Industrial Valves Production Line Bottleneck Analysis: A Computer Based Simulation Approach

Sepideh Khalafi, Sadigh Raissi

Abstract: Nowadays, optimization of production processes is considered as one of the main concerns in industry of installations. It is a difficult task with respect to wideness of systems and complexity of behaviors, so it requires consuming a noticeable quantity of time and cost. prediction of system behavior and performance of processes after exertion of the given changes may be either a difficult task that is exposed to uncertainty and or requires taking time and waste of sources in order to characterize the results derived from employing the executed changes. The present essay is mainly intended to present an effective and reliable model by means of stimulation approach toward recognizing of bottleneck in manufacturing aerators (ventilation filters) and industrial valves in order to reduce time period for delivery of orders. The results of current investigation led to predict of reduced time for delivery of orders up to 49%.

Index Terms: Computer Simulation, Production rate, Design of experiment, Bottleneck Analysis

1 Introduction

The most important resources affecting the performance of a production line are the congestion points, ordinarily known as bottlenecks. Such congestion points limit the overall performance and represent the resources a designer must invest to obtain significant improvements. Development and setup various industrial production lines is one of the development axes, which most of world countries select it to improve their own economic status so that by this lever they are able to reduce their dependence on other countries rather than economic profitability and thereby to prove their self-sufficiency and independence further. Installations industry is considered as one of the most significant industries for which a lot of investment has been done. Installations industry is deemed as one of the most accurate, sensitive, and typically most cost-consuming industries. Nowadays, with respect to technological advancement, the manufacturing industries of aerators (ventilator systems) and industrial valves are trying to overtake the rivals and this is not possible unless with accurately planning and properly utilization from sources and facilities.Thus, with respect to systems complexity, the managers should implement planning properly by means of appropriate tools such as linear programming, dynamic planning, integer programming, simulation, and queue theory etc which exist for analysis of systems in order to prevent from wasting sources. Shukla et al [1] expressed that among the existing techniques, Computer-aid- simulation methods have many advantages while they consider simulation as one of the most powerful existing analytical tools for the responsible personnel in design and exploitation from these processes. Simulation includes developing computerized descriptive model of a system and implementation of that model to predict the operational performance of the modeled system [2] [3].

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With conducting a case study in pharmaceuticals industry, Workman [4] indicated that simulation modeling might be employed to perceive very much complicated processes like development process of drugs. His results showed that simulation of sources provides value for planning compared to traditional analysis models. Benedettini [5] deems characterization of system performance as the most important goal for simulation of manufacturing systems. The study on literature of subject matter during recent years reflects the importance of subject and several researches, which have been carried out regarding computerized simulation of manufacturing systems to resolve the complex problems in production and optimization. Zulch [6] built FEMOS (Fast Met Office Simulator) simulation software to assess manufacturing activities and their costs, which are spent in reengineering of manufacturing systems that resulted in 25% increase in production rate and 5% reduction in production costs. Then after passing several years, Vinod [7] has focused on modeling and simulations by Due-date Assignment methods Time, Scheduling decision rules, and Dynamic job shop production system. It was characterized in this system that two allocation methods i.e. Dynamic processing Plus Waiting (DPPW) and Dynamic Total Work Content (DTWK) have better performance in terms of criteria of fluid time and lags. Arreola-Risa et al [8] introduced a method for modeling and simulation and optimization of manufacturing- contingent inventory systems and adapted it in oil and gas industries, which has led to lower the costs remarkably. Wang et al [9] introduced a format for modeling, simulation, and optimization of complex processes in an automotive assemblage plant by means of ARENA software. Han et al [10] have proposed a methodology and framework to simulate manufacturing systems and production with focus on animation and image making in assemblage line for better perception by the managers in their decision making with tridimensional space. Kayasa [11] deals with evaluation of the selected and comparative manufacturing systems through simulation and presentation of an innovative and optimal structure for them so that to lead 6% increase in assemblage rate and reduced 6% costs of machineries. Salleh et al [12] have simulated pure manufacturing and production in the broad-based Total Quality Management (TQM) system by means of *Delmia Quest* software. In this investigation, daily manufacturing rate has increased 10.3%. El-Tamimi et al [13] analyzed Flexible Manufacturing Systems (FMS) by *Visual Slam AwSim* simulation software, Bottleneck Model, and Petrinet Model where the present case study has improved total productivity (accurately number of produced work piece). Seleim et al [14] have dealt with several simulation techniques for changeable manufacturing and production systems and comparison and analysis on weak and strong points in each of them. Hvolby et al [15] have presented a heuristic technique and framework for simulation of manufacturing changes in small- and medium- size manufacturing systems to making decision regarding the future production strategies. This study has led to reduction of 7-8days in time period for final assemblage in a manufacturing factory of industrial machineries. Zhang et al. [16] have conducted a study on the impact of operational variables such as production speed, rate of waste materials, maintenance speed, repairs on manufacturing and production by means of simulation and optimization so that finally a reliable theoretical framework was purposed. Diaz et al [17] assessed and analyzed pure and clean strategies to improve production with simulation of manufacturing and production in production concrete environments. In a conducted case study, total costs of production have been reduced up to 10.8%.

2 Recognition of System

This article is mainly purposed to present an effective and reliable model by taking simulation approach toward recognition of bottlenecks in production line for Subway Ventilation Filter Holder in Shahrokhi Industrial Group Plants in order to detect the best scenario for removal of bottlenecks and reduced time of orders delivery. Design of production line for Subway Ventilation Filter Holder is extremely crucial so that only Shahrokhi Industrial Group may manufacture this product in production line in Iran. The manufacturing process of this product is as follows: 10 sheets with diameter of 1.25mm and dimensions (1250*2500mm) have been transferred from warehouse to workstation no 16 and cutting operation was done of these sheets so that they cut each of metallic sheets into four equal size with dimensions (625*1250mm). The cut sheets including 40 sheets were brought to workstation no 14. Punch operator puts each sheet on punching apparatus and punching operation starts on these work pieces. 2.5 filter points are punched on each sheet and then they are returned to workstation no 16. Each sheet is cut with dimensions (125*600mm) by two workers. To execute bending operation, each sheet is brought to workstation no 15 by a flexible robot and after forming in workstation 4, Clinch operation is done on them in workstation no 12. At this phase of operation, the work pieces are connected together by a worker. Welding operation is done in workstation no 20. At this workstation, special grid (lacing) is prepared by foreigner contractors and they weld this lattice to the middle part of main body by CO_2 welding technology. In workstation no 10, first filter holder is assembled and after final cleaning and paint spraying, 7 pieces of this product with dimensions (600*600mm) are packed inside a box. Fig (1) shows the conceptual model of manufacturing process of Subway Ventilation Filter Holder.

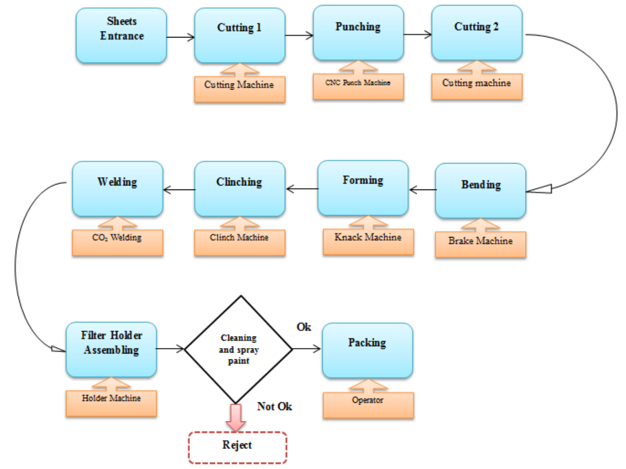

Fig 1. Conceptual model of manufacturing process of Subway Ventilation Filter Holder

3 Design of Simulation Model

Enterprise Dynamic (ED) software is one of the most effective simulation software that is used for simulation of concrete event and with respect to its special capabilities; the system status can be seen as it occurred in real situation. This production line has been presented by ED simulation software and given in Fig (2) on the plant main layout after determination of operation process of manufacturing Subway Ventilation Filter Holder and computation of time distribution function for work operation processing under the existing situation .server atoms have been used for executing Cutting, Punching, Bending, Forming, Clinching, and Holder operations. Assembler has been utilized for doing the Packing, Welding, and Filter Holder operations. Furthermore, Atom Carousel Sever was employed for cleaning and pain spraying operation and transporter atoms were used for all transportations.

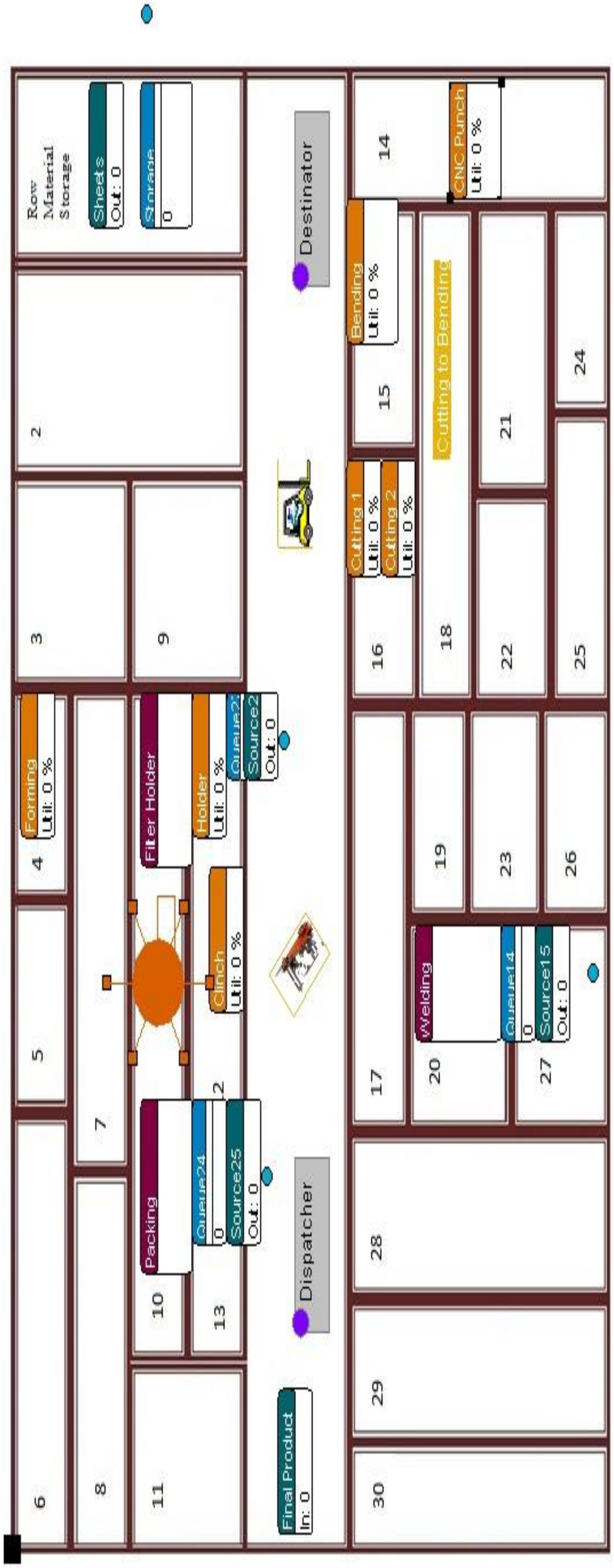

Fig 2. Subway Ventilation Filter Holder Production Line Model in ED Simulation Software

In order to derive stochastic distribution function of processing time in each of operations, this process was done by sampling and time measurement for 150 units throughout this operation and for example the given results for Punch Operation are shown in Table 1 and also distribution function for Punch Operation is indicated in Fig 3. The stochastic distribution function for processing time in other operations plus specifications of any operation is displayed in Table 2.

TABLE 1

PUNCH OPERATION TIME (S) FOR 150 SAMPLES

384	374	387	390	392	376	384	387	391	388
392	382	382	393	362	378	370	379	389	391
373	378	384	380	386	387	374	381	362	394
377	371	380	369	383	377	405	394	358	387
369	380	385	390	380	399	378	386	390	384
392	386	375	365	402	377	384	389	384	374
378	382	398	374	391	386	381	372	380	382
368	385	375	382	386	374	380	387	365	393
407	393	380	387	373	402	392	391	374	386
377	380	377	373	374	381	366	389	382	390
386	388	368	373	379	384	394	380	396	388
395	384	376	368	385	391	380	378	380	372
378	381	383	382	389	384	401	386	401	376
388	380	389	389	361	370	369	387	398	380
391	388	372	387	375	398	383	399	379	389

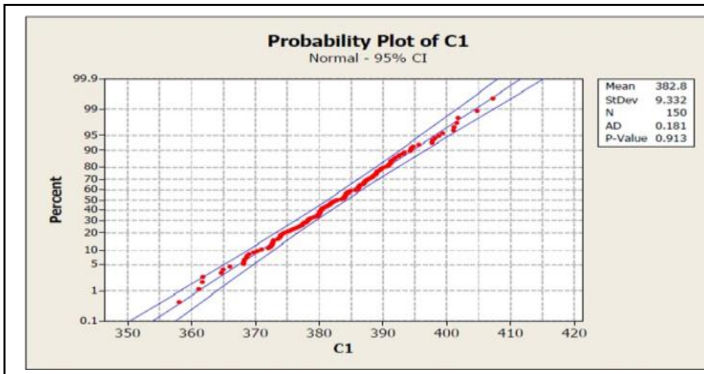

Fig 3. Distribution Function for Punch Operation

TABLE 2

THE STOCHASTIC DISTRIBUTION FUNCTION FOR PROCESSING TIME(S)

Operation Name	Distribution Function	specifications
Sheets Entrance	N(436.3,11.43)	
Cutting 1	N(26.929,0.9827)	Cut to 4 pieces
CNC Punch	N(382.8,9.332)	
Cutting 2	N(40.20,9.175)	
Bending	LogNormal(4.872,0.07193)	
Forming	Gamma(1424,0.02591)	
Clinch	Gamma(2676,0.02041)	Joint 2 pieces
Welding	N(188.5,1)	
Holder	N(802.2,9.710)	
Filter Holder	N(419.2,9.840)	
Carousel Server	LogNormal(4.628,0.07665)	

Packing	LogNormal(4.975,0.06963)	
Transporter		Speed:1 m/s Load Time : 30(s) Unload Time : 30 (s)
Advanced Transporter		Speed:10 m/s Load Time : 30(s) Unload Time : 30 (s) Load Quantity : 10
Cutting to Bending		Rotation Speed:20 m/s Load Time : 30(s) Unload Time : 30 (s)

4 Analysis of Simulation Results

4.1 Simulation results on existing status

According to 30 runs of designed model, we concluded at 95% level of confidence that daily production rate is ranged from 51.38 to 107.24 and mean time for manufacturing of one product unit is 363.13sec, which are given in details along with a sample of other parameters of System Performance Measurement and results in Table 3 in which ED software reported these 30 run times of execution and test. It should be noted that any run time period is equal to 8-hour work-shift and Warm-up Period has been considered as 8hours per any run in this system.

TABLE 3

Samples of Performance Factor Measurement of system implementation in ED

	Ave.	St. Dev.	Lower bound (95%)	Upper bound (95%)	Min	Max
Atom : Final Product						
Produced per day	79.31	27.93	68.88	89.74	35	147
Atom : CNC Punch						
Status Busy	0.14	0.05	0.12	0.16	0.06	0.26
Status Blocked	0.86	0.05	0.84	0.88	0.74	0.94
Atom : Cutting 1						
Status Busy	0	0	0	0	0	0
Status Blocked	1	0	1	1	1	1
Atom : Holder						
Status Busy	0.15	0.05	0.13	0.17	0.06	0.28
Status Blocked	0.85	0.05	0.83	0.87	0.72	0.94
Atom : Welding						
Status Idle	0.89	0.05	0.87	0.91	0.74	0.96
Status Busy	0.03	0.01	0.03	0.04	0.01	0.06
Status Collecting	0.01	0.02	0	0.01	0	0.08
Status Distributing	0.07	0.03	0.06	0.08	0.02	0.14
Atom : Packing						
Status Idle	0.18	0.16	0.12	0.24	0.03	0.58
Status Busy	0	0	0	0	0	0
Status Collecting	0.82	0.16	0.76	0.88	0.42	0.97

With observation of the present model during run and especially the reports which have been purposed by ED software about simulation of system, one could easily analyze this system and purpose the strategies to improve its performance. For instance, according to Table 3, 100% of time periods are busy and blocked for CNC Punch, Cutting 1, and Holder Operations and this represents the bottleneck point in these three operations in this production line. Welding operation is busy only in 11% of time period; therefore, its manufacturing capacity is not optimally employed.

4.2 Validation of model

It may be imagined that simulation test only includes recognition of this system and building its computerized model so for this reason only program related aspects and certain simulation languages are addressed in some training courses while building system model by a computerized language is only one of the needed steps for this purpose. The importance of this subject is increased further when its results are utilized for a real system. It should be more sure there as possible that the model is valid and reliable and it can simulate behavior of the system. Moreover, derived raw results from running of the model are analyzed in order to purpose more accurate judgments concerning to the system. This model was run 25 times in ED software environment to validate it so the run time results in simulation environment are given in Table 4.

TABLE 4

The Run Results in ED

80	78	78	79	80
81	79	82	79	78
77	79	80	80	80
80	83	79	80	81
79	82	80	80	79

The mean and standard deviation estimated are 79.62 and 13.85, respectively. validation is mainly concerned with making sure our robust model provides useful results by being a close enough approximation to the real system. Here this form of analysis is done by performing a one sample t statistical hypothesis testing on the difference between the mean of the selected output of the computer simulation model (PFM) and the same data gathered from the real system.
Expression (1) shows hypothesis test and the null hypothesis for simulation model at 95% confidence level.

$$\begin{cases} H_0: \mu = 79.62 \\ H_1: \mu \neq 79.62 \end{cases} \quad (1)$$

To calculate test value, we use Expression (2) by assuming known value of variance.

$$Z = \frac{\overline{X} - \overline{Y}}{\delta / \sqrt{n}} \quad (2)$$

With respect to data in this problem, z-value is set 1.66. On the other hand, z-test acceptable area is ranged [-1.66,+1.66] $[Z_{\alpha/2}, -Z_{\alpha/2}]$. Given that z-value is placed within the aforesaid interval so null hypothesis H_0 is rejected as a result the model is valid. Consequently the ED model is ready to answer the question for which it was created to answer.

4.3 Design of scenarios and sensitivity analysis

By considering the presented reports in Table 3, the effective controllable factors on efficiency of production line are reported in Table 5.

TABLE 5
THE EFFECTIVE CONTROLLABLE FACTORS ON EFFICIENCY OF PRODUCTION LINE

Code	Taken strategy
1	3.5 hours daily overtime for Cutting 1 operation
2	3.5 hours daily overtime for CNC Punch operation
3	3.5 hours daily overtime for holder operation
4	Purchase of another Cutter machine
5	Purchase of another CNC Punch machine
6	Hiring of 2 extra workforce for Holder Operation
7	Purchase of Brake machine for Holder operation

At this step, several scenarios were executed for this problem with changing effective controllable factors (Xs) in simulation model that is justifiable technically and economically and it is acquired for any mean time period of manufacturing of each product (Y_1) so these are seen in Table (6). It should be noticed that any scenario is executed based on the suggested model for 30 run times at 95% confidence level.

TABLE 6
THE PROPOSED SCENARIOS

PFM	Current Situation	Scenario 1.	Scenario 2.	Scenario 3.	Scenario 4.
X1	26.929	26.929	13.465	26.929	13.465
X2	382.8	382.8	191.4	382.8	191.4
X3	802.2	802.2	401.1	802.2	
X4	0	26.929		26.929	
X5	0	0.983		0.983	
X6	0	382.8		382.8	
X7	0	9.332		9.332	
X8	0	802.2			
X9	0	9.710			
X10	0			204.2	204.2
Mean Time for Producing Product (s)	363.13	217.87	279.61	185.19	243.29

With respect to the aforementioned suggested scenarios and the executed runs for each of them as well as comparison of the given results per scenario, it is obvious that scenario 3 is selected as the optimal scenario that leads to reduced time period for delivery of orders up to 49% .

5 CONCLUSION

IThis paper was mainly intended to present an effective and reliable model by taking simulation approach in order to recognize bottlenecks in production line for aerators (air filters) and industrial valves and to find the best scenario to remove critical bottlenecks and reducing the time period in delivery of orders. With respect to the aforesaid suggested scenarios and the executed runs for each of them as well as comparison among the given results for each scenario, it was concluded that scenario codified as No. 3 is selected as the best scenario among feasible suggestions in such a way that it leads to reduce the lead time to deliver demands up to 49%. The current survey may be utilized as an applied model by other enterprises in study and improvement of manufacturing system before or during production period.

REFERENCES

[1] Shukla, S. K., Tiwari, M., Wan, H.-D & Shankar, R. (2010), Optimization of the supply chain network: Simulation, Taguchi, and Psychoclonal algorithm embedded approach. *Computers & Industrial Engineering, 29-39*.

[2] Banks, J., J.S. Carson, B.L. Nelson, and D.M. Nicol (1995). *Discrete Event System Simulation*, 3rd edition.

[3] Banks,J.(1998).*Principles of simulation* , Handbook of simulation , Wiley Interscience, New York.

[4] Workman R.; 2000; *Simulation of the drug development process: A case study from the pharmaceutical industry*; Winter Simulation Conference.

[5] Benedettini, O., & Tjahjono, B. (2009). Towards an improved tool to facilitate simulation modeling of complex manufacturing systems. *The International Journal of Advanced Manufacturing Technology* (43), 191-199.

[6] Zulch, G., & Brinkmeier, B. (1998). Simulation of activity costs for the reengineering of production systems. *International Journal of Production Economics*, 711-722.

[7] Vinod, V., & Sridharan, R. (2011). Simulation modeling and analysis of due-date assignment methods and scheduling decision rules in a dynamic job shop production system. *International Journal of Production Economics*, 127-164.

[8] Arreola-Risa, A., Giménez-García, V. M., & Martínez-Parra, J. L. (2011). Optimizing stochastic production-inventory systems: A heuristic based on simulation and regression analysis. *European Journal of Operational Research*, 107-118.

[9] Wang, J., Chang, Q., Xiao, G., Wang, N., & Li, S. (2011). Data driven production modeling and simulation of complex automobile general assembly plant. *Computers in Industry*, 765-775.

[10] Han, S. H., Al-Hussein, M., Al-Jibouri, S., & Yu, H. (2011). Automated post-simulation visualization of modular building production assembly line. *Automation in Construction*, 229-236.

[11] Kayasa, M. J., & Herrmann, C. (2012). A Simulation-based Evaluation of Selective and Adaptive Production Systems (SAPS) Supported by Quality Strategy in Production. *45th CIRP Conference on Manufacturing Systems,* 14-19.

[12] Salleh, N. A., Kasolang, S., & Jaffar, A. (2012). Simulation of Integrated Total Quality Management (TQM) with Lean Manufacturing (LM) Practices in Forming Process Using Delmia Quest. *International Symposium on Robotics and Intelligent Sensors,* (IRIS 2012) (1707-1702). SciVerse ScienceDirect.

[13] El-Tamimi, A. M., Abidi, M. H., Mian, S. H., & Aalam, J. (2012). Analysis of performance measures of flexible manufacturing system. *Journal of King Saud University - Engineering Sciences*, 115-129.

[14] Seleim, A., Azab, A., & AlGeddawy, T. (2012). Simulation Methods for Changeable Manufacturing. *45th CIRP Conference on Manufacturing Systems,*(184-179). Procedia CIRP.

[15] Hvolby, H.-H., Svensson, C., & Steger-Jensen, K. (2012). Simulation of production setup changes in an SME. CENTERIS 2012 - Conference on ENTERprise Information Systems / HCIST 2012 - *International Conference on Health and Social Care Information Systems and Technologies* (648-643). Procedia Technology.

[16] Zhang, R., Chiang, W.-C., & Wu, C. (2013). Investigating the impact of operational variables on manufacturing cost by simulation optimization. *International Journal of Production Economics*.

[17] Diaz-Elsayed, N., Jondral, A., Greinacher, S., Dornfeld, D., & Lanza, G. (2013). Assessment of lean and green strategies by simulation of manufacturing systems in discrete production environments. *CIRP Annals - Manufacturing Technology*.