indices, number of indices admitted, supplier and date of execution. Structure of the data and their linkage was shown in Fig. 4.

In order to effectively conduct the purchase process, the department of logistics and supply described additional information needs, apart from the basic information obtained from determining the demand. **A need for information on overdue supplies was issued.** Occurrence of overdue supplies may interfere with the MRP loop and falsely suggest a need for ordering a part that is not currently in stock. It is important to know that a certain part was already ordered and ought to be in stock already, but the supply is overdue. As far as production planning is concerned overdue supplies imply a delay in schedule realisation. Since information on planned supply dates and real admittance dates are stored in the system it is possible to determine the status of a supply in the ERP system.

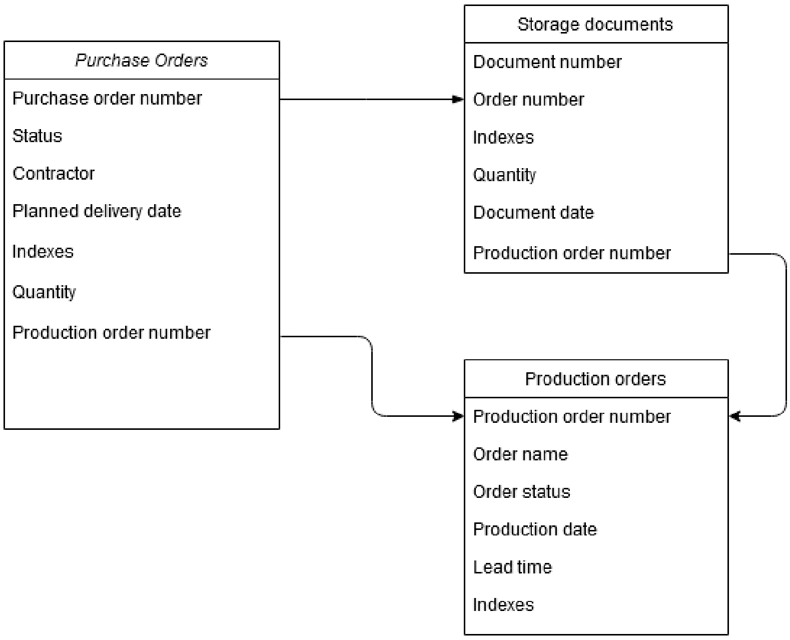


Fig. 4. Structure of data in ERP IMPULS EVO

Another report required by the purchase department was **a linkage of a production commission and orders and order statuses.** These information are logically linked in the ERP system, but there is not a single template which would combine the data and allow for its multidimensional analysis. The purchases department would gain a fast access to information on **what materials were already ordered and delivered to the analysed production commission.** This information is very important from the point of view of production manager. This report can be supplemented by adding information on planned dates (weeks) of supplies which would allow for a more effective operations management in manufacturing workshop. Since these structures are linked, it is possible to create such a compilation.

The last report is a **list of orders planned for the current week**. This information is valuable for the warehouse to know about the number of planned entries connected to new supplies. It would therefore be able to work more effectively.

5. DESIGNING A REPORT SYSTEM

As presented above, all data necessary for a set of reports to be presented is located in the ERP system. Moreover, logical linkages between the data exist and are shown in structures of the database. It is therefore theoretically possible to design a tool that would support information needs of the department of logistics and purchases. Since those information are located in various modules of the ERP system it would be necessary to aggregate it on the level of the database. In order to achieve that a SQL query was generated to aggregate all data necessary for one database view (SQL 2010) (Fig. 5).

```
SELECT DISTINCT
PZZ.PURCHASE_ORDER_NUMBER,
V.DATE_OF_REGISTRATION,
V.COUNTERPARTY_NAME,
V.YEAR_NO,
V.PERIOD_NO,
V.PRODUCTION_ORDER_NUMBER,
PZZ.PART_INDEX,
I.PART_NAME,
PZZ.ORDERED_QTY,
PZZ.PURCHASE_UNIT_OF_MEASURE,
PZZ.DELIVERY_DATE,
PZZ.ORDER_STATUS,
SZ.ORDER_STATUS_NAME,
PZZ.AMOUNT_RECEIVED,
PZZ.AMOUNT_ORDERED,
PZZ.WAREHOUSE,
M.WAREHOUSE_SYMBOL,

FROM
```

Fig. 5. Fragment of the SQL query

Moreover, on the level of the database view necessary mathematical and logical operations in order to create additional dimensions necessary to fulfil all information needs. For example, upon comparing the delivery date with the current date (sysdate) it can be determined whether the delivery is overdue (and how many days overdue), determine the number of the week on the basis of the date etc.

Aggregating the necessary data into one structure is the first step to enabling a multidimensional analysis based on OLAP cubes. This analysis method allows one to base all reports, and therefore information, on one source of data.

Once data is aggregated in one structure, it is necessary to introduce the report in a tool enabling one to present and analyse the obtained data. Although it would seem natural to place such a compilation in the ERP system in defined reports, there are limitations to this operation. Not all staff requiring this data has access to the ERP system as well as the skill required for operating it. Moreover, IT systems offer a limited number of licences and the users allowed to use it. Purchasing additional licences to enable the access to several reports is economically unjustified.

Due to these limitations it was decided to employ MS Excel for report preparation. This software is widely used in the company, the program is accessible and well-known for every employee.

In order to transfer the data from database to a spreadsheet Online Data Base Connection technology was used. ODBC tool creates a direct connection between the spreadsheet and the database (in this case view of the database). Since it is a fixed connection instead of the data being exported whenever a modification occurs in the source tables (new record in the form of a new order appears or a status of an order changes) the updates will be seen after refreshing the connection new/modified orders. The program refreshes every 10–20s, which is the time required for a ERP report of a similar volume to be created. Data in Excel is presented in form of a table (Fig. 6).

PURCHASE_ORDER_NUMBER	PURCHASE_CONFIRMATION	INSERT_DATE	CONTRACTOR_NAME	YEAR_NO	PERIOD_NO	RESPONSIBLE_PERS	PRODUCTION_ORDER_NUMBER	INDEXE
ZZK[redacted]9/92	Y	03.07.2019 00:00	TU[redacted]onal Sp. z o.o.	19	7	PJ[redacted]	ZP[redacted]19	2674
ZZK[redacted]9/92	Y	03.07.2019 00:00	"C[redacted]z o.o.	19	7	PJ[redacted]	ZP[redacted]19	98188
ZZK[redacted]9/92	Y	03.07.2019 00:00	TU[redacted]onal Sp. z o.o.	19	7	PJ[redacted]	ZP[redacted]19	2672
ZZK[redacted]9/92	Y	03.07.2019 00:00	TU[redacted]onal Sp. z o.o.	19	7	PJ[redacted]	ZP[redacted]19	126514
ZZK[redacted]9/92	Y	03.07.2019 00:00	"C[redacted]z o.o.	19	7	PJ[redacted]	ZP[redacted]19	61807
ZZK[redacted]9/92	Y	03.07.2019 00:00	"C[redacted]z o.o.	19	7	PJ[redacted]	ZP[redacted]19	93305
ZZK[redacted]9/92	Y	03.07.2019 00:00	TU[redacted]onal Sp. z o.o.	19	7	PJ[redacted]	ZP[redacted]19	109272
ZZK[redacted]9/92	Y	02.07.2019 00:00	"C[redacted]z o.o.	19	7	PJ[redacted]	ZP[redacted]19	98188
ZZK[redacted]9/92	Y	02.07.2019 00:00	"C[redacted]z o.o.	19	7	PJ[redacted]	ZP[redacted]19	61807
ZZK[redacted]9/92	Y	02.07.2019 00:00	"C[redacted]z o.o.	19	7	PJ[redacted]	ZP[redacted]19	107811
ZZK[redacted]9/92	Y	02.07.2019 00:00	"C[redacted]z o.o.	19	7	PJ[redacted]	ZP[redacted]19	38604
ZZK[redacted]9/92	Y	03.07.2019 00:00	"C[redacted]z o.o.	19	7	PJ[redacted]	ZP[redacted]19	21413
ZZK[redacted]9/92	Y	03.07.2019 00:00	"C[redacted]z o.o.	19	7	PJ[redacted]	ZP[redacted]19	38604
ZZK[redacted]9/92	Y	02.07.2019 00:00	"C[redacted]z o.o.	19	7	PJ[redacted]	ZP[redacted]19	21413
ZZK[redacted]9/92	Y	03.07.2019 00:00	TU[redacted]onal Sp. z o.o.	19	7	PJ[redacted]	ZP[redacted]19	2709
ZZK[redacted]9/92	Y	03.07.2019 00:00	"C[redacted]z o.o.	19	7	PJ[redacted]	ZP[redacted]19	107811

Fig. 6. Table with data on an Excel spreadsheet

In order to visualise reports mechanism of pivot tables was employed. On the basis of data in the table an OLAP (online analytic process) cube is created. Presenting data in a pivot table allows one to conduct all operations typical for multidimensional analysis on OLAP cubes, such as drill-up and drill-down, select, sort, filter etc. Tool of pivot tables allows one to freely "rotate" the cube.

„Rotating" selected dimensions of the cube allows one to prepare a proper view of data fulfilling information needs. The first report was a compilation of orders divided into overdue and not overdue. Status of the delivery was set as a report filter. The rows were number of days overdue, order status, contractor, number of the order and name of the part (Fig. 7).

YEAR_NO	19
PERIOD_NO	
PRODUCTION_ORDER_NUMBER	
IF_EXPIRED	overdue delivery

DAYS_OF_EXPIRED	STATUS_NAME	CONTRACTOR_NAME	PURCHASE_ORDER_NUMBER	INDEXE_NAME	ORDERED_QTY	AMOUNT_RECEIVED	AMOUNT_TO_PARTY
1	Partial delivery	"QU[redacted]o.o.	Z[redacted]019/92	LO[redacted]	2	2	0
				LO[redacted]	16	10	6
				LO[redacted]	4	2	2
				LO[redacted]	36	30	6
				LO[redacted]	4	2	2
				Łoż[redacted]	8	5	3
				Po[redacted]	3	2	1
				SE[redacted]	12	6	6
				SE[redacted]	2	1	1
				SE[redacted]	4	2	2
				SE[redacted]	14	10	4
17	GENERATED	AST[redacted]	Z[redacted]019/94	Be[redacted]	8	0	8
				Ka[redacted]	40	0	40
				Na[redacted]	40	0	40
					193	**72**	**121**

Fig. 7. Report of overdue deliveries

The second report (Fig. 8) informs one on deliveries of parts to a certain order planned for selected weeks. The dimensions of the OLAP cube ought to be "rotated". The main filter will be the number of the order and the following elements will be removed from the rows: number of days overdue, number of the order. Columns of the report will be the numbers of weeks for which the deliveries are planned.

YEAR_NO	19
PERIOD_NO	
PRODUCTION_ORDER_NUMBER	Z[redacted]/19

Suma z AMOUNT_RECEIVED			SUPPLY_MONTH / SUPPLY_WEEK					
			5		5 Sum	6	6 Sum	Total
STATUS_NAME	CONTRACTOR_NAME	INDEXE_NAME	21	22		24		
DELIVERED IN STOCK	[redacted]	[redacted]XKR Profilex				4	4	4
		L[redacted]	2		2			2
		P[redacted]r Twist Plus C/22				12	12	12
Partial delivery	[redacted]	L[redacted]		2	2			2
		L[redacted]		10	10			10
		L[redacted]		2	2			2
		L[redacted]		30	30			30
		L[redacted] kulkowe		2	2			2
		Ł[redacted]		5	5			5
		P[redacted]		2	2			2
		S[redacted]		6	6			6
		S[redacted]		1	1			1
		S[redacted]		2	2			2
		S[redacted]		10	10			10
Total			2	72	74	16	16	90

Fig. 8. Delivery report until the production order

Report of deliveries planned for the current week (Fig. 9) was also created on the basis of the same data as the remaining compilations. The data was presented by properly selecting the dimensions in such a way that the created perspective answers the information need.

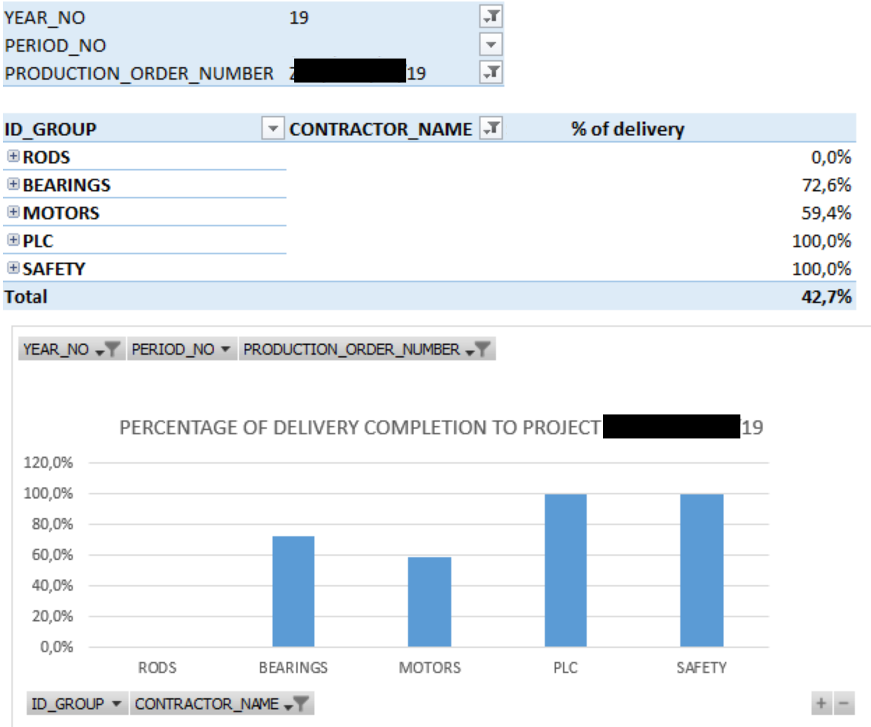
YEAR_NO	19
PERIOD_NO	
this_week	22

STATUS_NAME	PRODUCTION_ORD	CONTRACTOR_NAME	INDEXE_NAME	ORDERED_QTY	AMOUNT_TO_P	AMOUNT_RECEIVED
DELIVERED IN STOCK	ZP[redacted]19	"QU[redacted]o.o.	3 000[redacted]fil	4	0	4
			LOZY[redacted]	2	0	2
			Pas [redacted]Plu	12	0	12
GENERATED	ZP[redacted]19	AST [redacted]	[redacted]	88	88	0
Partial delivery	ZP[redacted]19	"QU[redacted]o.o.	LOZY[redacted]	2	0	2
			LOZY[redacted]	16	6	10
			LOZY[redacted]	4	2	2
			LOZY[redacted]	36	6	30
			LOZY[redacted]e	4	2	2
			Łoży[redacted]	8	3	5
			Podp[redacted]	3	1	2
			SEGE[redacted]	12	6	6
			SEGE[redacted]	2	1	1
			SEGE[redacted]	4	2	2
			SEGE[redacted]	14	4	10
Total				211	121	90

Fig. 9. Report of deliveries planned for the current week

The data was presented in MS Excel, which is well-known to the employees. After a while of working with the report system a new information need was observed – **percent of order realisation for each index group for a certain order.** Since all the required data was already available within the structures of the OLAP cube the staff was able to create such a report (Fig. 10). Employing this solution allowed the company not only to avoid purchasing licences for the ERP system and its report module (as well as creating a new report), but also to gain a tool for the employees to independently fulfil their information needs.

The report system was implemented in a manufacturing enterprise from the sector of small and medium-sized enterprises. The main users were the staff from the department of logistics and purchases, production manager with the department of production planning and warehouse workers. Implementing a solution available for all those users enhanced communication between those units. Should a query about a certain delivery or project arise, the user was able to search the report system first and in the case of lack of information, contact the purchase department.



YEAR_NO	19	
PERIOD_NO		
PRODUCTION_ORDER_NUMBER	[redacted]19	

ID_GROUP	CONTRACTOR_NAME	% of delivery
RODS		0,0%
BEARINGS		72,6%
MOTORS		59,4%
PLC		100,0%
SAFETY		100,0%
Total		**42,7%**

Fig. 10. View of the report for selected production orders

Moreover, communication with the purchase department was based on a given number of order. Previously the workers asked about the status of a part X in project A. Now, using numbers of orders (previously not available to the production department, since the data was stored in other modules of the ERP systems) facilitates searching the information in the purchase department. Apart from communication, operational planning was also enhanced. Production manager was able to plan the tasks for the upcoming week more efficiently and in-detail.

5. SUMMARY AND CONCLUSIONS

An efficiently functioning procurement department is one of the key elements of efficacy and low-cost of any production enterprise. Lack of timely delivery of elements results in production being stopped, which implicates high cost as well as loss of customers. On the other hand, purchasing too much too soon results in an increase of upkeep and stock depreciation.

Correct decision-making in terms of purchases requires access to aggregated data, which poses a serious problem in non-repetitive and multi-product manufacturing. Although the majority of manufacturing enterprises in developed countries have access to more or less advanced ERP systems, it is often impossible access present information in a fast and aggregated manner, which is a key element in the decision-making process in a dynamic environment.

To address this problem in one of enterprises realising small-lot make-to-order production a report system based on business intelligence technology was implemented. OLAP cube technology allowed for multi-dimensional data analysis. On the basis of data in the ERP system it is possible to:

– Quickly generate a compilation of overdue deliveries,
– Generate information on the type of material ordered and delivered to the analysed production order,
– Preparing a compilation of orders planned for the current week.

In order to make this solution available for small and medium-sized enterprises it was decided to implement this report system to the widely known MS Excel. The solution presented in this study was implemented in the analysed enterprise.

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