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Organization of production lines

B. Sc. Level

Mechanical Engineering

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Abstract

The objective of this project is the organization of productions lines in one factory call “POLEDWOOD” located in Cracow, Poland. This factory manly works in the furniture sector. They produce four type of desks and they need organization the lines for produce the desk with less cost as possible.

For this study, we have information about previous costumer’s orders exactly all the orders of 2011, 2012 and a half of 2013 and we need to know how many desks we need to produce in stock a week. We calculate the number of machines that we need for produce this stock. Too we study about the number of workers that we need and how many shifts it will be necessary.

For manufacturing the furniture, we calculate how to cut the wood. and all the times for cut, drill and grove and edge the wood.

For assembly the desks we make a BOOM structure for have a general vision of components that we need. We calculate all the times that we need for assembly the desks and we do an assembly instruction because the workers need the instructions for assembly the furniture.

For finish we make a layout for reducing the costs, movements and have a good distribution of the warehouse and production plant.

Keywords: organization, manufacturing, assembly

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1. Introduction

Nowadays there is lot of competitive in a globalised world. The customers' requirements which keep increasing, makes the company, independently of their size, work more efficient and in a shorter period of time. For that reason, the companies need keep working hard to improve constantly their process and being able to answer to any changes in a volatile market.

The main objective of any company is to obtain the mayor benefits with the minimum costs searching for the best way of efficiency and looking to be more competitive in the globalised market.

The aim of this research is to propose an organization plan in the production line to minimize the costs.

The essay its composed by four major groups.

The first one is the analyse of the orders of the clients in the last years of each furniture, calculating the minimum security stock that we need of each furniture to be sure of an efficient and fast answer to the orders of the clients.

In addition, the second one is the study of the manufacture process, minimizing the remains of the raw material and calculating all the time spent to prepare the raw material

In the third point we could find all the components and elements needed for the montage of the desks, the instructions that the operators should use for the montage and the requirement times for the assembly.

To finish with, we can find the calculations to know the number of machines we need to satisfy the necessities of the clients and also a production plant layout.

2. Furniture

Then we can see the four desks that the company do:

- ELBIU/7/10

Image 1. Desk ELBIU/7/10.

This is a desk called ELBIU/7/10. It is composed by the body and one drawer.

- ELBIU/7/12

Image 2. Desk ELBIU/7/12.

This is a desk called ELBIU/7/12. It is composed only by the body.

- ELBIU/7/14

Image 3. Desk ELBIU/7/14.

This is a desk called ELBIU/7/14. It is composed by the body, three drawers and one cabinet.

- ELBIU/7/16

Image 4. Desk ELBIU/7/16.

This is a desk called ELBIU/7/12. It is composed only by the body too.

3. Costumer Order Analysis

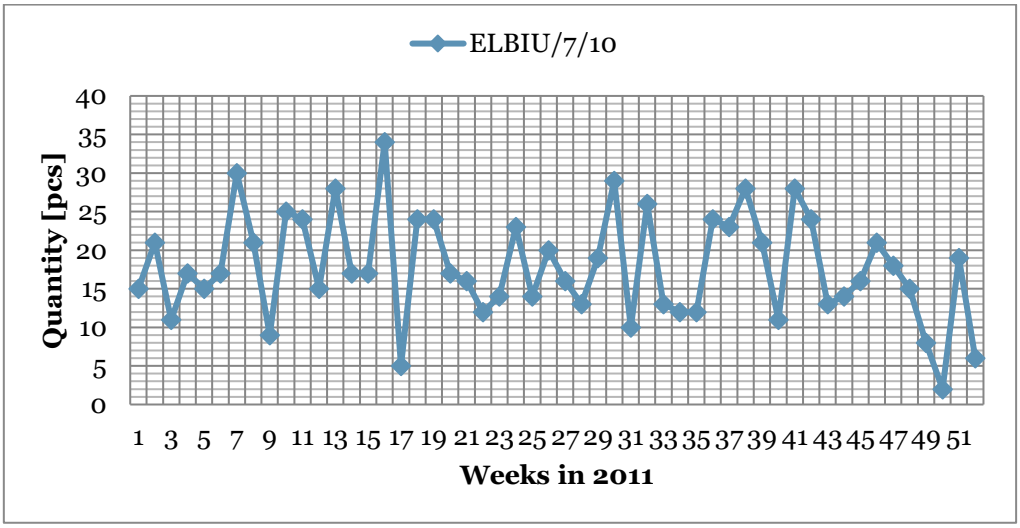
We analyse the historical data about customer orders. The data (included in file Customer_Orders.xlsx) cover the period of 2011-2013 (2 and a half year).

- 2011 (251 working days) was 6 557 customer orders (29 738 order items),
- 2012 (252 working days) was 6 438 customer orders (29 043 order items),
- Year 2013 (251 working days) is a current year (the last real day is a 31 of May, it is a 104 working day in 2013). 2013 includes, first half year – 104 days – it is historical data and additionally already received customer orders in planning horizon (2 x CLT next weeks, decreasing till 23 of August 2013 – next 59 working days), 3 530 customer orders (16 080 order items).

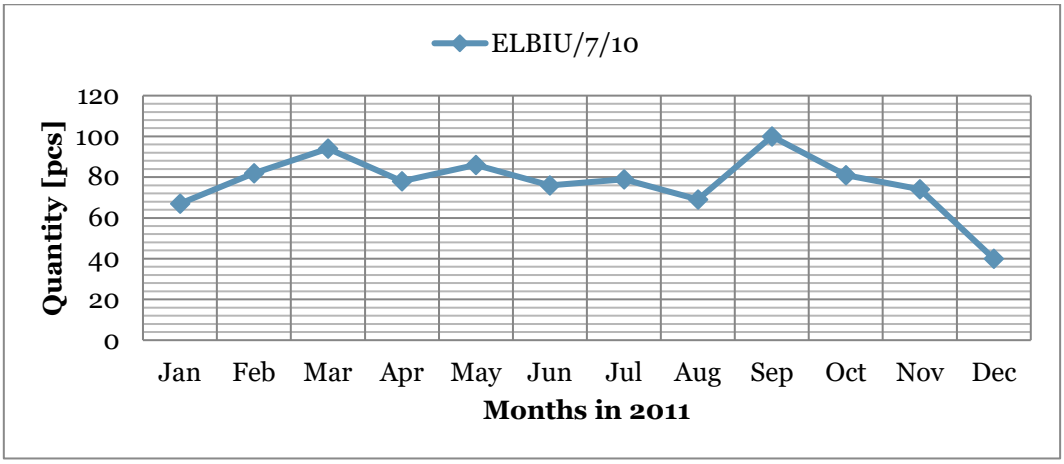
Demand on each product is variable and discontinuous (not every day each product can be sold). Therefore, the data aggregation in longer periods (weeks, months) is necessary. First of all, data (grouped by product ID) about quantity (given in order item) are aggregated each day from different orders. Then this data is aggregated weekly and monthly in given year.

3.1. ELBIU/7/10

- 2011 weekly and monthly distribution of demand:

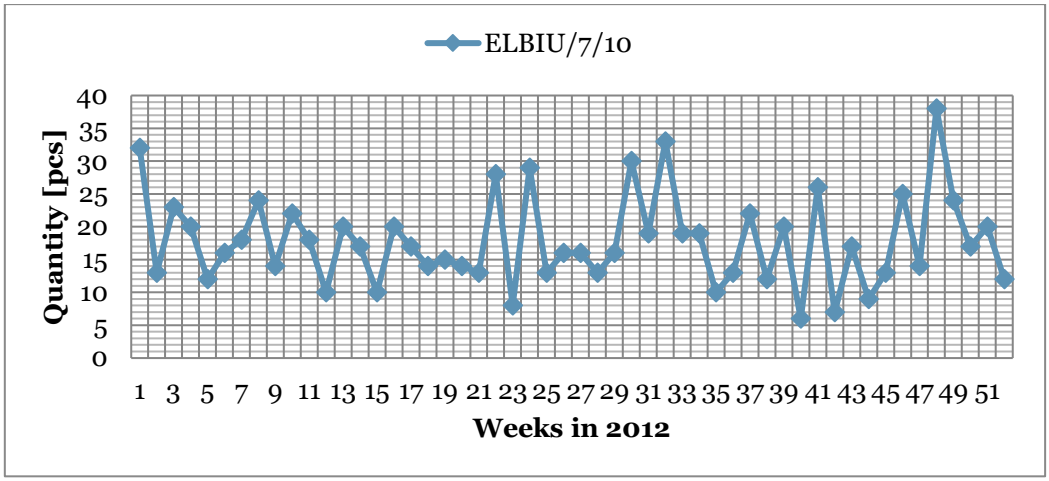


Graphic 1. 2011 demand in weeks ELBIU/7/10.

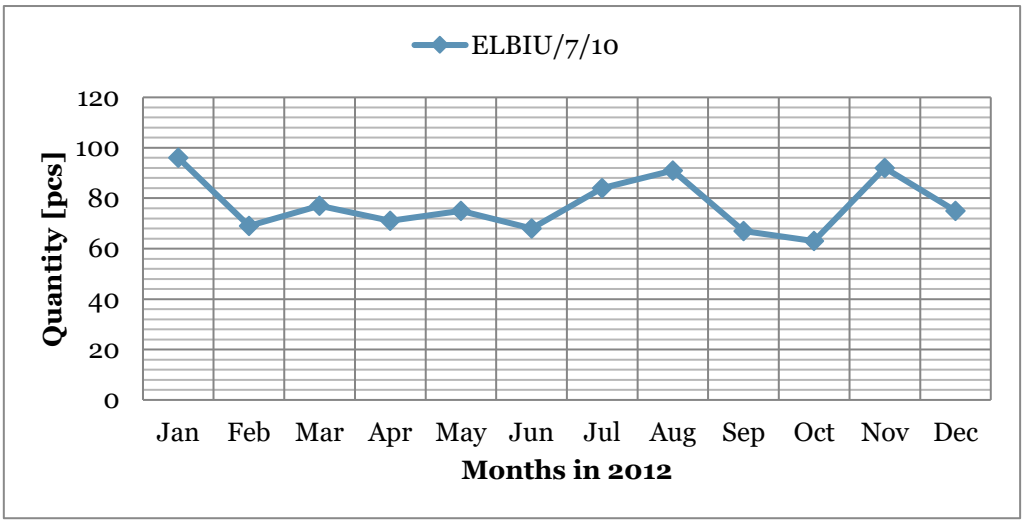


Graphic 2. 2011 demand in months ELBIU/7/10.

- 2012 weekly and monthly distribution of demand:

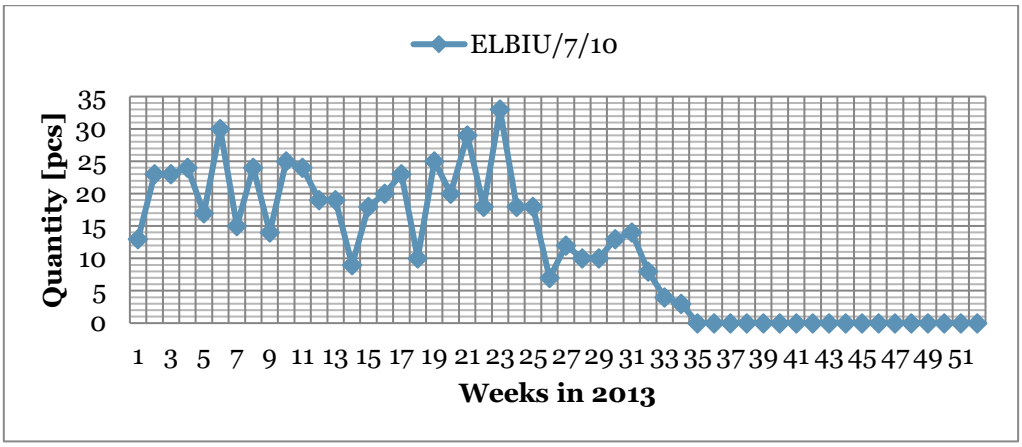


Graphic 3. 2012 demand in weeks ELBIU/7/10.

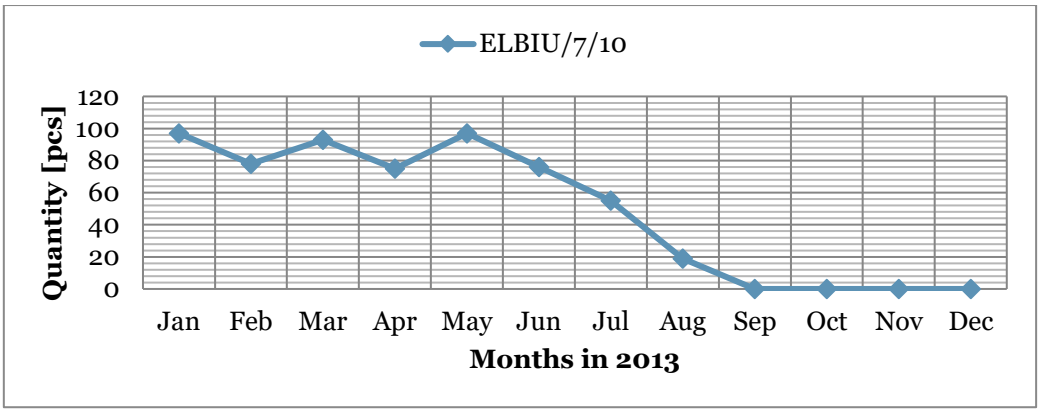


Graphic 4. 2012 demand in months ELBIU/7/10.

- 2013 weekly and monthly distribution of demand (half year data):



Graphic 5. 2013 demand in weeks ELBIU/7/10.



Graphic 6. 2013 demand in months ELBIU/7/10.

Based on above data we have to make a forecast for a second half of 2013 year. For better results we should analyse the weekly demand instead of monthly demand (statistically it has less data, only 12 per year).
Let's take a look on historical demand of ELBIU/7/10 furniture during years (weeks) 2011-2013:

ELBIU/7/10	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Year 2011	15	21	11	17	15	17	30	21	9	25	24	15	28	17
Year 2012	32	13	23	20	12	16	18	24	14	22	18	10	20	17
Year 2013	2	11	13	23	23	24	17	30	15	24	14	25	24	19
	January					February				March				
Average	16,3	15,0	15,7	20,0	16,7	19,0	21,7	25,0	12,7	23,7	18,7	16,7	24,0	17,7
Std. Dev.	15,0	5,3	6,4	3,0	5,7	4,4	7,2	4,6	3,2	1,5	5,0	7,6	4,0	1,2
4W Avg.	16,8				20,6				17,9				19,5	
4W St. Dev	7,7				5,8				5,9				6,9	
Forecast M	17				21				18				20	
Forecast W	16	15	16	20	17	19	22	25	13	24	19	17	24	18

ELBIU/7/10	15	16	17	18	19	20	21	22	23	24	25	26	27
Year 2011	17	34	5	24	24	17	16	12	14	23	14	20	16
Year 2012	10	20	17	14	15	14	13	28	8	29	13	16	16
Year 2013	19	9	18	20	23	10	25	20	29	18	33	18	18
	April				May					June			
Average	15,3	21,0	13,3	19,3	20,7	13,7	18,0	20,0	17,0	23,3	20,0	18,0	16,7
Std. Dev.	4,7	12,5	7,2	5,0	4,9	3,5	6,2	8,0	10,8	5,5	11,3	2,0	1,2
4W Avg.			16,8				19,6				16,4		
4W St. Dev			5,7				7,2				6,2		
Forecast M			17				20				16		
Forecast W	15	21	13	19	21	14	18	20	17	23	20	18	17

ELBIU/7/10	28	29	30	31	32	33	34	35	36	37	38	39	40
Year 2011	13	19	29	10	26	13	12	12	24	23	28	21	11
Year 2012	13	16	30	19	33	19	19	10	13	22	12	20	6
Year 2013	7	12	10	10	13	14	8	4	3				
	July				August				September				
Average	11,0	15,7	23,0	13,0	24,0	15,3	13,0	8,7	13,3	22,5	20,0	20,5	8,5
Std. Dev.	3,5	3,5	11,3	5,2	10,1	3,2	5,6	4,2	10,5	0,7	11,3	0,7	3,5
4W Avg.		18,9				12,6				17,9			
4W St. Dev		8,5				6,1				7,4			
Forecast M		19				13				18			
Forecast W	11	16	23	13	24	15	13	9	13	23	20	21	9

ELBIU/7/10	41	42	43	44	45	46	47	48	49	50	51	52
Year 2011	28	24	13	14	16	21	18	15	8	2	19	6
Year 2012	26	7	17	9	13	25	14	38	24	17	20	12
Year 2013												
	October				November				December			
Average	27,0	15,5	15,0	11,5	14,5	23,0	16,0	26,5	16,0	9,5	19,5	9,0
Std. Dev.	1,4	12,0	2,8	3,5	2,1	2,8	2,8	16,3	11,3	10,6	0,7	4,2
4W Avg.	17,3				20,0				13,5			
4W St. Dev	7,9				8,3				7,7			
Forecast M	17				20				14			
Forecast W	27	16	15	12	15	23	16	27	16	10	20	9

Table 1. Calculation historical demand ELBIU/7/10.

First row includes numbers of weeks. First column includes following data:

- **Year 2011** (Y1) – weekly demand in 2011, the number represents how many pieces of product was sold during each week,
- **Year 2012** (Y2) – weekly demand in 2012,
- **Year 2013** (Y3) – weekly demand in 2013,
- **Average** (AW) – average value of demand in the same week from 3 years,

- **Std.Dev.** (SDW) – standard deviation value of demand in the same week from 3 years,
- **4W Avg.** (AM)– average value of demand of 4 weeks (one month) from 3 years,
- **4W St.Dev.** (SDM) – standard deviation value of demand of 4 weeks (one month) from 3 years,
- **Forecast M** (FM)– forecast based on monthly prediction (4 weeks),
- **Forecast W** (FW) – forecast based on weekly prediction (1 week).

Because demand frequently is seasonal we can try calculate the average from the same weeks (given by number) in next years:

$$A_w(t) = \frac{\sum_{i=1}^{n} Y_i(t)}{n}$$

To evaluate the coincidence between years (if there is seasonal demand) we have to calculate also standard deviation:

$$SD_W(t) = \sigma_W(t) = \sqrt{\frac{\sum_{i=1}^{n}((Y_i(t) - A_W(t))^2}{n}}$$

The same calculations we can made for monthly demand, but there is one problem – in calendar we have 12 months which are different with total number of days. Because of this sometimes, in planning, we use 13 months scheme where each week has 4 weeks (28 days).
Taking this into consideration we can calculate the monthly average from demand (aggregating each next 4 weeks together):

$$A_M(m) = \frac{\sum_{j=1}^{4} A_W(j)}{4}$$

And also monthly standard deviation:

$$SD_w(t) = \sigma_w(t) = \sqrt{\frac{\sum_{i=1}^{4}((Y_i(j) - A_M(m))^2}{4}}$$

Weekly forecast can be the same as average calculated before (week by week):

$$F_W(w) = A_W(w)$$

Monthly forecast can be equal to monthly average (and each week in given month will be the same):

$$F_M(m) = A_M(m)$$

Final results:

ELBIU/7/10	Y_Sum	Y_Avg	Sigma	SL	SL	z	SS	
Year 2011	926	17,8	6,9	85%	0,85	1,036	7,1	
Year 2012	926	17,8	6,9	85%	0,85	1,036	7,2	
Year 2013	605	16,8	7,7	85%	0,85	1,036	8,0	**SS**
		17,5	7,2	0,9	0,9	1,0	7,4	8

Table 2. Calculation Security Stock ELBIU/7/10.

Finally, we can calculate:

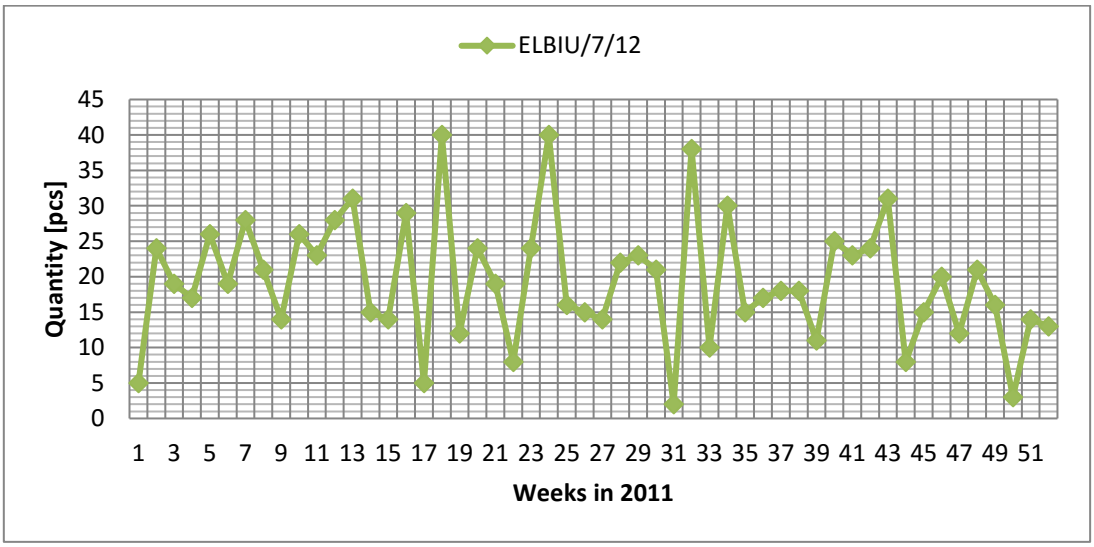
- **Y_Sum** – yearly sum of demand
- **Y_Avg** – weekly average demand
- **Sigma** – weekly standard deviation of demand
- **SL** – Service Level assumed by the company management stuff,
- **z** – coefficient which represent probability density taken from Gaussian distribution
- **SS** – safety stock of inventory.

$$SS = z * \sigma$$

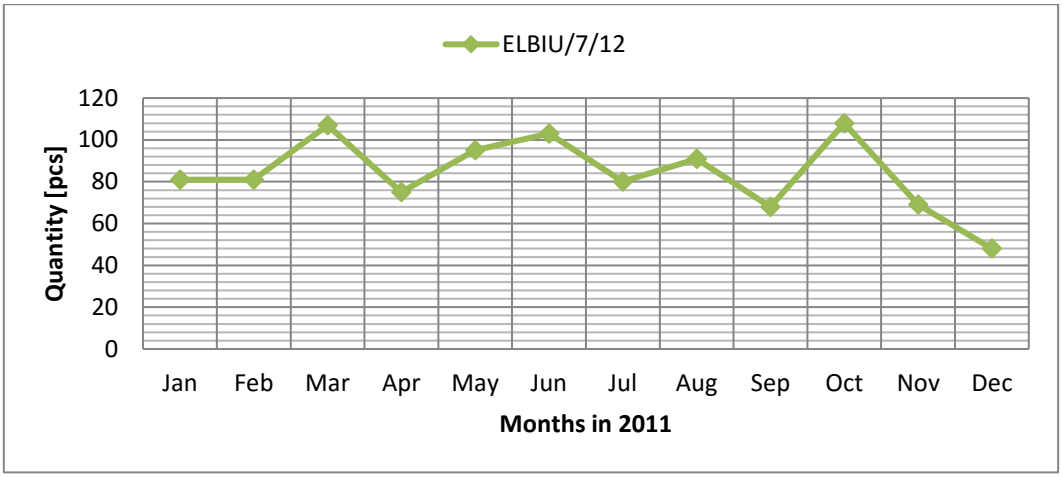
Based on this calculation we can consider the value of safety stock should be not less than 8 pieces in stock.

3.2. ELBIU/7/12

- 2011 weekly and monthly distribution of demand:

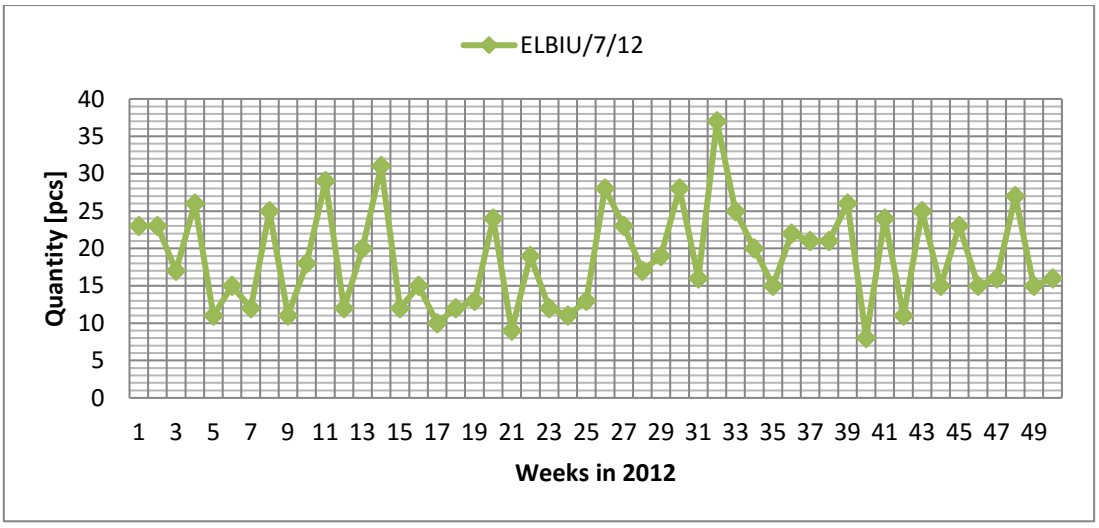


Graphic 7. 2011 demand in weeks ELBIU/7/12.

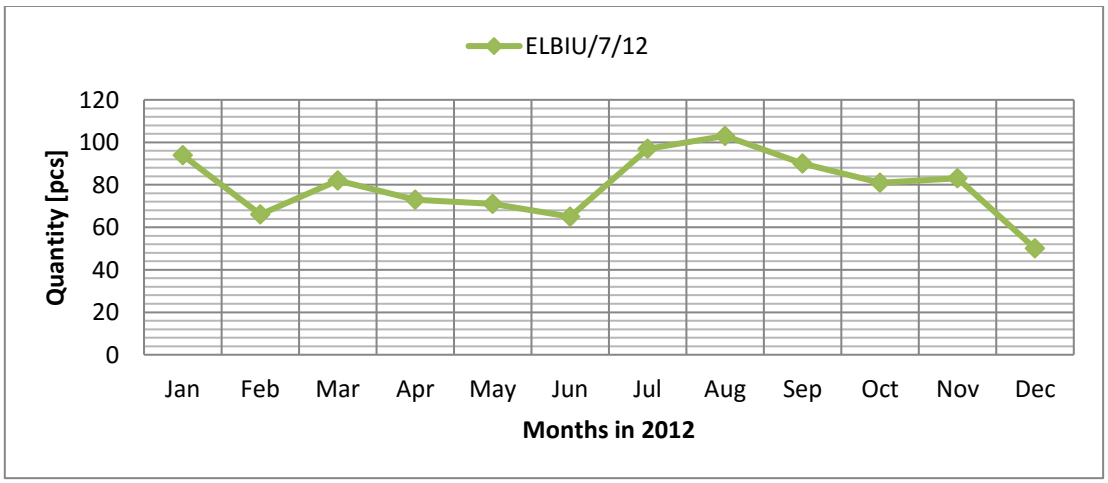


Graphic 8. 2011 demand in months ELBIU/7/12.

- 2012 weekly and monthly distribution of demand:

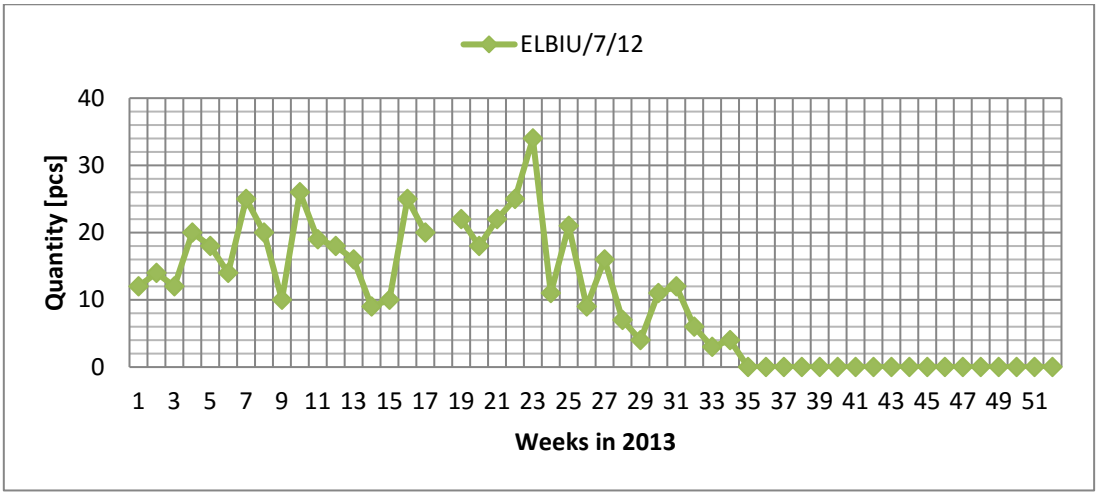


Graphic 9. 2012 demand in weeks ELBIU/7/12.

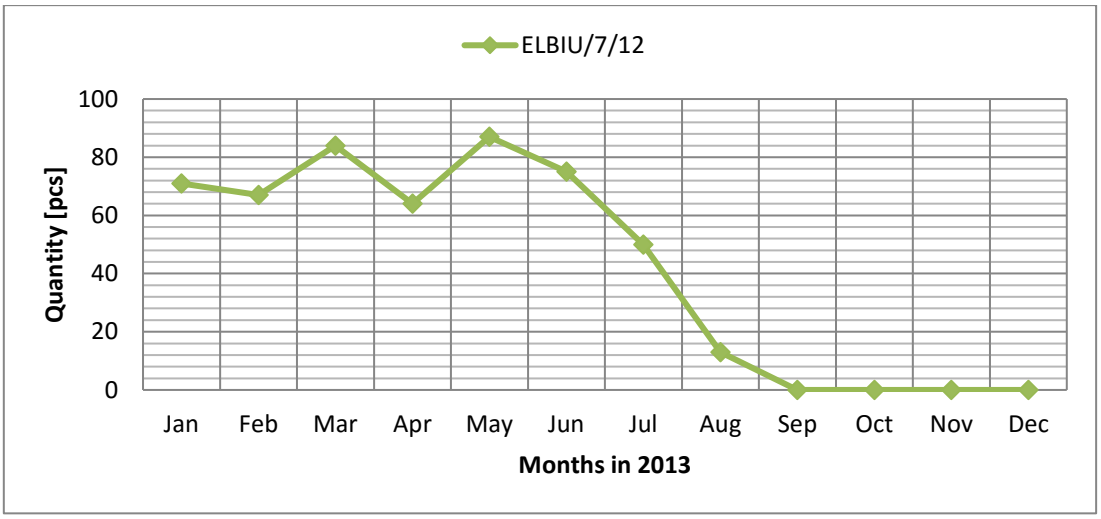


Graphic 10. 2012 demand in months ELBIU/7/12.

- 2013 weekly and monthly distribution of demand (half year data):



Graphic 11. 2013 demand in weeks ELBIU/7/12.



Graphic 12. 2013 demand in months ELBIU/7/12.

Let's take a look on historical demand of ELBIU/7/12 furniture during years (weeks) 2011-2013:

ELBIU/7/12	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Year 2011	5	24	19	17	26	19	28	21	14	26	23	28	31	15
Year 2012	23	23	17	26	11	15	12	25	11	18	29	12	20	31
Year 2013	2	10	12	14	12	20	18	14	25	20	10	26	19	18
	January					February				March				
Average	10,0	19,0	16,0	19,0	16,3	18,0	19,3	20,0	16,7	21,3	20,7	22,0	23,3	21,3
Std. Dev.	11,4	7,8	3,6	6,2	8,4	2,6	8,1	5,6	7,4	4,2	9,7	8,7	6,7	8,5
4W Avg.	16,0				18,4				20,2				19,1	
4W St. Dev	7,7				5,8				7,0				7,4	
Forecast M	16				18				20				19	
Forecast W	10	19	16	19	16	18	19	20	17	21	21	22	23	21

ELBIU/7/12	15	16	17	18	19	20	21	22	23	24	25	26	27
Year 2011	14	29	5	40	12	24	19	8	24	40	16	15	14
Year 2012	12	15	10	12	13	24	9	19	12	11	13	28	23
Year 2013	16	9	10	25	20	0	22	18	22	25	34	11	21
	April				May					June			
Average	14,0	17,7	8,3	25,7	15,0	16,0	16,7	15,0	19,3	25,3	21,0	18,0	19,3
Std. Dev.	2,0	10,3	2,9	14,0	4,4	13,9	6,8	6,1	6,4	14,5	11,4	8,9	4,7
4W Avg.			16,3				19,1				18,6		
4W St. Dev			10,8				8,8				7,3		
Forecast M			16				19				19		
Forecast W	14	18	8	26	15	16	17	15	19	25	21	18	19

ELBIU/7/12	28	29	30	31	32	33	34	35	36	37	38	39	40
Year 2011	22	23	21	2	38	10	30	15	17	18	18	11	25
Year 2012	17	19	28	16	37	25	20	15	22	21	21	26	8
Year 2013	9	16	7	4	11	12	6	3	4				
	July				August				September				
Average	16,0	19,3	18,7	7,3	28,7	15,7	18,7	11,0	14,3	19,5	19,5	18,5	16,5
Std. Dev.	6,6	3,5	10,7	7,6	15,3	8,1	12,1	6,9	9,3	2,1	2,1	10,6	12,0
4W Avg.		18,5				14,9				18,5			
4W St. Dev		11,8				8,4				6,3			
Forecast M		19				15				19			
Forecast W	16	19	19	7	29	16	19	11	14	20	20	19	17

ELBIU/7/12		41	42	43	44	45	46	47	48	49	50	51	52
Year 2011		23	24	31	8	15	20	12	21	16	3	14	13
Year 2012		24	11	25	15	23	15	16	27	15	16	7	10
Year 2013													
		October				November				December			
Average		23,5	17,5	28,0	11,5	19,0	17,5	14,0	24,0	15,5	9,5	10,5	11,5
Std. Dev.		0,7	9,2	4,2	4,9	5,7	3,5	2,8	4,2	0,7	9,2	4,9	2,1
4W Avg.		20,1				18,6				11,8			
4W St. Dev		7,9				5,0				4,7			
Forecast M		20				19				12			
Forecast W		24	18	28	12	19	18	14	24	16	10	11	12

Table 3. Calculation historical demand ELBIU/7/12.

Final results:

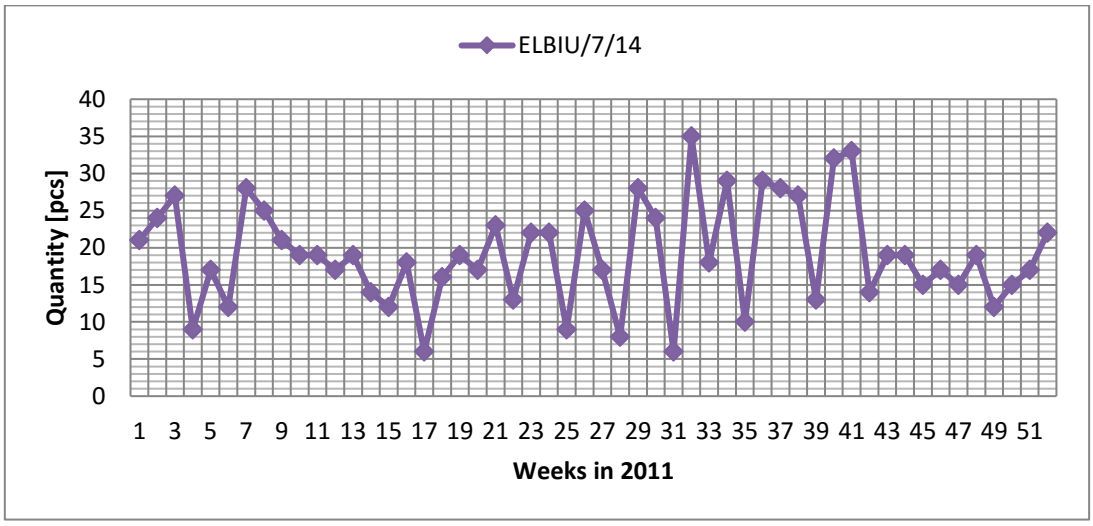
ELBIU/7/12	Y_Sum	Y_Avg	Sigma	SL	SL	z	SS	
Year 2011	1006	19,3	8,7	85%	0,85	1,036	9,0	
Year 2012	953	18,3	6,8	85%	0,85	1,036	7,0	
Year 2013	525	14,6	7,9	85%	0,85	1,036	8,1	**SS**
		17,4	7,8	0,9	0,9	1,0	8,1	9

Table 4. Calculation Security Stock ELBIU/7/12.

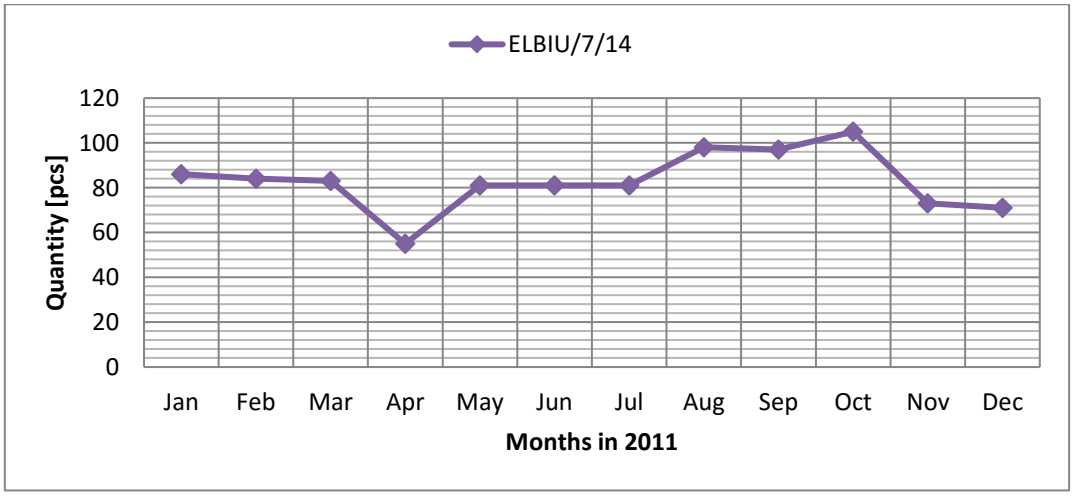
Based on this calculation we can consider the value of safety stock should be not less than 9 pieces in stock.

3.3. ELBIU/7/14

- 2011 weekly and monthly distribution of demand:

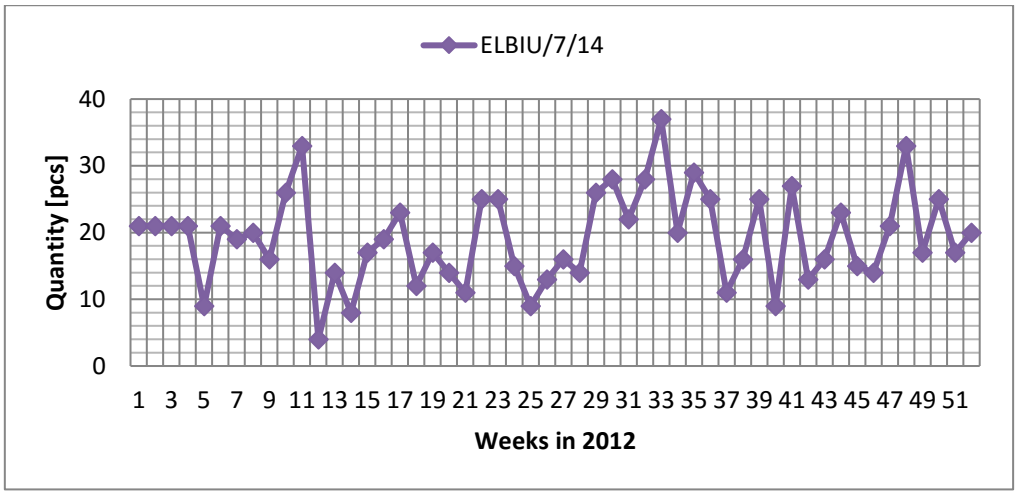


Graphic 13. 2011 demand in weeks ELBIU/7/14.

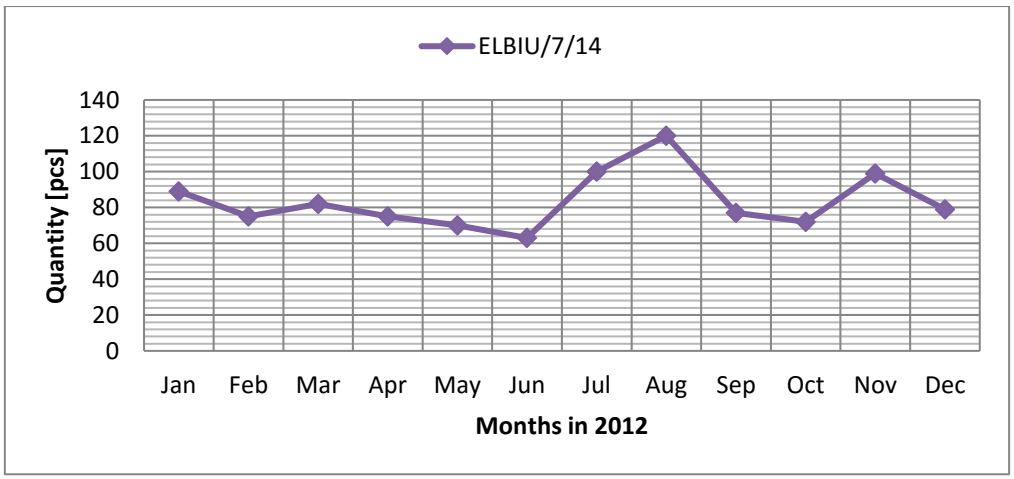


Graphic 14. 2011 demand in months ELBIU/7/14.

- 2012 weekly and monthly distribution of demand:

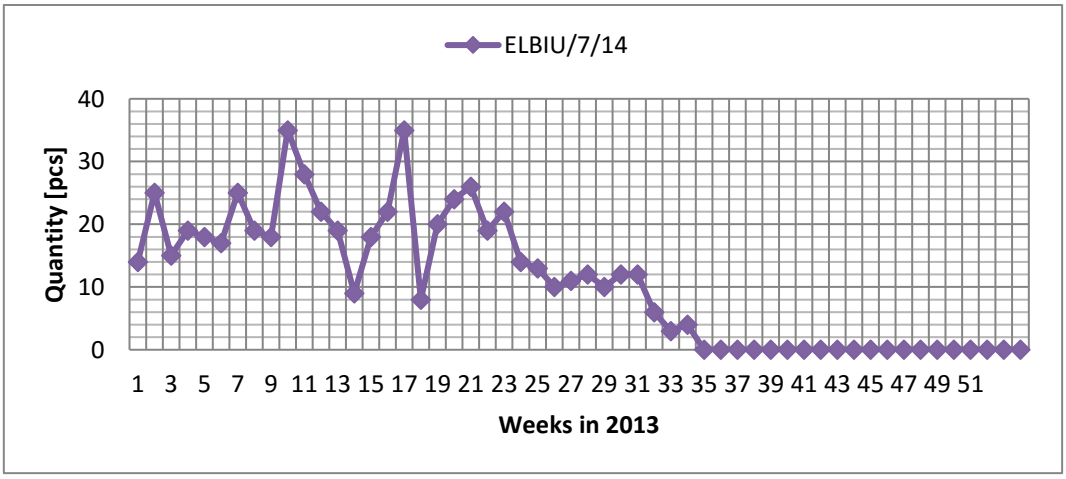


Graphic 15. 2012 demand in weeks ELBIU/7/14.

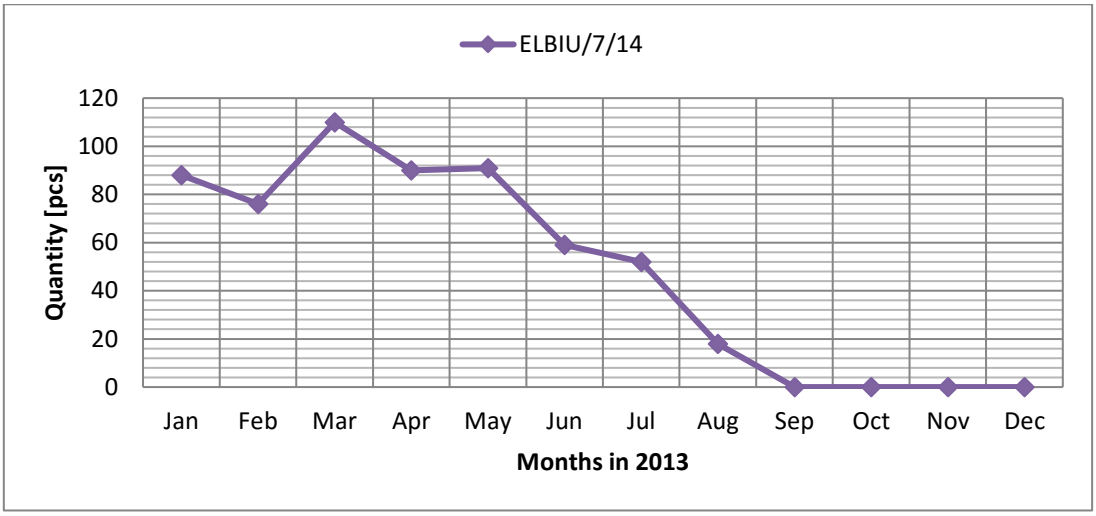


Graphic 16. 2012 demand in months ELBIU/7/14.

- 2013 weekly and monthly distribution of demand (half year data):



Graphic 17. 2013 demand in weeks ELBIU/7/14.



Graphic 16. 2013 demand in months ELBIU/7/14.

Let's take a look on historical demand of ELBIU/7/14 furniture during years (weeks) 2011-2013:

ELBIU/7/14	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Year 2011	21	24	27	9	17	12	28	25	21	19	19	17	19	14
Year 2012	21	21	21	21	9	21	19	20	16	26	33	4	14	8
Year 2013	0	14	14	25	15	19	18	17	25	19	18	35	28	22
	January					February				March				
Average	14,0	19,7	20,7	18,3	13,7	17,3	21,7	20,7	20,7	21,3	23,3	18,7	20,3	14,7
Std. Dev.	12,1	5,1	6,5	8,3	4,2	4,7	5,5	4,0	4,5	4,0	8,4	15,6	7,1	7,0
4W Avg.	18,2				18,3				21,0				16,6	
4W St. Dev	7,7				5,1				8,2				5,6	
Forecast M	18				18				21				17	
Forecast W	14	20	21	18	14	17	22	21	21	21	23	19	20	15

ELBIU/7/14	15	16	17	18	19	20	21	22	23	24	25	26	27
Year 2011	12	18	6	16	19	17	23	13	22	22	9	25	17
Year 2012	17	19	23	12	17	14	11	25	25	15	9	13	16
Year 2013	19	9	18	22	35	8	20	24	26	19	22	14	13
	April				May					June			
Average	16,0	15,3	15,7	16,7	23,7	13,0	18,0	20,7	24,3	18,7	13,3	17,3	15,3
Std. Dev.	3,6	5,5	8,7	5,0	9,9	4,6	6,2	6,7	2,1	3,5	7,5	6,7	2,1
4W Avg.			17,3				20,4				14,2		
4W St. Dev			7,5				5,0				5,2		
Forecast M			17				20				14		
Forecast W	16	15	16	17	24	13	18	21	24	19	13	17	15

ELBIU/7/14	28	29	30	31	32	33	34	35	36	37	38	39	40
Year 2011	8	28	24	6	35	18	29	10	29	28	27	13	32
Year 2012	14	26	28	22	28	37	20	29	25	11	16	25	9
Year 2013	10	11	12	10	12	12	6	3	4				
	July				August				September				
Average	10,7	21,7	21,3	12,7	25,0	22,3	18,3	14,0	19,3	19,5	21,5	19,0	20,5
Std. Dev.	3,1	9,3	8,3	8,3	11,8	13,1	11,6	13,5	13,4	12,0	7,8	8,5	16,3
4W Avg.		20,2				18,5				20,1			
4W St. Dev		9,4				11,4				8,9			
Forecast M		20				19				20			
Forecast W	11	22	21	13	25	22	18	14	19	20	22	19	21

ELBIU/7/14	41	42	43	44	45	46	47	48	49	50	51	52
Year 2011	33	14	19	19	15	17	15	19	12	15	17	22
Year 2012	27	13	16	23	15	14	21	33	17	25	17	20
Year 2013												
	October				November				December			
Average	30,0	13,5	17,5	21,0	15,0	15,5	18,0	26,0	14,5	20,0	17,0	21,0
Std. Dev.	4,2	0,7	2,1	2,8	0,0	2,1	4,2	9,9	3,5	7,1	0,0	1,4
4W Avg.	20,5				18,6				18,1			
4W St. Dev	6,8				6,3				4,1			
Forecast M	21				19				18			
Forecast W	30	14	18	21	15	16	18	26	15	20	17	21

Table 5. Calculation historical demand ELBIU/7/14.

Final results:

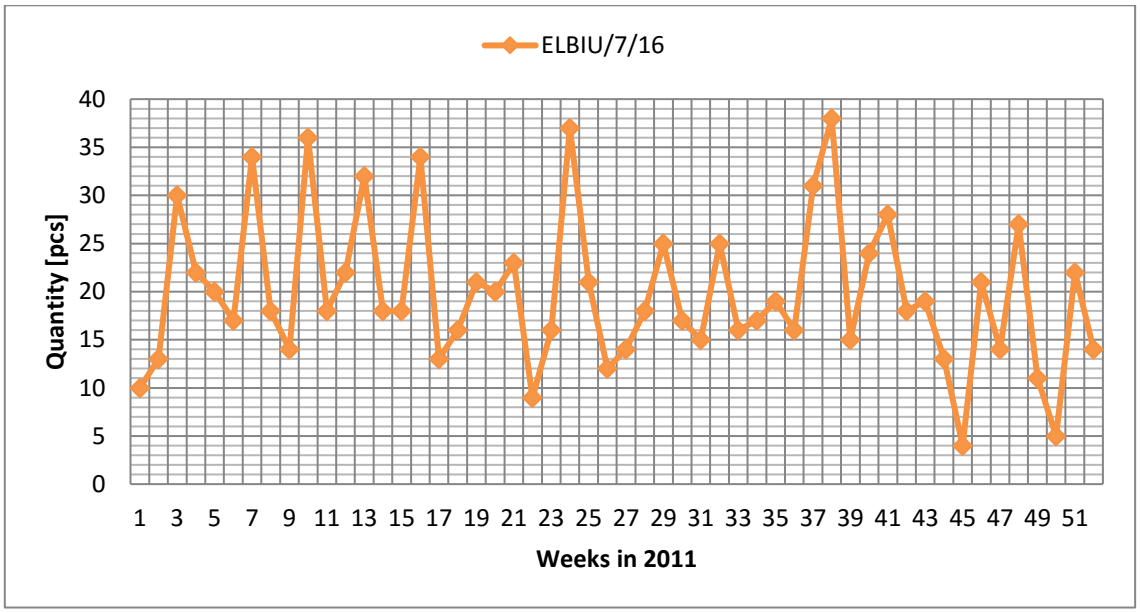
ELBIU/7/14	Y_Sum	Y_Avg	Sigma	SL	SL	z	SS	
Year 2011	995	19,1	6,9	85%	0,85	1,036	7,2	
Year 2012	1001	19,3	7,0	85%	0,85	1,036	7,2	
Year 2013	598	16,6	8,1	85%	0,85	1,036	8,4	SS
		18,3	7,3	0,9	0,9	1,0	7,6	8

Table 6. Calculation Security Stock ELBIU/7/14.

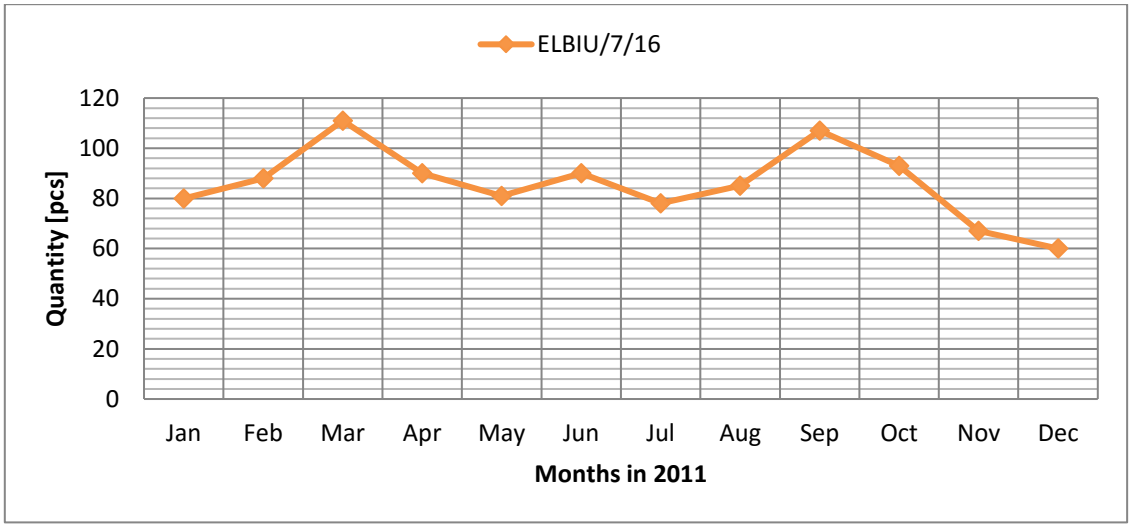
Based on this calculation we can consider the value of safety stock should be not less than 8 pieces in stock.

3.4. ELBIU/7/14

- 2011 weekly and monthly distribution of demand:

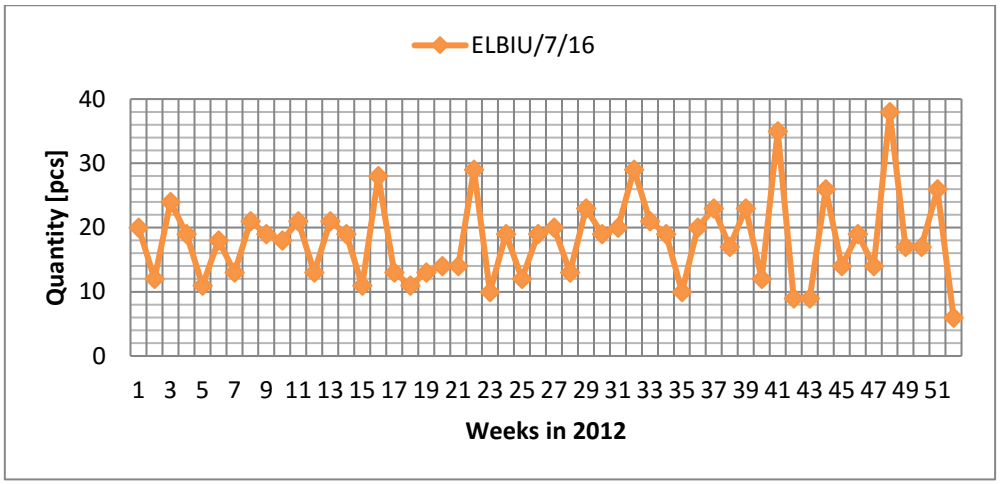


Graphic 17. 2011 demand in weeks ELBIU/7/16.

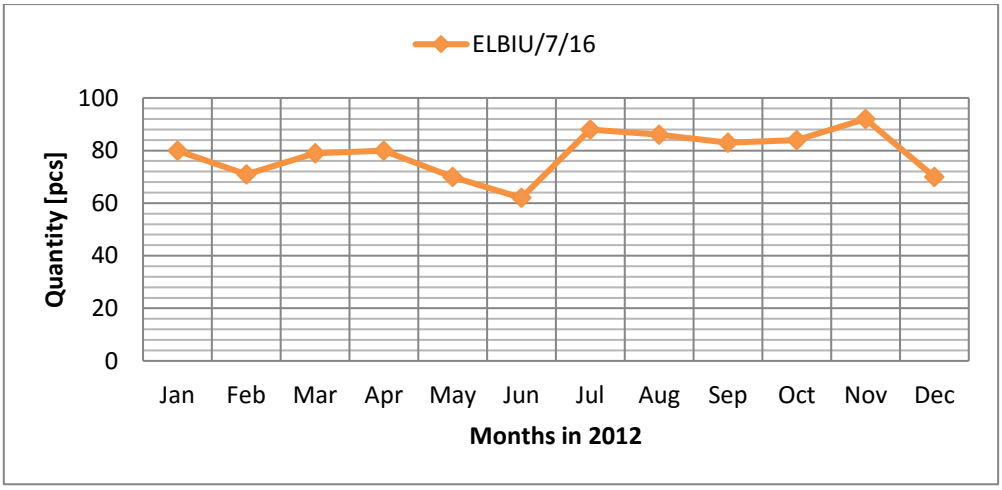


Graphic 18. 2011 demand in months ELBIU/7/16.

- 2012 weekly and monthly distribution of demand:

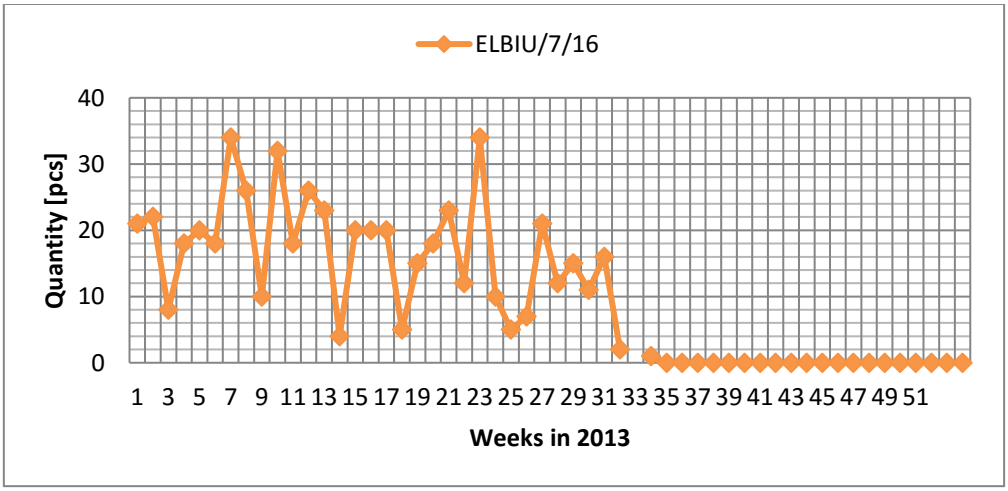


Graphic 19. 2012 demand in weeks ELBIU/7/16.



Graphic 20. 2012 demand in months ELBIU/7/16.

- 2013 weekly and monthly distribution of demand (half year data):



Graphic 21. 2013 demand in weeks ELBIU/7/16.

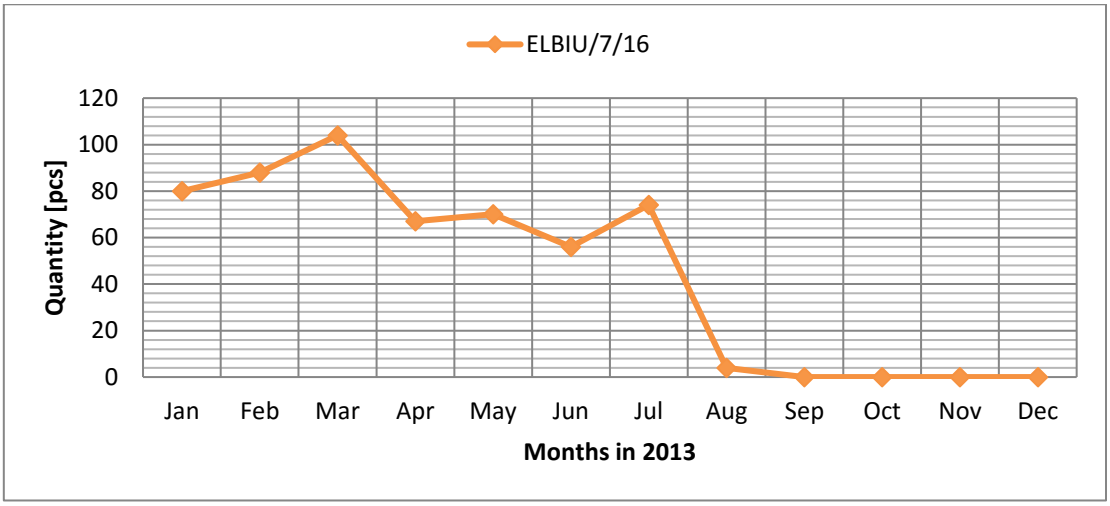


Image 22. 2013 demand in months ELBIU/7/16.

Let's take a look on historical demand of ELBIU/7/16 furniture during years (weeks) 2011-2013:

ELBIU/7/16	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Year 2011	10	13	30	22	20	17	34	18	14	36	18	22	32	18
Year 2012	20	12	24	19	11	18	13	21	19	18	21	13	21	19
Year 2013	4	17	21	22	8	18	20	18	34	26	10	32	18	26
	January					February				March				
Average	11,3	14,0	25,0	21,0	13,0	17,7	22,3	19,0	22,3	26,7	16,3	22,3	23,7	21,0
Std. Dev.	8,1	2,6	4,6	1,7	6,2	0,6	10,7	1,7	10,4	9,0	5,7	9,5	7,4	4,4
4W Avg.	17,8				18,0				21,9				21,0	
4W St. Dev	7,1				6,4				8,5				8,5	
Forecast M	18				18				22				21	
Forecast W	11	14	25	21	13	18	22	19	22	27	16	22	24	21

ELBIU/7/16	15	16	17	18	19	20	21	22	23	24	25	26	27
Year 2011	18	34	13	16	21	20	23	9	16	37	21	12	14
Year 2012	11	28	13	11	13	14	14	29	10	19	12	19	20
Year 2013	23	4	20	20	20	5	15	18	23	12	34	10	5
	April				May					June			
Average	17,3	22,0	15,3	15,7	18,0	13,0	17,3	18,7	16,3	22,7	22,3	13,7	13,0
Std. Dev.	6,0	15,9	4,0	4,5	4,4	7,5	4,9	10,0	6,5	12,9	11,1	4,7	7,5
4W Avg.			15,5				18,8				15,4		
4W St. Dev			4,9				8,2				7,7		
Forecast M			16				19				15		
Forecast W	17	22	15	16	18	13	17	19	16	23	22	14	13

ELBIU/7/16	28	29	30	31	32	33	34	35	36	37	38	39	40
Year 2011	18	25	17	15	25	16	17	19	16	31	38	15	24
Year 2012	13	23	19	20	29	21	19	10	20	23	17	23	12
Year 2013	7	21	12	15	11	16	2	0	1				
	July				August				September				
Average	12,7	23,0	16,0	16,7	21,7	17,7	12,7	9,7	12,3	27,0	27,5	19,0	18,0
Std. Dev.	5,5	2,0	3,6	2,9	9,5	2,9	9,3	9,5	10,0	5,7	14,8	5,7	8,5
4W Avg.		19,3				13,1				22,9			
4W St. Dev		5,6				7,8				8,5			
Forecast M		19				13				23			
Forecast W	13	23	16	17	22	18	13	10	12	27	28	19	18

ELBIU/7/16	41	42	43	44	45	46	47	48	49	50	51	52
Year 2011	28	18	19	13	4	21	14	27	11	5	22	14
Year 2012	35	9	9	26	14	19	14	38	17	17	26	6
Year 2013												
	October				November				December			
Average	31,5	13,5	14,0	19,5	9,0	20,0	14,0	32,5	14,0	11,0	24,0	10,0
Std. Dev.	4,9	6,4	7,1	9,2	7,1	1,4	0,0	7,8	4,2	8,5	2,8	5,7
4W Avg.	19,6				18,9				14,8			
4W St. Dev	9,4				10,2				7,3			
Forecast M	20				19				15			
Forecast W	32	14	14	20	9	20	14	33	14	11	24	10

Table 7. Calculation historical demand ELBIU/7/16.

Final results:

ELBIU/7/16	Y_Sum	Y_Avg	Sigma	SL	SL	z	SS	
Year 2011	1030	19,8	7,8	85%	0,85	1,036	8,1	
Year 2012	941	18,1	6,6	85%	0,85	1,036	6,8	
Year 2013	568	15,8	9,0	85%	0,85	1,036	9,3	SS
		17,9	7,8	0,9	0,9	1,0	8,1	9

Table 8. Calculation Security Stock ELBIU/7/16.

Based on this calculation we can consider the value of safety stock should be not less than 9 pieces in stock.

4. Manufacturing process planning

We should start with manufacturing system and necessary operations. The most of produced parts are made from MDF or HDF boards. The raw material is a sheet which have to be cut-off on smaller parts. Next step is a drilling and milling holes, which are necessary to put in different kind of fasteners (needed to join MDF boards together). Finally, some sides of boards need to be banded.

The MDF or HDF can be purchased on the market in the form of large sheets:

- **HDF 3**, sheet dimensions 2800 x 2070, thickness 3 mm; purpose of use: furniture back side wall,
- **MDF 12**, sheet dimensions 2800 x 2070, thickness 12 mm; purpose of use: drawer side walls,
- **MDF 16**, sheet dimensions 2800 x 2070, thickness 16 mm; purpose of use: fronts (doors),
- **MDF 18**, sheet dimensions 2800 x 2070, thickness 18 mm; purpose of use: internal structural walls of furniture (walls and shelves),
- **MDF 22**, sheet dimensions 2800 x 2070, thickness 22 mm; purpose of use: external structural walls of furniture,
- **MDF 32**, sheet dimensions 2800 x 2070, thickness 32 mm; purpose of use: working elements, worktop, top and bottom walls of furniture.

The process will be as follow:

- Operation 1 = Workstation S1: cutting-off MDF/HDF sheets.
- Operation 2 = Workstation S2: drilling/milling holes.
- Operation 3 = Workstation S3: edge vacuum veneering with MDF edge banding tape.

4.1. Cutting off MDF/HDF sheets

First it is necessary to find a machine to perform this operation. We decided to use a CNC circular saw MJ300:

Image 5. CNC circular saw MJ300.

It has following parameters:

Model	**MJ300**
Maximum length of the panel (mm)	3000
Maximum width of the panel (mm)	2800
Maximum thickness of panel (mm)	80
Main blade rotation (rpm)	4500-57000
Angle of the main saw	90º-45
Power (kw/v/Hz)	5,5/380/50
Machine size (mm)	3200x2800x1000
Net weight (kg)	1200

Table 9. CNC circular saw MJ300 parameters.

And the disk for MDF cut-off is: 300x30x3.2/2.2 z=96 GA:

Image 6. Disk 300x30x3,2/2,2 z=96..

We need cut off each MDF and HDF sheets at the required dimensions. Also, we need to find the most economical method to cut the sheets. The goal is to get the least scraps. The input materials have the same dimensions for the MDF and the HDF sheets. Only the thickness differs between each board.
INPUT Materials: Ls = 2 800 mm, Hs = 2 070 mm
Assumptions:
- We don't make a cutting-off plan for different parts size. Each component is cut-off from full size MDF/HDF sheet separately.
- For one MDF/HDF sheet we need to find optimal way of cut-off for given part to minimize the scrap. It causes that from one sheet we get always the same number of cut-off boards (here is an area [m_2] usage) and scrap (in form of chips and small unnecessary boards).

Our task is to find the optimal way of boards cut-off from one MDF sheet. We can decide only about the horizontal or vertical placement of board in sheet. The minimum of scrap is the criterion of optimization.
Moreover, we need to consider also:

- Each full MDF sheet must be aligned, it means that from each side we need to cut-of material with width 15 mm!
- Each cut-off generates the loss of material (is changed into chips) and it is equal to disk saw width, typically it is 4.5 mm.

4.1.1. ELBIU/7/10

The calculation for each sheet of the way the most economic to get the most of parts:
INPUT MATERIALS: Ls = 2800 mm Hs=2070 mm

ITEM	Dimension		Formula		Choice variant	Number of parts
	Lf (m)	Hf (m)	N1	N2		
C1	0,674	0,64	12	12	1	12
C2	0,674	0,64	12	12	1	12
C3	0,718	0,64	9	8	1	9
C4	1	0,64	6	8	2	8
C5	0,3	0,64	27	24	1	27
C6	0,255	0,601	30	28	1	30
C7	0,607	0,4	20	18	1	20
C8	0,678	0,156	48	51	2	51
C9	0,255	0,156	120	119	1	120
C10	0,5	0,1	95	104	2	104
C11	0,5	0,1	95	104	2	104
C12	0,215	0,086	264	270	2	270
C13	0,255	0,509	30	35	2	35
C14	0,249	0,15	130	136	2	136

Table 10. Choice variant and number of parts ELBIU/7/10.

You can find all the calculations in file Cut_off.xlsx.

Now it is time to calculate the cutting time. The components of time standard for cutting-off operation are:

- **Setup time *tpz*** [min] which includes:
  - All organizational activities related to entering and leaving work on given stand, e.g. equipping machine tools with work holders (chucks, centres etc.) and cutting tools, etc.
- Value n [pcs] defines the batch or production order size,
- Time per unit *tj* [min]:
  - **Production time tw**, which can be presented as a sum of **Machine time tg [min]** and **Auxiliary time tp [min]**, includes all activities directly connected with production of one piece of product.
  - **Complementary time tu** which is a sum of **Service time to [min]** and **Physiological time tf [min]** (e.g. idle time for breakfast or rest, typically it is

30 minutes of worker break during one 8 hours shift). To simplify it, we can use additive method, and assume that is equal up to 20% of production time *tw* [min].

- **Machine time tg [min]** is understood as a time of tool contact with the workpiece during cutting,
- **Auxiliary time tp [min]**, which includes activities necessary to realize machining, e.g. setup and position change of workpiece, tool change, feed or rotational speed change.

To find out the time per unit *tj* we have to calculate:

$$t_j = t_w + t_u = t_w + 0{,}2 * t_w = 1{,}2 * t_w = 1{,}2 * (t_g + t_p)$$

This is the estimation of time to cut off each MDF board:

ITEM	Dimensions		Number of parts P	Number of cutting following the direction		tg per sheet (min)	tp per sheet (min)	tw per sheet (min)	tj per part (min)
	Lb (m)	Hb (m)		DLs	DHs				
C1	0,674	0,64	12	4	3	8,63	14,38	27,61	2,30
C2	0,674	0,64	12	4	3	8,63	14,38	27,61	2,30
C3	0,718	0,64	9	3	3	6,74	11,50	21,89	2,43
C4	1	0,64	8	4	2	5,26	9,59	17,81	2,23
C5	0,3	0,64	27	9	3	10,34	20,21	36,66	1,36
C6	0,255	0,601	30	10	3	10,94	21,67	39,13	1,30
C7	0,607	0,4	20	4	5	11,51	19,68	37,43	1,87
C8	0,678	0,156	51	17	3	15,14	28,49	52,36	1,03
C9	0,255	0,156	120	10	12	40,51	78,08	56,05	1,19
C10	0,5	0,1	104	26	4	27,03	58,91	39,13	0,99
C11	0,5	0,1	104	26	4	27,03	58,91	103,12	1,87
C12	0,215	0,086	270	30	9	66,65	146,39	255,65	1,03
C13	0,255	0,509	35	5	7	17,08	29,63	56,05	1,60
C14	0,249	0,15	136	17	8	38,37	79,63	141,59	1,05
				Total time (min)		293,83	591,46	912,10	22,55
				Total time (h)		4,90	9,86	15,20	0,38
						Average time (min)			1,61

Table 11. Times Cut-off ELBIU/7/10.

You can find the calculations of each MDF board in the file StandardTime_Cut.xlsx.

4.1.2. ELBIU/7/12

The calculation for each sheet of the way the most economic to get the most of parts:
INPUT MATERIALS: Ls = 2800 mm Hs=2070 mm

ITEM	Dimensions		Formula		Choice variant	Number of parts
	Lf (m)	Hf (m)	n1	n2		
C1	0,718	0,64	9	8	1	9
C2	0,718	0,64	9	8	1	9
C3	0,42	0,12	96	88	1	96
C4	0,42	0,12	96	88	1	96
C5	0,746	0,12	48	44	1	48
C6	1,2	0,64	6	4	1	6
C7	0,702	0,47	12	10	1	12
C8	1,155	0,32	12	8	1	12

Table 12. Choice variant and number of parts ELBIU/7/12.

You can find all the calculations in file Cut_off.xlsx.

Now it is time to calculate the cutting time. This is the estimation of time to cut off each MDF board:

ITEM	Dimensions		Number of parts P	Number of cutting following the direction		tg per sheet (min)	tp per sheet (min)	tw per sheet (min)	tj per part (min)
	Lb (m)	Hb (m)		DLs	DHs				
C1	0,718	0,64	9	3	9	6,74	11,50	21,89	2,43
C2	0,718	0,64	9	3	9	6,74	11,50	21,89	2,43
C3	0,42	0,12	96	16	96	40,85	70,50	133,62	1,39
C4	0,42	0,12	96	16	96	40,85	70,50	133,62	1,39
C5	0,746	0,12	48	16	48	31,25	48,94	96,22	2,00
C6	1,2	0,64	6	3	6	6,14	10,05	19,43	3,24
C7	0,702	0,47	12	4	12	8,63	14,38	27,61	2,30
C8	1,155	0,32	12	6	12	11,20	17,24	34,12	2,84
				Total time (min)		152,38	254,62	488,40	18,03
				Total time (h)		2,54	4,24	8,14	0,30
						Average time (min)			2,25

Table 13. Times Cut-off ELBIU/7/12.

You can find the calculations of each MDF board in the file StandardTime_Cut.xlsx.

4.1.3. ELBIU/7/14

The calculation for each sheet of the way the most economic to get the most of parts:
INPUT MATERIALS: Ls = 2800 mm Hs=2070 mm

ITEM	Dimensions		Formula		Choice variant	Number of parts
	Lf (m)	Hf (m)	n1	n2		
C1	0,674	0,64	12	12	1	12
C2	0,674	0,64	12	12	1	12
C3	0,674	0,64	12	12	1	12
C4	0,674	0,64	12	12	1	12
C5	1,4	0,64	3	4	2	3
C6	0,38	0,64	21	20	1	21
C7	0,355	0,603	21	20	1	21
C8	0,633	0,4	20	18	1	20
C9	0,641	0,574	12	12	1	12
C10	0,335	0,674	24	24	1	24
C11	0,5	0,1	95	104	2	104
C12	0,5	0,1	95	104	2	104
C13	0,295	0,087	198	180	1	198
C14	0,5	0,13	75	80	2	80
C15	0,5	0,13	75	80	2	80
C16	0,295	0,117	144	132	1	144
C17	0,305	0,509	24	30	2	30
C18	0,329	0,516	24	30	2	30
C19	0,329	0,146	104	108	2	104
C20	0,329	0,216	72	72	1	72

Table 14. Choice variant and number of parts ELBIU/7/14.

You can find all the calculations in file Cut_off.xlsx.

Now it is time to calculate the cutting time. This is the estimation of time to cut off each MDF board:

ITEM	Dimensions		Number of parts P	Number of cutting following the direction		tg per sheet (min)	tp per sheet (min)	tw per sheet (min)	tj per part (min)
	Lb (m)	Hb (m)		DLs	DHs				
C1	0,674	0,64	12	4	3	7,34	12,95	24,35	2,03
C2	0,674	0,64	12	4	3	7,34	12,95	24,35	2,03
C3	0,674	0,64	12	4	3	7,34	12,95	24,35	2,03
C4	0,674	0,64	12	4	3	7,34	12,95	24,35	2,03
C5	1,4	0,64	3	1	4	3,17	6,39	11,48	2,87
C6	0,38	0,64	21	7	3	9,14	17,31	31,74	1,51
C7	0,355	0,603	21	7	3	9,14	17,31	31,74	1,51
C8	0,633	0,4	20	4	5	11,51	19,68	37,43	1,87

C9	0,641	0,574	12	4	3	7,34	12,95	238,88	2,03
C10	0,335	0,674	24	8	3	9,74	18,76	31,74	1,43
C11	0,5	0,1	104	26	4	27,03	58,91	103,12	1,51
C12	0,5	0,1	104	26	4	27,03	58,91	103,12	1,87
C13	0,295	0,087	198	9	22	68,96	130,11	238,88	1,21
C14	0,5	0,13	80	20	4	22,23	48,96	85,43	1,07
C15	0,5	0,13	80	20	4	22,23	48,96	85,43	1,07
C16	0,295	0,117	144	9	16	50,45	95,41	175,02	1,22
C17	0,305	0,509	30	5	6	14,80	25,95	48,89	1,63
C18	0,329	0,516	30	5	6	14,80	25,95	48,89	1,63
C19	0,329	0,146	104	18	6	30,40	63,70	112,92	1,05
C20	0,329	0,216	72	8	9	27,05	51,56	94,34	1,31
				Total time (min)		384,34	752,66	1576,45	32,89
				Total time (h)		6,41	12,54	26,27	0,55
						Average time (min)			1,64

Table 15. Times Cut-off ELBIU/7/14.

You can find the calculations of each MDF board in the file StandardTime_Cut.xlsx.

4.1.4. ELBIU/7/16

The calculation for each sheet of the way the most economic to get the most of parts:
INPUT MATERIALS: Ls = 2800 mm Hs=2070 mm

ITEM	Dimensions		Formula		Choice variant	Number of parts
	Lf (m)	Hf (m)	n1	n2		
C1	0,718	0,64	9	8	1	9
C2	0,718	0,64	9	8	1	9
C3	1,6	0,64	3	4	2	4
C4	1,555	0,12	16	22	2	22
C5	1,555	0,32	6	8	2	8

Table 16. Choice variant and number of parts ELBIU/7/16.

You can find all the calculations in file Cut_off.xlsx.

Now it is time to calculate the cutting time. This is the estimation of time to cut off each MDF board:

ITEM	Dimensions		Number of parts P	Number of cutting following the direction		tg per sheet (min)	tp per sheet (min)	tw per sheet (min)	tj per part (min)
	Lb (m)	Hb (m)		DLs	DHs				
C1	0,718	0,64	9	3	3	6,74	11,50	21,89	2,43
C2	0,718	0,64	9	3	3	6,74	11,50	21,89	2,43

C3	1,6	0,64	4	4	1	3,17	6,39	11,48	2,87
C4	1,555	0,12	22	22	1	6,77	15,11	26,25	1,19
C5	1,555	0,32	8	8	1	3,97	8,66	15,16	1,89
				Total time (min)		27,39	53,17	96,67	10,82
				Total time (h)		0,46	0,89	1,61	0,18
						Average time (min)			2,16

Table 17. Times Cut-off ELBIU/7/16.

You can find the calculations of each MDF board in the file StandardTime_Cut.xlsx.

4.2. Drilling and milling holes

First, it is necessary to find a machine to perform this operation. There was decided to use a CNC work center for all the drilling and grooving operations, and the CNC machine called Uniflex S, belongs to the company called Morbidelli, was chosen.

Image 7. CNC Uniflex S.

It has following parameters:

Uniflex S		
Working area (X , Y)	mm	3000 x 1300
Boring units	n.	2
Indep. vertical spindles (on each boring group)	n.	31
Indep. horizontal spindles (on each boring unit)	n.	fino a 10

Electrospindle power HSK 63F	kW	6,6
Saw-blade unit power	kW	2,2
Panel thickness (min-max)	mm	10-80
Machine size	mm	8538x3121

Table 18. CNC Uniflex S parameters.

4.2.1. ELBIU/7/10

We need to estimate the time needed to drill and groove each MDF board. For it we create a table to calculate and estimate the time needed to drill and groove each MDF board.

ITEM	Length Lb (m)	Thickness T (m)	nº of edges to drill Ed	nº of face to drill Fd	nº of holes per face Hs	nº of gooves to make Gm	tg per part (min)	tp per part (min)	tw per part (min)	tj per part (min)
C1	0,674	0,022	2	1	25	0	1,19	4,30	5,49	6,59
C2	0,674	0,022	2	2	31	0	2,82	9,60	12,42	14,90
C3	0,718	0,022	1	1	12	0	0,57	2,90	3,47	4,17
C4	1	0,032	0	1	15	0	0,96	3,10	4,06	4,87
C5	0,3	0,032	0	1	10	0	0,64	2,60	3,24	3,89
C6	0,255	0,018	2	0	3	0	0,07	0,20	0,27	0,33
C7	0,607	0,018	0	0	0	0	0,00	0,00	0,00	0,00
C8	0,678	0,018	2	1	8	0	0,36	2,60	2,96	3,55
C9	0,255	0,018	2	1	8	0	0,36	2,60	2,96	3,55
C10	0,5	0,012	2	1	5	1	0,33	2,40	2,73	3,28
C11	0,5	0,012	2	1	5	1	0,33	2,40	2,73	3,28
C12	0,215	0,012	2	0	4	0	0,05	0,20	0,25	0,30
C13	0,255	0,003	0	0	0	0	0,00	0,00	0,00	0,00
C14	0,249	0,022	0	1	6	1	0,35	2,30	2,65	3,18
				Total time (min)			8,03	35,20	43,23	51,88
							Average time (min)			3,71

Table 18. Times Drill and Grove ELBIU/7/10.

The production time **tw** (min), machine time **tg** (min), auxiliary time **tp** (min) can be estimated for each part with assumptions:

$$tg = (Ed + Fd * Hs * \frac{2 * T}{Vf_{drill}}) + (Gm * \frac{Lb}{Vf_{grove}})$$

With:
Ed - number of edges to drill for each part
Fd - number of faces to drill for each part

Hs - number of holes' series to drill per face for each part
Gm - number of grooves to make for each part
T - MDF board thickness (mm)
Lb - length of the MDF board (= length of the groove)
Vfdrill - feed rate of driller (m/min)
Vfgroove - feed rate of blade (m/min)

Assumption:

Vfdrill = **1 m/min**
Vfgroove = **3 m/min**

$$tp = \left(tp_{place} + tp_{program} + \left(2 * tp_{movegoback}\right) + \left((Ed + Hs + Gm) * tp_{movework}\right) + tp_{putdown}\right) + ((Fd - 1) * \left(tp_{place}tp_{program} + \left(2 * tp_{movegoback}\right) + (Hs * tp_{movework}) + tp_{putdown}\right))$$

With:
tpplace - time to place the MDF board on the machine (min)
tpmovework - time to move the MDF board automatically in the machine to make the different holes' series (min)
tpmovegoback - time to move the MDF board automatically to go inside (to start the operation) or outside (when the operation is finished) of the machine (min)
tpputdown -time to put down the finished MDF board (min)
tpprogram - time to program the information on the machine (min)

Assumption:

tpplace = 0,4 min
tpmovework = 0,1 min
tpmovegoback = 0,3 min
tpputdown = 0,3 min
tpprogram = 0,3 min

$$tw = tp + tg$$

With:
tp - auxiliary time (min)
tg - machine time (min)

The time per part **tj** (min) will be calculated using the following equation:

$$tj = 1{,}2 * tw$$

With:
1.2 - physiological coefficient
tw - production time (min)

4.2.2. ELBIU/7/12

The times to grove and drill of this furniture are:

ITEM	Length Lb (m)	Thickness T (m)	nº of edges to drill Ed	nº of face to drill Fd	nº of holes per face Hs	nº of gooves to make Gm	tg per part (min)	tp per part (min)	tw per part (min)	tj per part (min)
C1	0,718	0,022	1	1	13	0	0,62	3,00	3,62	4,34
C2	0,718	0,022	1	1	13	0	0,62	3,00	3,62	4,34
C3	0,42	0,018	2	1	10	0	0,43	2,80	3,23	3,88
C4	0,42	0,018	2	1	10	0	0,43	2,80	3,23	3,88
C5	0,746	0,018	1	1	6	0	0,25	2,30	2,55	3,06
C6	1,2	0,032	0	1	20	0	1,28	3,60	4,88	5,86
C7	0,702	0,018	0	0	0	0	0,00	0,00	0,00	0,00
C8	1,155	0,018	2	0	6	0	0,07	0,20	0,27	0,33
				Total time (min)			3,70	17,70	21,40	25,68
							Average time (min)			3,21

Table 19. Times Drill and Grove ELBIU/7/12.

4.2.3. ELBIU/7/14

The times for grove and drill of this furniture are:

ITEM	Length Lb (m)	Thickness T (m)	nº of edges to drill Ed	nº of face to drill Fd	nº of holes per face Hs	nº of gooves to make Gm	tg per part (min)	tp per part (min)	tw per part (min)	tj per part (min)
C1	0,674	0,022	2	1	27	0	1,28	4,50	5,78	6,93
C2	0,674	0,022	2	2	27	0	2,46	8,80	11,26	13,52
C3	0,674	0,022	2	2	40	0	3,61	11,40	15,01	18,01
C4	0,674	0,022	2	1	33	0	1,54	5,10	6,64	7,97
C5	1,4	0,032	0	1	20	0	1,28	3,60	4,88	5,86
C6	0,38	0,032	0	1	10	0	0,64	2,60	3,24	3,89
C7	0,355	0,018	2	0	6	0	0,07	0,20	0,27	0,33
C8	0,633	0,018	0	0	0	0	0,00	0,00	0,00	0,00
C9	0,641	0,018	2	0	6	0	0,07	0,20	0,27	0,33
C10	0,335	0,018	2	0	6	0	0,07	0,20	0,27	0,33
C11	0,5	0,012	2	1	6	1	0,36	2,50	2,86	3,43
C12	0,5	0,012	2	0	6	1	0,21	0,30	0,51	0,62
C13	0,295	0,012	2	1	4	0	0,14	2,20	2,34	2,81
C14	0,5	0,012	2	1	6	1	0,36	2,50	2,86	3,43
C15	0,5	0,012	2	1	6	1	0,36	2,50	2,86	3,43
C16	0,295	0,012	2	0	4	0	0,05	0,20	0,25	0,30
C17	0,305	0,003	0	0	0	0	0,00	0,00	0,00	0,00
C18	0,329	0,016	0	1	8	0	0,26	2,40	2,66	3,19

C19	0,329	0,016	0	1	6	1	0,30	2,30	2,60	3,12
C20	0,329	0,016	0	1	6	1	0,30	2,30	2,60	3,12
				Total time (min)			13,37	53,80	67,17	80,60
							Average time (min)			4,03

Table 20. Times Drill and Grove ELBIU/7/14.

4.2.4. ELBIU/7/16

The times to grove and drill FOR this furniture are:

ITEM	Length Lb (m)	Thickness T (m)	nº of edges to drill Ed	nº of face to drill Fd	nº of holes per face Hs	nº of gooves to make Gm	tg per part (min)	tp per part (min)	tw per part (min)	tj per part (min)
C1	0,718	0,022	1	1	13	0	0,62	3,00	3,62	4,34
C2	0,718	0,022	1	1	13	0	0,62	3,00	3,62	4,34
C3	1,6	0,032	0	1	10	0	0,64	2,60	3,24	3,89
C4	1,555	0,018	2	1	6	0	0,29	2,40	2,69	3,23
C5	1,555	0,018	2	0	6	0	0,07	0,20	0,27	0,33
				Total time (min)			2,23	11,20	13,43	16,12
							Average time (min)			3,22

Table 21. Times Drill and Grove ELBIU/7/16.

4.3. Edge vacuum veneering with MDF edge banding tape

First, it is necessary to find a machine to perform this operation. It was decided to use an edge bander. The automatic edge bander called Olimpic k600 belongs to the company called SCM was chosen.

Image 8. Olimpic k600.

It has following parameters:

Model	**K600**
Edge thickness (mm)	0,4
Panel thickness (mm)	8-60
Feed speed (m/min)	11-16
Compressed air (bar)	6
Machine size (mm)	5273x1988

Table 22. Olimpic k600 parameters.

4.3.1. ELBIU/7/10

We create a table for calculate and estimate the time for edge banding each MDF board.

ITEM	Length Lb (m)	Height (Hb)(m)	nº of edges to cover Ec	tg per part (min)	tp per part (min)	tw per part (min)	tj per part (min)
C1	0,674	0,64	2	0,84	1,00	1,84	2,21
C2	0,674	0,64	2	0,84	1,00	1,84	2,21
C3	0,718	0,64	2	0,84	1,00	1,84	2,21
C4	1	0,64	4	1,69	1,70	3,39	4,06
C5	0,3	0,64	4	1,69	1,70	3,39	4,06
C6	0,255	0,601	1	0,42	0,65	1,07	1,29
C7	0,607	0,4	3	1,26	1,35	2,61	3,14
C8	0,678	0,156	1	0,42	0,65	1,07	1,29
C9	0,255	0,156	1	0,42	0,65	1,07	1,29
C10	0,5	0,1	1	0,42	0,65	1,07	1,29
C11	0,5	0,1	1	0,42	0,65	1,07	1,29
C12	0,215	0,086	1	0,42	0,65	1,07	1,29
C13	0,255	0,509	0	0,00	0,30	0,30	0,36
C14	0,249	0,15	4	1,69	1,70	3,39	4,06
		Total time (min)		11,38	13,65	25,03	30,03
				Average time (min)			2,15

Table 23. Edge banding times ELBIU/7/10.

The production time **tw** (min), machine time **tg** (min), auxiliary time **tp** (min) can be estimated for each part with assumptions:

$$tg = Ec * \frac{Lmachine}{Vf}$$

With:
Lmachine - machine distance of operation of banding tape (mm)
Ec - number of edge to cover for each part
Vf - feed rate (m/min)

Assumption:
Vf = 11 m/min
Lmachine = 4635 mm

$$\boldsymbol{tp = (Ec * tp_{place}) + ((Ec - 1) * tp_{move}) + tp_{putdown} + tp_{program}}$$

tpplace - time to place the MDF board on the machine (min)
tpmove - time to move the MDF board already banding at least one time and to replace it at the entrance of the machine to banding tape a new edge (min)
tpputdown -time to put down the finished MDF board (min)
tpprogram - time to program the information on the machine (min)

Assumption:
tpplace = 0,15 min
tpmove = 0,2 min
tpputdown = 0,2 min
tpprogram = 0,3 min

$$tw = tp + tg$$

With:
tp - auxiliary time (min)
tg - machine time (min)

The time per part **tj** (min) will be calculated using the following equation:

$$tj = 1{,}2 * tw$$

With:
1.2 - physiological coefficient
tw - production time (min)

4.3.2. ELBIU/7/12

The times to edge banding of this furniture are:

ITEM	Length Lb (m)	Height (Hb)(m)	nº of edges to cover Ec	tg per part (min)	tp per part (min)	tw per part (min)	tj per part (min)
C1	0,674	0,64	2	0,84	1,00	1,84	2,21
C2	0,674	0,64	2	0,84	1,00	1,84	2,21
C3	0,718	0,64	2	0,84	1,00	1,84	2,21
C4	1	0,64	2	0,84	1,00	1,84	2,21

C5	0,3	0,64	0	0,00	0,30	0,30	0,36
C6	0,255	0,601	4	1,69	1,70	3,39	4,06
C7	0,607	0,4	3	1,26	1,35	2,61	3,14
C8	0,678	0,156	1	0,42	0,65	1,07	1,29
		Total time (min)		6,74	8,00	14,74	17,69
				Average time (min)			2,21

Table 24. Edge banding times ELBIU/7/12.

4.3.3. ELBIU/7/14

The times to edge banding of this furniture are:

ITEM	Length Lb (m)	Height (Hb)(m)	nº of edges to cover Ec	tg per part (min)	tp per part (min)	tw per part (min)	tj per part (min)
C1	0,674	0,64	2	0,84	1,00	1,84	2,21
C2	0,674	0,64	2	0,84	1,00	1,84	2,21
C3	0,718	0,64	2	0,84	1,00	1,84	2,21
C4	1	0,64	2	0,84	1,00	1,84	2,21
C5	0,3	0,64	4	1,69	1,70	3,39	4,06
C6	0,255	0,601	4	1,69	1,70	3,39	4,06
C7	0,607	0,4	1	0,42	0,65	1,07	1,29
C8	0,678	0,156	3	1,26	1,35	2,61	3,14
C9	0,255	0,156	0	0,00	0,30	0,30	0,36
C10	0,5	0,1	0	0,00	0,30	0,30	0,36
C11	0,5	0,1	1	0,42	0,65	1,07	1,29
C12	0,215	0,086	1	0,42	0,65	1,07	1,29
C13	0,255	0,509	1	0,42	0,65	1,07	1,29
C14	0,249	0,15	1	0,42	0,65	1,07	1,29
C15	0,255	0,156	1	0,42	0,65	1,07	1,29
C16	0,5	0,1	1	0,42	0,65	1,07	1,29
C17	0,5	0,1	0	0,00	0,30	0,30	0,36
C18	0,215	0,086	4	1,69	1,70	3,39	4,06
C19	0,255	0,509	4	1,69	1,70	3,39	4,06
C20	0,249	0,15	4	1,69	1,70	3,39	4,06
		Total time (min)		16,01	19,30	35,31	42,37
				Average time (min)			2,12

Table 25. Edge banding times ELBIU/7/14.

4.3.4. ELBIU/7/16

The times to edge banding of this furniture are:

ITEM	Length Lb (m)	Height (Hb)(m)	nº of edges to cover Ec	tg per part (min)	tp per part (min)	tw per part (min)	tj per part (min)
C1	0,674	0,64	2	0,84	1,00	1,84	2,21
C2	0,674	0,64	2	0,84	1,00	1,84	2,21
C3	0,718	0,64	4	1,69	1,70	3,39	4,06
C4	1	0,64	1	0,42	0,65	1,07	1,29
C5	0,3	0,64	1	0,42	0,65	1,07	1,29
		Total time (min)		4,21	5,00	9,21	11,06
				Average time (min)			2,21

Table 26. Edge banding times ELBIU/7/16.

5. Assembly process planning

Component or end item comprising of a number of parts or subassemblies put together to perform a specific function, and capable of disassembly without destruction. What may be an assembly at one point, however, may be a subassembly at another.
The assembly process can be divided, depending on the level of details, on:

- Assembly operation – main unit of assembly process, typically realized on one manufacturing stand and by one worker (sometimes by team of workers), can consist of many assembly tasks. Create assemblies.
- Assembly task – the sequence of assembly actions. Create subassemblies.
- Assembly action – assembly part sequence, at least two parts are needed to make an assembly action.

These assembly activities create the hierarchical structure of product and its assembly process:

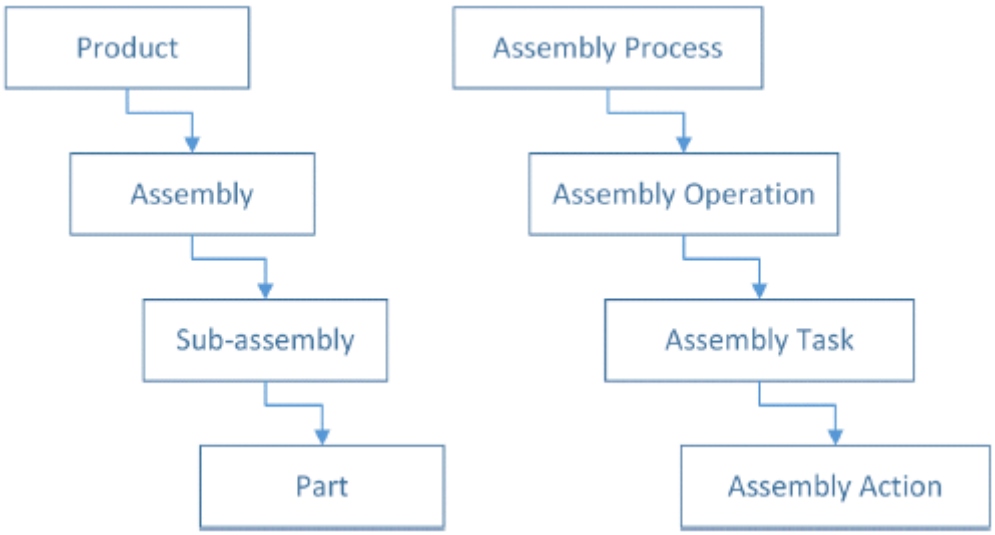


Diagram 1. Hierarchical structure assembly.

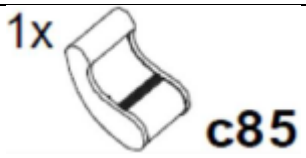
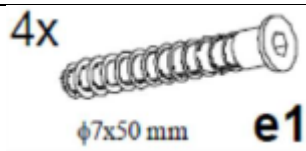
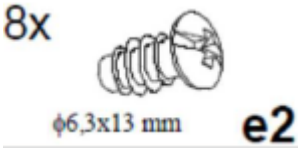
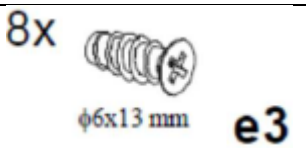
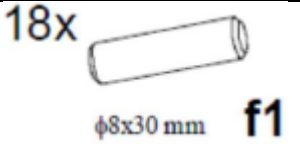
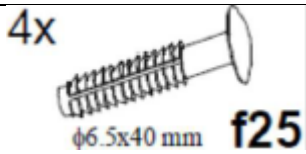
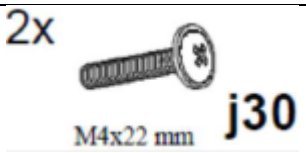
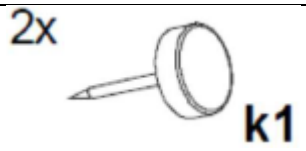
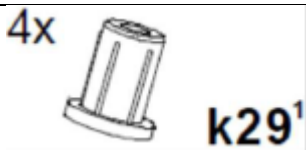
Planning of the assembly process can be realized in following steps:

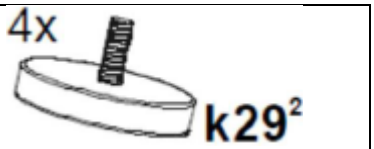
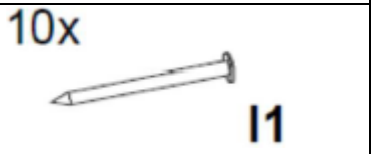
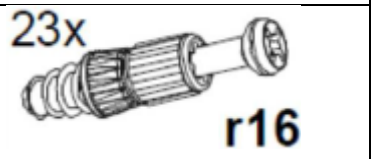
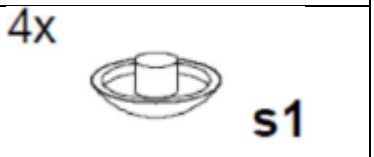
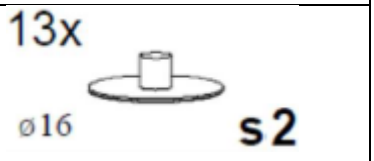
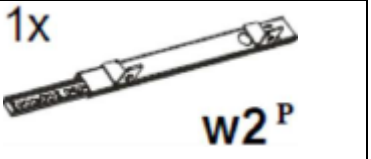
- Identification of assembly activities with division on assembly operations (realized on different workstations), tasks and actions.
- In each operation, identification of assembly manual tasks and actions list,
- Manual task and actions duration – time standardization.
- Calculation of standard time of manual actions, tasks, operations time and balance of tasks using *Yamazumi* chart.

5.1. BOM Structure

For these products the assembly instructions are available. Based on it we can find out the full list of necessary parts. Parts, from the source point of view, can be divided into two main groups:

- Purchased – standard parts which can be easily bought on market. This is a list of accessories that we need for assembly our desks.

Nº	ID	Name	Picture
1	**c85**	Door handle	
2	**e1**	Confirmat screw	
3	**e2**	Bolt	
4	**e3**	Bolt	
5	**f1**	Wooden dowel	
6	**f25**	Plastic peg	
7	**j30**	Screw	
8	**k1**	pin	
9	**k29-1**	Base of plastic leg	

10	**k29-2**	Plastic leg	
11	**l1**	Nail	
12	**r1**	Excenter fitting #16	
13	**r3**	Excenter fitting #22	
14	**r16**	Retaining pin	
15	**s1**	Bolt plug	
16	**s2**	Eccentric plug	
17	**s4**	Screw plug	
18	**w2L**	Left drawer slider	
19	**w2P**	Right drawer slider	

20	**w43L**	Left drawer slider	
21	**w43P**	Right drawer slider	

Table 27. Purchased elements.

More information about purchase materials in file List of parts and data.xlsx

- Produced – here can be own production or cooperation.

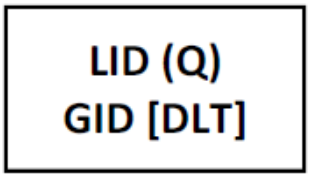
All the information production materials in file List of parts and data.xlsx.

The BOM is a hierarchical structure which have to represent also the assembly process. The BOM includes physical components but sometimes we need to add phantom item. We can distinguish the following list of item types and its codes:

Code	Item Type	Descriptiom
F	Final product	Represents finished goods
S	Sub-assembly	Phantom, represents some stage of e.g. assembly unit
A	Accessory	Purchased parts
C	Component	Produced parts
M	Material	Materials used in production

Table 28. List of items types.

The BOM should represent the assembly process. Therefore, we have to carefully analyse given assembly instruction (you can see the assembly instructions in files ELBIU-7-10.pdf, ELBIU-7-12.pdf, ELBIU-7-14.pdf, ELBIU-7-16.pdf). It can have graphical representation as a hierarchical tree, where structure of connections includes the assembly process. Each node represents the Item in the form of rectangle with following information:



- **LID** – local ID in BOM structure,
- **Q** – Quantity, the number of pieces per parent item! Sometimes can be measured in [kg], [m^2], [m^3] etc.
- **GID** – global ID of part in company,
- **DLT** – Delivery Lead Time-

After assembly process analysis, we can create two phantom items:

- **S1** – it is a sub-assembly of furniture body,
- **S2** – it is a drawer, there are two drawers.

5.1.1. ELBIU/7/10

The BOM structure for this desk:

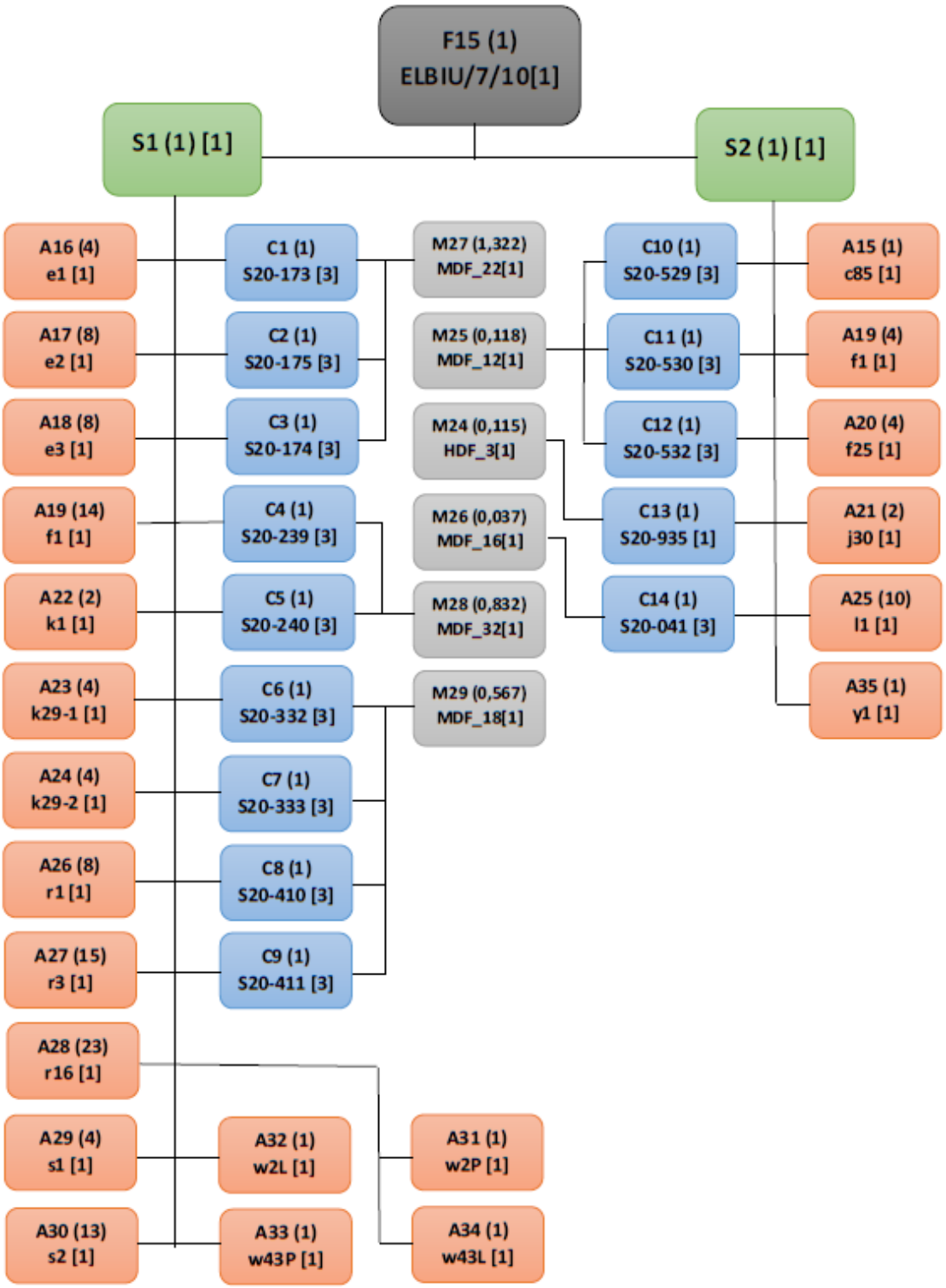


Diagram 2. BOM Structure ELBIU/7/10.

5.1.2. ELBIU/7/12

The BOM structure for this desk:

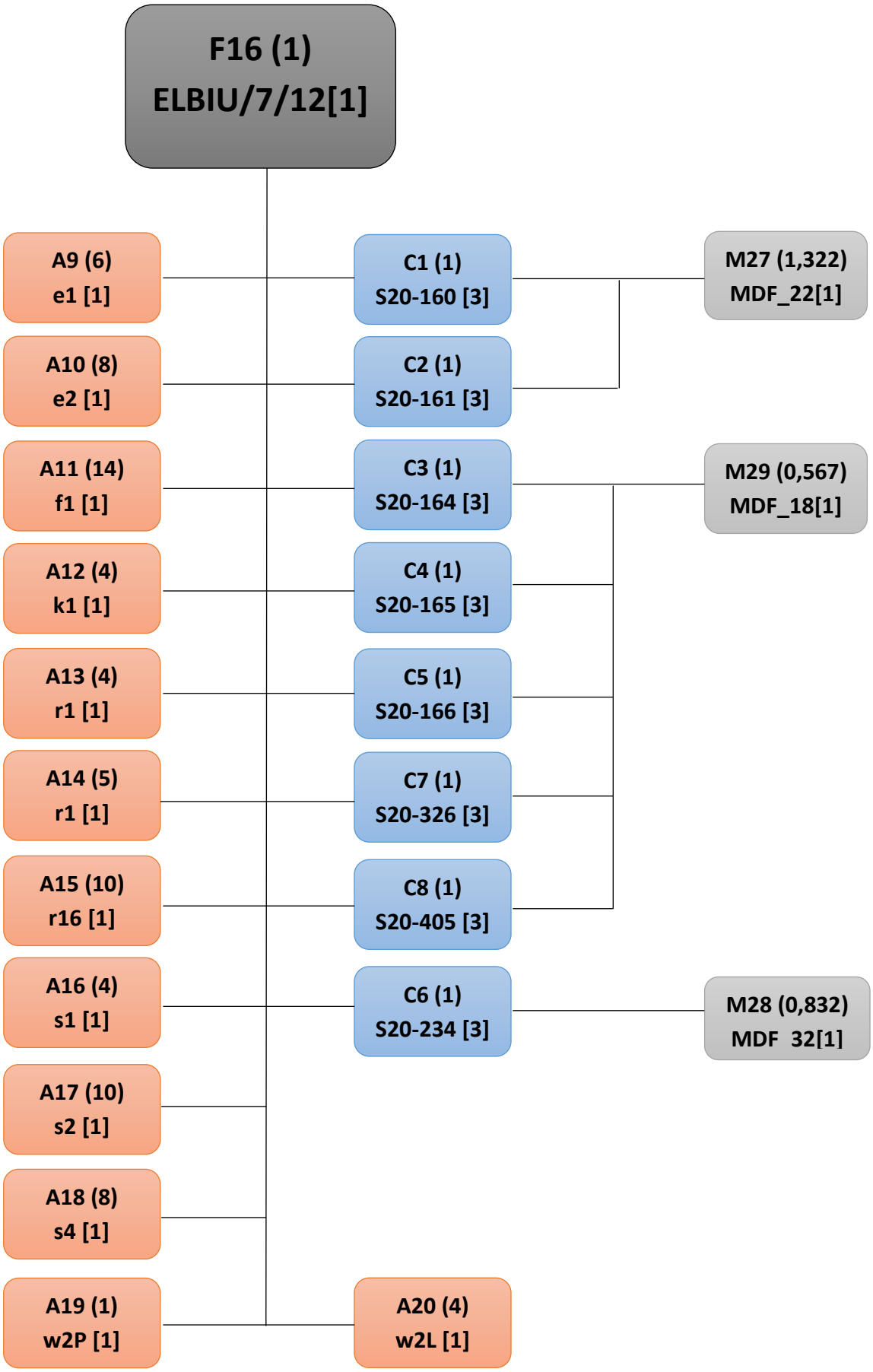


Diagram 3. BOM Structure ELBIU/7/12.

5.1.3. ELBIU/7/14

The BOM structure for this desk:

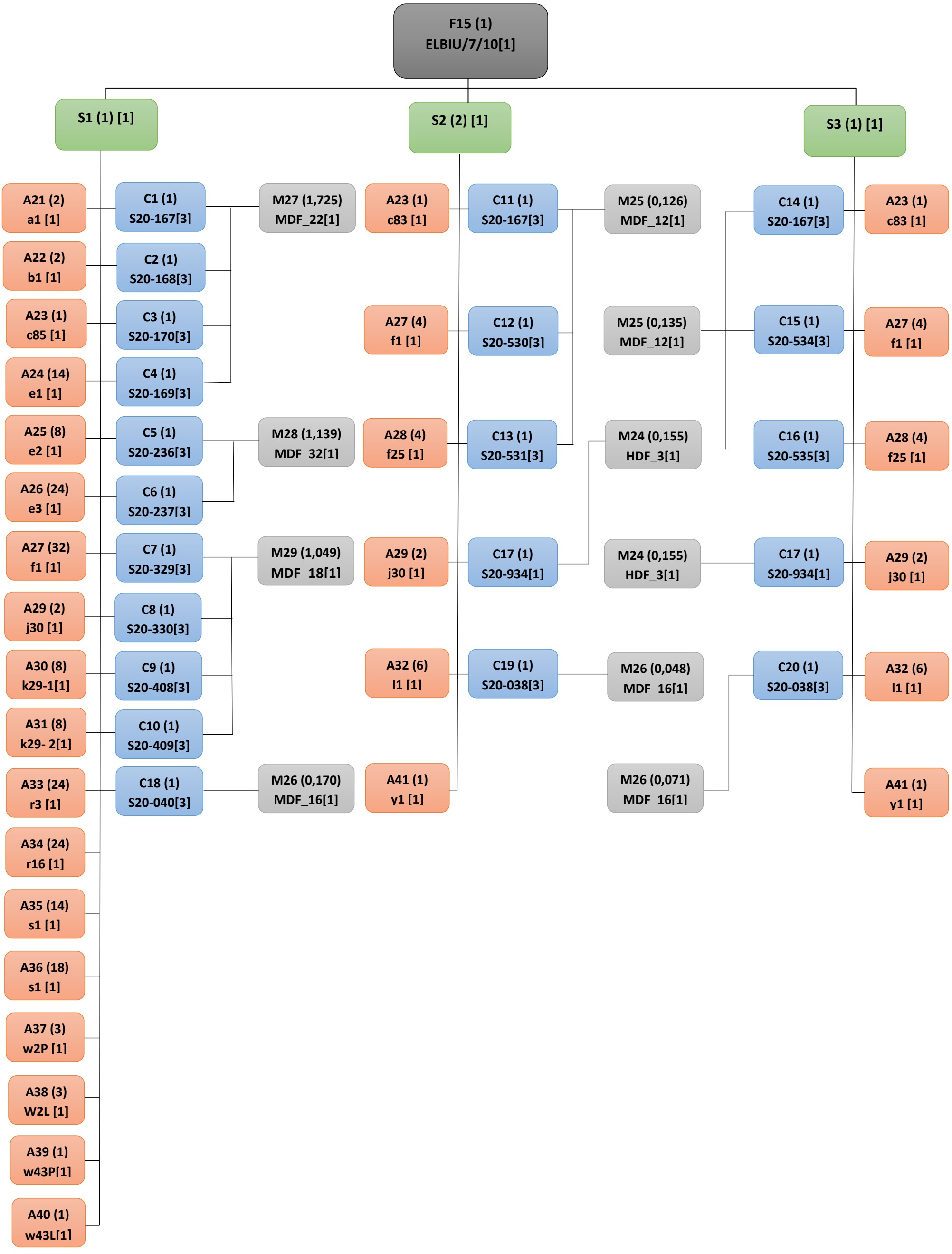


Diagram 4. BOM Structure ELBIU/7/14.

5.1.4. ELBIU/7/16

The BOM structure for this desk:

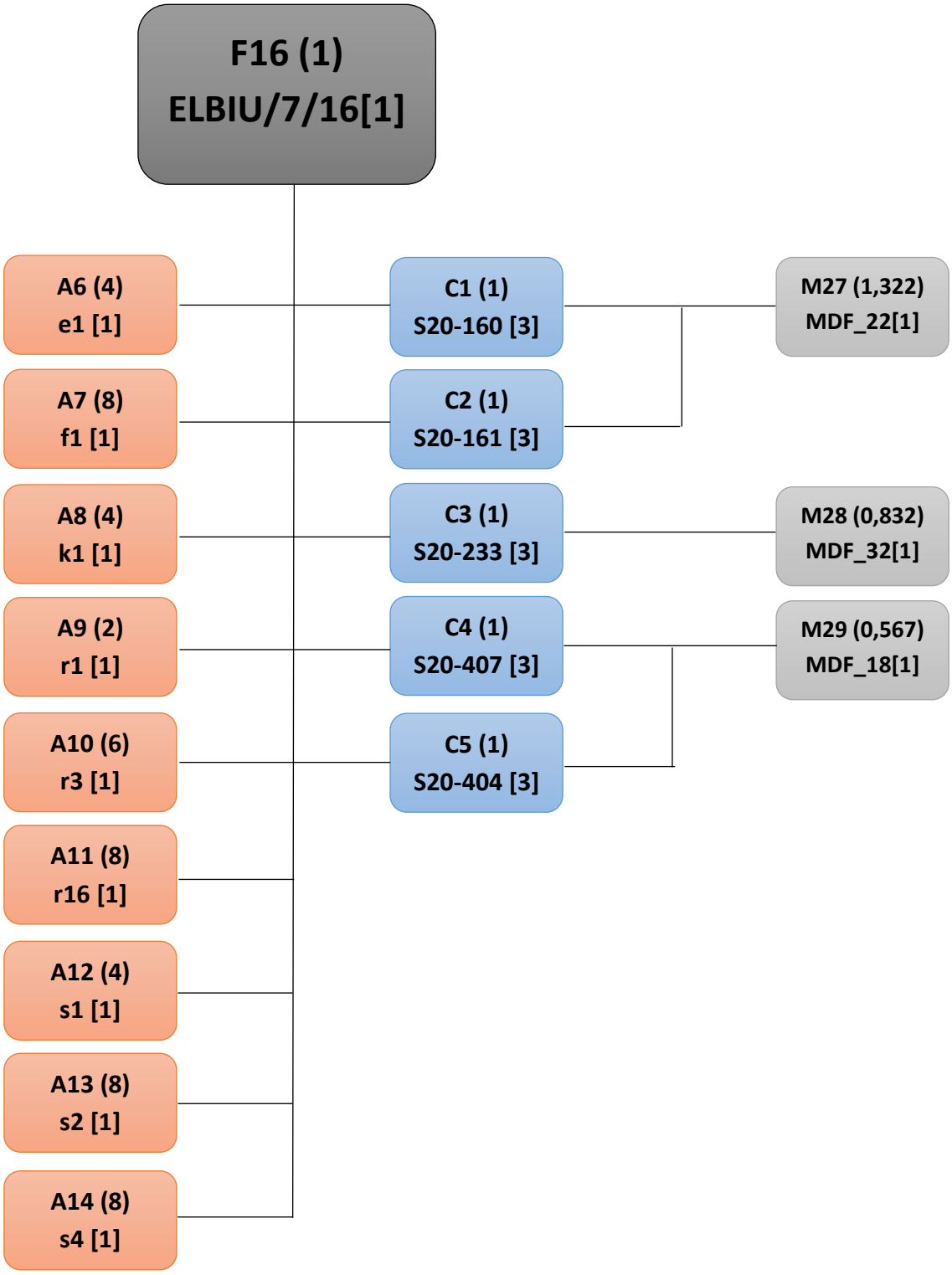


Diagram 5. BOM Structure ELBIU/7/16.

5.2. Instructions

5.2.1. ELBIU/7/10

- **General assembly process plan**

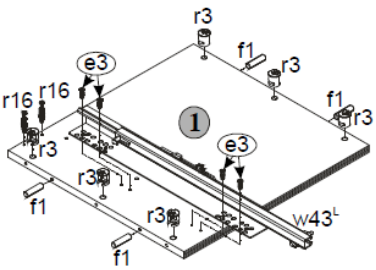
General assembly process plan consists of assembly operations list. General assembly for this desk:

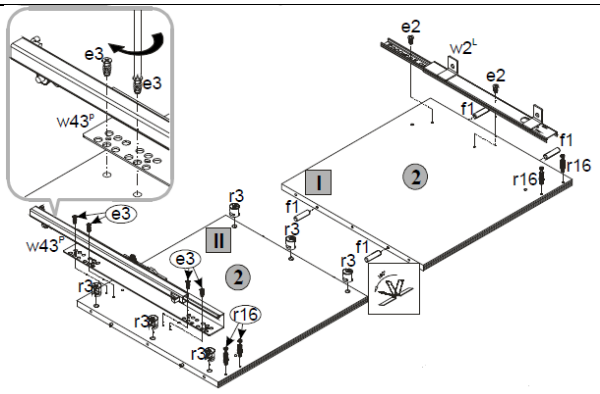
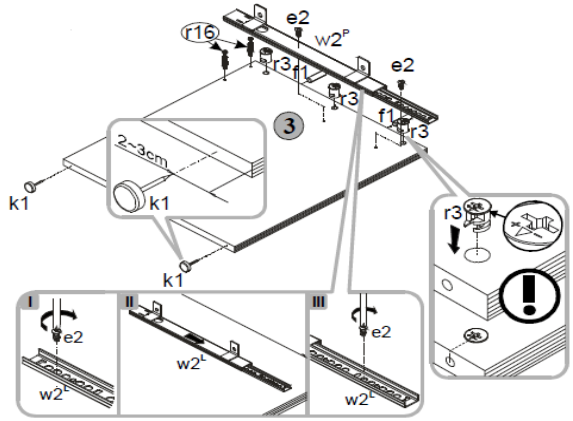
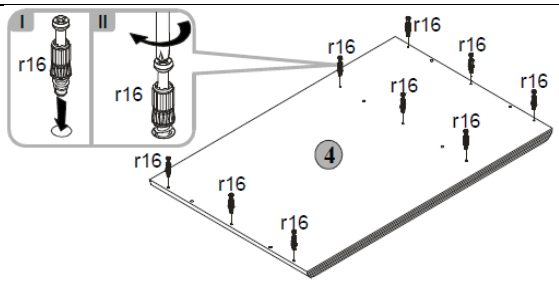
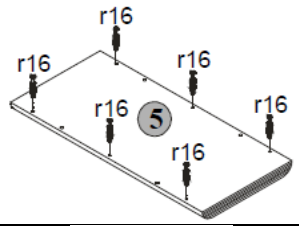
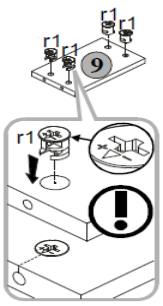
ID	Operation description	Tools
OP01	Equipping the MDF boards with the appropriate accessories	Hammer Screwdriver
OP02	Assembly of main body	Allen key Screwdriver Hammer
OP03	Assembly of drawer	Hammer Screwdriver
OP04	Final assembly of furniture	Screwdriver

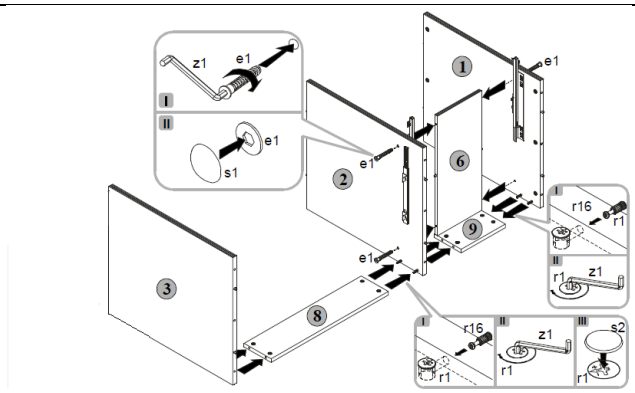
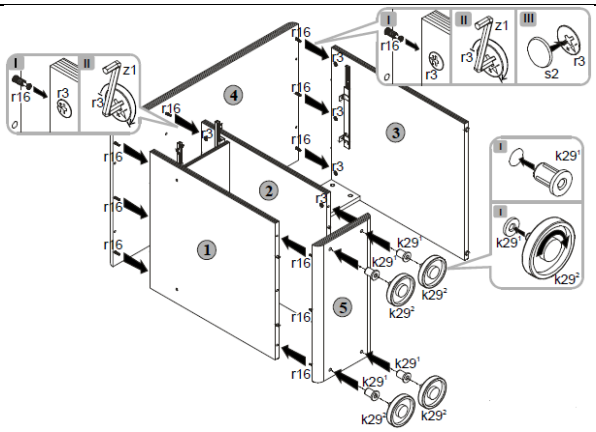
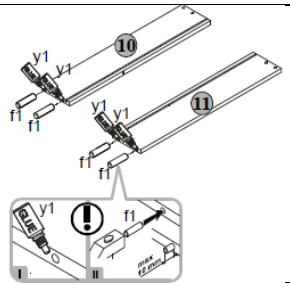
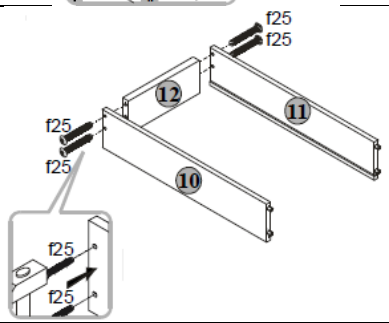
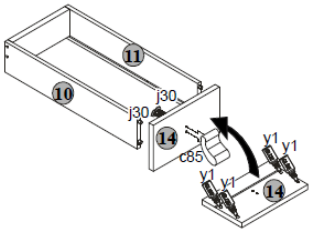
Table 29. General assembly ELBIU/7/10.

- **Detailed assembly process plan**

Detailed assembly operation plan is a list of necessary assembly steps like tasks and actions. Based on given instruction we have to prepare detailed list of assembly steps. We need to follow it step by step trying to describe all necessary assembly tasks. For this desk:

1		1- Place the left drawer slider **w43L** (x1) with the bolts **e3** (x4). 2- Push the wooden dowels **f1** (x4) in the corresponding holes with a hammer. 3- Put the excenter fittings **r3** (x6) in the corresponding holes.
2		1- Place and screw the retaining pins **r16** (x2) in the corresponding holes. 2- Place the left drawer slider **w2L** (x1) with the bolts **e3** (x2). ON THE OTHER SIDE OF THE BOARD: 3- Place and screw the retaining pins **r16** (x2) in the corresponding

		holes. 4- Place the right drawer slider **w43P** (x1) with the bolts **e3** (x4). 5- Push the wooden dowels **f1** (x4) in the corresponding holes with a hammer. 6- Put the excenter fittings **r3** (x6) in the corresponding holes.
3		1- Place the right drawer slider **w2P** (x1) with the bolts **e3** (x2). 2- Place and screw the retaining pins **r16** (x2) in the corresponding holes. 3- Push the wooden dowels **f1** (x4) in the corresponding holes with a hammer. 4- Put the excenter fittings **r3** (x3) in the corresponding holes. 5- Push the pins **k1** (x2) in the corresponding place.
4		1- Place and screw the retaining pins **r16** (x9) in the corresponding holes.
5		1- Place and screw the retaining pins **r16** (x6) in the corresponding holes.
6		1- Put the excenter fittings **r1** (x4) in the corresponding holes.

7		1- Assemble the boards **C1, C2, C3, C6, C8** and **C9**. Block the eight excenter fittings **r16** to fix the assembly. 2- Screw the bolts **e1** (x4) in the corresponding holes. 3- Put the eccentric plugs **s2** (x4) on the head of excenter fittings **r1** to hide the heads and put the bolt plug **s1** (x4) on the head of bolts **e1** to hide the heads.
8		1- Assemble the board **C4** and **C5** with the subset **C1-C2-C3-C6-C8-C9**. Block the nine excenter fittings **r16** to fix the assembly. 2- Put the eccentric plugs **s2** (x9) on the head of excenter fittings **r1** to hide the heads. 3- Place the base of plastic legs **k29-1** (x4) on the board **C5.** 4- Screw the plastic legs **k29-2** (x4) on each base of plastic leg **k29-1** (x4).
9		1- Put of the glue **y1** in the hole and push the wooden dowel **f1** (x4), in the corresponding hole with a hammer. (x2 Boards **C10** and **C11**)
10		1- Assemble the boards **C10** and **C11** on **C12**. Push the eight plastic pegs **f25** (x4) with a hammer to fix the assemblies.
11		1- Put of the glue **y1** in the holes of board **C14** and assemble **C14** in the wooden dowels **f1** of the subset **C10-C11-C12**. 2- Place the door handle **c85** (x1) and fix it with screws **j30** (x2).

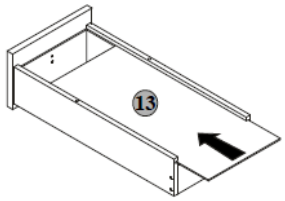
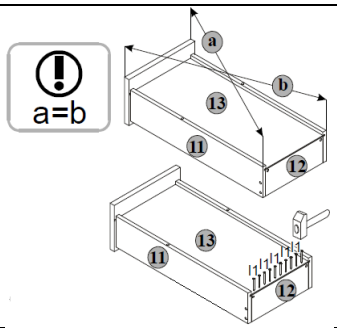
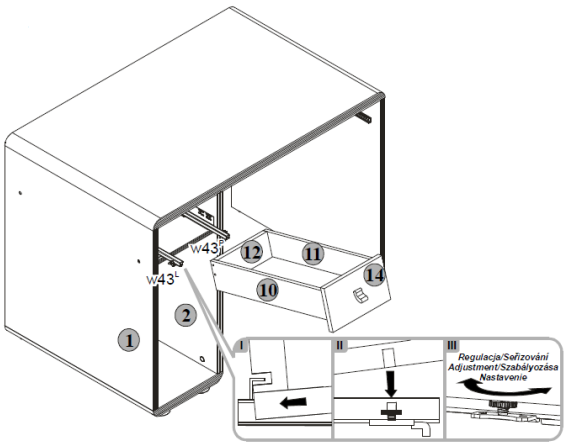
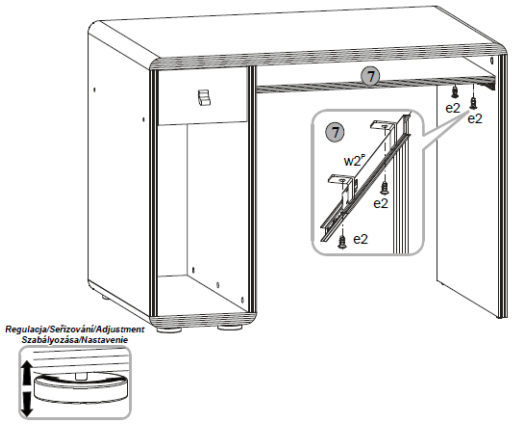
12		1- Slide the fireboard **C13** on subset **C10-C11-C12-C14**.
13		1- Before nailing the fibreboard **C13**, make sure that the diagonals are equal (a=b). 2- Nail the fibreboard **C13** to the back of drawer with the nails **l1** (x10).
14		1- Put in place the drawer as shown in the drawing: I- Slide the drawer in the drawer sliders **w43**. II- Put the notch of drawer on the adjustable head of the drawer sliders **w43**. III- Adjust the height with the head for a good translation guidance of drawer.
15		1- Put and screw the bolts **e2** (x4) in the corresponding holes with the screwdriver. 2- Adjust the height of the furniture with the plastic legs **k29.**

Table 30. Detail assembly ELBIU/7/10.

5.2.2. ELBIU/7/12

- **General assembly process plan**

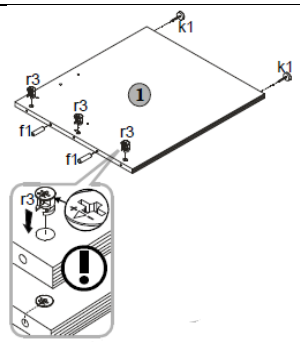
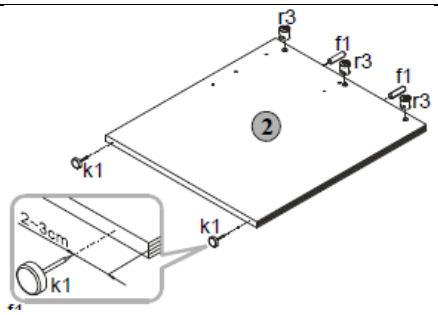
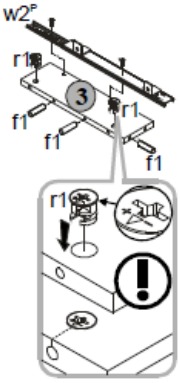
General assembly for ELBIU/7/12:

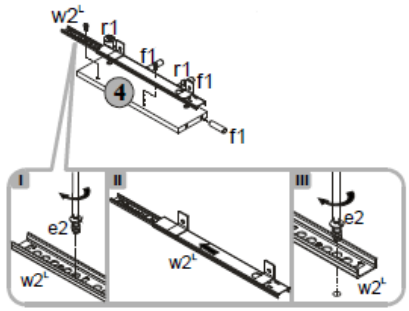
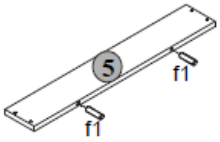
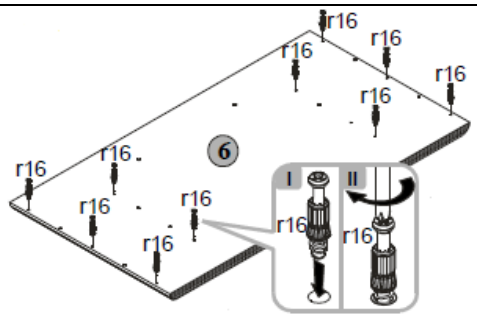
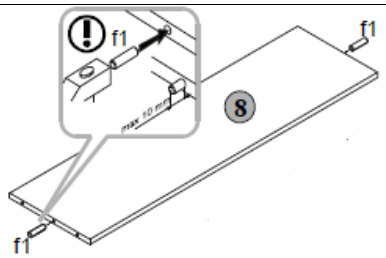
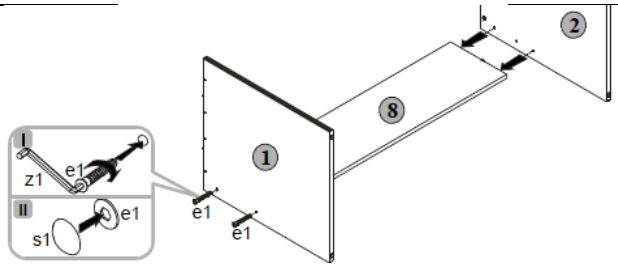
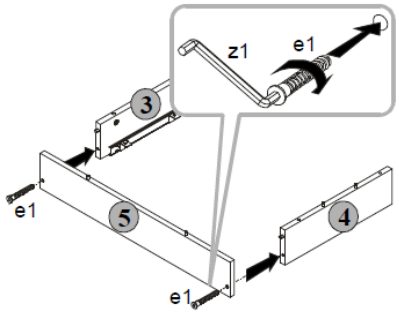
ID	Operation description	Tools
OP01	Equipping the MDF boards with the appropriate accessories	Hammer Screwdriver
OP02	Assembly of main body	Allen key Screwdriver Hammer
OP04	Final assembly of furniture	Screwdriver

Table 31. General assambly ELBIU/7/12.

- **Detailed assembly process plan**

Detail assembly process plan for desk ELBIU/7/12:

1		1- Push the wooden dowels **f1** (x2) in the corresponding holes with a hammer. 2- Put the excenter fittings **r3** (x3) in the corresponding holes. 3- Push the pins **k1** (x2) in the corresponding place.
2		1- Push the wooden dowels **f1** (x2) in the corresponding holes with a hammer. 2- Push the excenter fittings **r3** (x3) in the corresponding holes. 3- Put the pins **k1** (x2) in the corresponding place.
3		1- Place the right drawer slider **w2P** (x1) with the bolts **e3** (x2). 2- Push the wooden dowels **f1** (x3) in the corresponding holes with a hammer. 3- Put the excenter fittings **r1** (x2) in the corresponding holes.

4		1- Place the left drawer slider **w2L** (x1) with the bolts **e3** (x2). 2- Push the wooden dowels **f1** (x3) in the corresponding holes with a hammer. 3- Put the excenter fittings **r1** (x2) in the corresponding holes.
5		1- Push the wooden dowels **f1** (x2) in the corresponding holes with a hammer.
6		1- Place and screw the retaining pins **r16** (x10) in the corresponding holes.
7		1- Push the wooden dowels **f1** (x2) in the corresponding holes with a hammer.
8		1- Assemble the boards **C1, C2** and **C8**. Screw the bolts **e1** (x4) in the corresponding holes to fix the assembly. 2- Put the bolt plug **s1** (x4) on the head of bolts **e1** to hide the heads.
9		1- Assemble the boards **C3, C4** and **C5**. Screw the bolts **e1** (x2) in the corresponding holes to fix the assembly.

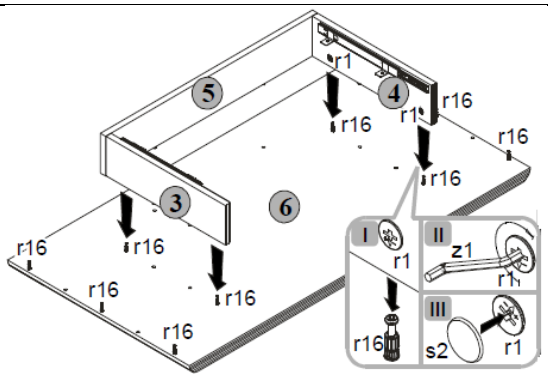
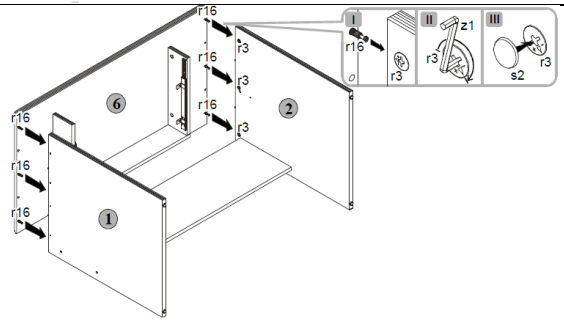
10		1- Assemble the board **C6** with the subset **C3-C4-C5**. Block the four excenter fittings **r16** to fix the assembly. 2- Put the eccentric plugs **s2** (x2) on the head of excenter fittings **r1** to hide the heads.
11		1- Assemble the subset **C3-C4-C5-C6** with the subset **C1-C2-C8**. Block the six excenter fittings **r16** to fix the assembly. 2- Put the eccentric plugs **s2** (x6) on the head of excenter fittings **r3** to hide the heads.

Table 32. Detail assembly ELBIU/7/12.

5.2.3. ELBIU/7/14

- **General assembly process plan**

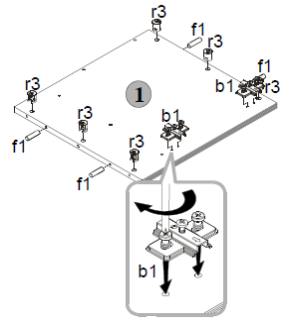
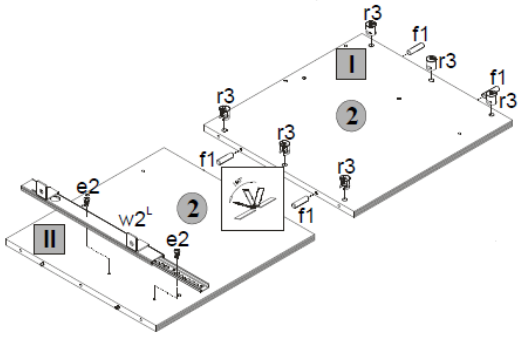
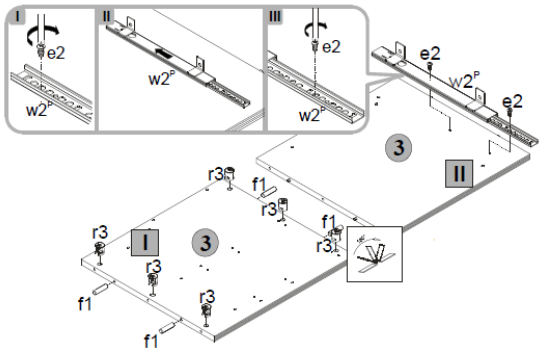
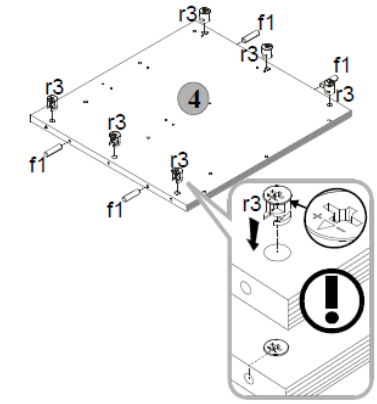
General assembly for ELBIU/7/14:

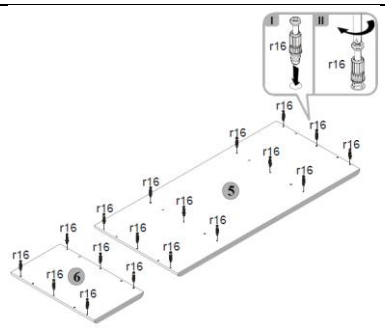
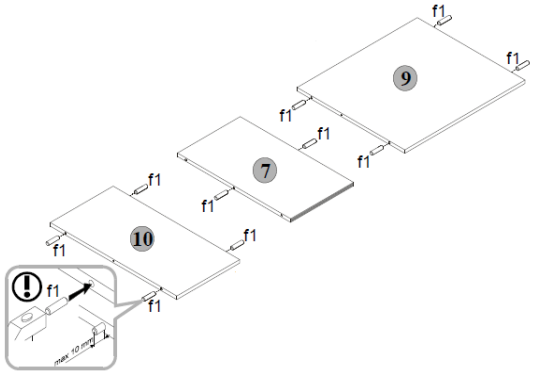
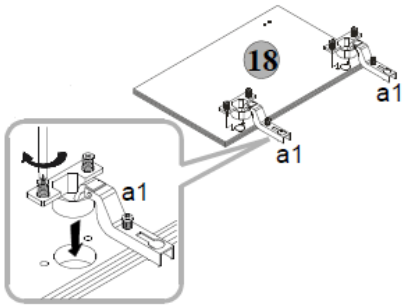
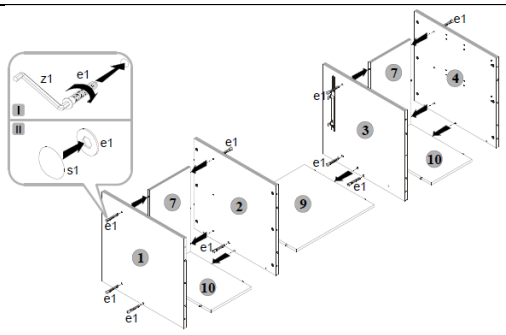
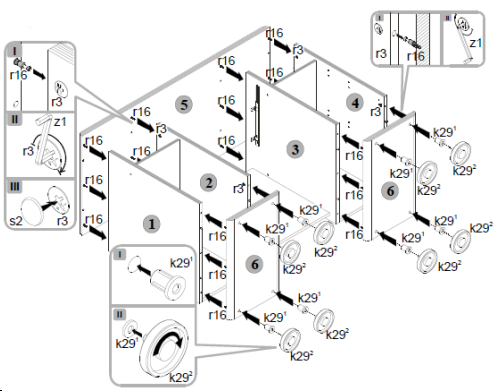
ID	Operation description	Tools
OP01	Equipping the MDF boards with the appropriate accessories	Hammer Screwdriver
OP02	Assembly of main body	Allen key Screwdriver Hammer
OP03	Assembly of drawer	Hammer Screwdriver
OP04	Final assembly of furniture	Screwdriver

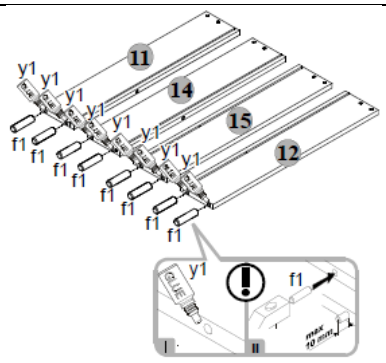
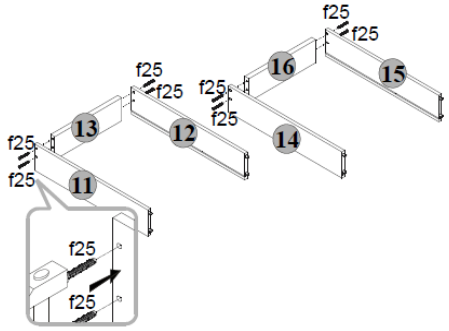
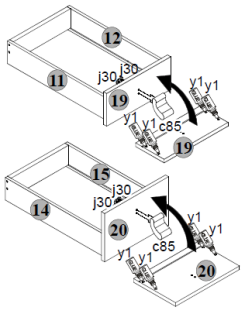
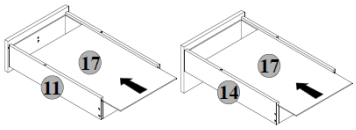
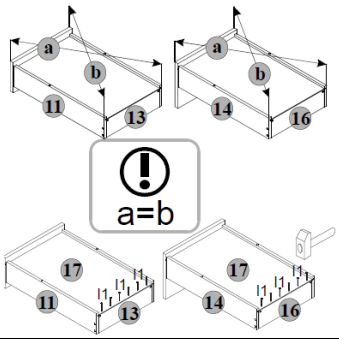
Table 33. General assembly ELBIU/7/14.

- **Detailed assembly process plan**

Detail assembly process plan for desk ELBIU/7/14:

1		1- Place and screw the mounting plates **b1** (x2) on the board with the screwdriver. 2- Push the wooden dowels **f1** (x2) in the corresponding holes with a hammer. 3- Put the excenter fittings **r3** (x6) in the corresponding holes.
2		1- Place the left drawer slider **w2L** (x1) with the bolts **e3** (x2). ON THE OTHER PART OF THE BOARD: 1- Push the wooden dowels **f1** (x4) in the corresponding holes with a hammer. 2- Put the excenter fittings **r3** (x6) in the corresponding holes.
3		1- Place the right drawer slider **w2P** (x1) with the bolts **e3** (x2). ON THE OTHER PART OF THE BOARD: 1- Push the wooden dowels **f1** (x4) in the corresponding holes with a hammer. 2- Put the excenter fittings **r3** (x6) in the corresponding holes.
4		1- Push the wooden dowels **f1** (x4) in the corresponding holes with a hammer. 2- Put the excenter fittings **r3** (x6) in the corresponding holes.

5		1- Place and screw the retaining pins **r16** (x18) in the corresponding holes.
6		1- Push the wooden dowels **f1** (x10) in the corresponding holes with a hammer.
7		1- Place and screw the concealed hinge **a1** (x2) on the board with the screwdriver.
8		1- Assemble the boards **C1, C2, C3, C4, C7** (x2)**, C9** and **C10** (x2). Screw the bolts **e1** (x16) in the corresponding holes to fix the assembly. 2- Put the bolt plug **s1** (x14) on the head of bolts **e1** to hide the heads.
9		1- Assemble the board **C5** and **C6** (X2) with the subset **C1-C2-C3-C4- C7** (x2)**-C9-C10** (x2). Block the twenty-four excenter fittings **r16** to fix the assembly. 2- Put the eccentric plugs **s2** (x18) on the head of excenter fittings **r3** to hide the heads. 3- Place the base of plastic legs **k29-1** (x8) on the board **C5.**

		4- Screw the plastic legs **k29-2** (x8) on each base of plastic leg **k29-1** (x8).
10		1- Put of the glue **y1** in the hole and push the wooden dowel **f1** (x12), in the corresponding hole with a hammer.
11		1- Assemble the boards **C11** (x2) and **C12**(x2) on **C13**(x2). Push the eight plastic pegs **f25** (x8) with a hammer to fix the assemblies and assemble the boards **C14** and **C15** on **C16**. Push the four plastic pegs **f25** (x4) with a hammer to fix the assemblies.
12		1- Put of the glue **y1** in the holes of boards **C19** (x2) and **C20** and assemble **C19** (x2) in the wooden dowels **f1** of the subset **C11**(x2)-**C12**(x20)-**C13**(x2) and assemble **C20** in the wooden dowels **f1** of the subset **C14-C15-C16**. 2- Place the door handle **c85** (x3) and fix it with screws **j30** (x6).
13		1- Slide the fireboard **C17** (x3) on subset **C11**(x2)-**C12**(x20)-**C13**(x2)-**C19**(x2) and **C14-C15-C16-C20**.
14		1- Before nailing the fibreboards **C17** (x3), make sure that the diagonals are equal (a=b). 2- Nail the fibreboards **C17** (x3) to the back of drawer with the nails **l1** (x18).

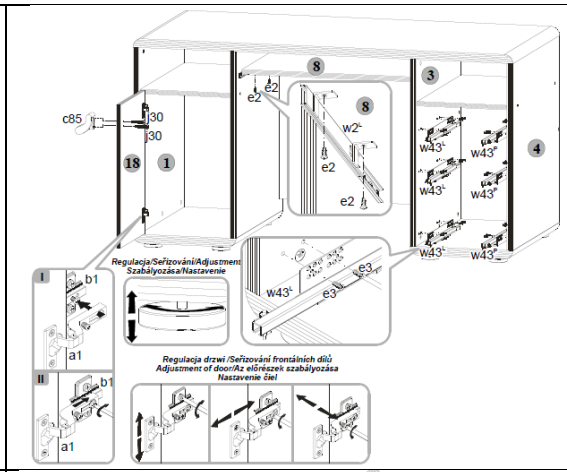
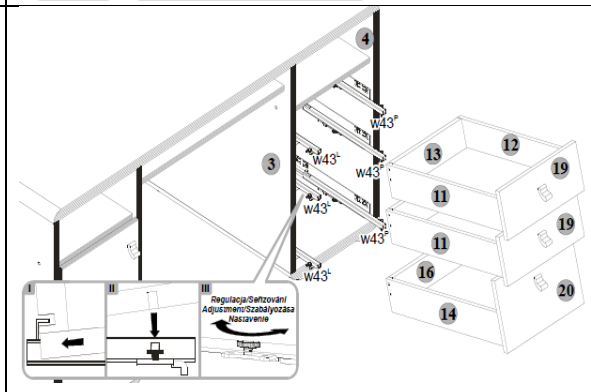
15		1- Put and screw the bolts **e2** (x4) in the corresponding holes with the screwdriver. 4- Adjust the door with the adjustable screws. 5- For door **C18**, place the door handle **c85** (x1) and fix it with two screws **j30** (x2). 6- Adjust the height of the furniture with the plastic legs **k29.**
16		1- Put in place the drawer as shown in the drawing: I- Slide the drawer in the drawer sliders **w43**. II- Put the notch of drawer on the adjustable head of the drawer sliders **w43**. III- Adjust the height with the head for a good translation guidance of drawer.

Table 34. Detail assembly ELBIU/7/14.

5.2.4. ELBIU/7/16

- **General assembly process plan**

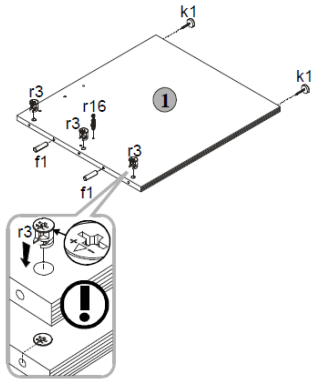
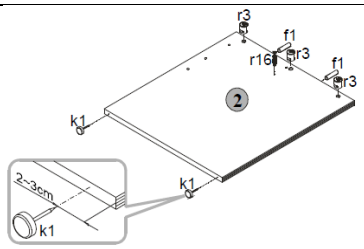
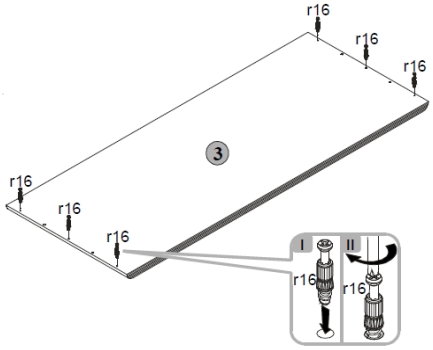
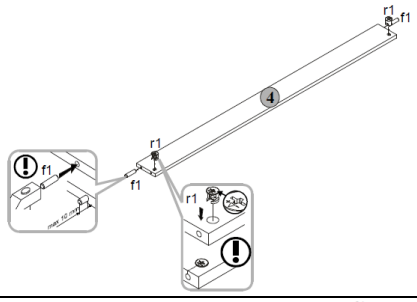
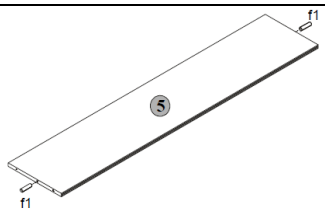
General assembly for ELBIU/7/16:

ID	Operation description	Tools
OP01	Equipping the MDF boards with the appropriate accessories	Hammer Screwdriver
OP02	Assembly of main body	Allen key Screwdriver Hammer
OP04	Final assembly of furniture	Screwdriver

Table 35. General assembly ELBIU/7/16.

- **Detailed assembly process plan**

Detail assembly process plan for desk ELBIU/7/16:

1		1- Push the wooden dowels **f1** (x2) in the corresponding holes with a hammer. 2- Put the excenter fittings **r3** (x3) in the corresponding holes. 3- Push the pins **k1** (x2) in the corresponding place.
2		1- Push the wooden dowels **f1** (x2) in the corresponding holes with a hammer. 2- Put the excenter fittings **r3** (x3) in the corresponding holes. 3- Push the pins **k1** (x2) in the corresponding place.
3		1- Place and screw the retaining pins **r16** (x16) in the corresponding holes.
4		1- Push the wooden dowels **f1** (x2) in the corresponding holes with a hammer. 2- Put the excenter fittings **r1** (x2) in the corresponding holes.
5		1- Push the wooden dowels **f1** (x2) in the corresponding holes with a hammer.

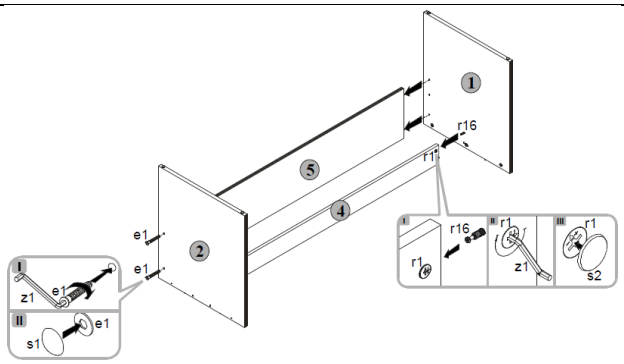
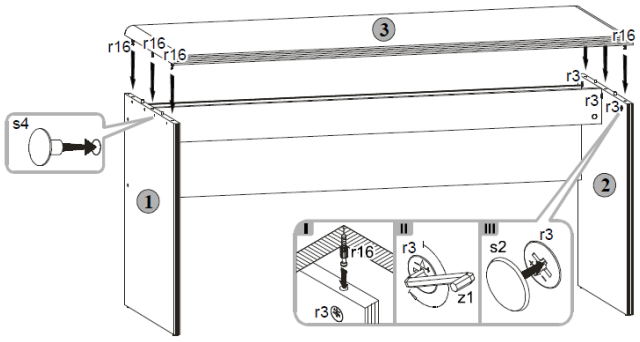
6		1- Assemble the board **C1, C2, C4** and **C5**. Block the two excenter fittings **r16** to fix the board **C4** and screw the bolts **e1** (x4) in the corresponding holes to fix the rest of the assembly. 2- Put the eccentric plugs **s2** (x2) on the head of excenter fittings **r1** to hide the heads and put the bolt plug **s1** (x4) on the head of bolts **e1** to hide the heads.
7		1- Assemble the board **C3** with the subset **C1-C2-C4-C5**. Block the six excenter fittings **r16** to fix the assembly. 2- Put the eccentric plugs **s2** (x6) on the head of excenter fittings **r1** to hide the heads and put the screw plug **s4** (x8) on the head of excenter fittings **r3**.

Table 36. Detail assembly ELBIU/7/16.

5.3. Standard assembly time

In production process planning we can find the decision making problem, where the main goal is to minimize amount of work.
The worktime standard is very important for effective process planning.
It helps to better organize the manufacturing process, e.g. shortening of cycle time and increasing resource total load time. It helps us also in proper process organization and give us some tips for continuous improvement. In the field of work standards can be distinguished, based on type of measure of human effort, the following variants:

- Standard work time
- Standard quantity of product.
- Standard quantity of the product
- Standard use of the crew

The worktime standard can be divided into the following components, which represent **activities** occurred in production system:

- **setuptime *tpz* [min],**
- **time per unit *tj* [min].**

The worktime standard *T* [min] can be calculated using following formula:

$$T = T_{pz} + n * t_j$$

Setuptime *tpz* means all organizational activities related to entering and leaving work on given stand, e.g. equipping machine tools with workholder (chucks, centres etc.) and cutting tools. The value *n* describes given batch size. Time per unit *tj* can be calculated as sum of production time *tw* and complementary time *tu*.

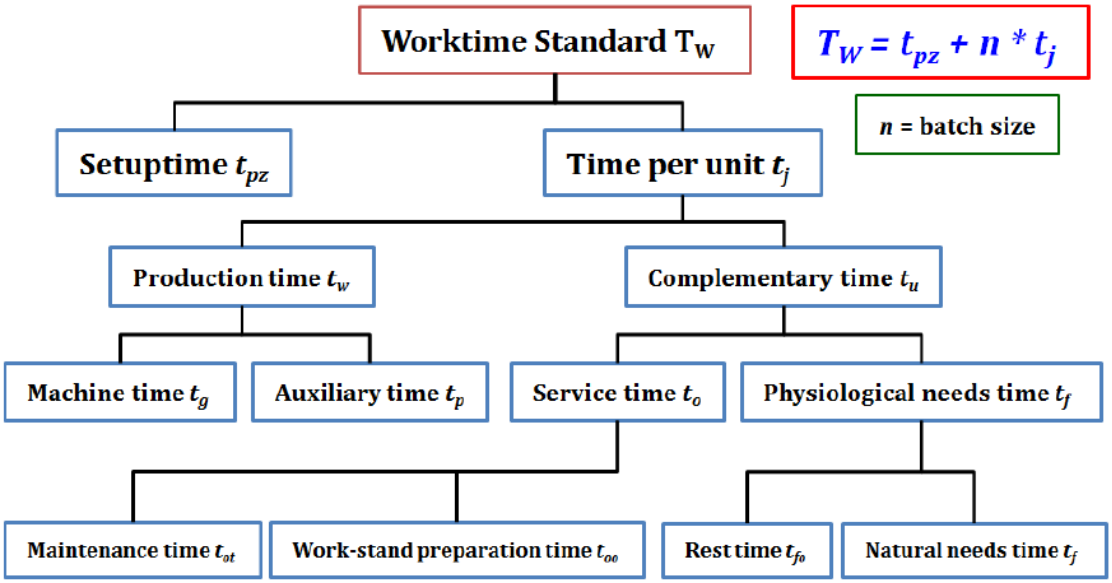


Diagram 6. Worktime Standard.

Formulas:

$$t_p = number\ of\ times * t_{psomething}$$

With:
tp - auxiliary time (min)
tpsomething - table time (min)

$$t_g = repetition * t_{ssomething}$$

With:
tg - assembly time (mm)
tssomething - table time (min)

$$t_w = t_p + t_g$$

With:
tp - auxiliary time (min)
tg - assembly time (mm)

tstandard	min	sec	Nominations
tsplace	0,1	6	time to place an element
tsscrew	0,3	18	time to screw a screw
tsblock	0,1	6	time to block a excenter fitting
tspush	0,2	12	time to push a dowel with a hammer
tsput	0,1	6	time to put an element
tsassemble	0,5	30	time to assemble the different part
tscheck	1	60	time to check the diagonal or 90° of one drawer
tstrace	0,5	30	time to trace a line with a pen
tsnail	0,2	12	time to nail a nail
tsglue	0,2	12	time to put of the glue
tsslide	0,2	12	time to slide an element
tsajust	0,5	30	time to ajust an element

Table 37. Production standard time.

tpreparation	min	sec	Nominations
tptake	0,4	24	time to take a element
tpputdown	0,3	18	time to put down a element
tpturn	0,1	6	time to turn a element
tpstock	2	120	time to put the furniture en stock

Table 38. Production repetition time.

5.3.1. ELBIU/7/10

The times of assembly of this desks are:

EQUIPMENT BOARDS					
	tp (min)	**Repetition**	**ts (min)**	**tg (min)**	**tw (min)**
Take the board C1	0,4				0,4
Place the left drawer slider **w43L** (x1)		1	0,1	0,1	0,1
Screw it with the bolts **e3** (x4)		4	0,3	1,2	1,2
Push the wooden dowels **f1** (x4)		4	0,2	0,8	0,8
Put the excenter fittings **r3** (x6)		6	0,1	0,6	0,6
Put down the equipped board C1	0,3				0,3
TOTAL	0,7			2,7	3,4

Take the board C2	0,4				0,4
Screw the retaining pins **r16** (x2)		2	0,3	0,6	0,6
Place the left drawer slider **w2L** (x1)		1	0,1	0,1	0,1
Screw it with the bolts **e3** (x2)		2	0,3	0,6	0,6
Turn the board of 180° to change the side	0,1				0,1
Screw the retaining pins **r16** (x2)		2	0,3	0,6	0,6

Place the right drawer slider **w43P** (x1)		1	0,1	0,1	0,1
Screw it with the bolts **e3** (x4)		4	0,3	1,2	1,2
Push the wooden dowels **f1** (x4)		4	0,2	0,8	0,8
Put the excenter fittings **r3** (x6)		6	0,1	0,6	0,6
Put down the equipped board C2	0,3				0,3
TOTAL	0,8			4,6	5,4

Take the board C3	0,4				0,4
Place the right drawer slider **w2P** (x1)		1	0,1	0,1	0,1
Screw it with the bolts **e3** (x2)		2	0,3	0,6	0,6
Screw the retaining pins **r16** (x2)		2	0,3	0,6	0,6
Push the wooden dowels **f1** (x4)		4	0,2	0,8	0,8
Put the excenter fittings **r3** (x3)		3	0,1	0,3	0,3
Push the pins **k1** (x2)		2	0,2	0,4	0,4
Put down the equipped board C3	0,3				0,3
TOTAL	0,7			2,8	3,5

Take the board C4	0,4				0,4
Screw the retaining pins **r16** (x9)		9	0,3	2,7	2,7
Put down the equipped board C4	0,3				0,3
TOTAL	0,7			2,7	3,4

	tp (min)	**Repetition**	**ts (min)**	**tg (min)**	**tw (min)**
Take the board C5	0,4				0,4
Screw the retaining pins **r16** (x6)		6	0,3	1,8	1,8
Put down the equipped board C5	0,3				0,3
TOTAL	0,7			1,8	2,5

Take the board C4	0,4				0,4
Put the excenter fittings **r1** (x4)		4	0,1	0,4	0,4
Put down the equipped board C4	0,3				0,3
TOTAL	0,7			0,4	1,1

BODY ASSEMBLY

	tp (min)	**Repetition**	**ts (min)**	**tg (min)**	**tw (min)**
Take the boards C1, C2, C3, C6, C8 and C9	2,4				2,4
Assemble the boards **C1, C2, C3, C6, C8** and **C9**		5	0,5	2,5	2,5
Block the eight excenter fittings **r16**		8	0,1	0,8	0,8
Screw the bolts **e1** (x4)		4	0,3	1,2	1,2
Put the eccentric plugs **s2** (x4)		4	0,1	0,4	0,4

Put the bolt plug **s1** (x4)		4	0,1	0,4	0,4
TOTAL	2,4			5,3	7,7

Take the boards C4 and C5	0,8				0,8
Assemble **C4** and **C5** on the subset **C1-C2-C3-C6-C8-C9**		2	0,5	1	1
Block the nine excenter fittings **r16**		9	0,1	0,9	0,9
Put the eccentric plugs **s2** (x9)		9	0,1	0,9	0,9
Place the base of plastic legs **k29-1** (x4)		4	0,1	0,4	0,4
Screw the plastic legs **k29-2** (x4)		4	0,3	1,2	1,2
Put down the subset C1-C2-C3-C6-C8-C9-C4-C5	0,3				0,3
TOTAL	1,1			4,4	5,5

MAKING THE DRAWERS

	tp (min)	**Repetition**	**ts (min)**	**tg (min)**	**tw (min)**
Take the boards C10 and C11	1,2				1,2
Put of the glue **y1** in the hole		4	0,2	0,8	0,8
Push the wooden dowel **f1** (x4)		4	0,2	0,8	0,8
TOTAL	1,2			1,6	2,8

Take the board C12	0,4				0,4
Assemble the boards **C10** and **C11** on **C12**		1	0,5	0,5	0,5
Push the eight plastic pegs **f25**		8	0,2	1,6	1,6
TOTAL	0,4			2,1	2,5

Take the board C14	0,4				0,4
Put of the glue y1 in the four holes of the board **C14**		4	0,2	0,8	0,8
Assemble the board **C18** with the subset **C10-C11-C12**		1	0,5	0,5	0,5
Place the door handles **c85** (x1)		1	0,1	0,1	0,1
Screw it with the screws **j30** (x2)		2	0,3	0,6	0,6
TOTAL	0,4			1,3	2,4

Take the board C13	0,4				0,4
Slide the board **C13** on subset **C10-C11-C12-C14**		1	0,2	0,2	0,2
TOTAL	0,4			0,2	0,6

Turn the drawers on the good side	0,1				0,1
Make sure that the diagonals are equal (a=b)		1	1	1	1
Nail the board **C13** with ten nails **l1** (x10)		10	0,2	2	2

TOTAL	0,1			3	3,1

FINAL ASSEMBLY					
	tp (min)	**Repetition**	**ts (min)**	**tg (min)**	**tw (min)**
Slide the drawer in the drawer sliders **w43**		1	0,2	0,2	0,2
Put the notch of drawer on the adjustable head		1	0,2	0,2	0,2
Adjust the height with the head		1	0,2	0,2	0,2
TOTAL	0			0,4	0,6
Screw it with the bolts **e2** (x4)		4	0,3	1,2	1,2
Adjust the height with the plastic legs **k29**		4	0,5	2	2
Stock the furniture	2				2
TOTAL	2			3,2	5,2
TOTAL TIME OF ASSEMBLY FURNITURE ELBIU-7-10 (min)					**49,7**

Table 39. Assembly time ELBIU/7/10.

5.3.2. ELBIU/7/12

The times of assembly of this desks are:

EQUIPMENT BOARDS					
	tp (min)	**Repetition**	**ts (min)**	**tg (min)**	**tw (min)**
Take the board C1	0,4				0,4
Push the wooden dowels **f1** (x2)		2	0,2	0,4	0,4
Put the excenter fittings **r3** (x3)		3	0,1	0,3	0,3
Push the pins **k1** (x2)		2	0,2	0,4	0,4
Put down the equipped board C1	0,3				0,3
TOTAL	0,7			0,7	1,8
Take the board C2	0,4				0,4
Push the wooden dowels **f1** (x2)		2	0,2	0,4	0,4
Put the excenter fittings **r3** (x3)		3	0,1	0,3	0,3
Push the pins **k1** (x2)		2	0,2	0,4	0,4
Put down the equipped board C2	0,3				0,3
TOTAL	0,7			0,7	1,8

Take the board C3	0,4				0,4
Place the right drawer slider **w2P** (x1)		1	0,1	0,1	0,1
Screw it with the bolts **e3** (x2)		2	0,3	0,6	0,6
Push the wooden dowels **f1** (x4)		3	0,2	0,6	0,6
Put the excenter fittings **r1** (x3)		3	0,1	0,3	0,3
Put down the equipped board C3	0,3				0,3
TOTAL	0,7			1,6	2,3

Take the board C4	0,4				0,4
Place the left drawer slider **w2L** (x1)		1	0,1	0,1	0,1
Screw it with the bolts **e3** (x2)		2	0,3	0,6	0,6
Push the wooden dowels **f1** (x4)		3	0,2	0,6	0,6
Put the excenter fittings **r1** (x3)		3	0,1	0,3	0,3
Put down the equipped board C4	0,3				0,3
TOTAL	0,7			1,6	2,3

Push the wooden dowels **f1** (x2)		2	0,2	0,4	0,4
Put down the equipped board C5	0,3				0,3
TOTAL	0,3			0,4	0,7

Take the board C6	0,4				0,4
Put down the equipped board C6	0,3				0,3
TOTAL	0,7			0	0,7

Take the board C8	0,4				0,4
Push the wooden dowels **f1** (x2)		2	0,2	0,4	0,4
TOTAL	0,4			0,4	0,8

BODY ASSEMBLY

	tp (min)	**Repetition**	**ts (min)**	**tg (min)**	**tw (min)**
Take the boards C1, C2 and C8	1,2				1,2
Assemble the boards **C1, C2** and **C8**		2	0,5	1	1
Screw the bolts **e1** (x4)		4	0,3	1,2	1,2
Put the bolt plug **s1** (x4)		4	0,1	0,4	0,4
Put down the subset C1-C2-C8	0,3				0,3
TOTAL	1,5			2,6	4,1

Take the boards C3, C4 and C5	1,2				1,2
Assemble the boards **C3, C4** and **C5**		2	0,5	1	1
Screw the bolts **e1** (x2)		2	0,3	0,6	0,6
TOTAL	1,2			1,6	2,8

Take the board C6	0,4				0,4
Assemble **C6** on the subset **C3-C4-C5**		1	0,5	0,5	0,5
Block the four excenter fittings **r16**		4	0,1	0,4	0,4
Put the eccentric plugs **s2** (x2)		2	0,1	0,2	0,2
TOTAL	0,4			1,1	1,5

Take the subset C1-C2-C8	0,8				0,8
Assemble the subset **C1-C2-C8** on the subset **C3-C4-C5-C6**		1	0,5	0,5	0,5
Block the six excenter fittings **r16**		6	0,1	0,6	0,6
Put the eccentric plugs **s2** (x6)		6	0,1	0,6	0,6
TOTAL	0,8			1,7	2,5

FINAL ASSEMBLY					
	tp (min)	**Repetition**	**ts (min)**	**tg (min)**	**tw (min)**
Screw it with the bolts **e2** (x4)		4	0,3	1,2	1,2
Put the screw plug **s4** (x8)		8	0,1	0,8	0,8
Stock the furniture	2				2
TOTAL	2			2	4

TOTAL TIME OF ASSEMBLY FURNITURE ELBIU-7-12 (min)	**29**

Table 40. Assembly time ELBIU/7/12.

5.3.3. ELBIU/7/14

The times of assembly of this desks are:

EQUIPMENT BOARDS					
	tp (min)	**Repetition**	**ts (min)**	**tg (min)**	**tw (min)**
Take the board C1	0,4				0,4
Place the mounting plates **b1** (x2)		2	0,1	0,2	0,2
Screw it with the two screws for each plates		4	0,3	1,2	1,2
Push the wooden dowels **f1** (x2)		2	0,2	0,4	0,4
Put the excenter fittings **r3** (x6)		6	0,1	0,6	0,6
Put down the equipped board C1	0,3				0,3
TOTAL	0,7			1	3,1

Take the board C2	0,4				0,4
Place the left drawer slider **w2L** (x1)		1	0,1	0,1	0,1
Screw it with the bolts **e3** (x2)		2	0,3	0,6	0,6
Turn the board of 180° to change the side	0,1				0,1
Push the wooden dowels **f1** (x4)		4	0,2	0,8	0,8
Put the excenter fittings **r3** (x6)		6	0,1	0,6	0,6
Put down the equipped board C2	0,3				0,3
TOTAL	0,8			2,1	2,9

Take the board C3	0,4				0,4
Place the right drawer slider **w2P** (x1)		1	0,1	0,1	0,1
Screw it with the bolts **e3** (x2)		2	0,3	0,6	0,6
Turn the board of 180° to change the side	0,1				0,1
Push the wooden dowels **f1** (x4)		4	0,2	0,8	0,8
Put the excenter fittings **r3** (x6)		6	0,1	0,6	0,6
Put down the equipped board C3	0,3				0,3
TOTAL	0,8			2,1	2,9

Take the board C4	0,4				0,4
Push the wooden dowels **f1** (x4)		4	0,2	0,8	0,8
Put the excenter fittings **r3** (x6)		6	0,1	0,6	0,6
Put down the equipped board C4	0,3				0,3
TOTAL	1,5			3,5	5

Take the board C5	0,4				0,4
Screw the retaining pins **r16** (x18)		18	0,3	5,4	5,4
Put down the equipped board C5	0,3				0,3
TOTAL	0,7			5,4	6,1

Take the board C7, C9 and C10	1,2				1,2
Push the wooden dowels **f1** (x10)		10	0,2	2	2
Put down the equipped board C4	0,3				0,3
TOTAL	1,5			2	3,5

Take the board C18	0,4				0,4
Place the concealed hinge **a1** (x2)		2	0,1	0,2	0,2
Screw it with the two screws for each plates		4	0,3	1,2	1,2
Put down the equipped board C1	0,3				0,3
TOTAL	0,7			1,4	2,1

BODY ASSEMBLY

	tp (min)	Repetition	ts (min)	tg (min)	tw (min)
Take the boards C1, C2, C3, C4, C7 (x2), C9 and C10 (X2)	3,6				3,6
Assemble the boards **C1, C2, C3, C4, C7** (x2), **C9** and **C10** (X2)		8	0,5	4	4
Screw the bolts **e1** (x16)		16	0,3	4,8	4,8
Put the bolt plug **s1** (x14)		14	0,1	1,4	1,4
TOTAL	3,6			10,2	13,8

Take the boards C5 and C6	0,8				0,8
Assemble **C5** and **C6** on the subset **C1-C2-C4-C7** (X2)-**C9-C10** (X2)		2	0,5	1	1
Block the twenty-four excenter fittings **r16**		24	0,1	2,4	2,4
Put the eccentric plugs **s2** (x18)		18	0,1	1,8	1,8
Place the base of plastic legs **k29-1** (x8)		8	0,1	0,8	0,8
Screw the plastic legs **k29-2** (x8)		8	0,3	2,4	2,4
Put down the subset C1-C2-C3-C6-C8-C9-C4-C5	0,3				0,3
TOTAL	1,1			8,4	9,5

MAKING THE DRAWERS

	tp (min)	Repetition	ts (min)	tg (min)	tw (min)
Take the boards C11 (x2), C12 (X2), C14 and C15	2,4				2,4
Put of the glue **y1** in the hole		12	0,2	2,4	2,4
Push the wooden dowel **f1** (x12)		12	0,2	2,4	2,4
TOTAL	2,4			4,8	7,2

Take the boards C13 and C16	0,4				0,4
Assemble **C11** (x2)and **C12** (x2)on **C13** (x2) and **C14** and **C15** on **C16**		3	0,5	1,5	1,5
Push the twelve plastic pegs **f25**		12	0,2	2,4	2,4
TOTAL	0,4			3,9	4,3

Take the boards C19 (x2) and C20	0,4				0,4
Put of the glue y1 in the twelve holes of the boards **C19** (x2) and **C20**		12	0,2	2,4	2,4
Assemble the board **C19** (X2) with the subset **C11**(x2)-**C12**(x2)-**C13**(x2)		2	0,5	1	1
Assemble the board **C20** with the subset **C14**-**C15**-**C16**		1	0,5	0,5	0,5

Place the door handles **c85** (x3)		3	0,1	0,3	0,3
Screw it with the screws **j30** (x6)		6	0,3	1,8	1,8
TOTAL	0,4			3,4	6,4

Take the boards C17 (x3)	0,4				0,4
Slide the board **C17** (x2) on subset **C11**(x2)-**C12**(x2)-**C13**(x2)-**C19**(x2)		2	0,2	0,4	0,4
Slide the board **C17** on subset **C14-C15-C16-C20**		1	0,2	0,2	0,2
TOTAL	0,4			0,4	1

Turn the drawers on the good side	0,1				0,1
Make sure that the diagonals are equal (a=b)		3	1	3	3
Nail the board **C17** (x3) with eighteen nails **l1** (x18)		18	0,2	3,6	3,6
TOTAL	0,1			6,6	6,7

FINAL ASSEMBLY

	tp (min)	Repetition	ts (min)	tg (min)	tw (min)
Screw the bolts **e2** (x4) with the screwdriver		4	0,3	1,2	1,2
Place the concealed hinges **a1** (x4)		4	0,1	0,4	0,4
Screw it with the screws **p51** (x8)		3	0,3	0,9	0,9
Place the door handle **c85** (x1)		1	0,1	0,1	0,1
Screw it with the screws **j30** (x2)		2	0,3	0,6	0,6
Adjust the height with the plastic legs **k29**		8	0,5	4	4
TOTAL	0			1,2	7,2

Slide the drawer in the drawer sliders **w43**		3	0,2	0,6	0,6
Put the notch of drawer on the adjustable head		3	0,2	0,6	0,6
Adjust the height with the head		3	0,2	0,6	0,6
Stock the furniture	2				2
TOTAL	2			1,8	3,8

TOTAL TIME OF ASSEMBLY FURNITURE ELBIU-7-12 (min)	**85,5**

Table 41. Assembly time ELBIU/7/14.

5.3.4. ELBIU/7/16

The times of assembly of this desks are:

EQUIPMENT BOARDS					
	tp (min)	**Repetition**	**ts (min)**	**tg (min)**	**tw (min)**
Take the board C1	0,4				0,4
Push the wooden dowels **f1** (x2)		2	0,2	0,4	0,4
Put the excenter fittings **r3** (x3)		3	0,1	0,3	0,3
Push the pins **k1** (x2)		2	0,2	0,4	0,4
Put down the equipped board C1	0,3				0,3
TOTAL	0,7			0,7	1,8
Take the board C2	0,4				0,4
Push the wooden dowels **f1** (x2)		2	0,2	0,4	0,4
Put the excenter fittings **r3** (x3)		3	0,1	0,3	0,3
Push the pins **k1** (x2)		2	0,2	0,4	0,4
Put down the equipped board C2	0,3				0,3
TOTAL	0,7			0,7	1,8
Take the board C3	0,4				0,4
Screw the retaining pins **r16** (x6)		6	0,3	1,8	1,8
Put down the equipped board C3	0,3				0,3
TOTAL	0,7			1,8	2,5
Take the board C4	0,4				0,4
Push the wooden dowels **f1** (x2)		2	0,2	0,4	0,4
Put the excenter fittings **r1** (x2)		2	0,1	0,2	0,2
Put down the equipped board C4	0,3				0,3
TOTAL	0,7			0,6	1,3
Take the board C5	0,4				0,4
Push the wooden dowels **f1** (x2)		2	0,2	0,4	0,4
Put down the equipped board C5	0,3				0,3
TOTAL	0,7			0,4	1,1

FINAL ASSEMBLY					
	tp (min)	**Repetition**	**ts (min)**	**tg (min)**	**tw (min)**
Take the boards C1, C2, C4 and C5	1,6				1,6
Assemble the boards **C1, C2, C4** and **C5**		3	0,5	1,5	1,5

Block the two excenter fittings **r16**		2	0,1	0,2	0,2
Screw the bolts **e1** (x4)		4	0,3	1,2	1,2
Put the eccentric plugs **s2** (x2)		2	0,1	0,2	0,2
Put the bolt plug **s1** (x4)		4	0,1	0,4	0,4
TOTAL	1,6			3,5	5,1

Take the boards C3	0,4				0,4
Assemble the boards **C3** on the subset **C1-C2-C4-C5**		1	0,5	0,5	0,5
Put the eccentric plugs **s2** (x6)		6	0,1	0,6	0,6
Put the screw plug **s4** (x8)		8	0,1	0,8	0,8
TOTAL	0,4			1,9	2,3

TOTAL TIME OF ASSEMBLY FURNITURE ELBIU-7-10 (min)	**15,9**

Table 42. Assembly time ELBIU/7/16.

6. Number of workstations and layout

6.1. Number of workstations

- ELBIU/7/10:

PRODUCTION SIZE DATA			
Parameter name	**Symbol**	**Value**	**Unit**
Production volumen of part per year	**P**	1000	(pieces/year)
Production volumen of part per year for coperation	**f1**	20%	(%)
Production volumen of part per year for spare parts	**f2**	15%	(%)
Defectiveness	**B**	0,8%	(%)
Economic factor of lot size	**q**	0,08	(-)

Table 43. Production size data ELBIU/7/10.

- **PV [pieces]** – Production Volume: is a number of pieces of product in given period of time.
- **f1 [%]** – Production volume correction factor based on fixed cooperation with other companies.
- **f2 [%]** – Production volume correction factor for spare parts (for service and repairs).
- **B [%]** – Defectiveness: is an average value of number of products which are not acceptable for customer (e.g. bad quality) expressed as percentage of own production volume.

TPV [pieces] – Total production volume is a sum of following factors:

$$TPV = PV * (1 + f1 + f2 + B) = 1000 * (1 + 0{,}2 + 0{,}15 + 0{,}008) = 1358$$

MAIN ORGANIZATIONAL DATA			
Parameter name	**Symbol**	**Value**	**Unit**
Number of working days per week	**Dw**	5	[day/week]
Number of shifts per working day	**NS**	2	[shift/day]
The working time per shift	**WT**	8	[h/shift]
Planned interruptions of work per shift	**PI**	0,58	[h/shift]

Table 44. Main organizational data ELBIU/7/10.

- ***DW*** – number of working days per week.
- ***NS*** – number of shifts per working day
- ***WT*** – the working time per shift
- ***PI*** – planned interruptions of work per shift
- **Shift** is a working unit defined by number of hours. Typically shift has 8 hours for employees.

During shift we have to predict some planned interruptions of work due to given by the law breaks for employees (e.g. breakfast break).

Therefore, we can calculate **Effective Standard Hours *ESHsh*** per shift as:

$$ESH_{sh} = WT - PI = 8 - 0.58 = 7{,}42$$

Than per year:

$$ASH_y = 52 * DW * NS * WT = 52 * 5 * 2 * 8 = 4160$$

$$ESH_y = 52 * DW * NS * (WT - PI) = 52 * 5 * 2 * (8 - 0{,}58) = 3859$$

Production Intensity *P* defines how many pieces have to be produced in given time unit (e.g. per hour) to realize accepted production volume ***TPV***.

$$P = \frac{TPV}{ESHy} = \frac{1358}{3858} = 0{,}35\ (\frac{pieces}{h})$$

Inverse of ***P*** defines **Tact Time *TT*** which set **production rate**:

$$P = \frac{ESHy}{TPV} = \frac{3858}{1358} = 2{,}84(\frac{h}{pieces})$$

Because we changed (rounded) Production Period, we need to calculate again **new value of production batch size *Npr***:

$$Nrp = Rn * P = 7{,}42 * 2{,}84 = 2{,}6\ pieces$$

Operation	Work Station	Tp (h)	Tj (h)	TOP	OL
Cut	CNC circular saw MJ300	0,19	0,38	1,18	0,16
Drill and Grove	CNC Uniflex S	0,59	0,86	2,84	0,38
Edge banding	Edge Bander Olimpic k600	0,23	0,50	1,53	0,21
Assembly	Operators	0,21	0,61	1,80	0,24

Table 43. Times ELBIU/7/10.

- **TOP –** Worktime Standard for all operation and manufacturing process:

$$TOP = Tp + Npr * Tj$$

- **OL –** Operation load:

$$OL = \frac{TOP}{Rn}$$

- ELBIU/7/12

PRODUCTION SIZE DATA			
Parameter name	**Symbol**	**Value**	**Unit**
Production volumen of part per year	**P**	1000	(pieces/year)
Production volumen of part per year for coperation	**f1**	20%	(%)
Production volumen of part per year for spare parts	**f2**	15%	(%)
Defectiveness	**B**	0,8%	(%)
Economic factor of lot size	**q**	0,08	(-)

RESULT			
Parameter name	**Symbol**	**Value**	**Unit**
Total product volume	**TPV**	1358	(pieces/year)

MAIN ORGANIZATIONAL DATA			
Para	**Symbol**	**Value**	**Unit**
Number of working days per week	**DW**	5	[day/week]
Number of shifts per working day	**NS**	2	[shift/day]
The working time per shift	**WT**	8	[h/shift]
Planned interruptions of work per shift	**PI**	0,58	[h/shift]

RESULT			
Parameter name	**Symbol**	**Value**	**Unit**
Total product volume	**ESHsh**	7,42	[h/shift]
Number of working days per week	**ASHy**	4160	[h/year]
Number of shifts per working day	**ESHy**	3858	[h/year]

Production intensity	**P**	0,35	(pieces /h)

Tact Time	**TT**	2,84	(h/piece)

New production batch size	**Npr**	2,6	(pieces)

Operation	Work Station	Tp (h)	Tj (h)	TOP	OL
Cut	CNC circular saw MJ300	0,16	0,30	0,94	0,13
Drill and Grove	CNC Uniflex S	0,30	0,43	1,41	0,19
Edge banding	Edge Bander Olimpic k600	0,13	0,29	0,90	0,12
Assembly	Operators	0,15	0,26	0,83	0,11

Table 44. Work station ELBIU/7/12.

- ELBIU/7/14

PRODUCTION SIZE DATA			
Parameter name	**Symbol**	**Value**	**Unit**
Production volumen of part per year	**P**	1000	(pieces/year)
Production volumen of part per year for coperation	**f1**	20%	(%)
Production volumen of part per year for spare parts	**f2**	15%	(%)
Defectiveness	**B**	0,8%	(%)
Economic factor of lot size	**q**	0,08	(-)

RESULT			
Parameter name	**Symbol**	**Value**	**Unit**
Total product volume	**TPV**	1358	(pieces/year)

MAIN ORGANIZATIONAL DATA			
Para	**Symbol**	**Value**	**Unit**
Number of working days per week	**DW**	5	[day/week]
Number of shifts per working day	**NS**	2	[shift/day]
The working time per shift	**WT**	8	[h/shift]
Planned interruptions of work per shift	**PI**	0,58	[h/shift]

RESULT			
Parameter name	**Symbol**	**Value**	**Unit**
Total product volume	**ESHsh**	7,42	[h/shift]
Number of working days per week	**ASHy**	4160	[h/year]
Number of shifts per working day	**ESHy**	3858	[h/year]

Production intensity	**P**	0,35	(pieces /h)

Tact Time	**TT**	2,84	(h/piece)

New production batch size	**Npr**	2,6	(pieces)

Operation	Work Station	Tp (h)	Tj (h)	TOP	OL
Cut	CNC circular saw MJ300	0,35	0,55	1,79	0,24
Drill and Grove	CNC Uniflex S	0,90	1,34	4,40	0,59
Edge banding	Edge Bander Olimpic k600	0,32	0,71	2,17	0,29
Assembly	Operators	0,29	0,97	2,82	0,38

Table 45. Work station ELBIU/7/14.

- ELBIU/7/16

PRODUCTION SIZE DATA			
Parameter name	**Symbol**	**Value**	**Unit**
Production volumen of part per year	**P**	1000	(pieces/year)
Production volumen of part per year for coperation	**f1**	20%	(%)
Production volumen of part per year for spare parts	**f2**	15%	(%)
Defectiveness	**B**	0,8%	(%)
Economic factor of lot size	**q**	0,08	(-)

RESULT			
Parameter name	**Symbol**	**Value**	**Unit**
Total product volume	**TPV**	1358	(pieces/year)

MAIN ORGANIZATIONAL DATA			
Para	**Symbol**	**Value**	**Unit**
Number of working days per week	**DW**	5	[day/week]
Number of shifts per working day	**NS**	2	[shift/day]
The working time per shift	**WT**	8	[h/shift]
Planned interruptions of work per shift	**PI**	0,58	[h/shift]

RESULT			
Parameter name	**Symbol**	**Value**	**Unit**
Total product volume	**ESHsh**	7,42	[h/shift]
Number of working days per week	**ASHy**	4160	[h/year]
Number of shifts per working day	**ESHy**	3858	[h/year]

Production intensity	**P**	0,35	(pieces /h)

Tact Time	**TT**	2,84	(h/piece)

New production batch size	**Npr**	2,6	(pieces)

Operation	Work Station	Tp (h)	Tj (h)	TOP	OL
Cut	CNC circular saw MJ300	0,10	0,18	0,57	0,08
Drill and Grove	CNC Uniflex S	0,19	0,27	0,89	0,12
Edge banding	Edge Bander Olimpic k600	0,08	0,18	0,56	0,08
Assembly	Operators	0,09	0,16	0,51	0,07

Table 46. Work station ELBIU/7/16.

- **Number of workstation:**

Operation	Work Station	TOTAL OL	NWS	SL
Cut	CNC circular saw MJ300	0,60	1,00	60,41%
Drill and Grove	CNC Uniflex S	1,29	2,00	64,36%
Edge banding	Edge Bander Olimpic k600	0,70	1,00	69,67%
Assembly	Operators	0,80	1,00	80,36%

Table 47. Final work stations.

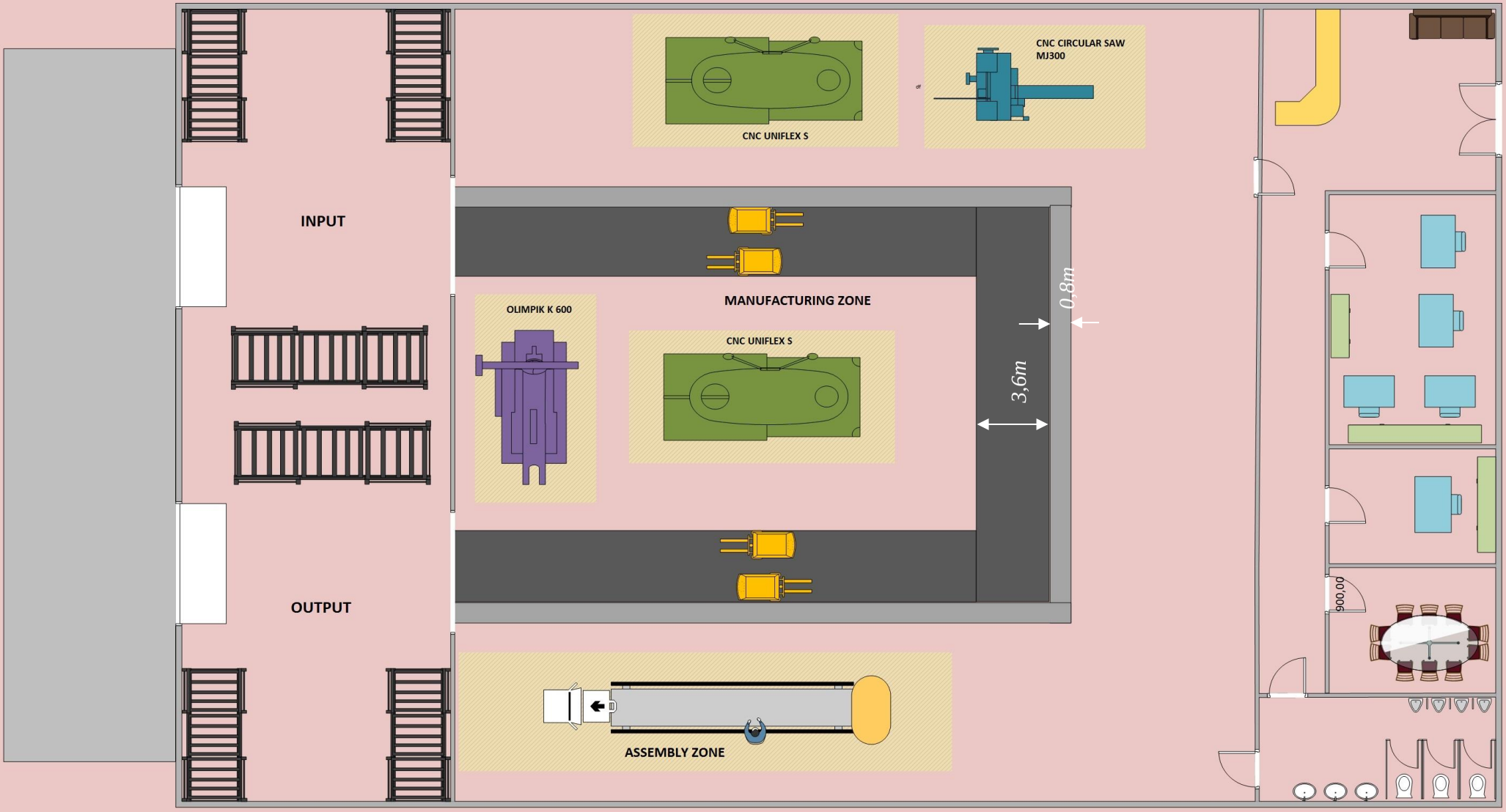
- **NWS** – Number of workstations

- For each machinetool and accepted amount of it, we can calculate **real value of machinetool load SL** (which should be lower than 100% but in real production environment should not exceed 95%):

$$SL = \frac{OL}{NWS}$$

If we work five days per week and we do two shift of 8 hours (one 6 a.m. - 2 p.m. and other 2 p.m. -10 p.m.) we only need one cut machine, two drill and grove machine, one machine for edge banding and only one operator per shift for assembly the furniture.

6.2. Layout


CNC UNIFLEX S
CNC CIRCULAR SAW
MJ300
INPUT
MANUFACTURING ZONE
OLIMPIK K 600
CNC UNIFLEX S
0,8m
3,6m
OUTPUT
900,00
ASSEMBLY ZONE

7. Conclusions

After the realization of the research about the organization of the production line of a Company dedicated to the furniture sector, collecting and analysing the information propose by the Dr Jacek Habel, we can get into the next conclusions:

- Through the old studies of the clients' orders, we can determine the volume of the future orders, as well as being provided of the minimum security stock to satisfy the necessities of the clients.
- Analysing the raw material, we can minimize the waste
- Throughout the study of the manufacture times, we can determine the time used in the manufacture of the raw material and times of assembly obtaining a better precision of the orders.
- Once the time and the orders have been analysed, we could also determine the number of machines needed to achieve the volume of furniture needed.

8. References

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