MPR271 Simulation of Production Systems

Examination Project Work

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Abstract:

Simulation plays an important role on production system analysis. A company is facing unstable production situation with low profit. Thus, authors take responsibility of modification for this company to raise production and profits and it mainly involves focusing on application of AutoMod software and Theory of Constraint. Iterations on modification continue to be executed until the final model is acquired. Lastly, digital factory is aslo significant aspect to moderise the production system.

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I. Introduction

1. Background

Emmy's Specialised Components, which is to manufacture and sell steel components for car engines, struggles with unstable production with current issues regarding facilities and personnel which makes customers and managers are unsatisfied. Authors are responsible to deliver investigations to modify and improve the production systems with limited budget to pursue higher benefits. And possible investments have been listed for modernising the production systems.

2. Purpose

To analyse the dynamic production flow by AutoMod, observe the possible weakness requiring modification. To make satisfied improvement on production systems within limited budget (225.000 Euro). The ultimate goal is to improve final production as much as possible by adding new machines and hiring new personnel, etc, to pursue higher profits and productions.

3. Objectives

Build the simulation model of current production systems in order to obtain the results of current production systems.

Observe all possible weakness requiring modifications.

Design and propose experiments for possible improvement using theory of constraints and experimental planning. The basic principle is to improve production as much as possible within limited budget.

Validate whether the change is deserved by comparing cost and benefits. If the new benefits are higher than costs in a time period (such as within 1600hrs), then it can be implemented.

Iterate: Continue to change and analyse the new results.

Executing the extra tasks to acquire a better system.

4. Problem formulation

For the current system, the final products in 1600 hours are 4645 and 6859 for 2 types of product variants respectively. It is found that the utilisation for measuring (68%) and worker no.1 (76%) are very high. They are identified as bottleneck to hinder the production system from producing more products. Potential change is to lift them, by training an employee with least utilisation to assist work no.1 and adding a new measuring machine.

5. Delimitations

In real factory, products are transported, such as by belts or AGV. Production transportation costs time surely from different section. However, in AutoMod, moving to next processes does not cost time, which differs from reality.

After the product is finished, they are put into boxes for packaging process, packaging machine is enough fast, and the area is big enough to handle. However, in reality, any process may be a bottleneck to hinder a higher production and cannot be assumed to be fast or big enough.

According to capitalism economy theory, when the more products are produced to the market, as a consequence, price will decrease. In the project, the price of products, even raw materials are set to stationary, which differs from reality.

II. Methodology

Simulation, is to represent a system with another with the purpose to study its dynamical behaviour or in a laboratory environment train the control of the system (Frantzén, 2021). This project is heavily depending on simulation of production systems through software, AutoMod. The essential of software is codes. Each load will read following line after it is created. Load might be placed on order list, be executed by resource, and sent to different process. By completing all procedure to set up a system, a base model can be observed for current production situation and further improvement.

The most typical identification for bottleneck is 'High Utilization, because it works continuously and make upstream process blocked and downstream process starved. It can be observed in AutoStat. Additionally, 'State' (including setup, block, idle, down and so forth) is introduced to codes so that bottlenecks can be identified. After identifying the bottlenecks for the system, they shall be modified within the budget. Meanwhile, the profit must be calculated to ensure this specific modification is worth (resulting in a positive profit).

By applying Theory of Constraints continuously, identifying bottlenecks and eliminating, a better production system can be determined.

To simulate a production system that is close to reality, the time distributions for resources and workers are given such as normal distribution, Weibull distribution and triangular distribution for cooling process, manual inspection and MTTR of cutting process respectively. When reading the codes, the time for one specific process may be various slightly since it is a distribution, not precise time.

III. Project realisation

The codes of basic model can be found in the attachment of this project. Referring to the code, firstly it is 'model initialisation' by creating first load to process and several dummy loads to downtime process. Then it is 'initialise variable' process, by setting a huge number of parameters such as parameter for distributions, parameter for MTTR, MTTF, etc. Afterward it is arriving procedure, 40 loads to send to warehouse every 4 hours, as specified. Following codes are for downtime: Machine will break down or personnel need to relax every time cycle. From line 261 to line 583, these codes are core of the production system, including cutting, turning, grinding, polishing, surface treatment, cooling, measuring and manual quality inspection. Lastly it is final part, send to finished goods (Q_Product) and count how many product is manufactured. So overall, a load will be send to warehouse, send to first process and following processes, and finally to finished goods. Meanwhile personnel take a rest and machines break down occasionally, and some of load is disposed, such as at manual inspection procedure. States are applied everywhere in codes to classify how resource is performed as idle, working, and so forth.

Then the output and performance (utilisation) of basic model can be recorded as table 1 and figure 1.

Table 1: Output of basic model

	Input			Output		
	Raw	Personnel	Machine	Variant 1	Variant 2	Bad
Number	2258	5	11	4645	6859	731
Cost/income (Euro)	106129	157500	44224	148640	178327	----
Total (Euro)	307853			326967		
Profit (Euro)	19114					

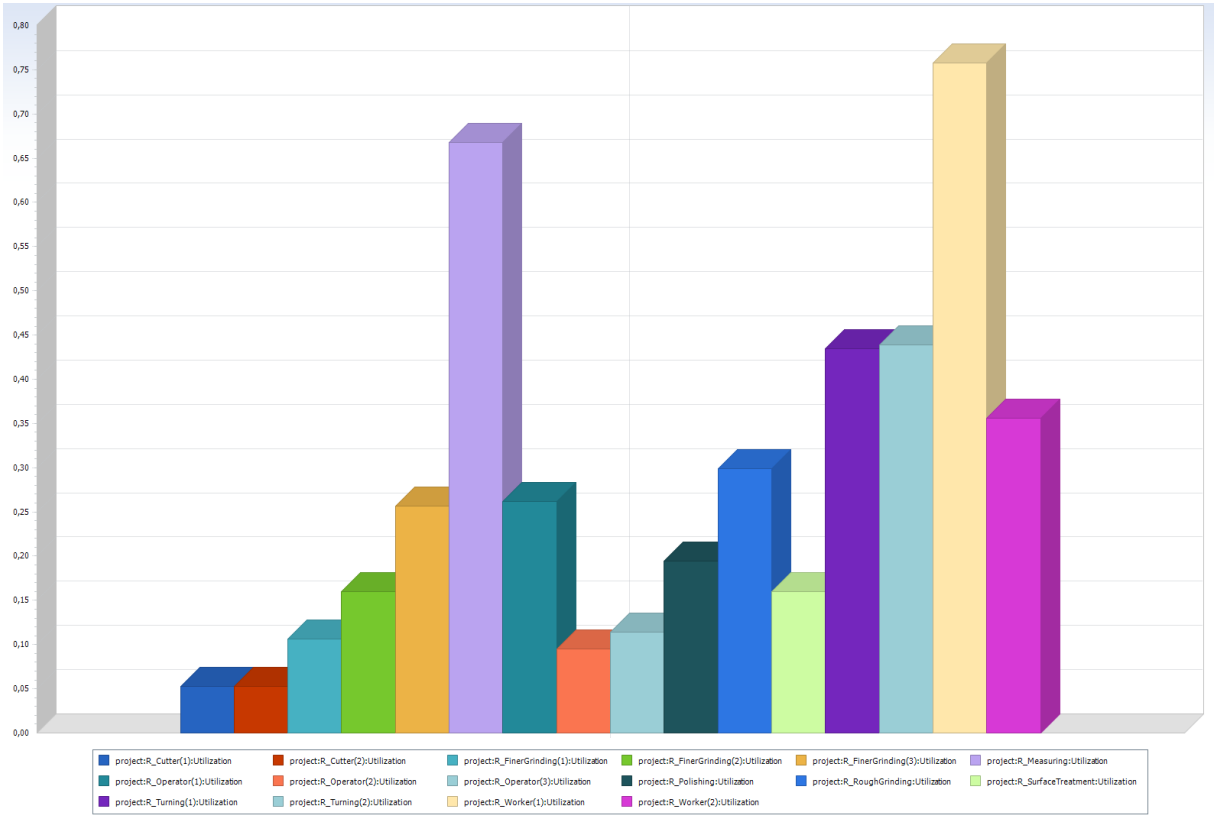

Figure 1: Performance of basic model

According to figure 1 above, it can be significantly found that the utilisation for measuring (68%) and worker no.1 (76%) is obviously higher than others. So they can identifying as bottleneck due to high utilisation, and these constraints require modifications to improve the production system. Note that 'state' can also be utilised for bottleneck analysis.

For measuring machine:

As the machine is running in most time. Reduction setup time on 10% can be considered firstly.

However, introducing a new measuring machine is much helpful on improvement of productions, compared with only reduction setup time which costs one third of new machine's cost. Therefore the next step is to investigate the effect on introducing a new machine and whether the new profit is higher than the cost.

In more details: Reduction time on setup can be considered at first, then second measuring machine can be added in parallel within previous measuring machine. Referring to experiences in modelling exercise, the production system will produce more loads if 2 types of loads are executed at independent machines which requires a setup time when switching load type. Therefore the modification is to add a new measuring machine that is only responsible for second load type meanwhile the existed machine is only to handle first load type.

For worker no.1:

It is important to adjust the optimal allocation of the work belonging to this personnel. The workload of worker no.1 shall be lightened, who is responsible for repairing cutting machines and turning machines.

In more details: New modifications can be divided into 3 types. First is to hire a new employee who is assigned to be responsible the exact same job of worker no.1. It involved the highest cost. Second and third are to train the least busy employee, operator no.2, to do either repairing cutting or turning machines. By comparing these 3 groups of modification and research on increment of production to observe whether the bottleneck is eliminated so that production increased. Then select the most effective way (least money but biggest increment) to implement.

Other change:

Considering to add some buffers downstream the machine at place where the downtime happens frequently. In this case, buffers will release loads so that upstream process is not affected by this downtime.

Iteration is also important. By introducing new modification, and observe whether profits of new increment are higher than investment in a fixed time period such as 1600 hours. If this modification is worthwhile, implement it and identify new constraints and investigate new modification.

After modification:

In this process it is meanwhile to observe whether the upstream and downstream machine are working properly. Additionally the overall product shall also be observed. Such as observation whether utilisation for measuring is lower and utilisation for surface treatment and manual quality inspection is higher (transform gentle tendency on the chart). Some modifications can also be addressed on up/downstream to improve the production system.

Assumption:

The polishing procedure requires a cleaning maintenance tasks for 10 mins every day. In this case, it is assumed that model runs for 470 min and breakdown for 10 min in codes. Same logic applies to other operators and workers (such as surface inspector works 53 min then take a 7-min-break)

IV. Project results

1. Road to acquire the first modification model

a. Adding second measuring machine

Calculation of machine costs:

As mentioned, machines cost 2 Euro per hour per machine when not working (idle or down) and 4 Euro when working (busy or processing). Therefore, 'state' is introduced when calculating how many hours the machine is working or not so that the final machine costs can be calculated for all within 1600hrs. Details about how states are classified and applied can be found codes of attachment of this project.

Changing codes of measuring part and downtime of measuring part, as well as relative queueing that is connected this process, the modification of second measuring machine can be implemented. Finally table 2 can be recorded.

Table 2: Output of modified model: Add measuring machine

	Input			Output	
	Raw	Personnel	Machine	Variant 1	Variant 2
Number	2453	5	11+1	5079	7433
Cost/income (Euro)	115291	157500	48064+15000	162528	193258
Total (Euro)	335855			355786	
Profit (Euro)	19931				

As shown on table 2, the profit is slightly higher than previous basic model, but it offers an intuitive idea for further modifications. Thus it can be implemented.

b. Reducing setup time of measuring machine

It is simple since of tuning the parameter of setup time is enough. Table 3 can be recorded.

Table 3: Output of modified model: Reduce 10% setup time on measuring machine

	Input			Output	
	Raw	Personnel	Machine	Variant 1	Variant 2
Number	2269	5	11	4690	6862
Cost/income (Euro)	106643	157500	44256+5000	150080	178412
Total (Euro)	313399			328492	
Profit (Euro)	15093				

As shown on table 3, the profit is even less than basic model, so this modification shall be abandoned.

c. Hiring a new worker to assist worker no.1

Change the resource of worker no.1 to 2 from 1 (in this way there are 2 'worker no.1'), and always make 1st person to take charge of cutting no.1 and turning no.1, same logic applies to 2nd person. Table 4 can be recorded.

Table 4: Output of modified model: Hiring a new worker to assist work no.1

	Input			Output	
	Raw	Personnel	Machine	Variant 1	Variant 2
Number	2560	5+1	11	5307	7762
Cost/income (Euro)	120320	157500+35000	45440	169824	201812
Total (Euro)	358260			371636	
Profit (Euro)	13376				

As shown on table 4, the profit is even less than basic model, but the increment on output is significant.

d. Instruct Operator no.2 to assist worker no.1

Just changing repairing process of either cutting or turning to involve operator no.2 to execute in current workload is enough. Table 5 and 6 can be recorded.

Table 5: Output of modified model: Instruct operator no.2 to assist work no.1's cutting

	Input			Output	
	Raw	Personnel	Machine	Variant 1	Variant 2
Number	2178	5	11	4445	6631
Cost/income (Euro)	102366	157500+12000	43936	142240	172406
Total (Euro)	315802			314646	
Profit (Euro)	-1156				

Table 6: Output of modified model: Instruct operator no.2 to assist work no.1's turning

	Input			Output	
	Raw	Personnel	Machine	Variant 1	Variant 2
Number	2409	5	11	5020	7262
Cost/income (Euro)	113223	157500+12000	44864	160640	188812
Total (Euro)	327587			349452	
Profit (Euro)	21865				

Obviously, instructing operator 2 to assist worker no.1's cutting is disappointing: It make negative profit. On the contrary, it is much better to assist turning, which brings more profit compared with basic model.

e. Adding buffer the place where breakdown takes place with more possibilities

In AutoMod, the data for total downtime of basic model can be acquired, which can be found in fig 2 below.

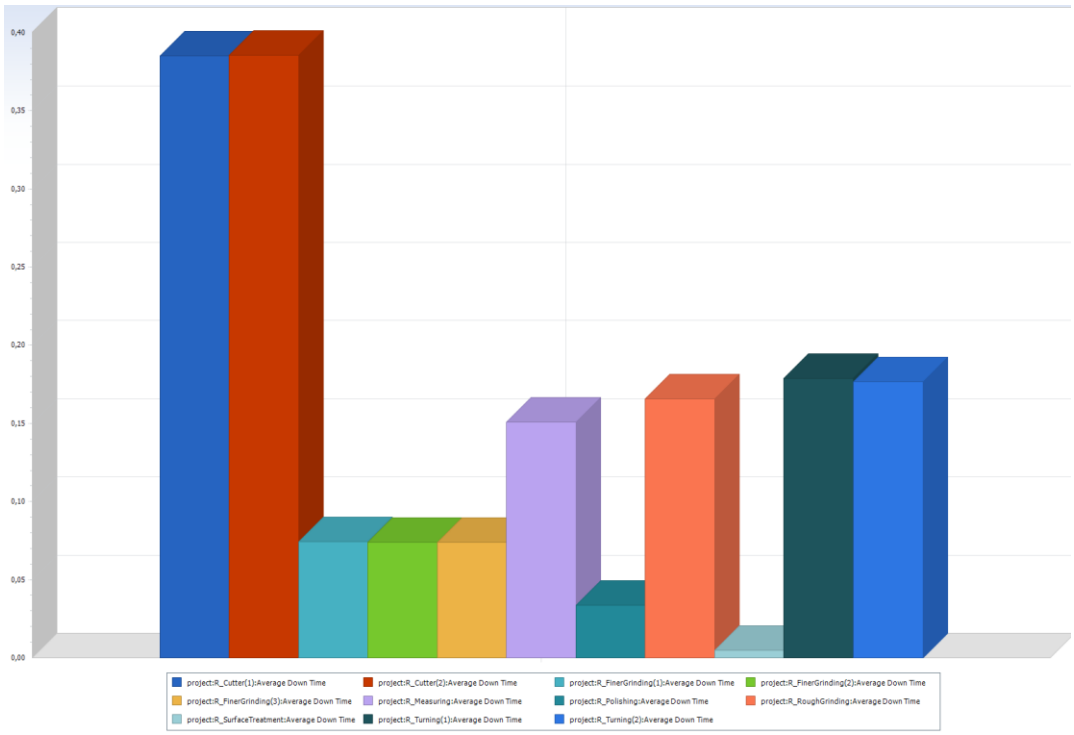

Figure 2: Total downtime for all machines

It is notable that breakdown takes place on cutting machines with more possibility. Therefore, changing the number of buffer in B1 from 1 to 6, is an initial guess. Table 7 can be recorded.

Table 7: Output of modified model: Increasing number of buffer in B1

	Input			Output	
	Raw	Personnel	Machine	Variant 1	Variant 2
Number	2326	5	11	4761	7108
Cost/income (Euro)	109332	157500	44448+3000	152352	184808
Total (Euro)	314270			337160	
Profit (Euro)	22890				

The price of buffer is cheap and there is no additional cost. As shown from table, the profit is much higher than basic model, so this approach should be definitely adopted. This results offer an intuitive modifications: Increasing number of buffer!

f. Add more buffer at B1 to B4

Referring to fig 2, measuring machine, rough grinding machine and turning machines are second highest breakdown possibility sectors. Therefore, increase number of buffer at B1 to B4 to 6,6,6,2 (increments of 5,3,3,1) respectively. Table 8 can be recorded.

Table 8: Output of modified model: Increasing number of buffer in B1-4

	Input			Output	
	Raw	Personnel	Machine	Variant 1	Variant 2
Number	2453	5	11	5017	7503
Cost/income (Euro)	115291	157500	45152+7200	160544	195078
Total (Euro)	325143			355622	
Profit (Euro)	30479				

As shown from table 8, now profit is much higher than that of basic model!

g. Overall modification for first model

So far, adding second measuring machine (€15,000), instruct operator (€12,000) to assist repairing of turning as well as adding 12 buffers to B1-4 (€7,200) should be adopted after a series of simulation, calculation and comparison. Now integrating these 3 approaches together. Table 9 can be recorded.

Table 9: Output of modified model: Increase buffer, double measurement machines and train operator no.2 to assist worker no.1 for repairing turning machines

	Input			Output	
	Raw	Personnel	Machine	Variant 1	Variant 2
Number	3012	5	12	6264	9194
Cost/income (Euro)	141564	157500+12000	50336+7200+15000	199872	239004
Total (Euro)	383600			438916	
Profit (Euro)	55316				

No, the profit finally change from 19.9k to 55.3k euro. It is a great success! But iteration shall be continuously conducted to acquire a better production system within budget. At the moment, utilisation graph is significant to be analysed to acquire an overall conclusion so that new bottlenecks can be identified. Figure 3 and 4 illustrate utilisation and downtime graph.

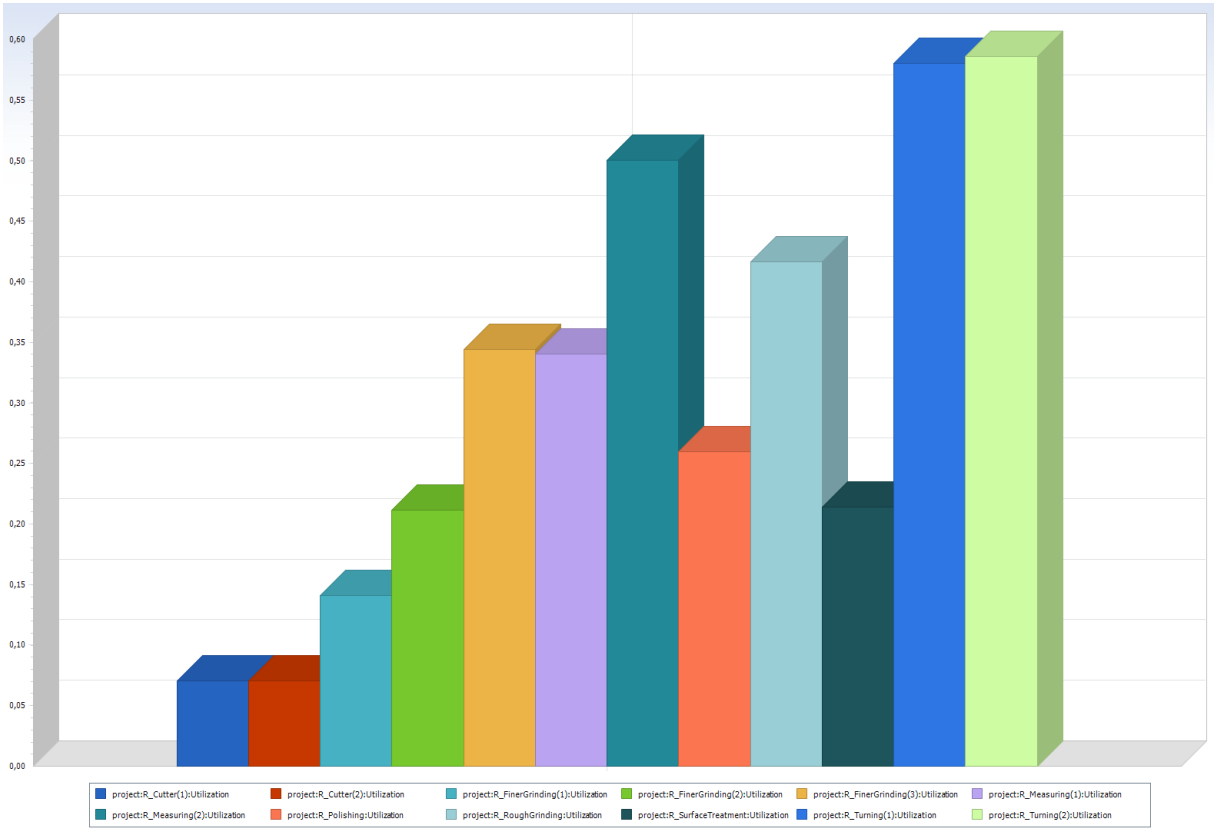

Figure 3: Performance of first modified model

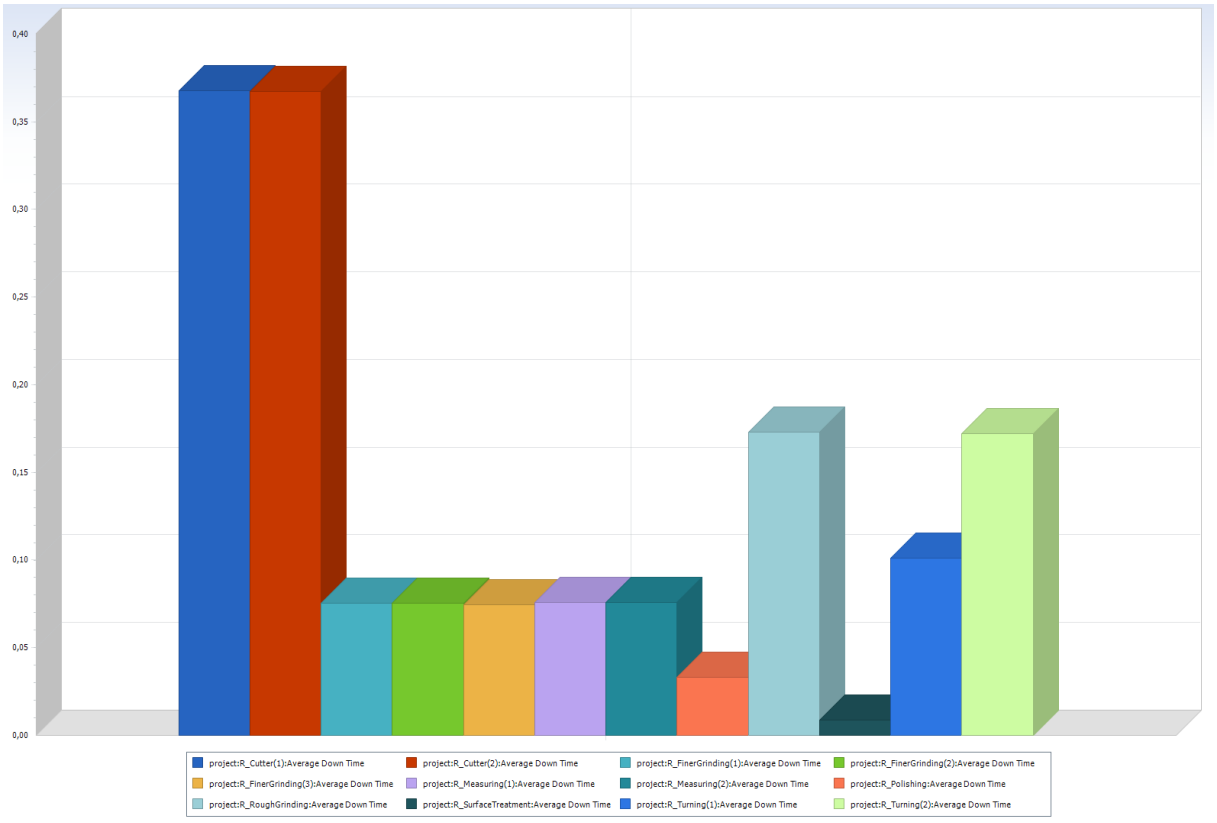

Figure 4: Total downtime for all machines (first modified model)

2. Road to acquire second modification model

Referring to fig 4, as cutting machines always break down, so it is necessary to continue to set more buffer downstream of cutting machines at B1. The value can be change to 11 from 6 now. Referring to fig 3, turning machines are identified as bottleneck this time due to high utilisation. Reduction on cycling time and introducing new turning machine(s) can be considered.

h. Invest on reduction on cycling time of turning machines

Tuning parameters of cycling time on turning machines to 80% or 50% of previously values can implement the idea of reduction on cycling time. Then Table 10 can be recorded as below.

Table 10: Output of modified model based on first modified version: Reduction on cycling time of turning machine

	Input (20% reduction)			Output	
	Raw	Personnel	Machine	Variant 1	Variant 2
Number	3424	5	12	7138	10451
Cost/income (Euro)	160928	157500+12000	51264+7200+15000+16000	228416	271726
Total (Euro)	419892			500142	
Profit (Euro)	80250				
	Input (50% reduction)			Output	
	Raw	Personnel	Machine	Variant 1	Variant 2
Number	3719	5	12	8124	11469
Cost/income (Euro)	174793	157500+12000	51168+7200+15000+40000	259968	298194
Total (Euro)	457661			558162	
Profit (Euro)	100501				

This modification is excellent since the current profits is 4 times as profits of basic model, and investing 50% reduction will bring 5.5k extra profit, therefore it can be adopted to be implemented.

i. Introducing new turning machines

It is definitely much helpful if 2 new turning machines are introduced. However, after single scenario experiments, the increments on profit is not expected to have a high output, instead, the new increment on production and profits is not satisfied. Besides, the price of turning

machines is extremely high, compared with other machines and fee on reduction cycling time. Thus, it is not adopted.

j. Tuning buffer size at B1-4

Referring to fig 4, cutting machines break down will highest possibility, rough grinding machine and turning machines are second highest breakdown possibility sectors. Therefore, increase number of buffer at B1 to B4 to 11,9,9,3 (increments of 5,3,3,1) respectively. Table 11 can be recorded.

Table 11: Output of modified model: Increase buffer at B1-4

	Input			Output	
	Raw	Personnel	Machine	Variant 1	Variant 2
Number	3113	5	12	6520	9423
Cost/income (Euro)	146311	157500+12000	50816+7200+15000+7200	208640	244998
Total (Euro)	396027			453638	
Profit (Euro)	57611				

The profit increment compared with table 9 is not that significant compared with first profit increment of firstly increasing on buffer size. So continuing to increase buffer size is not wisdom. Therefore there is no need to increase the buffer size anymore.

3. Final model

Finally the model can be submitted to Emmy's Specialised Components. So far, this model has 4 modification, 50% reduction on cycling time of turning machine (€40,000), adding second measuring machine (€15,000), instruct operator (€12,000) to assist repairing of turning as well as adding 12 buffers to B1-4 (€7,200). The schematic diagram and AutoMod model can be found in fig 5-6 below. Running model is illustrated in fig 7 (initial phase) and fig 8 (final phase). The effect of stack loads is applied for verification purpose and better view of the production system.

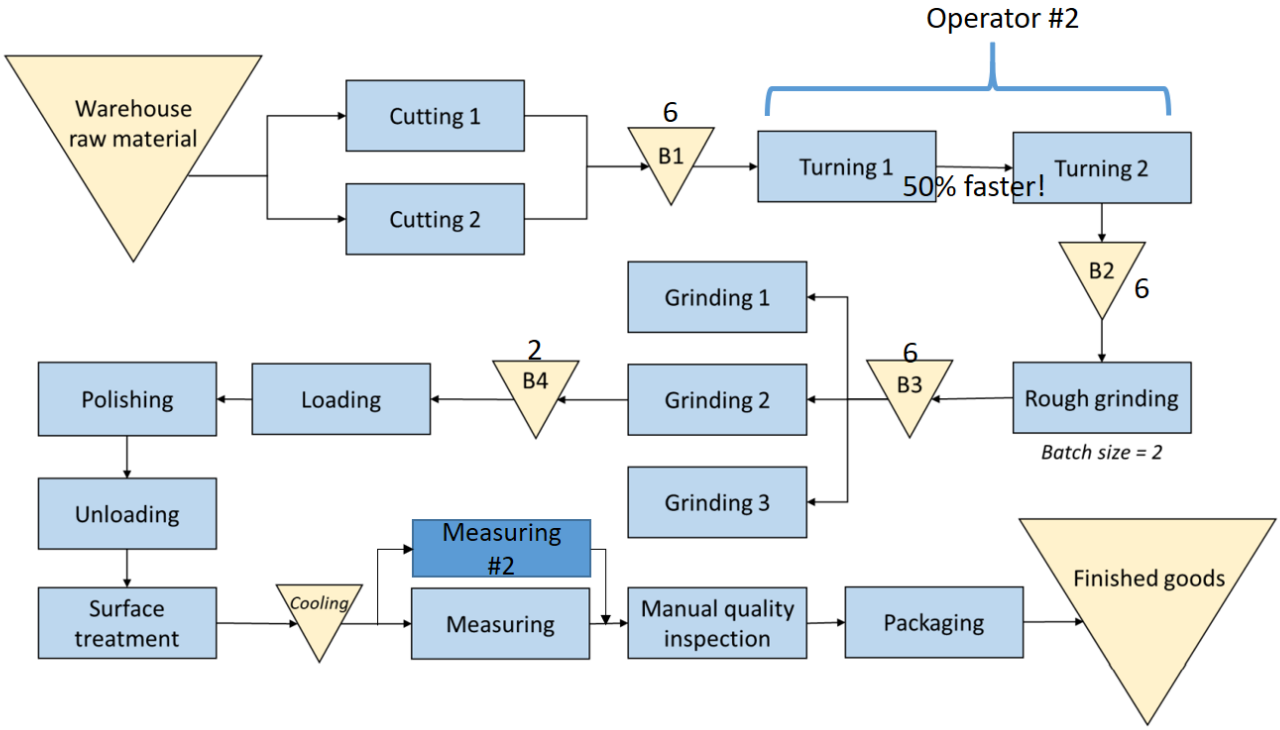

Figure 5: Final model by schematic diagram

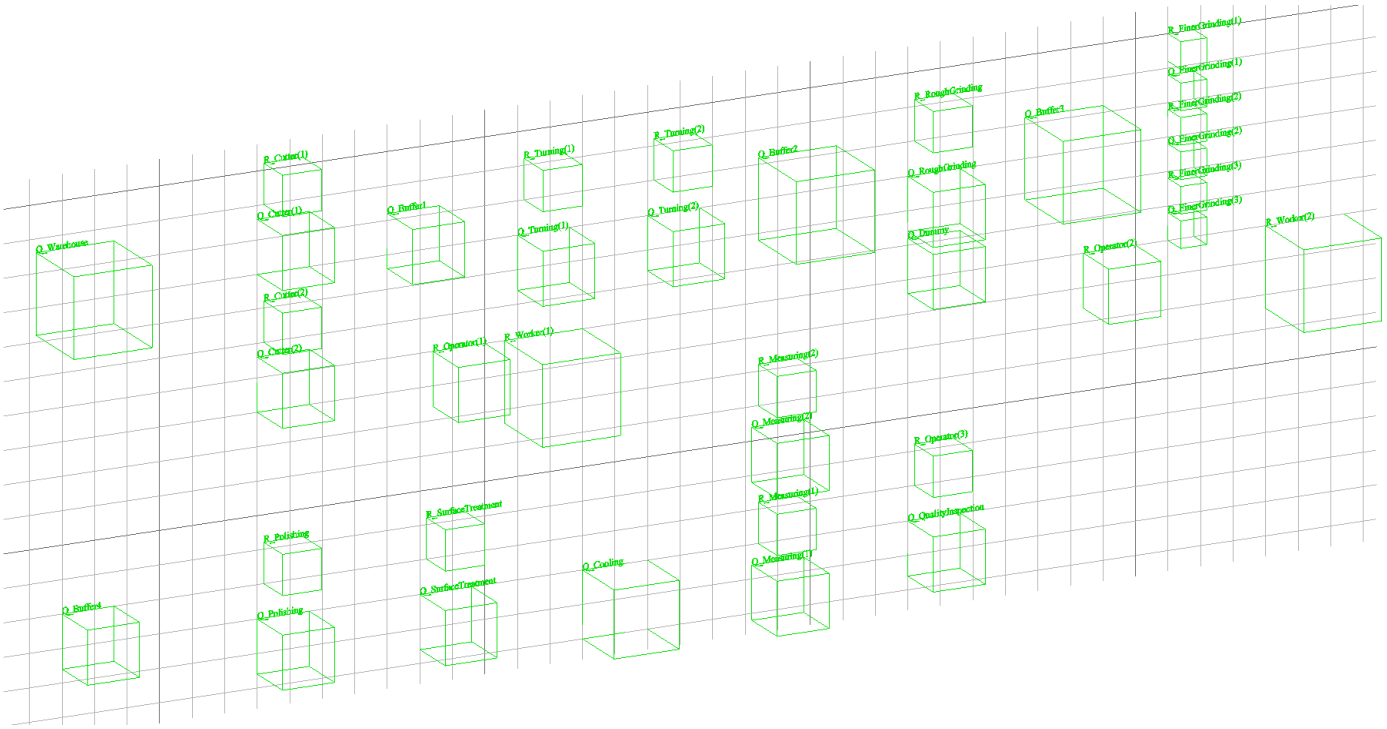

Figure 6: Final model by AutoMod

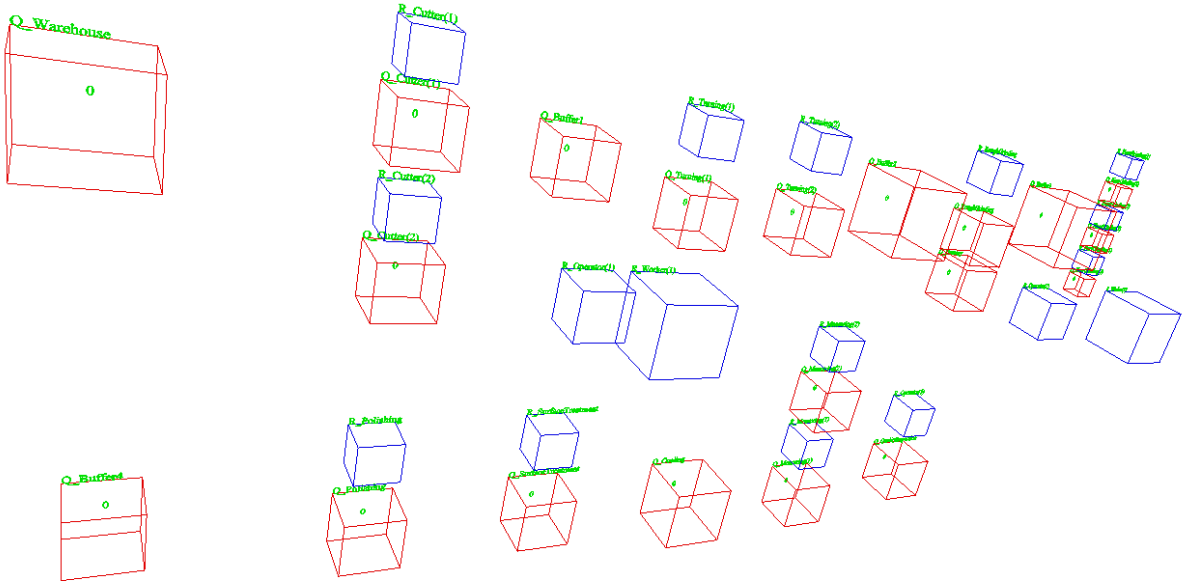

Figure 7: Final model when running (initial phase)

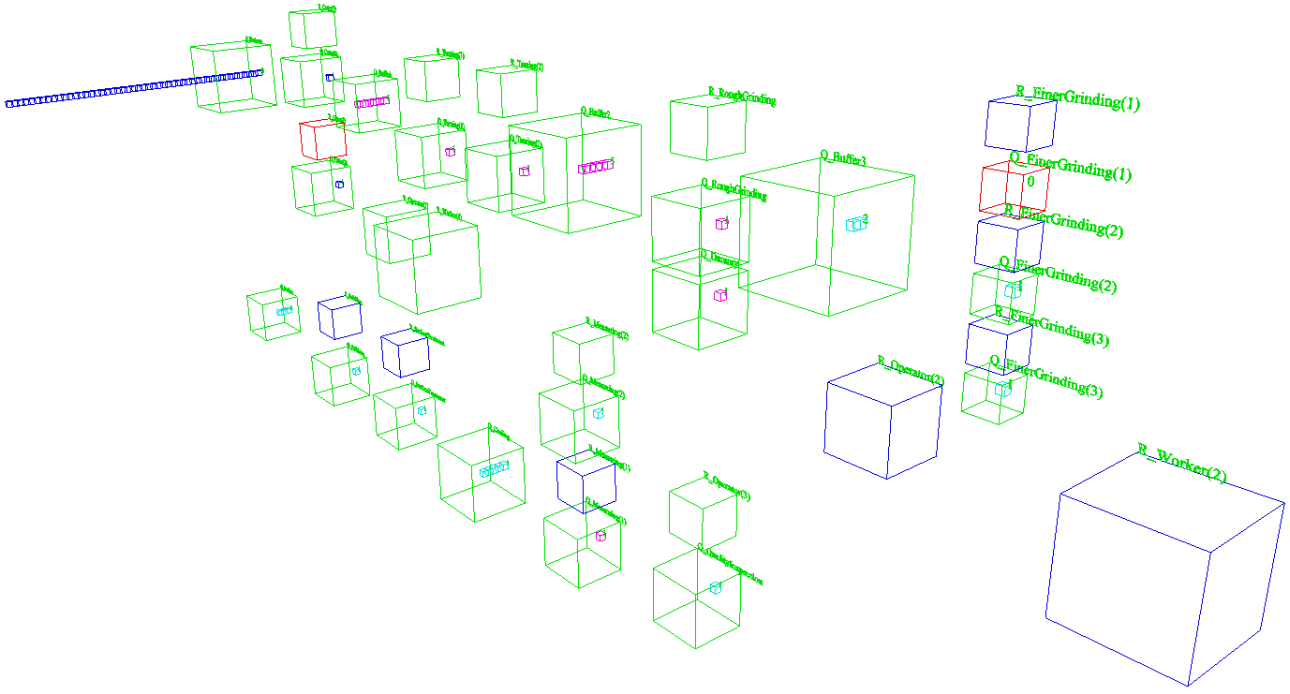

Figure 8: Final model when running (final phase)

Table 12 and 13 show the final output as well as the output changing from basic model to final model: By now, the profit is 5 times as that of basic model. Total cost rises for an increment of 150k Euro, but more important is that, the profit grows for an increment of 81k Euro from 19k Euro!

Table 12: Final output of modified model

	Input (50% reduction)			Output	
	Raw	Personnel	Machine	Variant 1	Variant 2
Number	3719	5	12	8124	11469
Cost/income (Euro)	174793	157500+12000	51168+7200+15000+40000	259968	298194
Total (Euro)	457661			558162	
Profit (Euro)	100501				

Table 13: Output changing from basic model to final model

	Input			Output	
	Raw	Personnel	Machine	Variant 1	Variant 2
Number	2258→3719	5	11→12	4645→8124	6859→11469
Total (Euro)	307853→457661			326967→558162	
Profit (Euro)	19114→100501				

4. Extra task A: Rework

Instead of disposing low quality product at manual quality inspection sector, it is mentioned to set up a rework procedure in surface treatment. Defect product and the product in front of defect product have to be sent back for rework, which are prioritised compared with upcoming loads. And rework is only done once at maximum. Figure 9 shows the AutoMod diagram and a rework buffer can be directly seen (As ticked in the box). Codes for this part can be found in appendix section at the end of this report.

However, after single scenario experiments, the increments on profit is not expected to have a high output, instead, the new increment on production and profits is not satisfied. The main reason is this procedure lowers the efficiency. The defect product is sent back, but it also involves one good product to be sent back, and make upcoming products waiting in the queues. If this modification is cancelled, product will go through these procedures and be classified as good for most product. But with this modification, it make product in front of defect that is supposed to have a 'good' quality, go back to previous procedure other than to final products section. Upcoming products have to wait due to low prioritisation. With these effects, a low efficiency is applied to the production system, and the profits is not good as that of basic model.

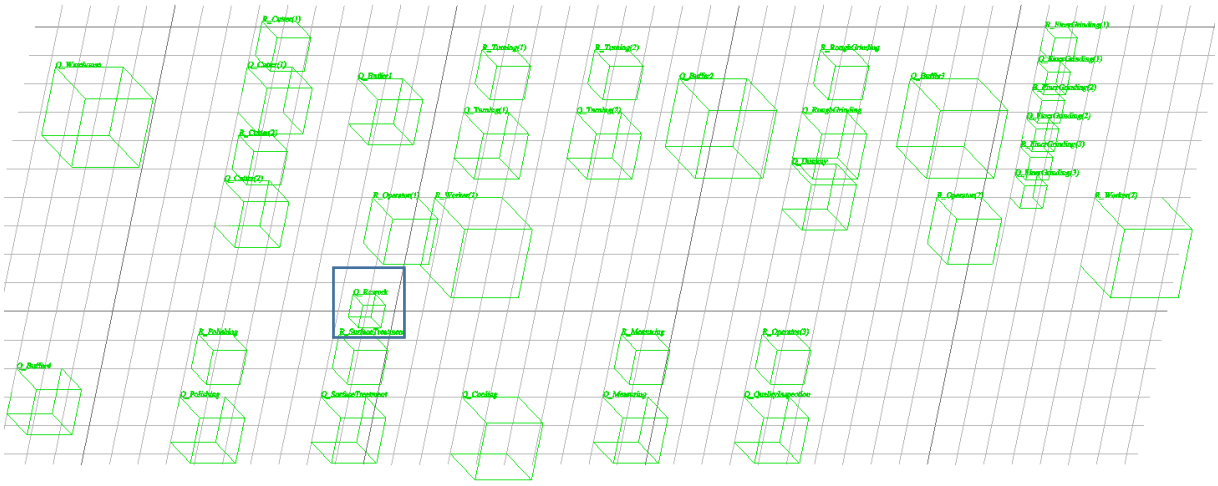

Figure 9: Codes for rework procedure

V. Discussion

The digital factory topic is researched by Kühn from Germany: It is an integrated approach to enhance the production systems. Simulation technology can be applied in virtual models on various level and stages to improve the product and process engineering, such as by softwares UGS and Delmia. The focus is the integration of various planning and simulation process. The first phase of the digital factory is to focus integrated production engineering, then the second phase includes the plant design and optimisation in a collaborative environment with production engineering. The third phase is to focus on operative production planning and control down to the factory floor (2006).

This project takes AutoMod as simulation tools in 2 dimensions. As described in delimitation, AutoMod simulation differs from real life. In real life, product is conveyed by belt, AGV, etc. It involves a multiple environment. Moreover, UGS software offers a chance to invest the simulation system into 3 dimensions, as shown on fig 10.

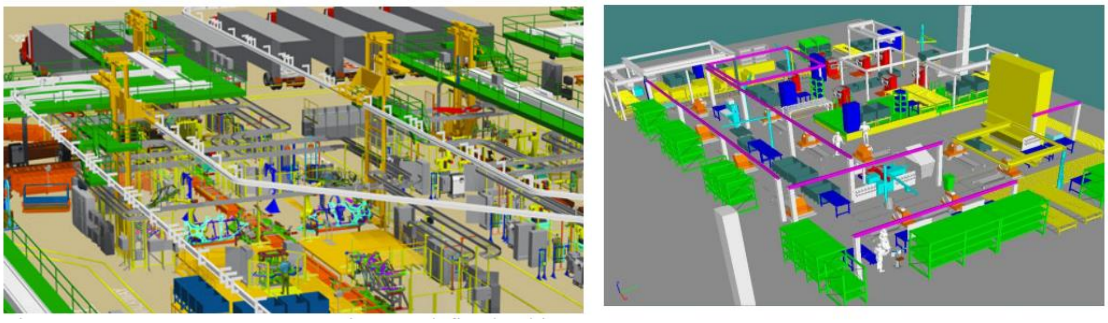

Figure 10: 3D Simulation examples (Kühn, 2006; Frantzén, 2021)

Building 3D model may be accurate for visualisation and give more realistic display. It can obtain the actual or dynamic positions of entities during the simulation. However, it takes significant longer time to develop, and production result won't differ too much.

Human resource simulation is also significant aspect to improve the production systems. This project does not involve detailed manning strategies, just instructing workers and operators to take their own responsibilities. Human Resource Simulation focuses on detailed design of manual operations, time analysis, ergonomic analysis, etc. It improves workplace ergonomics, optimised assembly cycle times, improving communication of planning results, so that it brings a wide number of positive effects.

Lastly, factory layouts or flow can be also optimised for simulation. It investigates how to be performed on alternate layout configurations and layout options compared so that to acquire best layout to improve the production system efficiency. Based on material flow distances, frequency and

cost, enhancing factory layout can result in a high efficiency, as consequence, production output can raise (Kühn, 2006).

Therefore, if more time is allowed, further research and improvement shall focus on these 3 topics: Build a 3D model, research on Human Resource Simulation and Optimisation on factory layout.

VI. Conclusion

Emmy's Specialised Components Company struggles with unstable production, with only 19k Euro profit. Simulation technique is applied to acquire a better production system. Theory of Constraints is applied to detected bottlenecks in order to acquire better production system. After authors' analysis by AutoMod software and a series of experiments, 4 modifications have been addressed, such as training current employee, purchasing new machine and buffer, and reducing cycling time. Now total profit has raised to 100k Euro, 5 times as before.

Digital factory is important for modern companies. If more time is allowed, authors will investigate and research on 3D model, Human Resource Simulation and Optimisation on factory layout.

VII. Reference

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Kühn, W. 2006. Digital Factory – Simulation Enhancing The Product And Production Engineering Process. In: *Proceedings of the 2006 Winter Simulation Conference, 3/4/5/6 December 2006, Monterey.*

Författaren Yuhui tog examen från *University of Leeds* i juli 2021, så referens antar Leeds Harvard (Mer info: Leeds Harvard basics | Leeds Harvard introduction | Library | University of Leeds).

VIII. Appendix

Extra task: Codes for rework

```
/*Surface Treatment*/
begin P_SurfaceTreatment arriving procedure
    move into Q_SurfaceTreatment
    order 1 load from OL_ReworkFull to continue
        in case order not filled order 1 load from OL_PolishingFull to continue
    //Surface Treatment
    use R_SurfaceTreatment for 75 sec
    //Refill
    inc VI_SurfaceTreatment by 1
    if VI_SurfaceTreatment = VI_SurfaceTreatmentTank then begin
        take down R_SurfaceTreatment
        get R_Operator(2)
        wait for u 3.5, 0.5 min
        free R_Operator(2)
        bring up R_SurfaceTreatment
        set VI_SurfaceTreatment = 0
    end
    //Space
    if Q_Cooling remaining space = 0 then begin
        set R_SurfaceTreatment active state = S_Blocked
        wait to be ordered on OL_CoolingFull
    end
    send to P_Cooling
end


/*Cooling*/
begin P_Cooling arriving procedure
    move into Q_Cooling

    order 1 load satisfying AI_Quality = 1 from OL_SurfaceFullRE to continue
        in case order not filled order 1 load from OL_SurfaceTreatmentFull to continue

    wait for u 7.5, 1.5 min
    if Q_Measuring remaining space = 0
        wait to be ordered on OL_MeasuringFull
    send to P_Measuring
end
```

```
/*Measuring*/
begin P_Measuring arriving procedure
    move into Q_Measuring
    order 1 load from OL_CoolingFull to continue
    //Setup
    if VI_PrevTypeMeasuring <> AI_Type then begin
        get R_Operator(2)
        get R_Measuring
        set R_Measuring active state = S_Setup
        set VI_MeasuringSetup = 1
        wait for u VI_MeasuringSetupTime(1), VI_MeasuringSetupTime(2) sec
        free R_Operator(2)
        free R_Measuring
        set VI_MeasuringSetup = 0
        set VI_PrevTypeMeasuring = AI_Type
    end
    //Measuring
    use R_Measuring for 295 sec
    //Space
    if Q_QualityInspection remaining space = 0 then begin
        set R_Measuring active state = S_Blocked
        set VI_MeasuringBlocked = 1
        wait to be ordered on OL_QualityInspectionFull
        set VI_MeasuringBlocked = 0
        if R_Measuring active state <> S_Down then
            set R_Measuring active state = S_Idle
    end
    send to P_QualityInspection
end
```

```
/*ManualQualityInspection*/
begin P_QualityInspection arriving procedure
    move into Q_QualityInspection
    order 1 load from OL_MeasuringFull to continue
    //Inspection
    use R_Operator(3) for weibull 2, 1 min
    //Some may crush
    set AI_Quality = oneof(0.06:1, 0.94:2)
        if AI_Quality = 1 then begin

            if AI_Rework = 0 then begin //Bad need Rework
                order 1 load from OL_Previous to continue
                if Q_Rework remaining space = 0 then
                    wait to be ordered on OL_ReworkFull
                move into Q_Rework
                order 1 load from OL_Previous to continue
                order 1 load from OL_QualityInspectionFull to continue
                if Q_SurfaceTreatment remaining space = 0 then
                    wait to be ordered on OL_SurfaceFullRE
                inc AI_Rework by 1
                send to P_SurfaceTreatment
            end

            if AI_Rework = 1 then begin //Reworked still bad
                order 1 load from OL_Previous to continue
                inc C_Scrap by 1
                move into Q_Garbage
                order 1 load from OL_QualityInspectionFull to continue
                send to die
            end
        end

        if AI_Quality = 2 then begin

            if AI_Rework = 0 then begin //Good without Rework
                order 1 load from OL_Previous to P_End
                if Q_Previous remaining space = 0
                    wait to be ordered on OL_PreviousFull
                move into Q_Previous
                order 1 load from OL_QualityInspectionFull to continue
                wait to be ordered on OL_Previous
                if Q_SurfaceTreatment remaining space = 0 then
                    wait to be ordered on OL_SurfaceFullRE
                inc AI_Rework by 1
                send to P_SurfaceTreatment
            end

            if AI_Rework = 1 then begin //Good but Reworked
                order 1 load from OL_Previous to P_End
                send to P_End
            end
        end
end
```