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MANUFACTURING WELDING LINE LAYOUT ANALYSIS IN ORDER TO REDUCE THE HUMAN RESOURCES INVOLVED

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Rezumat. *Această lucrare prezintă un studiu de caz cu privire la posibilitatea utilizării programului Delmia Quest pentru simularea funcționării unei linii de sudură manuală. Scopul acestei lucrări este de a înțelege linia și comportamentul acesteia și de a folosi software-ul de simulare pentru a optimiza linia. Pentru a putea optimiza această linie de fabricație prin încărcarea adecvată a resurselor umane, s-a folosit varianta de implantare propusă inițial, unde fiecare operație avea alocat câte un operator. Plecând de la rezultatele obținute cu ajutorul programului Delmia Quest, s-au căutat soluții de reducere a numărului de operatori din linia de fabricație, fără însă a afecta productivitatea acesteia.*

Abstract. *This paper presents a case study on the use of Delmia Quest software in the simulation of a manual welding line. The goal of this paper is to better understand the line and its behaviour and to use the simulation software in order to optimize the line. To be able to optimize the welding line by adequate charge of the resources, the initial welding line layout has been used, where each operation had allocated a welder. Starting from the obtained results with the Delmia Quest software, solutions to reduce the number of welders from the welding line have been searched, without affecting the line productivity.*

Key words: manufacturing layout, Delmia Quest, optimization, manual welding process.

1. Introduction

The study of the manufacturing lines and their optimization possibilities represent an interesting domain of process engineering. To do that some modelling and simulation software are needed. Discrete event simulation [1-3] is one of the most used tools of process simulation in areas like logistics, mechanics and production. To obtain the best results, we must use it right after the initial stage, where the process needs are defined. In this first stage, generally to each operation is allocated an operator and the cycle times for each operation are calculated starting from some basic process rules. So, after the initial 2D layout the team must conduct a simulation using software, such as Delmia Quest [4-8], to study the

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productivity of the manufacturing process and also the charge of each operator. The obtained results are then used to optimize the process and layout in terms of productivity and/or resources charge [9]. So, the modelling and simulation of the manufacturing line allow us to reduce the costs from the incipient stages of the project by choosing the right solution in terms of number of machines, workers and also manufacturing layout and surface usage optimization. That's because Delmia Quest can be used to simulate and get data from everything related to the production systems. Also, another great benefit of the simulation is the fact that it can reduce the time needed for the development and installation of a new manufacturing process in the plant.

2. Initial manufacturing line layout

In this first part of the paper we will evaluate the performance obtained by the welding line using the initial layout. In Figure 1 you can see the subframe representation.

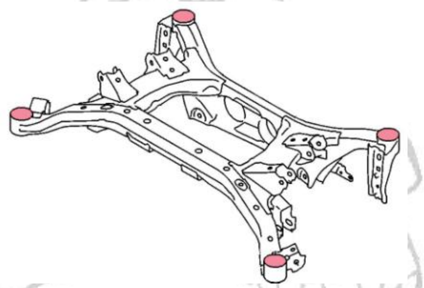

Fig. 1. The subframe representation.

2.1. Line layout and operation

The rear subframe welding line is a manual one with 7 operations and 7 workers, supervised by a line conductor. The production line is organised in three 8-hour shifts, each shift having 3 breaks. The time distribution of a shift is presented in Table 1.

Table 1. Breaks distribution in an 8-hour shift

Time(min)	*Activity*
0-120	Work
120-135	Break
135-240	Work
240-270	Break
270-360	Work
360-372	Break
372-480	Work

The time cycle of the line will be given by the biggest time cycle from the operations. In Table 2, you can see a short description of the operations from the manufacturing line and in Figure 2 a graph with the time cycle for each operation.

Table 2. Operation description and number of workers

Operation number	*Operation name*	*Type of operation*	*Number of workers*
110	Front right support welding	Manual MAG	1
112	Front left support welding	Manual MAG	1
120	Rear crossmember welding	Manual MAG	1
130	Primary assembly of the subframe	Manual MAG	1
140	Final assembly of the subframe	Manual MAG	1
150	Welding of the acoustic tie beam and marking	Manual MAG	1
180	Visual check and conditioning	Control table	1

The workers do manually all the welding lines. Also, each operator makes a visual check of his operation and attests the conformity by an individual marking.

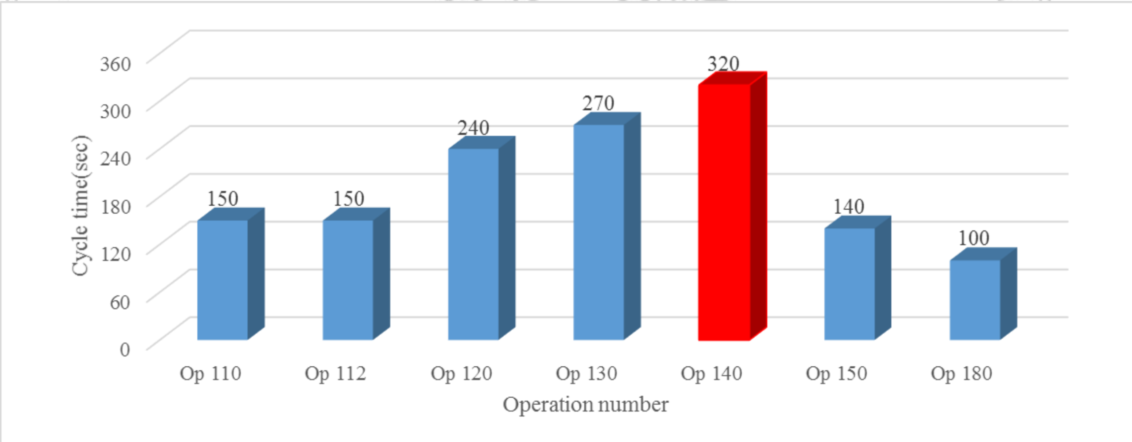

Fig. 2. The time cycle of each operation.

As we can see in Figure 2, the time cycle of the line is given by the operation 140, with a value of 320 seconds.

To obtain the finite product a number of specific parts for each operation is needed. Figure 3 shows a diagram of the number of parts needed for each operation, where P 01 to P 016 are the simple components, S 51 to S 56 are the welded subcomponents resulted from each welding operation and Op 110 to Op 180 are the machines where the assembly welding takes place.

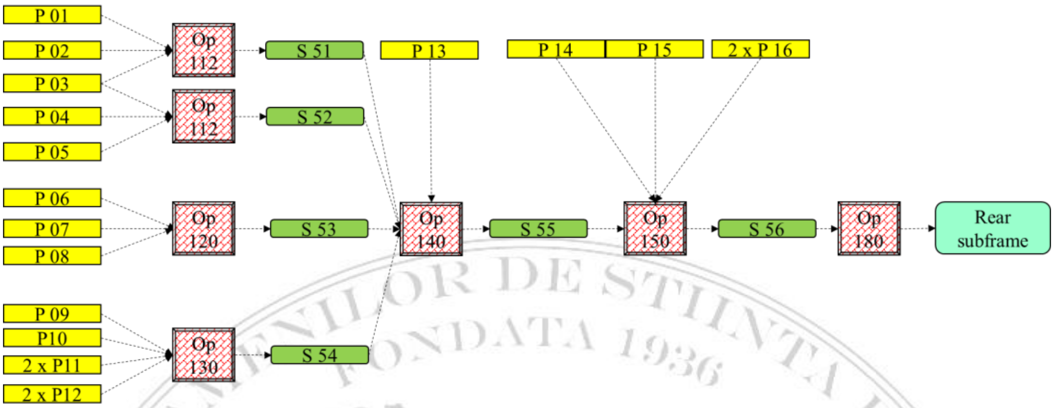

Fig. 3. Parts needed for each operation.

The initial layout of the welding line is presented in Figure 4. Here we can see all the machines, operators, and logistic areas and also the conveyors needed to transport the welded subcomponents between operations.

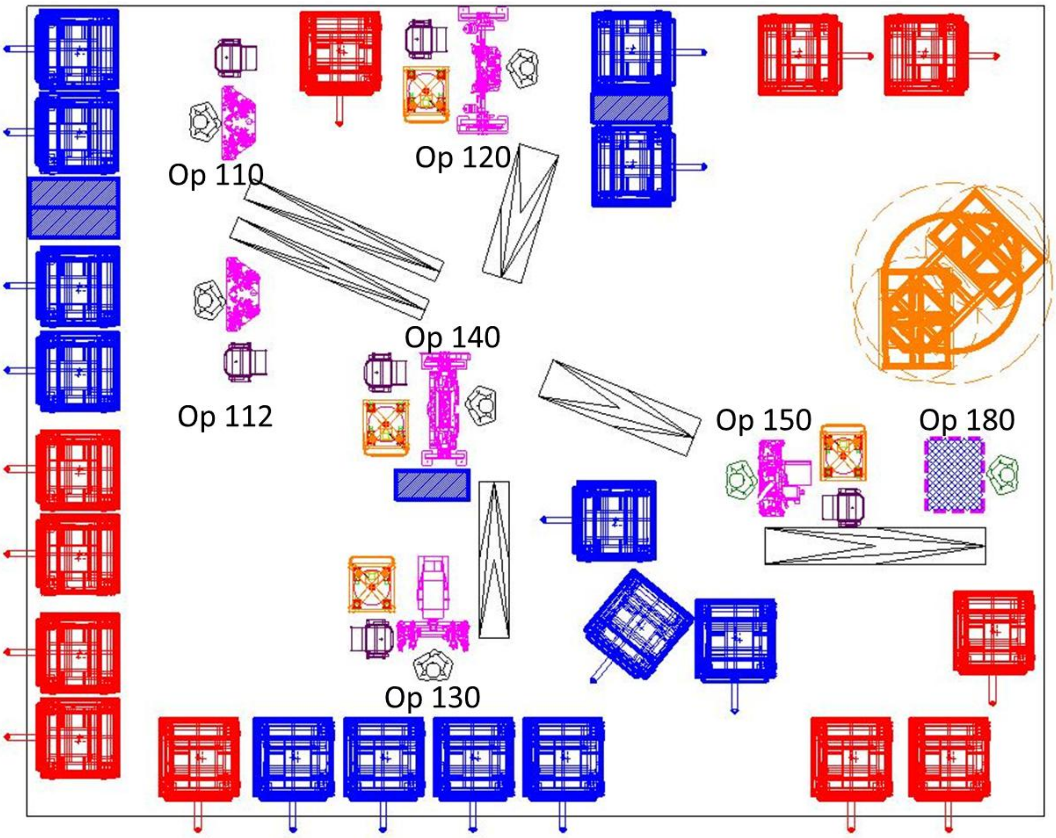

Fig. 4. Rear subframe welding line layout.

Operations 110 and 112 are similar, each one producing the right and left front support of the rear subframe. For operation 120, the welder needs 3 parts to obtain the rear cross member and for operation 130, the welder obtains the initial shape of the upper part of the subframe.

As you can see from the layout, the manufacturing layout is realized around operation 140 which gathers parts from the other operations and welds them together to get the final shape and geometry of the part. For operation 150 more parts are needed to attach the exhaust pipe on the subframe and also, the rear subframe receives its unique serial number. The final operation, number 180, is where takes place the final check of the part and then the conditioning of the parts in the specific package to be sent afterwards to the cataphoresis line, where the subframe receives its rust protecting coat.

2.2. Delmia Quest simulation of the initial layout

Starting with the given data from the previous section and using the Delmia Quest software, we have conducted a simulation to evaluate the charge of each machine, each operator and also the number of parts obtained during an 8-hour shift.

Figure 5 presents a screenshot taken during the simulation of the welding line.

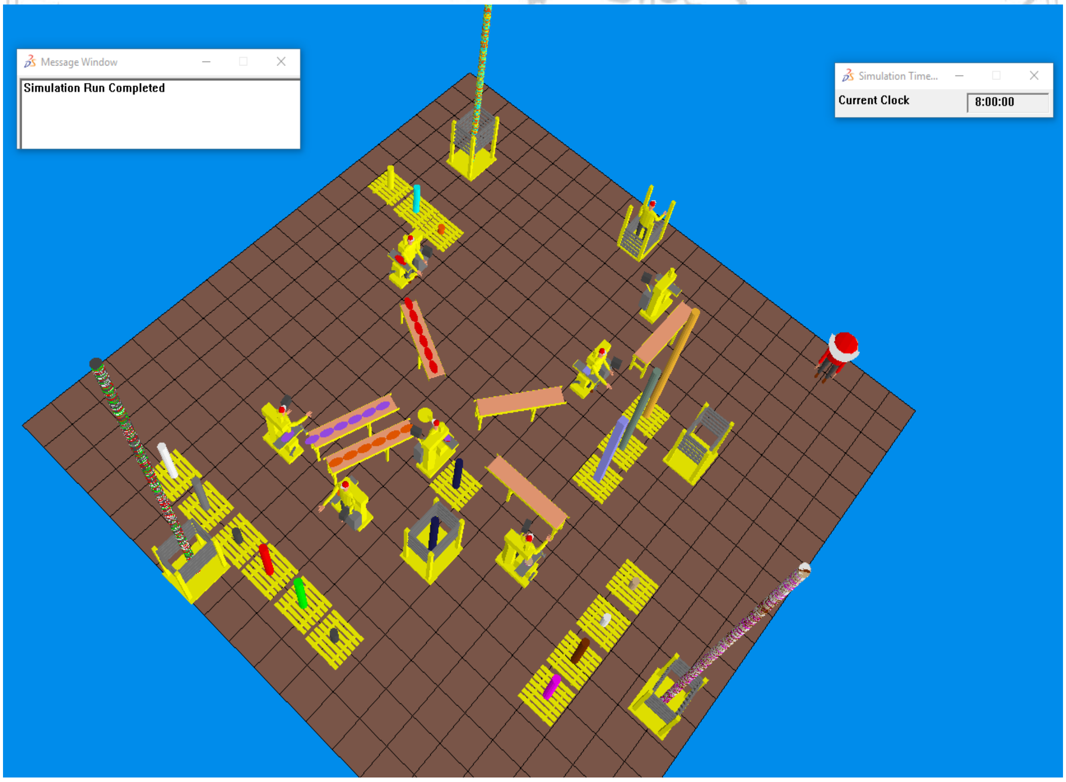

Fig. 5. Delmia Quest simulation.

After the 8-hour simulation, the number of rear subframes obtained is of 57.

The results in terms of operators and machine charge are presented in Figures 6 and 7.

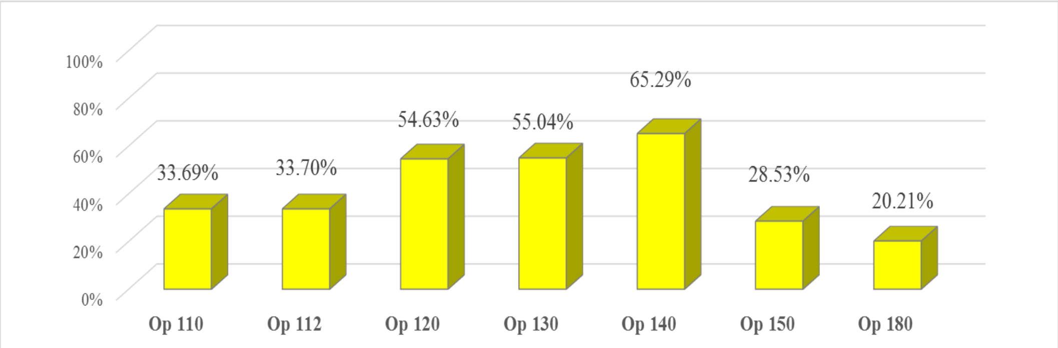

Fig. 6. Charging of the machines (initial layout).

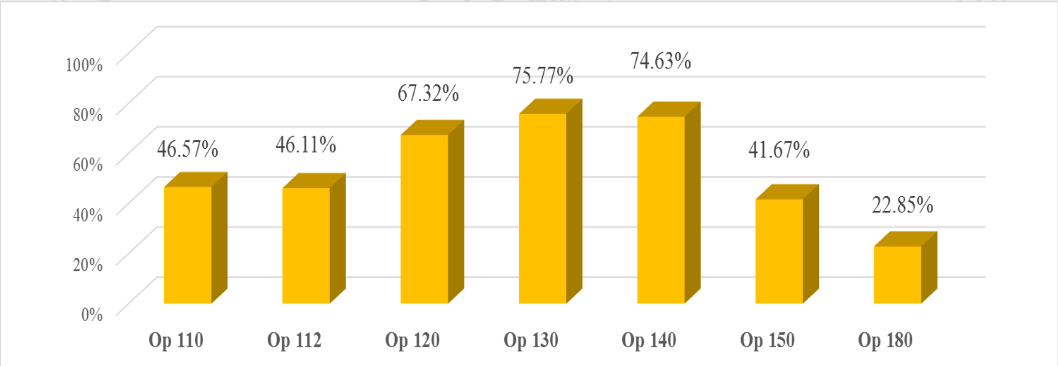

Fig. 7. Charging of the operators (initial layout).

As we can see from these results, the operators from 110,112, 150 and 180 are charged below 50%, so we must do something to give them more work to do, as long as they obtain the same number of rear subframe after the 8-hour shift.

2.3. Optimization of the charge of the operators

After analysing the data from Figure 7, we have the following solutions to optimise the process:

a) Use one operator at OP110 and OP112

b) Use one operator at OP150 and OP180

c) Use one operator at OP110 and OP112, and one operator at OP150 and OP180

The obtained results for each of the proposed solutions are presented in Figures 8 to 13.

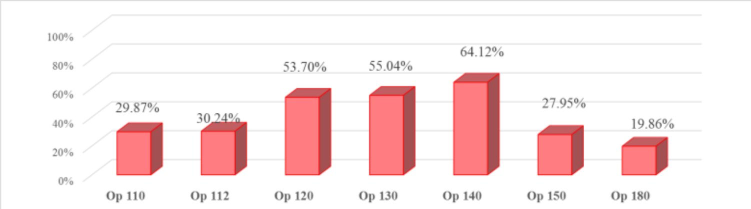

Fig. 8. Charging of the machines (case a).

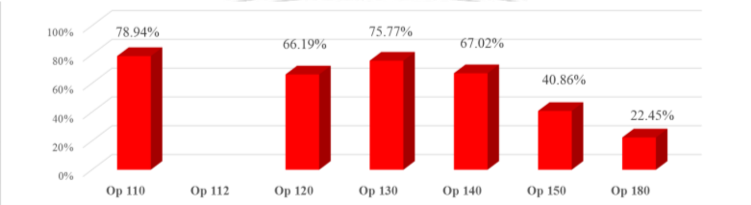

Fig. 9. Charging of the operators (case a).

Fig. 10. Charging of the machines (case b).

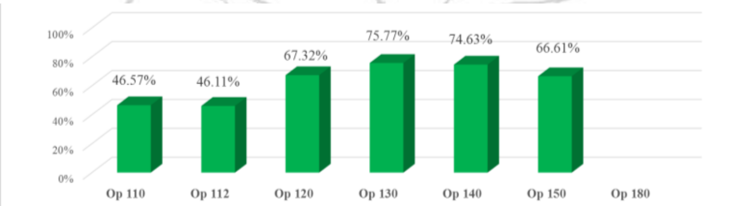

Fig. 11. Charging of the operators (case b).

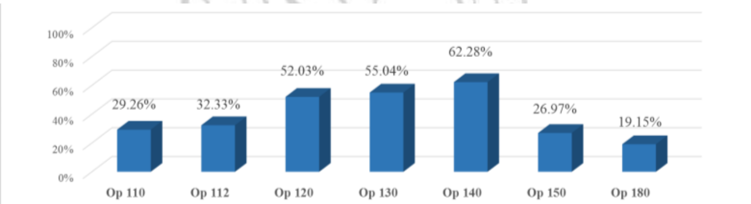

Fig. 12. Charging of the machines (case c).

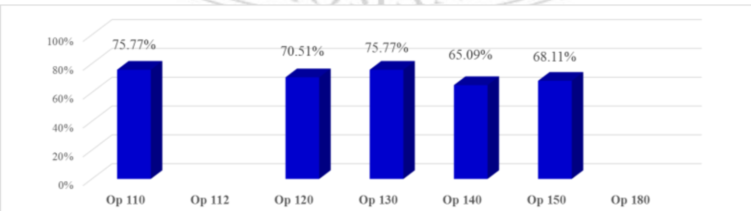

Fig. 13. Charging of the operators (case c).

The results are also presented in Tables 3 and 4 compared to the results of the initial simulation. The charge of operators is presented in graphical form in Figure 14. In terms of machine charge, the results are presented in Table 5 and in graphical form in Figure 15.

Table 3. Results of the Delmia Quest simulations

	Number of workers	*Average operator charge*	*Number of subparts*	*Number of subframes*
Original	7	53.56%	372	57
Variant A	6	58.54%	353	56
Variant B	6	62.84%	372	57
Variant C	5	71.05%	350	56

Table 4. Operator charge

	Op 110	Op 112	Op 120	Op 130	Op 140	Op 150	Op 180
Original	46.57%	46.11%	67.32%	75.77%	74.63%	41.67%	22.85%
Variant A	78.94%		66.19%	75.77%	67.02%	40.86%	22.45%
Variant B	46.57%	46.11%	67.32%	75.77%	74.63%	66.61%	
Variant C	75.77%		70.51%	75.77%	65.09%	68.11%	

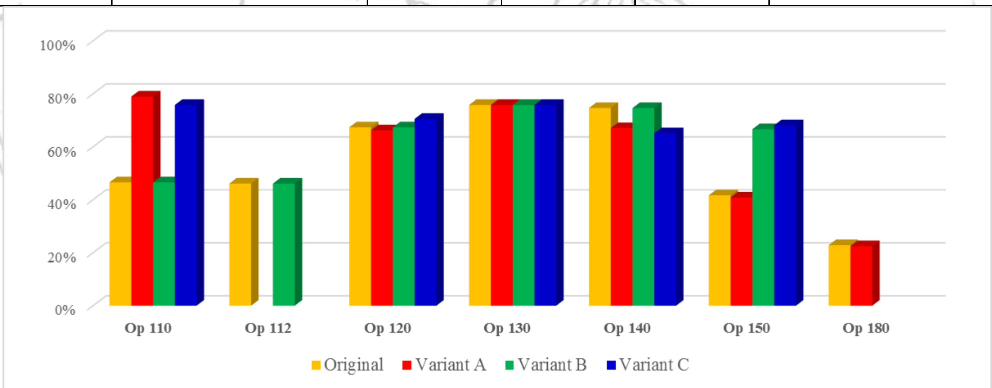

Fig. 14. Charging of the operators.

Table 5. Machine charge

	Op 110	Op 112	Op 120	Op 130	Op 140	Op 150	Op 180
Original	33.69%	33.7%	54.63%	55.04%	65.29%	28.53%	20.21%
Variant A	29.87%	30.24%	53.7%	55.04%	64.12%	27.95%	19.86%
Variant B	33.69%	33.7%	54.63%	55.04%	65.25%	28.5%	20.21%
Variant C	29.26%	32.33%	52.03%	55.04%	62.28%	26.97%	19.15%

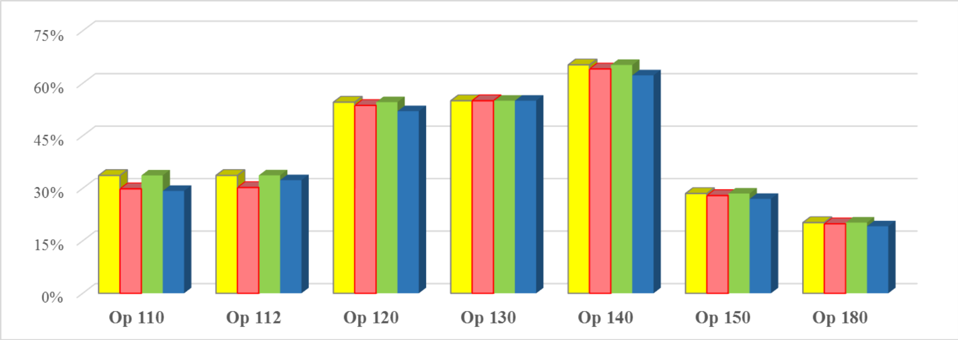

Fig. 15. Charging of the machines.

Conclusions

From the presented results we can conclude the following:

- If we want to keep the welding line productivity we need to use the variant B, which allows us to obtain the same number of subparts and also the rear subframes, but with the reduction of one operator.

- If we want a greater cost reduction and an increase in the charge of the operators we have to choose the variant C, which brings us an average operator charge of about 71%. The downside of this variant is that the number of obtained rear subframes is one unit lower (56 instead of 57), but the advantage is the reduction from 7 workers to 5 workers needed.
- The charge of the operators from 120, 130 and 140 is about the same for each of the 4 simulations, being a little lower for variants A and C, where also the number of the subparts obtained during the 8-hour shift is lower (about 350 compared to 370 subparts).

As general conclusions we can state that the use of numerical simulation helps us reduce the time needed to develop a product and so it can be used in all industry areas. The use of software that helps simulate a production line is welcomed in today's fast pacing industry. By starting from the initial layout and the calculate cycle times we can realise the simulation of a manufacturing line, and thus estimate the productivity of that process. Delmia QUEST is simulation software based on discrete event simulation and provides a powerful visualization for industrial engineers, manufacturing engineers, and management to develop and prove out best manufacturing flow practices throughout the production design process. Also, another advantage of numerical simulation software is that it is simpler to use and the fact that the user is able to realize multiple iterations in a short amount of time. So, the optimum solution for the manufacturing line layout can be obtained before the line is on the site. By doing so, we will avoid the supplementary costs caused by a poor charge of the operators, relocation of the machines or weak choice of the part transport means.

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