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COMPUTER AIDED ASSEMBLY PLANNING USING MS EXCEL SOFTWARE – A CASE STUDY

Abstract

The issue of planning assembly operations remains crucial decision-making area for many of manufacturing companies. It becomes particularly significant in case of small and medium enterprises that perform unit or small-scale production, where the option of applying specialized software is often very limited – both due to high purchase price, but also due to its applicability to single unit manufacturing, that is executed based on individual customer orders. The present article describes the possibility of applying the MS Excel spreadsheet in the planning of machine assembly processes. It emphasises, in particular, the method for using the spreadsheet in subsequent stages of the process, and the identification of possible causes that have impact on problems with the planning process. We performed our analysis on the basis of actual data from one of the machine industry enterprises that manufactures in central Poland.

1. INTRODUCTION

The growing, global competition means, that apart from low-cost manufacturing of products of appropriate quality, also the ability to quickly (and most of all timely) complete production orders becomes crucial for the development options of enterprises (Wikarek, Sitek & Nielsen, 2019; Świć & Gola, 2013). Therefore, what becomes a challenge in the organization of production processes are: correct planning, supervision and introduction of required corrective actions, in case of detrimental chance factors (Paprocka, Krenczyk & Burduk, 2021; Sobaszek, Gola & Kozłowski, 2017). There are numerous IT solutions that are designed to support the production manager's work (including ERS, MES class, and other systems) available commercially, but their applicability to small and medium enterprises manufacturing according to individual or small-series orders is very limited (Danilczuk & Gola, 2020). This is often due to the very cost of purchase of this type of software, or the difficulties in current update of production data (Tarigan, Siagian & Jie, 2021).

Assembly departments are frequently the decision areas of particular importance – as there the production processes are completed, by assembly teams, in manufacturing nests – rendering the detailed planning of the process more difficult due to teamwork character of the performed operations (Gola, 2014). What is more – we should bear in mind that the unit

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or small series scale of completed production further renders detailed planning non-economical (the time for such a planning process remains disproportionately long, when compared to the assembly time). Order completion time shortening requirements exert additional pressure – thus forcing the adoption of framework approach, using cheap and generally available IT tools (Cieśla & Mleczko, 2021).

Although the problem of production and assembly planning has been known for several years it is difficult to find publications where the issue of assembly planning has been investigated efficiently. Benjaafar and ElHafsi (Benjafar & Elhafsi, 2006), and ElHafsi (ElHafsi, 2009) studied the optimal production and inventory control of and assemble-to-order system with multiple components, one end product and multiple customer classes. Pang (Pang, 2015) analysed the optimal control problem for a continuous review assemble-to-order system with multiple demand classes and backordering. Remain and Wang (Remain and Wang, 2015) made and asymptotic analysis to minimize the long-run average cost of assemble-to-order inventory systems. On the other hand, Gyulai at al. (Gyulai & Monostori, 2017; Gyulai, Kadar & Monostori, 2014) introduced a novel conceptual framework that supported the periodic revision of the capacity allocation and determined the configuration of an assembly system. Manitz (Manitz, 2008) employed queuing network to analyse an assembly lines with the asynchronous material flow and evaluate its throughput. Ju et al. (Ju & Li, 2014; Ju, Li & Deng, 2017) employed the Bernoulli model to evaluate the selective assembly system performance efficiently. Li et al. (Li, Blumenfeld, Huang & Alden, 2009) summarized studies about performance analysis of serial lines, parallel lines and assembly and disassembly systems.

As the operating practice of small and medium enterprises demonstrates it is very often so (even if they hold licences for ERP class software) that the people responsible for planning assembly resort to spreadsheet software (eg. MS Excel). Albeit commonly perceived as a non-professional software it is one of the most frequent IT solutions to support the planning process (Kamath & Sarkar, 2020). The objective of the present article is to present the course of assembly planning process in an enterprise completing one-off and small series production, with use of the MS Excel spreadsheet. We put particular emphasis on comparative evaluation of theoretical considerations with industrial practice and identification of possible causes that have impact on issues in the planning processes. We performed our analysis using actual data from one of machine building enterprises that manufactures in Poland.

2. THE ASSEMBLY PLANNING PROCESS IN A MACHINE INDUSTRY ENTERPRISE – A CASE STUDY

2.1. The Characteristics of Enterprise Subject to Our Research

We present the potential of applying a spreadsheet for the needs of planning assembly processes on the example on a machine industry enterprise that is one of the leaders in innovative technologies in tobacco industry. The business activities of the enterprise include, in particular:

- **Manufacturing filter-forming and gluing machines.** The company offers complete production lines for etery type of filters. These include manufacturing, weathering, buffering, selection and composing multi-segmented filters.

- **Manufacturing tobacco reclaiming machines.** To avoid losses of raw material the company developed machines to reclaim tobacco from cigarettes, cigars, cigarillos, and other special purpose tobacco products.
- **Logistic systems.** The company has significant experience in developing logistics systems, such as bulk belt conveyors, systems for loading and unloading, and storage systems. It developed a proprietary product transport method adhering to the FIFO principle.

Fig. 1 presents selected machines manufactured in the company subject to our analysis 1.

Fig. 1. Selected machines manufactured as part of activities of the analyzed enterprise

The aforelisted, three main business activities of the enterprises, reflect the three departments of the company. Each of these has different operating characteristics, due to different type of machines manufactured. The article concentrates on the logistics systems department. In this department the assembly of machines, from the delivery of parts to the plant, to the packaging of the ready machine, takes 1.5 months to 3 months.

2.2. Characteristics of the assembly planning process

Figure 2 presents the diagram of the entire assembly planning process of the enterprise. This diagram presents the machine assembly stages in MS Excel files, and ERP type systems, and also reporting tools, including Sharepoint. The most elaborated files are further described herein, and presented in tables. These include files, such as:

- forecast,
- master plan,
- machine plan,
- production base,
- reports.

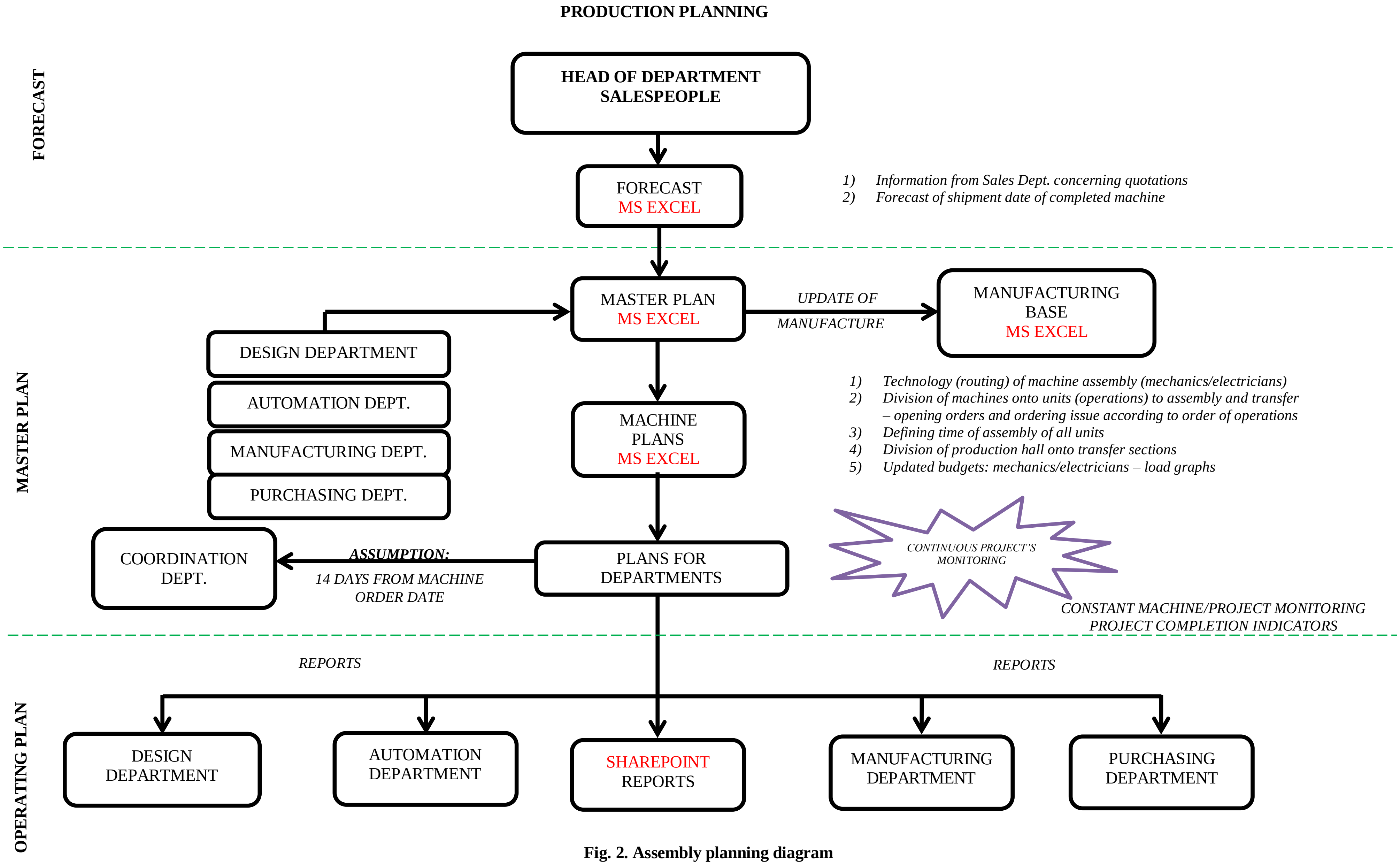


Fig. 2. Assembly planning diagram

The first stage of assembly planning process is the elaboration of sales forecast (table 1). The forecast is the basis for the head of the department, who receives information from sales department about orders or forecasts – quotes, which are 80-90% certain.

Tab. 1. Forecast

Customer Name	Final Destination	Project Manager	New issue (1)	Machine Type	Latest issue of specification	Shipment Date	Order status
Customer A	Romania	Adam Bernat	1	Mach.11	03_2017-01-20	27.03.2021	Ordered
Customer B	Russia	Michał Nowak	0	Mach.10	03_2016-08-30	27.03.2021	Ordered
Customer B	Russia	Michał Nowak	0	Mach. 10	03_2016-08-30	27.03.2021	Ordered
Customer B	Italy	Karol Kowal	0	Mach. 11	01_2016-12-02	03.04.2021	Ordered
Customer B	Italy	Marcin Celak	0	Mach. 11	01_2020-12-09	05.05.2021	Ordered
Customer B	Italy	Jan Drodek	0	Mach. 11	01_2020-10-10	26.05.2021	Ordered
Customer B	Italy	Marcin Celak	0	Mach. 10	01_2020-12-09	26.05.2021	Ordered
Customer B	Italy	Marcin Celak	0	Mach. 10	01_2020-12-09	26.05.2021	Ordered
Customer C	Russia	Michał Nowak	0	Mach. 11	01_2021-01-18	01.06.2021	Ordered
Customer C	Russia	Jan Drodek	0	Mach. 12	-	30.06.2021	Not ordered
Customer D	Sweden	Adam Bernat	1	Mach. 12	03_2021-01-23	30.06.2021	Ordered
Customer D	Sweden	Adam Bernat	1	Mach. 12	03_2021-01-23	30.06.2021	Ordered
Customer D	Russia	Michał Nowak	0	Mach. 11	00_2021-01-17	26.07.2021	Ordered
Customer A	Russia	Jan Drodek	0	Mach. 11	-	30.07.2021	Not ordered
Customer A	Russia	Jan Drodek	0	Mach. 11	-	31.07.2021	Not ordered

The forecasts are elaborated on the basis of potential customer orders. The specifics of the production does not allow for planning based on historical data. The plants are based mainly on quotations and the knowledge of board and management. The forecast is the basis for elaboration of the master plan (table 2), which includes a 12-month machine manufacturing information. This plan is elaborated mainly on the basis of analysis of manufacturing capacities, and the capacity of Purchasing Department. The analyzed master plan is forwarded to heads of the following departments: Design, Automation, Manufacturing, Purchasing to prepare them for the tasks and to give them opportunity to include their corrections concerning the timeline for the tasks. The master plan includes the dates of shipment of machines to the customer and the dates of end of machine assembly.

Tab. 2. Master plan

Customer	Country	Budget	Machine type	Change (1)	Specification rev.	Shipment	Status	End of manufacturing	Design	Automation	Manufacturirng	Purchasing
		hours		0 / 1								
Customer A	Romania	300	Machine 11	1	03_2017-01-20	27.03.2021	Ordered	27.03.2021				
Customer B	Russia	300	Machine 10	1	03_2016-08-30	27.03.2021	Ordered	27.03.2021				
Customer B	Russia	300	Machine 10	1	03_2016-08-30	27.03.2021	Ordered	27.03.2021				
Customer B	Italy	200	Machine 11	1	01_2016-12-02	03.04.2021	Ordered	03.04.2021				
Customer B	Italy	130	Machine 11	1	01_2020-12-09	05.05.2021	Ordered	05.05.2021				
Customer B	Italy	170	Machine 11	1	01_2020-10-10	26.05.2021	Ordered	12.05.2021				
Customer B	Italy	130	Machine 11	1	01_2020-12-09	26.05.2021	Ordered	12.05.2021				
Customer B	Italy	80	Machine 11	0	01_2020-12-09	26.05.2021	Ordered	26.05.2021				
Customer C	Russia	200	Machine 12	0	01_2021-01-18	01.06.2021	Ordered	01.06.2021				
Customer C	Russia	130	Machine 12	0	01_2021-01-18	30.06.2021	Ordered	30.06.2021				
Customer D	Sweden	170	Machine 10	0	03_2021-01-23	30.06.2021	Ordered	23.06.2021				
Customer D	Sweden	200	Machine 10	0	03_2021-01-23	30.06.2021	Ordered	23.06.2021				

The master plan of the department enables the collection, in a single location, of reliable planning information. This plan is made in an MS Excel file that can be accessed and edited simultaneously by all involved departments of the enterprise. This allows for greater elasticity and better practicality of data, without the need to wait for other departments to complete it. The data filing method was defined mainly for the purpose of specifying deadlines for each of the respective departments. Below is a schedule for data filling by all the departments and information what data will be taken into account when elaborating reports. What is of extreme importance for a new file that will be worked on by different departments is to prepare detailed file maintenance instructions (table 3):

Tab. 3. File filling instructions

Schedule for data filing: **1)** Heads of Mechanical and Electrical Design – till 3PM on Tuesday. **2)** Head of production preparation department – till 3PM on Wednesday. **3)** Head of purchasing department – till 3PM on Thursday. **4)** Head of automation department – confirm machine start till 2PM on Friday. **5)** File supervisor – generate reports for the next week, publish the new, updated file till 10AM on Monday.
PLEASE NOTE At 2PM on Fride the file editing by the department will be locked to general reports and update it.
Each newly introduced change will be highlighted in yellow
NOTES FOR SHAREPOINT REPORTS: *DESIGN DEPARTMENT:* **1)** Column: **Planned sending the material list**: the entered data cannot be changed *ELECTRICAL DEPARTMENT:* **1)** Column: **Planned sending the material list**: the entered data cannot be changed *MANUFACTURING DEPARTHEMTN :* **1)** Column: **Start of assembly:** the planned start assembly when all parts are available **2)** Column: **End of assembly:** real date of machine's shipment date
ATTENTION: Column: **Machine's shipment date** means the expected date of shipment to the customer Column: **End of assembly** means the real date of shipment realized by production department

Writing a detailed instruction is required, as the file is password-protected and connected with other file tabs, and certain file functions are automatically performed, which greatly simplifies and shortens the time of its completion, thus making it more readable for other users. Figure 3 presents a method for automatic updating and sharing a file.

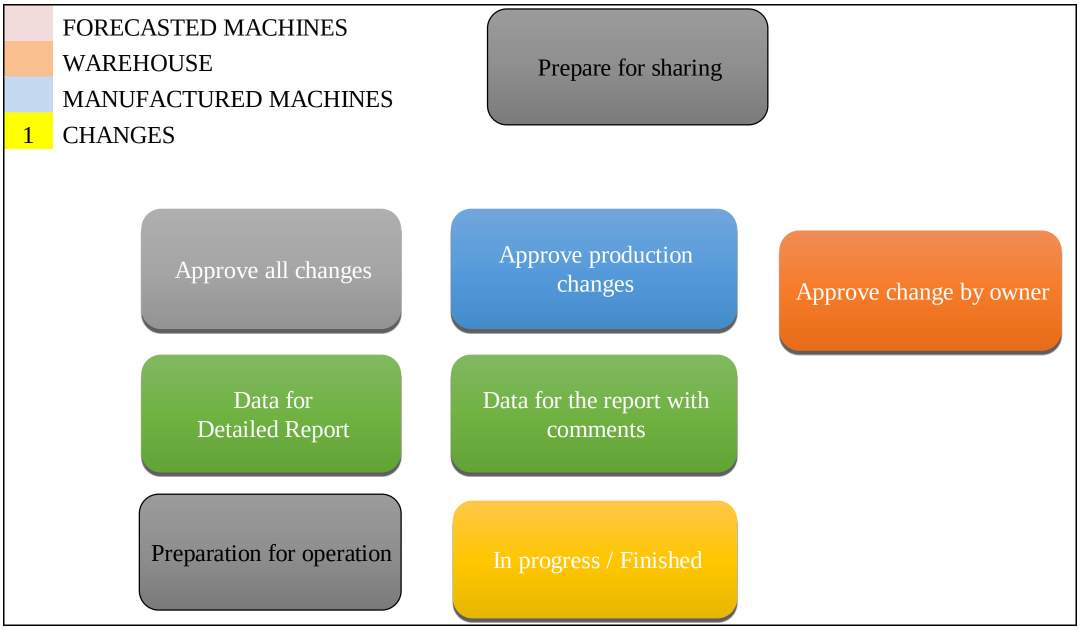


Fig. 3. Automation of master plan file

The master plan includes all departments that are involved and are involved in the implementation of the machine from the design phase to the shipment of the finished machine. When creating the master plan for the entire department, the data required for production planning at the tactical stage is analyzed first. The departments that significantly affect the assembly of the machine are identified and the data that will be required to create the main production planning file analyzed.

The data required for proper production planning in the Design Department (table 4) is:

- planned date for sending the mechanical Bill of Materials,
- date of sending the bill of materials (warehouse),
- date of sending the completed bill of materials.

Tab. 4. Work schedule - Design department

DESIGN DEPARTMENT			
Planned delivery of the bill of materials (END)	Sending the bill of materials (BACKUP)	Actual Bill of Materials Sent (END)	Notes
(YYYY-MM-DD)	(YYYY-MM-DD)	(YYYY-MM-DD)	
2019-03-31	2019-02-10	2019-05-31	
2019-03-31	2019-02-10	2019-05-31	
2019-03-31	2019-02-10	2019-05-31	

The data necessary for proper production planning in the Electrical Design and Automation Department (table 5) is:

- planned date for sending the electrical Bill of Materials,
- date of sending the bill of materials (warehouse),
- date of sending the completed bill of materials,
- the actual date of starting the commissioning of the machine by Automation specialists.

Tab. 5. Work schedule – Automation Department (own elaboration)

AUTOMATION DEPARTMENT				
Planned delivery of the bill of materials (END)	Sending the bill of materials (BACKUP)	Actual Bill of Materials Sent (END)	Starting the machine (START)	Notes
(YYYY-MM-DD)	(YYYY-MM-DD)	(YYYY-MM-DD)	(YYYY-MM-DD)	
2019-04-03	2019-02-11	2019-04-17	2019-10-26	
2019-04-03	2019-02-11	2019-04-17	2019-10-13	
2019-04-03	2019-02-11	2019-04-28	2019-11-03	

The data required for proper production planning in the Production Preparation Department (table 6) is:

- the date of commencement of mechanical assembly and thus the date on which the materials are to be delivered to the production hall – the date for Supply,
- readiness of the machine to run – information for Automation Engineers,
- date of completion of production to the state of packaged machine – readiness for shipment of the machine.

Tab. 6. Work schedule – Production Preparation Department

PRODUCTION PREPARATION DEPARTMENT			
Start of assembly	Ready to start the machine	Completion of assembly	Notes
(YYYY-MM-DD)	(YYYY-MM-DD)	(YYYY-MM-DD)	
2019-03-03	2019-10-26	2020-01-10	CLOSED
2019-03-02	2019-10-13	2020-01-10	CLOSED
2019-03-02	2019-11-03	2020-01-10	CLOSED

The data required for proper production planning in the Purchasing Department (table 7) is:

- planned date of delivery of materials, parts for assembly determined by the Production Preparation Department as the date of assembly commencement,
- Actual delivery date for all parts required for assembly.

Tab. 7. Work schedule – Purchasing Department

PURCHASING DEPARTMENT		
Date the part was delivered (PLANNED)	Date the part was delivered (END)	Notes
(YYYY-MM-DD)	(YYYY-MM-DD)	
2019-07-14	2019-07-22	
2020-01-15	2020-01-26	
2019-07-14	2019-07-14	

Reports created from the master plan:

1. Report for the machine/project (table 8) including stages, e.g. preparation of documentation, planned start/end of production, date of shipment of the machine confirmed to the customer, including the key (table 9).

Tab. 9. Report key

KEY:	
S	SHIPPING TO CUSTOMER
DESIGN DEPARTMENT	
DEP	START DESIGNING
DEF	FINISHING THE DESIGN
AUTOMATION DEPARTMENT	
ATP	START DESIGNING
ATF	FINISHING THE DESIGN
ATR	STARTING
PRODUCTION DEPARTMENT	
PPP	PLANNED START OF ASSEMBLY
PPA	ACTUAL START OF ASSEMBLY
PPR	READY TO START
PPF	COMPLETION OF ASSEMBLY
PURCHASING DEPARTMENT	
PUR	DATE OF DELIVERY OF PARTS

Tab. 8. Report from the master plan of the machine/project (own elaboration)

				2019	2020																		
Machine number: 19134			Month:	October	February		March		April		May		June		August			September		October			
Project number	Project statatus	Machine type	Production stages:	31	6	28	6	11	3	19	1	31	5	13	7	16	18	4	5	2	6	18	25
19134	CLOSED	Machine 16	MECHANICAL LIST	DEP																			
			ELECTRICAL LIST									ATF											
			PRODUCTION – ASSEMBLY			PPP				PPA												PPR	PPF
			STARTING					PUR															
			SHIPPING TO CUSTOMER																			ATR	
			MECHANICAL LIST																		S		
005539	CLOSED	Exit link	MECHANICAL LIST														DEF						
			ELECTRICAL LIST											ATF									
			PRODUCTION – ASSEMBLY													PPP			PPA			PPR	PPF
			STARTING																			ATR	
			SHIPPING TO CUSTOMER																		S		

2. The number of hours registered on the project, broken down by company employees and employees of external companies in relation to the allocated hourly budget (Fig. 4).

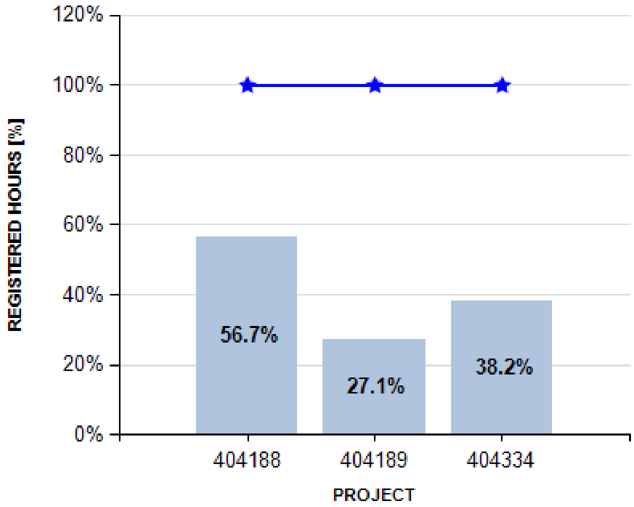


Fig. 4. Reporting project hours

3. The deadline for dispatch of machines by customer/coordinator shows the machines for the selected project coordinator (table 10).

Tab. 10. Timely shipment of machines by the customer/coordinator

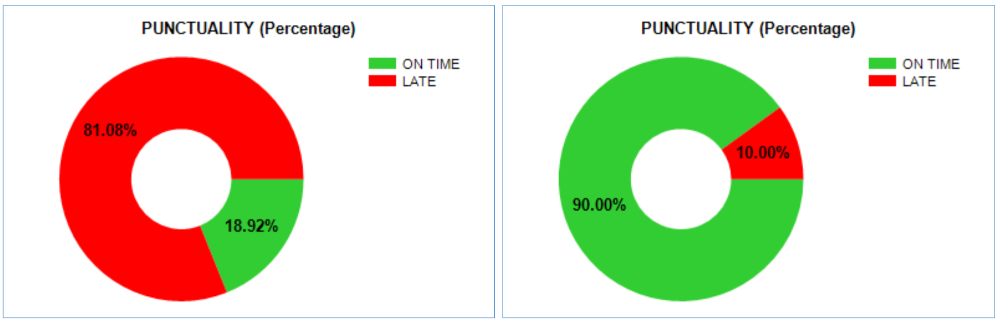
<table>
<tr><th>TYPE OF MACHINE</th><th>No. OF MACHINES</th><th>MACHINES ON TIME</th><th>MACHINES DELAYED</th></tr>
<tr><td rowspan="4">Machine 10</td><td>2</td><td>2</td><td>0</td></tr>
<tr><td>Machine No.</td><td>Project number</td><td>Project status</td><td>Customer</td><td>Place of dispatch</td><td>Project Coordinator</td><td>Send date</td><td>Completion of assembly</td><td>DISPATCH DATE</td></tr>
<tr><td>19124</td><td>005534</td><td>OPEN</td><td>Customer A</td><td>USA</td><td>Jan Kowalski</td><td>31-05-2019</td><td>28-05-2019</td><td>✓</td></tr>
<tr><td>19125</td><td>005533</td><td>OPEN</td><td>Customer A</td><td>USA</td><td>Jan Kowalski</td><td>31-05-2019</td><td>31-05-2019</td><td>✓</td></tr>
</table>

4. Machine shipment date in detail for a specific month or globally for a year – shows all machines monthly (table 11).

Tab. 11. Timely shipment of machines in detail

<table>
<tr><th>TYPE OF MACHINE</th><th>No. OF MACHINES</th><th>MACHINES ON TIME</th><th colspan="7">MACHINES DELAYED</th></tr>
<tr><td>Machine 1</td><td>1</td><td>0</td><td colspan="7">1</td></tr>
<tr><td rowspan="7">Machine 2</td><td>12</td><td>12</td><td colspan="7">0</td></tr>
<tr><td>Machine No.</td><td>Project number</td><td>Project status</td><td>Customer</td><td>Place of dispatch</td><td>Project Coordinator</td><td>Send date</td><td>Completion of assembly</td><td>DISPATCH DATE</td></tr>
<tr><td>10026</td><td>005569</td><td>CLOSED</td><td>Customer B</td><td>China</td><td>Marek Nowak</td><td>15-01-2019</td><td>21-11-2018</td><td>✓</td></tr>
<tr><td>10027</td><td>005548</td><td>CLOSED</td><td>Customer B</td><td>China</td><td>Marek Nowak</td><td>15-01-2019</td><td>23-11-2018</td><td>✓</td></tr>
<tr><td>10029</td><td>005650</td><td>CLOSED</td><td>Customer B</td><td>China</td><td>Marek Nowak</td><td>15-01-2019</td><td>27-11-2018</td><td>✓</td></tr>
<tr><td>10030</td><td>005751</td><td>CLOSED</td><td>Customer B</td><td>China</td><td>Jan Kowalski</td><td>15-01-2019</td><td>29-11-2018</td><td>✓</td></tr>
<tr><td>10038</td><td>005849</td><td>CLOSED</td><td>Customer B</td><td>China</td><td>Jan Kowalski</td><td>15-01-2019</td><td>03-12-2018</td><td>✓</td></tr>
<tr><td>Machine 4</td><td>13</td><td>13</td><td colspan="7">0</td></tr>
<tr><td>Machine 5</td><td>1</td><td>1</td><td colspan="7">0</td></tr>
<tr><td>Machine 6</td><td>1</td><td>0</td><td colspan="7">1</td></tr>
</table>

5. Timely shipment of machines (Fig. 5).



Timeliness of machine shipment – 09.2017 Timeliness of machine shipment – 02.2019

Fig. 5. Timeliness of machines – progress

The master production plan is broken down into operational plans – schedules (Table 12) elaborated in detail for the executive departments of the entire department.

Tab. 12. Schedule for the machine # 1

2019-01-14							Foreman	Marek Nowak
Customer	Coordinator	Machine	Production start (YYYY-MM-DD)	Starting the machine (YYYY-MM-DD)	End of production (YYYY-MM-DD)	*Dispatch date* (YYYY-MM-DD)	Production progress %	Status ORDERED/ NOT ORDERED
February 2019								
Customer A	Jan Kowalski	MACHINE 1	2018-12-10	2019-01-16	2019-02-08	2019-02-15	125.40%	ORDERED
Customer A	Jan Kowalski	MACHINE 1	2018-12-10	2019-01-25	2019-02-08	2019-02-15	74.90%	ORDERED
Customer A	Jan Kowalski	MACHINE 1	2018-12-17	2019-01-11	2019-02-15	2019-02-15	190.40%	ORDERED
Customer A	Jan Kowalski	MACHINE 1	2018-12-17	2019-02-01	2019-02-15	2019-02-15	75.70%	ORDERED
MARCH 2019								
CUSTOMER B	Adam Nowak	MACHINE 1	2018-09-20	2019-02-27	2019-03-07	2019-12-19	69.00%	ORDERED
CUSTOMER B	Adam Nowak	MACHINE 1	2019-01-16	2019-03-06	2019-03-14	2019-12-19	73.20%	ORDERED
CUSTOMER B	Adam Nowak	MACHINE 1	2019-01-23	2019-03-13	2019-03-21	2019-12-19	75.20%	ORDERED
APRIL 2019								
CUSTOMER C	Karol Boban	MACHINE 1	2019-01-21	2019-03-27	2019-04-04	2019-04-15	0.00%	ORDERED
CUSTOMER C	Karol Boban	MACHINE 1	2019-01-22	2019-03-31	2019-04-08	2019-04-15	0.00%	ORDERED
CUSTOMER C	Karol Boban	MACHINE 1	2019-01-23	2019-04-03	2019-04-11	2019-04-15	0.00%	ORDERED
CUSTOMER C	Karol Boban	MACHINE 1	2019-01-24	2019-04-07	2019-04-15	2019-04-15	0.00%	ORDERED
CUSTOMER B	Adam Nowak	MACHINE 1	2019-02-11	2019-04-08	2019-04-16	2019-04-30	0.00%	ORDERED

These schedules include sub-activities performed as part of the machine assembly process, such as parts delivery date, machine commissioning, quality control, testing and packaging. These schedules are updated at least once a week. The order card usually includes a dozen or so products and each product has a separate production schedule that takes the production capacity into account. Most often, production capacity is assigned to the appropriate type of product – of course, it will vary, according to the needs. The respective stages in the entire machine assembly process are defined, i.e. start of production, and thus delivery of the material to the production hall, start-up of the machine, machine tests, quality control and packaging. At this stage, many different tools are applied for production planning, such as: ERP class system (Manufacturing module), MS Office suite (Excel, Word), data reporting program and other internal systems of the company. All these tools allow for elaboration of detailed schedules.

Schedules are frequently updated and changed due to the specifics of the company. Planning according to *Make-To-Order* and *Make-To-Stock* methods are intertwined. The *pull* system for production is often applied – "bottom-up" planning, ie. replenishment of production capacity with orders that are planned for the future to ensure continuity of production.

Machines always consist of additional input and/or output links. The technology described in this way is used to set the date of commencement of machine assembly and thus define the demand for materials. The technology is also used to create and check the load on the production hall. The technology described in this way, together with the loads, allows (already at the stage of offering the machine to the customer), determining the possible earliest date of machine manufacturing, checking the current loads of the team. An exemplary plan of one of the machines with technology is presented in table 14.

Such a description of technology allows (starting from the end date) to determine the date of commencement of the assembly of the machine and the date of the machine's readiness for start-up and testing.

The report (Figure 6) created on the basis of these files, is elaborated for the purposes of automation and quality control. It contains the list of all machines that will be assembled first. The report is prepared for approximately two months, with the subsequent two weeks planned in greater detail.

Another important stage of production planning is also the creation of the production base (Table 15). The production base was created for the needs of the production manager and foremen. This database contains detailed production orders for each machine and links, loads with division into mechanics (Table 16, Fig. 7) and electricians. The production base has tabs with loads separately for mechanics and electricians along with a diagram, making it easier to check the loads of the entire department on an ongoing basis.

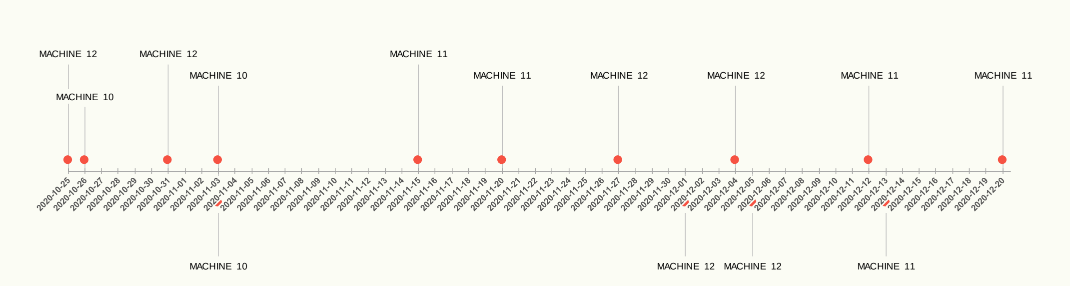
Table 14. Machine 1 schedule, including technology

2019-01-14
MACHINE 1

Customer	Coordinator	Machine No.	Week 1 January 2019	Week 2 January 2019	Week 3 January 2019	Week 4 January 2019	Week 5 January 2019	Week 6 February 2019	Week 7 February 2019	Week 8 February 2019	Week 9 February 2019	Week 10 March 2019	Week 11 March 2019	Week 12 March 2019	Week 13 March 2019
			2019												
			January					February				March			
February 2019															
Customer A	Jan Kowalski	90001	1M	1M	1M	1M	U+Q	P							
			1L	1L	1L	1L	U+Q	P							
Customer A	Jan Kowalski	90002	1M	1M	1M	1M	U+Q	P							
			1L	1L	1L	1L	U+Q	P							
Customer A	Jan Kowalski	90003	1M	1M	1M	1M	1M	U+Q	P						
				1L	1L	1L	1L	U+Q	P						
Customer A	Jan Kowalski	90004	1M	1M	1M	1M	1M	U+Q	P						
				1L	1L	1L	1L	U+Q	P						
MARCH 2019															
CUSTOMER B	Adam Nowak	37405	1M	1M	1M	1M	1M	1M	1M	1M	U+Q	P			
							1L	1L	1L	1L	U+Q	P			
CUSTOMER B	Adam Nowak	37401		1M	1M	1M	1M	1M	1M	1M	1M	U+Q	P		
								1L	1L	1L	1L	U+Q	P		
CUSTOMER B	Adam Nowak	37402			1M	1M	1M	1M	1M	1M	1M	1M	U+Q	P	
				-					1L	1L	1L	1L	U+Q	P	
APRIL 2019															
CUSTOMER C	Kamil Cebula	37403			-		1M	1M	1M	1M	1M	1M	1M	1M	U+Q
				-							1L	1L	1L	1L	U+Q
CUSTOMER C	Kamil Cebula	37404			-			1M	1M	1M	1M	1M	1M	1M	1M
				-								1L	1L	1L	1L
CUSTOMER C	Kamil Cebula	37405			-			1M	1M	1M	1M	1M	1M	1M	1M
				-								1L	1L	1L	1L
CUSTOMER C	Kamil Cebula	37406			-				1M	1M	1M	1M	1M	1M	1M
				-									1L	1L	1L
CUSTOMER B	Adam Nowak	37407							1M	1M	1M	1M	1M	1M	1M
				-									1L	1L	1L

AUTOMATION DEPARTMENT READINESS FOR START-UP

DECEMBER 2020



DETAILS

WEEK	START UP	MACHINE TYPE	CUSTOMER	PROD. FINAL	SHIPMENT DATE	FOREMAN
43	2020-10-25	MACHINE 12	China	2020-12-13	2021-01-05	Adam Nowak
	2020-10-26	MACHINE 10	Russia	2020-12-15	2021-04-14	Jan Kowalski
44	2020-10-31	MACHINE 12	China	2020-11-29	2021-01-05	Karol Boban
	2020-11-03	MACHINE 10	Russia	2020-12-15	2021-04-14	Karol Boban
	2020-11-03	MACHINE 10	China	2020-11-29	2021-01-05	Karol Boban
46	2020-11-15	MACHINE 11	China	2020-12-06	2021-01-05	Jan Kowalski
47	2020-11-20	MACHINE 11	China	2020-12-06	2021-01-05	Karol Boban
48	2020-11-27	MACHINE 12	Russia	2020-12-06	2021-01-10	Adam Nowak
	2020-12-01	MACHINE 12	China	2020-12-13	2021-01-05	Jan Kowalski
49	2020-12-04	MACHINE 12	Russia	2020-12-13	2020-12-13	Adam Nowak
	2020-12-05	MACHINE 12	USA	2020-12-14	2020-12-28	Jan Kowalski
50	2020-12-12	MACHINE 11	China	2020-12-20	2021-01-12	Karol Boban
	2020-12-13	MACHINE 11	Russia	2020-12-22	2020-12-22	Adam Nowak
51	2020-12-20	MACHINE 11	China	2021-01-10	2021-01-10	Adam Nowak

Fig. 6. Machine commissioning report

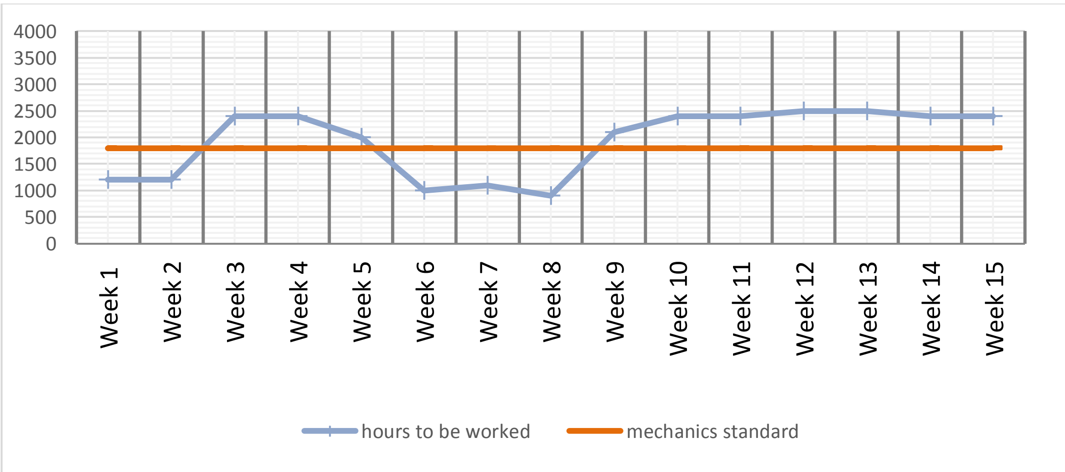


Fig. 7. Load diagram for the mechanical department (example)

Tab. 15. Production base

Project	Order	Machine	Customer	Mach. no.	Hours limit	Total hours	%	End	Team	Status	NOTES
4126	226287	Machine 1	Customer A	79075	200	100.08	50.1%	2021-06-30	Kowalski	Implemented	
4126	226288	Packaging	Customer A	79075	100	20.00	20.0%	2021-06-30	Nowak	Implemented	
4127	226837	Input link	Customer B	79075	170	3.00	1.0%	2021-06-30	Kowalski	Implemented	
4128	226915	Exit link	Customer B	79075	100	38.99	36.9%	2021-06-30	Kowalski	Implemented	
4123	226382	Machine 2	Customer B	79076	200	88.90	35.0%	2021-08-15	Kowal	Implemented	
4123	226383	Packaging	Customer B	79076	100	120.00	60.0%	2021-08-15	Boban	Implemented	
4124	227273	Input link	Customer C	79076	170	0.00	0.00%	2021-08-15	Boban	Planned	
4125	227274	Exit link	Customer C	79076	100	0.00	0.00%	2021-08-15	Boban	Planned	
4182	226384	Machine 3	Customer D	79079	200	0.00	0.00%	2021-08-15	Nowak	Planned	
4182	226385	Packaging	Customer D	79079	100	0.00	0.00%	2021-08-15	Nowak	Planned	

Tab. 16. Mechanical load

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15
hours to be worked	1200	1200	2400	2400	2000	1000	1100	900	2100	2400	2400	2500	2500	2400	2400
mechanics standard	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
absent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	January 2021	January 2021	January 2021	January 2021	January 2021	February 2021	February 2021	February 2021	February 2021	March 2021	March 2021	March 2021	March 2021	April 2021	April 2021

The final stage of the production planning process is data analysis after the machine assembly is completed. The most important objective here, and at the same time a challenge for the company, is the timely shipment of machines to the customer. Achieving this objective largely depends on correct production planning. Therefore, on the basis of the available data, this parameter is subject to evaluation and detailed analysis.

At this stage of creating planning and production schedules, the stage of machine assembly and information flow between departments was significantly improved. We were able to respond to changes much faster and they had a smaller impact on the change of the date of shipment of the machine to the customer. Work organization in the company and employees' knowledge of production plans both improved significantly.

3. SUMMARY AND CONCLUSIONS

The issue of planning individual stages of the production process is one of the crucial elements in every manufacturing company – its correctness determines the possibility of timely execution of orders, as well as the optimal use of production capacity. In the case of a high degree of individualization and high variability of orders as well as high complexity of manufactured products, correct planning of assembly processes becomes a challenge – it affects both the costs of the production process and the possibility of meeting the assumed order completion date. Unfortunately, despite the numerous available methods and IT tools dedicated to the needs of production planning and management, the process of planning assembly operations poses a significant practical problem – especially for enterprises from the SME sector, for which the purchase of this type of software is associated with excessive financial expenses. Moreover, it is also problematic since there is no production planning software that does not require an individual (and often costly) configuration tailored to the specifics of a given enterprise and its production. ERP-class programs – although extremely helpful, are not adapted to every type of enterprise and require a lot of commitment on the part of the employees who operate this system.

In order to overcome these problems (as presented in this article), it is possible to use generally available IT tools (e.g. in the form of spreadsheets), the use of which provides significant support – leading to a reduction in time losses and an increase in the efficiency of the planning process. The presented case confirms that this solution is very beneficial and, despite certain limitations, allows to achieve the assumed effect. The only condition in this respect is the necessity to use network solutions – enabling simultaneous work of representatives of various departments of the enterprise.

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