Available online at www.sciencedirect.com

ScienceDirect

IFAC PapersOnLine 55-10 (2022) 848–853

Disabled employees on the manufacturing line: Simulations of impact on performance and benefits for companies

Paweł Litwin * Dario Antonelli and Dorota Stadnicka***

** Faculty of Mechanical Engineering and Aeronautics, Rzeszow University of Technology, Rzeszow, Poland; (e-mail: plitwin@prz.edu.pl, dorota.stadnicka@prz.edu.pl).*

*** Department of Production Systems and Economics, Politecnico di Torino, Torino, Italy (e-mail: dario.antonelli@polito.it)*

Abstract: People with disabilities can be very valuable employees if their work is well organized and planned. However, because such employees have certain limits and additional rights, the organization and planning are more complex. This article aims to show how the employment of people with disabilities (PWDS) could influence the operation of a manufacturing line and what factors should be considered before assigning them manufacturing tasks. The analysis is supported by a simulation using combined System Dynamics and Discrete Event Simulation (respectively SDS and DES). A near-realistic case study is exploited, with data derived from existing manufacturing systems, for the sake of demonstration.

Keywords: manufacturing systems, modelling, system dynamics, discrete event simulation, disabled employees.

1. INTRODUCTION

The employment of workers with disabilities on a manufacturing line (ML) requires special attention in the planning and organization. It is because work efficiency and work performance can differ much from workers without disabilities. Social care in many countries provides financial incentives to motivate companies to employ workers with disabilities. In some countries, there is even a requirement to employ a percentage of disabled employees. To facilitate the participation of disabled workers in manufacturing operations, it is important to adopt proper task assignment and scheduling policies. Work efficiency is different depending on the kind of disability and influences manufacturing performance, costs, service level (SL), demand, etc. Simulation is an effective way to predict the effect of changes in the parameters of a manufacturing system (MS). Simulated experiments to design production scenarios can be supported by commercial tools like Tecnomatix Plant Simulation Software (Kłos and Trebuna, 2015), FlexSim (Antonelli and Stadnicka, 2018), Vensim (Stadnicka and Litwin, 2019), Enterprise Dynamics (Gola, 2019). Simulations allow to assess the performance of system operations after changes implementation.

To the authors' knowledge, the impact of the number of disabled workers and of kind of disability on the production factors was not considered until now in the production simulations and this gap is fill in this paper. As the problems involve strategic planning and at the same time, low-level operational scheduling, the paper makes use of simulation methods tailored to deal with different abstraction levels: SDS and DES. The studied effects of PWDS employments include: worker productivity, number of work breaks, SL, changes in product cost, and demand. The authors present the whole procedure in a way that allows it to be repeated in other instances and with different country regulations.

2. DISABLED WORKERS IN MANUFACTURING PROCESSES AND THEIR PERFORMANCE ANALYSIS

Employment leads to social integration and provides the financial resources needed for a dignified life. Many factors can influence the decision to hire disabled persons. On the one hand, there can be government subsidies for creating a work place for people w ith disabilities, and on the other hand, the fear that a disabled person's work would have a negative impact on ML performance. Someone who has a physical or mental impairment that has a significant effect on his or her ability to carry out normal day-to-day activities is called a disabled person (Disabled World, 2009). According to (WHO, 2021), about 15% of the world's population lives with some form of disability. In the works of (Rabiega, 2014) (Wagner et al., 2001), it is presented how different EU countries support employment of PWDS. In Germany, Italy, and in France if a company which employs more than 15 or 20 (France) persons does not employee a disabled person, it has to pay a penalty. In Poland, a company employing a disabled person even receives financial support. People with disabilities represent one-sixth of the EU's overall working-age population (Lecerf, 2020), but according to (Stefanos, 2013) in the EU, only 34% of people with disabilities work full-time. Additionally, the share of part-time work increases as the degree of disability increases. The unemployment rate is 28% for people with severe disabilities, 15% for people with moderate disabilities, and 10% for people without disabilities. Therefore, it is worth researching new policies to motivate employers to participate in PWDS in manufacturing processes (MP). In published works the problems of efficient PWDS engagement in MP were already discussed. In the work (Miralles et al., 2007), it

Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2022.09.518

is presented how work on an assembly line can be organized to involve PWDS in an assembly process. In the paper (Araújo et al., 2012) an assembly line worker assignment and balancing problem is discussed whether heterogeneous workers are engaged. In the work (Liu et al., 2021), a genetic algorithm was used to assign tasks to the production line. The aim is to minimize the cycle time under conditions of variable PWDS availability and limited availability of temporary workers. There are physical, intellectual, and mental disabilities, which may be of a slight, moderate, or severe level. In the paper, the authors, with the use of simulations, examine the influence of PWDS with chosen disability levels on ML performance.

To understand the potential behavior of an MS after any kind of reorganization, it is worth recurring to computer simulations. SDS and DES are widely used in MS at different levels of production planning. SDS is a method of building continuous simulation models that allows one to model the structure and dynamics of complex systems. Edghill and Towill (1989) focused on modeling orders, materials, and information flows in production systems. Stadnicka and Litwin (2017; 2019) proposed the use of SDS with Value Stream Mapping for detailed MS modeling. SD does not take into account the inherent stochastic nature of some industrial process parameters, such as process time or job arrival rate. SD is currently successfully used to analyze supply chains under the conditions of variable demand, supply or logistics problems, caused eg by the COVID19 epidemic (Ghadge et al., 2021).

DES is based on the numerical solution of queuing network theory problems. Simulations of the model, exploring different scenarios, make it possible to detect unexpected incompatibilities (Kellner et al., 1999). In addition to the difficulties in mapping a real system not fully known, there are some assumptions of queueing network theory that hinder the optimal correspondence with the real ML: pre-emptive servers and independence of service time from the length of queue.

Summarizing, both SD and DES system models emulate the behavior of the system and analyze the outcomes and performances under different circumstances (Sweetser, 1999). Additionally, the integration of both models in the same experiment to take advantage of the respective strengths of both approaches has been proposed in literature. In the work (Venkateswaran and Son, 2005) the SDS is used for long-term production planning and DES for short-term production planning. In the analysis of the manufacturing company, the authors of the work (Rabelo et al., 2005) use SDS to analyze the financial activities of the organization, while DES is used to model the ML. The methodology ensuring the integration and synchronization of both approaches in the modeling and simulation of an integrated production company is presented in (Helal, 2007). The article attempts to integrate both approaches to adapt the number of PWDS to market conditions (SDS) and assess the MS parameters (DES).

3. PROBLEM IDENTIFICATION AND RESEARCH QUESTIONS

In the present study, a benchmark ML is considered which consists of 4 parallel workstations with one employee for each. On the ML, workers with disabilities can be employed. The resulting planning problems which have been taken into consideration are:

- Different efficiency for workers with and without disabilities (simulable by SDS, DES).
- Unplanned breaks for workers with disabilities (DES).
- Dependence of the price on SL and demand (SDS).

Employees with disabilities require longer process times, whose amount depends on the type and level of disability. Furthermore, employees with disabilities can take unplanned breaks, which influence performance of the manufacturing line. The correct planning process and employee assignment should ensure obtaining high SL is obtained. It is worth highlighting that the government gives financial support to companies which employee people with disabilities. On the basis of the problems, the following research questions were set and taken into consideration in further analyses.

RQ1: What are the business rationales for employing PWDS?
RQ2: What is the influence of PWDS employment on product costs and how do they affect price and market demand?
RQ3: How does PWDS employment influence productivity and SL?

4. RESEARCH PROCEDURE AND METHODS

The research procedure (Figure 1) is divided into four main stages. The first one concerns establishing the goal of the work on the basis of the identified problem. The second stage is connected with the SDS performed on a strategic and tactical level. The third stage is the application of DES at the operational level. In the last part, the scientific contribution of the work was underlined. In problem identification (1) the important issues concerning the employment of PWDS (1.1) were discussed. Then, a general scheme of the ML (1.2), on which employees with disabilities can be engaged, was developed. Next, the SDS model (2) was created in Vensim by extracting the factors (2.1) that influence the ML performance. The relationships between factors were identified and applied to model (2.2).

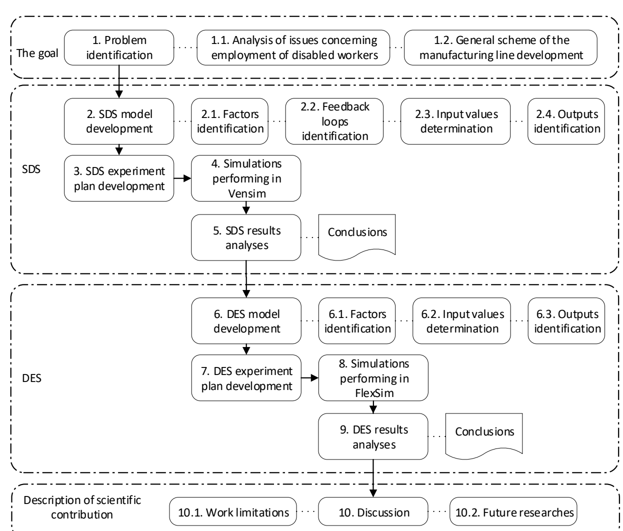

Figure 1. The research procedure.

Input values were determined (2.3) for different simulation scenarios. The SDS model incorporates strategic decisions related to SL. Furthermore, the model helps to make decisions on a tactical level. The decisions are related to the number of PWDS engaged. In step (2.4), the results of SDS were identified. The experiment was developed (3) and simulated (4). The results of the simulations were analyzed (5). After that, the assumptions for DES were established and the DES model was created in FlexSim (6). Factors influencing ML were identified and incorporated into the DES model (6.1). Input values were determined for different simulation scenarios (6.2). Possible results of the DES simulations were identified (6.3). Then, the experiment plan for DES was developed (7) and simulations were performed (8). The results of the simulations were discussed and conclusions were drawn. The SDS model is presented in Figure 2. The simplifications and assumptions made in this study are discussed below.

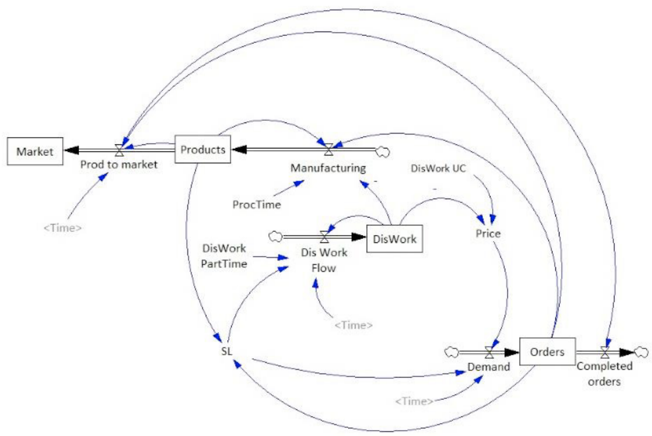

Figure 2. SDS model with disabled employees engaged

SDS was applied to analyze the influence of the following factors (inputs and outputs):

- Number of PWDS engaged in MP (DisWork);
- Demand, which is determined daily (Demand);
- Operating time (OT), which includes processing time (PT) and travel time (TT);
- Number of manufactured products (Products);
- Product price (Price), which includes the cost of labor, concerning workers with and without disabilities;
- Service level (SL), which is calculated daily by dividing the number of manufactured products by the number of ordered products (including backorders).

The SDS model considers the causal relationships between the factors mentioned above. Increasing the number of PWDS involved in the MP decreases the price (work cost) because the government subsidizes the employment of people with disabilities. At the same time, increasing the number of PWDS engaged in the MP decreases the quantity of manufactured products, because the efficiency of workers with disabilities is lower. If the demand decreases, the number of workers with disabilities involved in the MP can increase. An increase in price will decrease demand. Increase in SL will cause the demand to increase. Increasing the number of manufactured products increases SL. To determine realistic operating times, an experiment was performed in a manufacturing company. In the experiment, employees without disabilities (WTD) and employees with moderate intellectual disability (MID) were involved. They performed the same work. From the values obtained, min, max, mean, and standard deviation were calculated. The operating times for SDS were calculated taking into account the mean percentages obtained in the mentioned time study.

The elements of SDS model are defined as follows:

a. 'Manufacturing' - this flow simulates the MP efficiency. MP is carried out by 4 employees, a WTD performs the assembly process in 96 [s] and a MID in 240 [s] (1).

$$\text{Manufacturing} = ((4-\text{DisWork})/96) + \text{DisWork}/240 \quad (1)$$

b. 'Prod to market' - This process is responsible for sending manufactured products to the market after each shift. The number of products shipped is equal to or less than the number of products ordered (2).

Prod to market = IF Products>Orders THEN Orders ELSE Products (2)

c. 'SL' - The variable presents the calculation of SL (3).

$$\text{SL} = \text{Products} / \text{Orders} \quad (3)$$

If the number of products is lower than the number expected by customers, the SL goes down below 1, leading to customer dissatisfaction. Furthermore, with actual employee assignment, the company is not able to manufacture the expected number of products and possibly changes in employment in the ML should be considered.

d. 'DisWork Flow' (DWF) - The process presents the rules of assignment of PWDS to the process. This is decided after each shift based on SL (4).

DWF = IF SL >=0.99 AND DisWork<=3 THEN hire PWDS IF SL < 0.85 AND DisWork>=1, THEN dismiss PWDS (4)

If the SL is greater than or equal to 0.99 and the number of PWDS is less than 3 – one PWDS is hired. On the contrary, if the SL is less than 0.85, one PWDS is dismissed.

e. 'Price' - The variable presents how the product price will change depending on the MP cost (5).

$$\text{Price} = \text{CF} + ((\text{DisWork} * C_{MID}) + (4-\text{DisWork}) * \text{CWTD})) / 4 \quad (5)$$

The price of the product depends on the number of PWDS (DisWork), and number of employees without disabilities (4-DisWork), WTD unit labor cost (C_{WTD}), and MID unit labor cost (C_{MID}). C_F in the beginning of the formula represents fixed costs and unit profit (fixed for the sake of simplicity).

f. 'Demand' - the process presents how the demand changes according to SL and price (6).

$$\text{Demand} = (A_1 - B_1 * \text{Price} + A_2 + B_2 * \text{SL}) * \text{RandomNormal}(\text{min}, \text{max}, \text{mean}, \text{stdev}) \quad (6)$$

According to (6), the demand from the customer depends on price and SL. This is a simplified model of the complex dependence between demand and production factors described in detail in (Ray, 2005) and in (Qian, 2014). Demand is also a function of the actors taken into consideration: the manufacturer – final customer or the manufacturer – retailer. It also depends on the type of industry and product, as well as on the production type. The approach used here, for the sake of simplicity, says that demand increases with a decrease in the price and decreases with a decrease in the SL. A_1 and B_1 are the Demand-Price coefficients, and A_2 and B_2 are the Demand-SL coefficients. The demand is calculated at the end of each shift. To represent the fluctuations in actual demand, it is multiplied by a random normal value. The random component represents all other factors affecting demand. The normal distribution characteristics are: min=0.8, max=1.2, mean=1, stdev=0.068.

g. 'Orders' – represents the number of orders to be completed and is the result of subtracting the completed orders from the demand (7).

Orders = Demand - Completed Orders (7)

h. 'Completed orders' - the number of completed orders is equal to the number of products shipped to the market (8).

Completed orders = Prod to market (8)

5. RESULTS OF THE EXPERIMENTS

Six simulation experiments were planned (Table 1) with a simulation period of 1 year, corresponding to 250 working days (112500 minutes). In the first simulation experiment (SDS-1), the company decides the number of PWDS used after every working day depending on the value of SL. The total number of employees (WTD + MID) is always 4. The goal of the simulation is to observe the number of PWDSs engaged to provide a certain SL under dynamic market conditions. In subsequent simulations (SDS-2 – SDS-6) the number of employees with and without disabilities engaged in the MP is fixed, which means that it does not change during the simulation period. First, the SD model was used to determine the number of PWDSs for specific market conditions. The simulations were carried out under the assumption of government support in the amount of PLN 2,300 per month for every PWDS employed. The value of government support has an impact on the employment costs and on the product price.

Table 1. Experiment plan for SDS

Experiment	**SDS-1**	**SDS-2**	**SDS-3**
Employees	WTD+ MID=4	4 WTD	3 WTD 1 MID
Experiment	**SDS-4**	**SDS-5**	**SDS-6**
Employees	2 WTD 2 MID	1 WTD 3 MID	4 MID

The model assumes that a change in the number of PWDS occurs due to changes in the SL (4). In the SDS-1 experiment, the number of PWDS engaged on the ML can be changed after every working day. The simulation showed that, due to the variation in demand, the number of MID workers during the simulation period oscillates around 2. The mean value of the SL achieved is 0.91. The number of products manufactured during the simulation experiment is 188 583 pcs. The results of the SDS-1 experiment can be summarized by saying that the MS model under given market conditions most often requires the employment of 2 PWDS, with SL >=0.85.

The daily change in the number of PWDS is not a realistic employment practice, which is why in the next simulation experiments the parameters of the MS with a fixed number of PWDS were examined. The results presented in Table 2 indicate a decrease in prices together with an increase in the number of PWDS. The demand increases with increasing number of PWDS, reaching a maximum value of 768 pcs for 2 PWDS. I also corresponds to the maximum return. Then, the demand decreases as the number of PWDS increases, despite less costs for the company and corresponding lower selling price. The paradox is explained as demand also dependent on the SL, which clearly decreases when more PWDS. The decrease in SL is caused by the lower productivity of PWDS who need more time to do their work. The results presented in Table 2 show that for two PWDS the largest number of products (191 925 pcs) is delivered to the market. At the same time, high SL is maintained. The mean value of SL in the SDS-4 simulation is 0.96. However, to estimate the parameters of the production system more accurately, it is necessary to carry out DES experiments.

Table 2. Results of the SDS experiments; DD – daily demand, WU – worker utilization.

Experiment	**SDS-1**	**SDS-3**	**SDS-4**	**SDS-5**
No of PWDS	0 – 4	1	2	3
Mean SL	0.91	1	**0.96**	0.45
Price	2.22–2.5	2.43	2.36	2.29
Mean DD	752	738	768	619
No of products	188583	184545	**191925**	154069
Mean WU	98.6%	77.2%	97.5%	99.6%

The DES model is applied to represent manufacturing operations carried out on 4 workstations. The dispatcher assigns workers to the workstations of disposal operators without disabilities and operators with disabilities. The goal of DES was to assess a possible throughput (TH) taking into account the unplanned breaks of PWDS and the possibility of different assignment of workers to workstations. The following data were taken into consideration in model development: operating time for WTD and for MID with exponential distribution., travels, unplanned breaks for PWDS and available working time.

The DES model takes into account the random distribution of unplanned breaks that can be made by PWDS. In the DES (Table 3) experiments, the variables were connected with the employees who participated in the MP. In the first simulation experiment (DES-1), only WTD employees were engaged. In the fifth simulation experiment (DES-S5), only MID employees were engaged. The ML works with one shift. According to Polish law, PWDS can work a maximum of 7 hours (moderate and severe disability) per day. However, for this work, a simplification was applied and it was decided that in the simulations, all employees will work 7,5h.

Table 3. Experiment plan for DES simulations

Variable	Experiment				
	DES-1	DES-2	DES-3	DES-4	DES-5
Employees	4 WTD	3 WTD 1 MID	2 WTD 2 MID	1 WTD 3 MID	4 MID

Unplanned breaks were taken into consideration in DES experiments. The travel times are proportional to the distance traveled. They add little variability to the different workstations. Unplanned breaks indicators for MID are: Mean Time To Break (MTTB = 7,5h / 2); Mean Time Of Break (min MTOB = 480 s, max MTOB = 1 200 s).

In DES experiments, the maximum throughput time (TH) was obtained for each scenario. Since the simulations were stopped while TH achieved the demand value, the actual TH is presented in Table 4. The SL was calculated from formula **(8)**.

$$SL = TH / Demand \quad (8)$$

Table 4. DES experiment results

Experiment	DES-1	DES-2	DES-3	DES-4	DES-5
	4 WTD	3 WTD 1 MID	2 WTD 2 MID	1 WTD 3 MID	4 MID
TH max [pcs]	976	868	693	569	410
Demand [pcs]	695	738	768	619	517
TH real [pcs]	695	**738**	693	569	410
SL	1.0	1.0	0.90	0.92	0.79

From the results, it can be seen that in the case where demand equals 738 pcs, the SL was the highest (1.0) with 1 disabled worker on the manufacturing line. In the case when the demand equals 768 pcs, engagement of 2 PWDS results in SL equal to 0.9. The graphical presentation of employee utilization for scenario DES-3 is shown in Figure 3. In the scenario DES-3, 2 WTD operators and 2 MID operators were engaged.

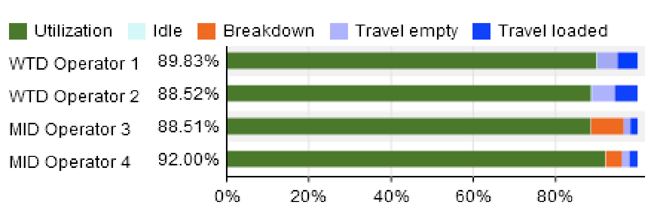

Figure 3. Worker utilization

In Figure 3, it is clear that utilization of all workers was similar. From the presented results we can see that adequate workers assignment will allow a similar amount of time for manufacturing by workers with and without disabilities. MID operators can be assigned mostly to the closest workstations to travel as little as possible. This way, even if they make breaks, the workers utilize similar time to manufacture products. The results of each workstation and the number of products manufactured by each worker are presented in Table 5. It can be seen that the mean number of products manufactured by WTD workers is 248 pcs. Although the mean number of products manufactured by workers MID is 98,5 pcs.

Table 5. The throughput from each workstation and number of products manufactured by workers

Workstation	TH [pcs]	Worker	Number of products [pcs]
1	230	WTD1	250
2	97	WTD2	246
3	105	MID1	97
4	261	MID2	100

6. DISCUSSION AND CONCLUSIONS

The final discussion is concentrated on the research questions that were the basis of the performed analysis. The RQ1 concerns the business rationale for employing PWDS. As a result of the lower efficiency of PWDS, increasing their share in manufacturing reduces the overall throughput of MS. Therefore, activation and, thus, improvement of quality of life should be the basic reason for employing PWDS. According to the reports studied, the percentage of PWDS is high and still growing, which is why creating jobs for PWDS is essential. However, from a business point of view, companies need to assess how PWDS will actually affect their internal business operations and meet the customer requirements. Therefore, RQ2 applies to the influence of PWDS employment on product price and market demand. Since companies with PWDS employees have additional external financial support, their costs of work become lower. Thanks to lower labor costs, the employment of PWDS helps reduce prices, which in turn increases demand. Companies have to meet this demand to retain customers. Therefore, RQ3 is how the employment of PWDS influences the fluctuation of productivity and SL. The SDS-1 experiment showed that, when disabled workers are employed, to achieve SL at least 0.85, two PWDS should be employed. Then, in a series of experiments SDS-2 to SDS-6 (each experiment with a fixed number of PWDS), it was confirmed that if two PWDS are employed, the annual production delivered to the market is the highest, (191 925 pcs), with a high average SL (0.96). Then, in the DES experiment, daily performance was determined with greater accuracy. In the DES experiment, the demand values obtained in the SDS experiment were used to calculate the SL. In the DES experiment, the largest number of products was delivered to the market when one PWDS – 738 pcs daily (184 500 pcs annually) at SL 1.0. In the case of employing two PWDS, the daily production volume was 693 pcs (173 250 pcs annually), at SL 0.9. Due to the incorporation of additional factors, the DES results should be considered more accurate; it is obvious that considering additional random breaks in the work and travel of employees will reduce the production volume. It should be noted that the results obtained are associated with the adopted cofinancing, the employment of PWDS, and the experimentally determined relationship between demand, price, and SL. Previous works (Miralles et al., 2007) (Araújo et al., 2012) did not take it into consideration. However, the results of the study confirm the business rationale for employing PWDS. The presentation of evidence (not only social, but also economic) on the rightfulness of employing workers with disabilities and the methodology of the analysis are the main contributions of this work to science.

Ensuring employment for PWDS is a major challenge for today's society. It is well known to be an important factor in improving the quality of life of disabled people. This study has shown that employing PWDS in a regulated labor market can also benefit companies within certain limits. Moreover, the presented methodology can be applied for other cases where different circumstances exist to determine the best option for PWDS engagement in an ML. The present study has some limitations. The first concern the available working time, which should be different for employees with and without disabilities. In future research, it will be included in the simulation models. The second one is that the equilibrium point is dramatically sensitive to subsidies determined locally (an external variable) and that every change in national policy could have a dramatic effect on the employment figures for PWDS. The prompt update of the model is required to continue to have meaningful indications.

REFERENCES

Antonelli, D., Stadnicka, D. (2018). Combining factory simulation with value stream mapping: A critical discussion, in: Procedia CIRP. Elsevier B.V., pp. 30–35.

Araújo, F.F.B., Costa, A.M., Miralles, C. (2012). Two extensions for the ALWABP: Parallel stations and collaborative approach. Int. J. Prod. Econ. 140, 483–495.

Disabled World. (2009). Definitions of Disability : Disabled World. https://www.disabled-world.com/definitions/disability-definitions.php (accessed 4.12.21).

Edghill, J.S., Towill, D.R., Husband, T. (1989). Dynamic Behaviour of Fundamental Manufacturing System Design Strategies. CIRP Ann. - Manuf. Technol. 38, 465–468.

Ghadge A., Er M., Ivanov D., Chaudhuri A. (2021). Visualisation of ripple effect in supply chains under long-term, simultaneous disruptions: a system dynamics approach. Int. J. Prod. Res.

Gola, A. (2019). Reliability analysis of reconfigurable manufacturing system structures using computer simulation methods. Eksploat. i Niezawodn. 21, 90–102.

Helal, M. (2007). A methodology for integrating and synchronizing the system dynamics and discrete event simulation paradigms. 25 Int. Conf. Syst. Dyn. Soc. 3, 1–24.

Kellner, M.I., Madachy, R.J., Raffo, D.M. (1999). Software process simulation modeling: Why? What? How? J. Syst. Softw. 46, 91–105.

Kłos, S., Trebuna, P. (2015). Using computer simulation method to improve throughput of production systems by buffers and workers allocation. Manag. Prod. Eng. Rev. 6, 60–69.

Lecerf M. (2020). Employment and disability in the European Union. European Parl. Research Service. PE 651.932.

Liu M., Liu Z., Chu F., Liu R., Zheng F., Chu C. (2021). Risk-averse assembly line worker assignment and balancing problem with limited temporary workers and moving workers. Int. J. Prod. Res.

Miralles, C., García-Sabater, J.P., Andrés, C., Cardos, M. (2007). Advantages of assembly lines in Sheltered Work Centres for Disabled. A case study. Int. J. Prod. Econ. 110, 187–197.

Qian, L. (2014). Market-based supplier selection with price, delivery time, and service level dependent demand. Int. J. Prod. Econ. 147, 697–706.

Rabelo, L., Helal, M., Jones, A., Min, H.S. (2005). Enterprise simulation: A hybrid system approach. Int. J. Comput. Integr. Manuf. 18, 498–508.

Rabiega, H. (2014). Jak kraje UE wspierają zatrudnianie osób niepełnosprawnych? GazetaPrawna.pl. https://serwisy.gazetaprawna.pl/praca-i-kariera/artykuly/808559,jak-kraje-ue-wspieraja-zatrudnianie-osob-niepelnosprawnych.html.

Ray, S. (2005). An integrated operations-marketing model for innovative products and services. Int. J. Prod. Econ. 95, 327–345.

Stadnicka, D., Litwin, P. (2019). Value stream mapping and system dynamics integration for manufacturing line modelling and analysis. Int. J. Prod. Econ. 208, 400–411.

Stadnicka, D., Litwin, P. (2017). VSM Based System Dynamics Analysis to Determine Manufacturing Processes Performance Indicators, in: DEStech Transactions on Eng. and Techn. Research. pp. 290–295.

Stefanos (2013). European comparative data on Europe 2020 & People with disabilities Final report prepared by Stefanos Grammenos from Centre for European Social and Economic Policy (CESEP ASBL) on behalf of the Academic Network of European Disability Experts.

Sweetser, A. (1999). A Comparison of System Dynamics (SD) and Discrete Event Simulation (DES), in: 17th Int. Conf. of the System Dynamics Society. pp. 20–23.

Venkateswaran, J., Son, Y.J. (2005). Hybrid system dynamic - Discrete event simulation-based architecture for hierarchical production planning. Int. J. Prod. Res. 43, 4397–4429.

Wagner, J., Schnabel, C., Kölling, A. (2001). Threshold Values in German Labor Law and Job Dynamics in Small Firms: The Case of the Disability Law. IZA Discuss. Pap. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=288294 (accessed 4.12.21).

WHO (2021). Disability and health, https://www.who.int/news-room/fact-sheets/detail/disability-and-health.