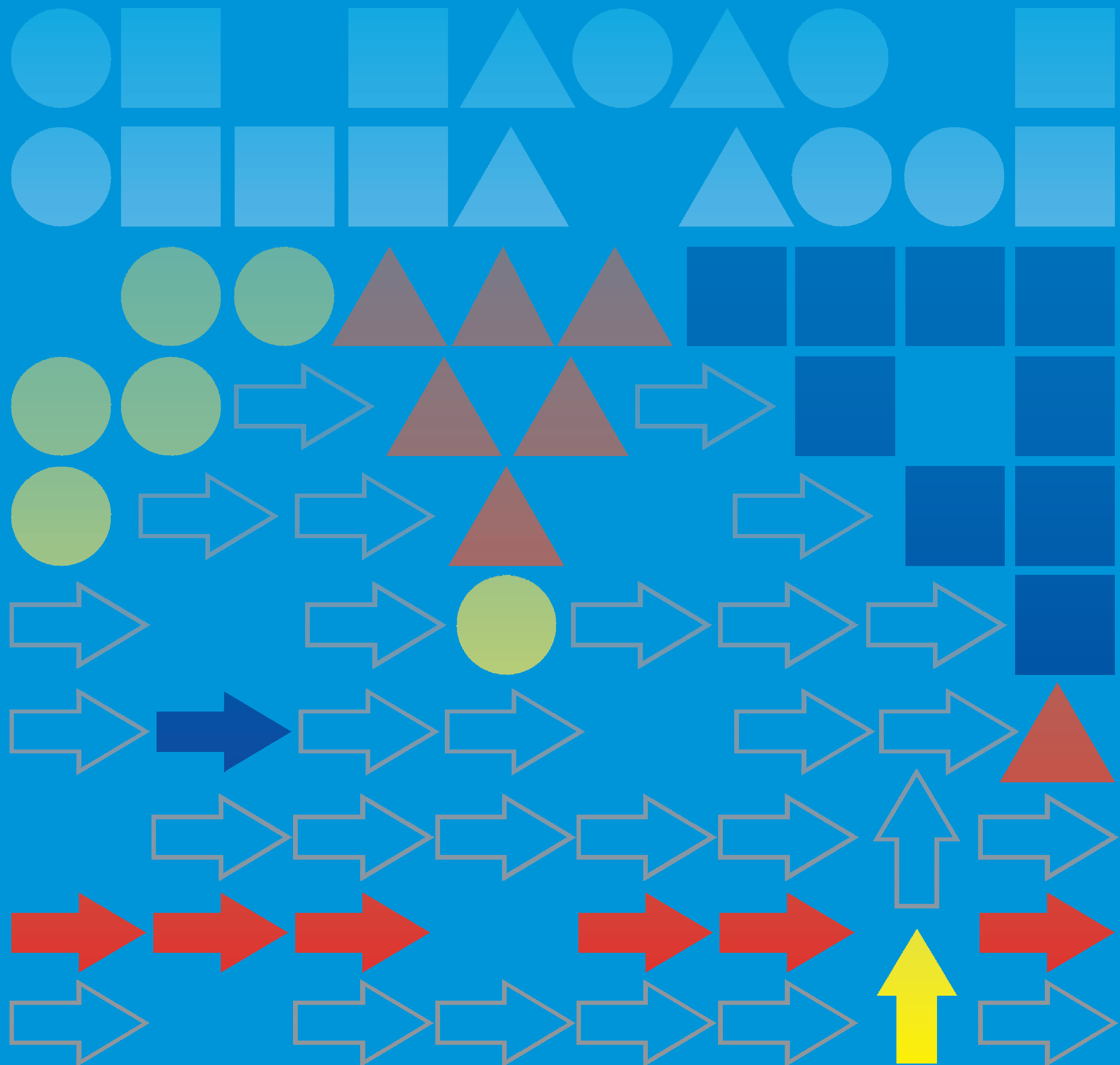
ACTA SIMULATIO

International Scientific Journal about Simulation

electronic journal
ISSN 1339-9640

2023 Volume 9 Issue 2



CONTENTS

(JUNE 2023)

https://doi.org/10.22306/asim.v9i2.95

Received: 26 Feb. 2023
Revised: 20 Mar. 2023
Accepted: 15 Apr. 2023

Power of digitalization: statistical analysis of European SMEs

Laura Lachvajderova
Technical University of Košice, Faculty of Mechanical Engineering, Department of Business Management and Environmental Engineering, Park Komenského 5, 04200, Košice, Slovak Republic, EU, laura.lachvajderova@tuke.sk (corresponding author)

Richard Duda
Technical University of Košice, Faculty of Mechanical Engineering, Department of Industrial and Digital Engineering, Park Komenského 9, 04200, Košice, Slovak Republic, EU, richard.duda@tuke.sk

Martin Trebuna
Technical University of Košice, Faculty of Mechanical Engineering, Department of Industrial and Digital Engineering, Park Komenského 9, 04200, Košice, Slovak Republic, EU, matrin.trebuna@tuke.sk

Marek Mizerak
Technical University of Košice, Faculty of Mechanical Engineering, Department of Industrial and Digital Engineering, Park Komenského 9, 04200, Košice, Slovak Republic, EU, marek.mizerak@tuke.sk

Keywords: analysis, digitalization, small and medium-sized enterprises.

Abstract: The ongoing effects of the pandemic have led to a heightened adoption of digital technologies among businesses. Acknowledging the importance of small and medium-sized enterprises (SMEs), the European Commission emphasizes the need for support in digitalization efforts. The study focuses on investigating the influence of digitalization on SME performance by analyzing data from 27 EU countries using econometric analysis. A thorough literature review explores the relationship between digitalization and SME performance. The findings of our study provide valuable insights for policymakers, suggesting the integration of digital tools into the infrastructure of SMEs, and also serve as inspiration for future research in this area.

1 Introduction

According to the European Commission, more than 98% of all businesses in the European Union (EU) are small and medium-sized enterprises (SMEs), and they account for approximately two-thirds of total employment. SMEs make a significant contribution to the EU's gross domestic product (GDP), comprising over half of the added value in the non-financial corporate economy [1]. Despite the considerable impact of the COVID-19 pandemic on SMEs throughout the EU, these businesses have demonstrated their resilience and ability to adapt to the challenges [2]. Various measures have been implemented to support them, including easing regulations, providing financial assistance, and implementing targeted programs for digitalization and innovation support. The digitalization of SMEs can have a positive effect on their value added and performance by streamlining processes and production, enhancing service quality and productivity, improving collaboration and communication within the company, and enhancing the customer experience. These improvements can contribute to increased value added and improved performance for SMEs, directly influencing their business growth and development. Furthermore, digitalization enables SMEs to better compete in the market, which is crucial for success and maintaining a competitive advantage [3].

While research on digitalization's impact on SME performance is growing, the specific effects are not yet well-established. Rigorous scientific studies are needed to systematically investigate its influence on productivity, profitability, innovation, competitiveness, and customer satisfaction. These studies should employ quantitative analysis, case studies, surveys, or experiments, collecting data on SMEs' digitalization initiatives and objectively measuring performance outcomes. Well-designed research is necessary, considering confounding factors, utilizing appropriate statistical analyses, and acknowledging contextual influences. Conducting scientific investigations into digitalization's effects on SME performance can provide valuable insights and evidence-based recommendations for SMEs, policymakers, and stakeholders to optimize digital transformation and improve business performance [4].

This study aims to examine the relationship between digitalization and business performance, specifically investigating whether digitized companies tend to be more prosperous and achieve higher performance levels. The research focused on a sample of 27 European Union member countries (EU27) and utilized a regression model for panel data over a 5-year period (2017-2021). By using the EU27 sample, the study provides a concentrated and comprehensive analysis of the EU context, facilitating comparative assessments, bolstering statistical power, and leveraging relevant data availability. The findings of this research contribute to the existing literature by enhancing the understanding of factors influencing business digitalization and offering empirical evidence on how the integration of digital technologies impacts SME performance within the EU.

2 Literature review

Digital transformation varies among companies depending on the industry and is influenced by factors such as the adoption of advanced technologies, evolving customer needs, market size, and the specific business sector [5]. Boundary companies that prioritize digitalization tend to achieve higher long-term productivity and revenue compared to less digitally-oriented companies [6]. SMEs can leverage digital technologies to support their business functions, such as utilizing social media applications, open-source software, mobile security, e-commerce platforms, video conferencing, instant messaging, and shared calendars, which may be either paid or free [7]. Additionally, tools like Big Data, Blockchain, Artificial Intelligence, and the Internet of Things offer further potential for enhancing SME performance economically, socially, and environmentally [8].

Companies' digital transformation levels vary based on contextual factors and can be grouped into three categories: highly digitally mature SMEs that quickly adapt to digitalization, SMEs with liquidity issues that only digitize their sales function, and SMEs with limited digital literacy but strong social capital seeking digital partners [9]. Successful digital transformation requires investment in various dimensions, including infrastructure, IT technologies, intellectual and strategic aspects, formal and informal structures, culture, and social factors [10]. Optimal performance outcomes require significant operational changes externally and internally [11]. Overcoming obstacles and challenges involves adapting business models, knowledge, and technologies, while increasing the benefits of digital technology adoption necessitates innovative business model development [12]. Conflicting findings exist regarding the impact of digitization on SME performance. For example, a recent study (2021) suggests that digital technologies have a limited effect on innovative performance, with R&D expenditures being a more reliable predictor of innovation [13]. This study challenges the notion that digital technologies necessarily enhance innovative performance. Considering these findings and building upon the existing literature, a research question was formulated to investigate the influence of digitalization on firm performance: *'Does digitalization affect SMEs performance?'*

3 Methodology

3.1 Research measure

In this chapter, we will summarize the key indicators (variables) relevant to our research, which fall under the category of quantitative research approaches. These methods prioritize the identification of causal relationships rather than individual experiences or beliefs, enhancing objectivity. As our study utilizes publicly available data, it can be replicated. The evaluation of the study's overall quality relies on criteria such as reliability and validity. Our aim is to ensure consistent and stable results when applying the same data in future studies. To achieve this, we have relied on reliable sources, including:

- Eurostat: the statistical office of the European Union.
- European Commission: the executive branch of the EU, providing information on EU policies, programs, and activities.

The study involves conducting an econometric analysis using panel data to examine the influence of digitalization on SME performance and validate our hypotheses. The dataset comprises 135 observations gathered from 27 EU countries over a period of five years. To address the research question and assess the validity of the established hypotheses, a panel dataset spanning from 2017 to 2021 was created. The panel data method was selected for its capability to track the same individuals over time, facilitating the analysis of dynamic responses and controlling for unobserved heterogeneity within data containing both cross-sectional and time series elements [14]. Utilizing panel data offers several advantages, as highlighted by [15], including increased variability, reduced collinearity between variables, greater degrees of freedom, enhanced efficiency, and the ability to account for individual heterogeneity, resulting in more informative data. The statistical analysis was performed using EViews 12 [16]. Table 1 presents the four variables derived from the dataset that will be observed.

Table 1 Descriptive statistics variables

Dependent variable	Interpretation	Unit
Value added	Share of the total value added of EU27 SMEs	%
Independent variable		%
Integration of digital technologies	Level of implementation and use of digital technologies in EU27 SMEs	%
Control variable		%
Total investment	Percentage of GDP for each of the EU27 countries	%

The aforementioned independent variable will be used to address the research question. As discussed in [17,18], there is a reciprocal relationship between the dependent and independent variables. Higher value-added can contribute to employment growth, while increased employment can enhance productive performance, thereby fostering value-added growth. Furthermore, the integration of digital technologies across various business domains can improve operational efficiency and speed. Total investment can facilitate job creation, spur the development of new products and services, and stimulate economic growth.

3.2 Theoretical background

For the analysis of panel data, we employed the Least Squares Dummy Variables (LSDV) method, which is specifically tailored for this type of data. The LSDV method enables the inclusion of individual-specific effects, resulting in more accurate and reliable estimates [19]. It is worth mentioning that the assumption of homoscedasticity is crucial for obtaining dependable results using the LSDV method. To address the research question, we will utilize a linear regression model with regression equation (1), which incorporates both the dependent and independent variables. This model depicts the connection between the independent variable and the dependent variable, illustrating how changes in the independent variable can influence the dependent variable.

$$Y_{it} = \alpha + \beta X_{it} + \lambda_t + \varepsilon_{it} \qquad (1)$$

Where:
- Y_{it} represents the dependent variable for a specific observation (country) *i* at a given time *t* (year);
- X_{it} corresponds to the independent (explanatory) variable for the same observation *i* at time *t*;
- α represents the country-specific intercept;
- β denotes the coefficient associated with the independent variable X_{it};
- λ_t represents the time-fixed effect, which includes time dummy variables for the respective time period *t*;
- ε_{it} signifies the error term for observation *i* during time period *t*.

Building upon equation (1) and considering the number of dependent and independent variables, the resulting equation in our study can be formulated as follows:

$$VA_{SMEs_{it}} = \alpha + \beta_0(IntDigTech_{SMEs}) + \\ +\beta_2(\text{Total\_inv})_{it} + \lambda_t + \varepsilon_{it} \qquad (2)$$

Where:
- VA_{SMEs} is a dependent variable;
- $IntDigTech_{SMEs}$ is an independent variable;
- Total_inv is a control variable.

The purpose of regression analysis is to investigate the relationship between independent and control variables and the dependent variable. In order to determine the suitable model specification, which includes deciding whether to use pooled data or incorporate fixed effects or random effects to address heterogeneity, we conducted several tests. Fixed effects are utilized to examine whether there are distinct intercepts for each entity, which remain constant over time. This approach assumes that the relationships between explanatory and dependent variables are consistent on average and over time, with specific assumptions about the independent variable and error distribution. On the other hand, random effects aim to capture effects beyond specific values of the independent variable, eliminating the need for precise assumptions about the variables. Our proposed model aims to understand the relationship between the integration of digital technologies at the SMEs level and the value added by SMEs. To confirm the necessary effects of the model, we will conduct a series of tests on the data, including a Hausman test to determine whether to use fixed effects or random effects in our model specifications.

4 Results and discussion

To assess the spread of values in our analysis, we will present descriptive statistics of the variables used. We will include measures such as the mean, median, and standard deviation, which indicate how closely data points align with a normal distribution. When data follows a standard or Gaussian distribution, the mean and median typically have similar values. After examining Table 2, we note that all variables in the model display means and medians that are close in value, suggesting that all variables are assumed to follow a normal distribution.

Table 2 Descriptive statistics of variables

Variable	Mean	Median	Standard Deviation
Value added	58.257	58.000	8.259
IntDigTech	40.319	38.000	14.809
Total_inv	22.141	22.500	2.980

Table 3 presents the correlation matrix, which reveals that no correlation surpassing 0.7 or below -0.7 was found. Following a general guideline [20], this indicates the lack of significant correlations among the variables.

Table 3 Correlations matrix

Variable	Value added	IntDigTech	Total_inv
Value added	1		
IntDigTech	-0.424	1	
Total_inv	-0.186	0.197	1

Acta Simulatio - International Scientific Journal about Simulation
Volume: 9 2023 Issue: 2 Pages: 15-20 ISSN 1339-9640

In the next step, we will perform a Hausman test to select the suitable method for conducting regression analysis on the data. The Hausman test evaluates the following hypotheses:

- H0: The random effects model is more suitable for this study.
- H1: The fixed effects model is more suitable for this study.

Based on the information provided in Table 7, the calculated p-value is lower than the significance level of 0.05 or 5%. Thus, we reject the null hypothesis (H0) and accept the alternative hypothesis (H1), indicating that the fixed effects model is more appropriate for our study.

Table 4 Hausman test

Chi-Square Statistic	19.065
Chi-Square Statistic Probability	0.0001

The final results of the panel data regression analysis using the fixed effects model and LSDV method are displayed in Figure 1. The analysis demonstrates that the coefficient of the independent variable (IntDigTech) is statistically significant, indicated by its significant estimate at the 5% level of significance. This indicates that, on average, a one unit increase in IntDigTech is associated with a 0.0658 unit increase in value added, based on the data sample (assuming other factors remain constant).

Dependent Variable: VALUE_ADDED
Method: Panel Least Squares
Date: 06/20/23 Time: 14:25
Sample: 2017 2021
Periods included: 5
Cross-sections included: 27
Total panel (balanced) observations: 135

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	50.59168	9.143313	5.533189	0.0000
INT_DIG_TECH	0.065883	0.040637	1.621252	0.1079
TOTAL_INV	0.226230	0.427006	0.529805	0.5974

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.834939	Mean dependent var	58.25704
Adjusted R-squared	0.791338	S.D. dependent var	8.258921
S.E. of regression	3.772639	Akaike info criterion	5.681220
Sum squared resid	1508.677	Schwarz criterion	6.305316
Log likelihood	-354.4824	Hannan-Quinn criter.	5.934835
F-statistic	19.14951	Durbin-Watson stat	1.624245
Prob(F-statistic)	0.000000		

Figure 1 Panel data regression results

The results indicate the statistical significance of the independent variables, as evident from the R-Squared and Adjusted R-Squared values. The regression model's R-Squared value is 0.834939, indicating the proportion of variability in the dependent variable explained by the independent variable. This value ranges from 0 to 1, where 0 implies that the independent variable has no explanatory power for the dependent variable, while 1 suggests that the independent variable (IntDigTech) perfectly explains the dependent variable (Value added). The obtained R-Squared value in our case is relatively high, indicating a strong relationship between the variables and underscoring the statistical significance of the regression model. Consequently, we can infer that the model supports a positive causal relationship between the variables.

In this study, ensuring measurement validity (construct validity) was of utmost importance as it sought to obtain accurate measurements that align with the concept under investigation. Quantitative research inherently faces the challenge of potential inaccuracies in variable measurement. To tackle this issue, we incorporated control variables that have a robust theoretical and empirical association with the topic.

The integration of digital technologies by SMEs presents opportunities to develop unique resources, enhance efficiency, and increase productivity, thereby gaining a competitive advantage in a highly competitive market. Additionally, digitalization enables SMEs to acquire new competencies, skills, and knowledge, empowering them to introduce innovative processes and products. However, SMEs often face challenges when adopting digital technologies due to limited financial and human resources. While financial constraints are a significant factor, our study's main focus is not on the influence of the control variable related to finances on the overall outcome. We carefully selected control variables based on their impact on the dependent variables, although it is important to acknowledge that these variables share their influence with numerous other indicators. Despite the limited financial resources of SMEs, the selected control variables remain relevant within the context of our study.

With confidence in the validity of our results, we can assert that the independent variable (IntDigTech), which represents the degree of digitalization in EU27 SMEs, exerts a significant and substantial impact on the dependent variable (value added). The value added serves as an indicator of SME performance in EU27. This confirmation establishes a reciprocal causal relationship between these variables, effectively answering our research question.

5 Conclusions

Our study aimed to investigate the influence of digitalization on business performance, specifically focusing on SMEs in the EU27 from 2017 to 2021. We collected datasets for both the dependent variable, representing business performance, and the independent variable, representing the level of digitalization among SMEs in the EU27 during the specified timeframe. To conduct our analysis, we transformed the individual variable datasets into panel data, which was crucial for regression analysis. The statistical software EViews 12 was chosen for the analysis based on the data nature, applicable tests, and study objectives.

The results of the panel data analysis indicate that the extent of digitalization within SMEs can contribute to an increase in value added and have a significant impact on their overall performance in the EU27. However, it is important to note that the study period encompassed the effects of the COVID-19 pandemic, which imposed certain limitations on traditional business development and accelerated the adoption of digital solutions. We believe that our research findings can inspire future studies and provide valuable insights for researchers and policymakers, emphasizing the substantial role of digitalization in enhancing SME performance. One of the main limitations of our research was the availability of data for indicators measuring SME performance. In future research, expanding the sample to a global scale would be beneficial, allowing access to a wider range of variables measuring both digitalization and business performance.

Acknowledgements
This paper was developed within the implementation of the projects VEGA 1-0340-2021 The im-pact of a pandemic and the subsequent economic crisis on the development of digitization of en-terprises and society in Slovakia, VEGA 1/0508/22 Innovative and digital technologies in manufacturing and logistics processes and systems, VEGA 1/0438/20 Interaction of digital technologies to support software and hardware communication of the advanced production system platform, KEGA 020TUKE-4/2023 Systematic development of the competence profile of students of industrial and digital engineering in the process of higher education, APVV-17-0258 Digital engineering elements application in innovation and optimization of production flows and APVV-19-0418 Intelligent solutions to enhance business innovation capability in the process of transforming them into smart businesses.

References

[1] Eurostat, https://ec.europa.eu/eurostat: Value added of the non-financial business economy by size class of employment, [Online], Available: https://ec.europa.eu/eurostat/databrowser/view/tin00147/default/table?lang=en [05 Feb 2023], 2023.

[2] European Commission, https://commission.europa.eu/index_en: Internal Market, Industry, Entrepreneurship and SMEs: Standardisation and SMEs, [Online], Available: https://single-market-economy.ec.europa.eu/smes/sme-strategy/improving-smes-access-marktets/standardisation-and-smes_en [05 Feb 2023], 2023.

[3] PROHL-SCHWENKE, K., KLEINALTENKAMP, M.: How business customers judge customer success management, *Industrial Marketing Management*, Vol. 96, pp. 197-212, 2021. https://doi.org/10.1016/j.indmarman.2021.05.004

[4] CURRAJ, E.: *Business digitalization of SMEs in Albania: Innovative approaches and their impact on performance*, Dissertation, European University of Tirana, 2018.

[5] GIACOSA, E., CULASSO, F., CROCCO, E.: Customer agility in the modern automotive sector: How lead management shapes agile digital companies, *Technological Forecasting and Social Change*, Vol. 175, 121362, 2022. https://doi.org/10.1016/j.techfore.2021.121362

[6] FERNANDEZ-VIDAL, J., GONZALEZ, R., GASCO, J., LLOPIS, J.: Digitalization and corporate transformation: The case of European oil & gas firms, *Technological Forecasting and Social Change*, Vol. 174, 121293, 2022. https://doi.org/10.1016/j.techfore.2021.121293

[7] TREBUNA, P., PEKARCIKOVA, M., DIC, M.: Comparing Modern Manufacturing Tools and Their Effect on Zero-Defect Manufac-turing Strategies, *Applied Sciences*, Vol. 12, No. 22, pp. 1-17, 2022. https://doi.org/10.3390/app122211487

[8] TEPLICKÁ, K., HURNÁ, S., SEŇOVÁ, A.: Design of Workplace Layout Using the 5S Method in the Area of Quality Management System, Quality - Access to Success = Calitatea - acces la succes : revista de sisteme de management, *Journal of Management Systems*, Vol. 22, No. 183, pp. 91-95, 2021.

[9] SANIUK, S., GRABOWSKA, S., STRAKA, M.: Identification of Social and Economic Expectations: Contextual Reasons for the Trans-formation Process of Industry 4.0 into the Industry 5.0 Concept, *Sustainability*, Vol. 14, No. 3, pp. 1-20, 2022. https://doi.org/10.3390/su14031391

[10] GRZNÁR, P., GREGOR, M., KRAJČOVIČ, M., MOZOL, Š., SCHICKERLE, M., VAVRÍK, V., ĎURICA, L., MARSCHALL, M., BIELIK, T.: Modeling and Simulation of Processes in a Factory of the Future, *Applied Sciences*, Vol. 10, No. 13, pp. 1-24, 2020. https://doi.org/10.3390/app10134503

[11] SUHÁNYI, L., SUHÁNYIOVÁ, A., KOREČKO, J., BEDNÁROVÁ, L., KÁDÁROVÁ, J., DERKAWI, H., BAČOVÁ, K.: Relations between the inflow of foreign direct investments and economic indicators in OECD countries, *Acta Montanistica Slovaca*, Vol. 26, No. 4, pp. 810-824, 2021. https://doi.org/10.46544/AMS.v26i4.17

[12] KOPEC, J., PEKARCÍKOVÁ, M., DIC, M., LACHVAJDEROVÁ, L.: Analysis of the big data concept and its use for logistics processes, *Advanced Logistic Systems - Theory and Practice*, Vol. 16, No. 1, pp. 85-91, 2022. https://doi.org/10.32971/als.2022.008

[13] KLIMENT, M., PEKARCIKOVA, M., TREBUNA, P., TREBUNA, M.: Application of TestBed 4.0 Technology within the Implementation of Industry 4.0 in Teaching Methods of Industrial Engineering as

Well as Industrial Practice, *Sustainability*, Vol. 13, No. 16, pp. 1-16, 2021. https://doi.org/10.3390/su13168963

[14] HSIAO, C.: Panel data analysis—advantages and challenges, *TEST*, Vol. 16, pp. 1-22, 2007. https://doi.org/10.1007/s11749-007-0046-x

[15] GEWEKE, J., HOROWITZ, J., PESARAN, H.: *Econometrics: A Bird's Eye View*, CWPE 0655, [Online], Available: https://www.econ.cam.ac.uk/research-files/repec/cam/pdf/cwpe0655.pdf [05 Feb 2023], 2006.

[16] Quantitative Micro Software; Eviews 12, Quantitative Micro Software: Irvine, CA, USA, [Online], Available: https://www.eviews.com/home.html [06 Feb 2023], 2022.

[17] RUPEIKA-APOGA, R., BULE, L., PETROVSKA, K.: Digital Transformation of Small and Medium Enterprises: Aspects of Public Support, *Journal of Risk and Financial Management*, Vol. 15, No. 2, pp. 1-21, 2022. https://doi.org/10.3390/jrfm15020045

[18] KHALIL, A., ABDELLI, M.E.A., MOGAJI, E.: Do Digital Technologies Influence the Relationship between the COVID-19 Crisis and SMEs' Resilience in Developing Countries?, *Journal of Open Innovation: Technology, Market, and Complexity*, Vol. 8, No. 2, pp. 1-14, 2022. https://doi.org/10.3390/joitmc8020100

[19] WEN, J., FAROOQ, U., TABASH, I.M., EL REFAE, A.G., AHMED, J., HAIDER SUBHANI, B.: Government green environmental concerns and corporate real investment decisions: Does financial sector development matter?, *Energy Policy*, Vol. 158, No. November, 112585, 2021. https://doi.org/10.1016/j.enpol.2021.112585

[20] YU, L., LIU, W., WANG, X., YE, Z., TAN, Q., QIU, W., NIE, X., LI, M., WANG, B., CHEN, W.: A review of practical statistical methods used in epidemiological studies to estimate the health effects of multi-pollutant mixture, *Environmental Pollution*, Vol. 306, No. August, 119356, 2022. https://doi.org/10.1016/j.envpol.2022.119356

Review process

Single-blind peer review process.

Acta Simulatio - International Scientific Journal about Simulation
Volume: 9 2023 Issue: 2 Pages: 21-25 ISSN 1339-9640

https://doi.org/10.22306/asim.v9i2.99

Received: 09 Apr. 2023
Revised: 02 May 2023
Accepted: 18 May 2023

Design of simulation experiments using Central Composite Design

Milan Gregor
Department of Industrial Engineering, University of Žilina, Univerzitná 8215/1, 010 26 Žilina, Slovak Republic, EU, milan.gregor@fstroj.uniza.sk
Patrik Grznar
Department of Industrial Engineering, University of Žilina, Univerzitná 8215/1, 010 26 Žilina, Slovak Republic, EU, patrik.grznar@fstroj.uniza.sk (corresponding author)
Stefan Mozol
Department of Industrial Engineering, University of Žilina, Univerzitná 8215/1, 010 26 Žilina, Slovak Republic, EU, stefan.mozol@fstroj.uniza.sk
Lucia Mozolova
Department of Industrial Engineering, University of Žilina, Univerzitná 8215/1, 010 26 Žilina, Slovak Republic, EU, lucia.mozolova@fstroj.uniza.sk

Keywords: Central Composite Design, simulation experiments, design of experiments, Draper-Lin CCD plan.
Abstract: In the context of research and development, it is key to achieve accurate and reliable results. However, often to obtain these results, a large number of experiments must be performed, which can significantly extend the research time and increase computational requirements. The solution to these problems may be efficient experimental planning, which allows for a reduction in the number of trials and optimization of the process. This article provides an insight into Central Composite Design (CCD) and its use in simulation experiments. We introduce various types of CCD designs, such as CCC (Central Composite Circumscribed), CCF (Central Composite Face centered), and CCI (Central Composite Inscribed), and analyze their use in creating second-order regression models. We also discuss the specific advantages and disadvantages of these approaches, as well as their possible alternatives, such as the Draper-Lin CCD design.

1 Introduction

Simulation experiments are today an integral part of research and development in various fields of science and technology. Their effectiveness and accuracy, however, largely depend on proper planning and design of these experiments or significant computational power to carry out all the experiments [1,2]. Since a large number of experiments often need to be carried out, especially in simulations, it is necessary to approach experimental design [3]. When creating models based on Response Surface Methodology (RSM), we often need to calculate both linear and nonlinear (quadratic) terms and two-factor interactions. To do this, all factors must be set at least on 3 levels. For this reason, the use of Full Factorial Design (FFD) method is inefficient as it would require a large number of trials [4].

One of the popular alternatives to FFD, used by many researchers, is Central Composite Design (CCD) [5]. These designs are suitable for creating nonlinear descriptive models. The structure of a CCD design consists of a cube, star, and central point, providing a comprehensive framework for evaluating interactions between multiple factors at different levels.

The core of the article is to address various aspects of CCD designs, including its various types such as CCC (Central Composite Circumscribed), CCF (Central Composite Face centered), and CCI (Central Composite Inscribed). We will also deal with the process of creating these designs, as well as their use in research. Various types of CCD designs are proposed and used, depending on the needs and possibilities within experimentation. The article analyzes the advantages and disadvantages of these different approaches with a description of how CCD designs are used to create second-order regression models and how these models help scientists better understand and interpret their data.

2 Methodology

Before we define the details and technical aspects of using Central Composite Design (CCD), it is important to emphasize that the basic philosophy of this approach is efficiency and accuracy in evaluating experimental data. Since our models often require the calculation of both linear and nonlinear (quadratic) terms and two-factor interactions, it is necessary to set all factors to at least three levels. This puts us in a situation where the use of Full Factorial Design (FFD) or Unifactorial Experiments (UFE) may seem inefficient due to the number of trials needed. At this point, CCD becomes an attractive alternative. CCD provides us with a structure that includes a cube, a star, and a central point, thus allowing a comprehensive evaluation of interactions between multiple factors at different levels. The principle of creation is shown in Figure. 1.

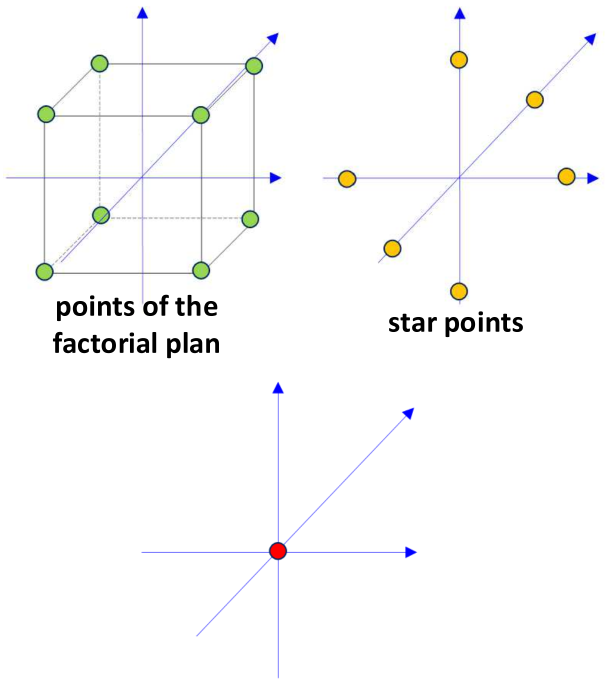


Figure 1 Principle of CCD design creation [6]

Now let's look more closely at how this design is created and what specific benefits its use brings within research experiments. For practical experimentation purposes, several types of CCD designs were proposed. The most famous are plans of type [7]:

- CCC (Central Composite Circumscribed) – rotatable plan, α = 1.4142, which uses 5 factor levels.
- CCF (Central Composite Face centered) – plan centered on the face, α = 1, which uses 3 factor levels, is used if it is not possible to set the factors to 5 levels.
- CCI (Central Composite Inscribed) – inscribed plan, which we get if we replace the coded values (+1) and (-1) with numbers (+1/α) and (-1/α) and the axial values (+α) and (-α) replace the numbers (+1) and (-1). This type of plan is used if it is not possible to set the factor levels within the range (-α) to (+α).

An example of the principle of creating CCC and CCF plans is shown in Figure 2.

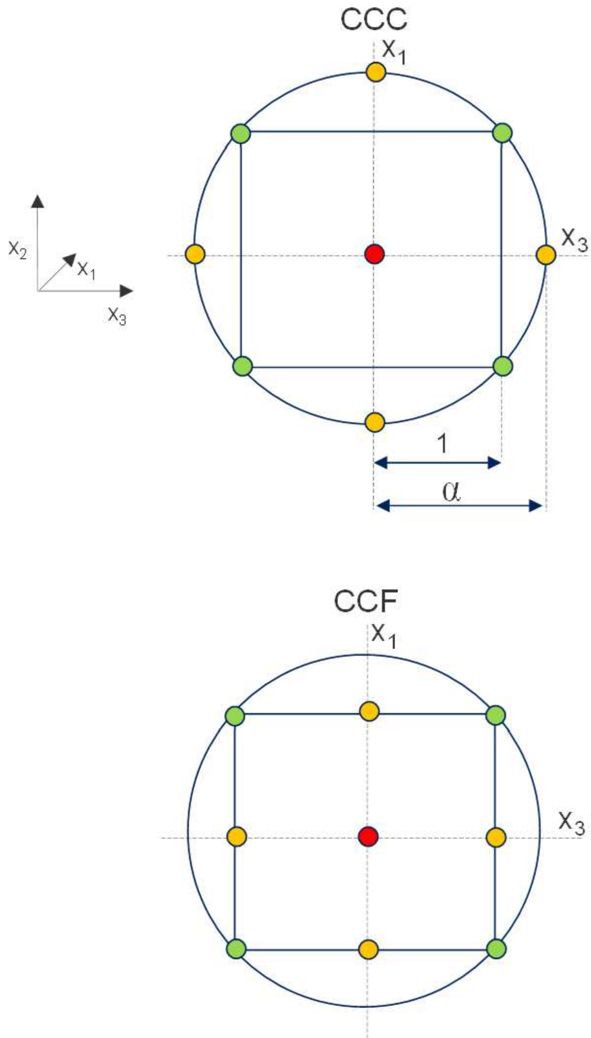


Figure 2 Principle of creating CCC and CCF plans

CCD designs use two-stage experiment designs (Table 1). In the first stage, a regular two-level experiment design is used. In the second stage, additional missing trials are added to the first stage design.

Table 1 Principle of creating CCD experiment designs

Trial	x1	x2	x3
1	**- 1**	**-1**	**-1**
2	**- 1**	**-1**	**1**
3	**- 1**	**1**	**-1**
4	**- 1**	**1**	**1**
5	**1**	**-1**	**-1**
6	**1**	**-1**	**1**
7	**1**	**1**	**-1**
8	**1**	**1**	**1**
9	**- α**	**0**	**0**
10	**+ α**	**0**	**0**
11	**0**	**- α**	**0**
12	**0**	**+ α**	**0**

Acta Simulatio - International Scientific Journal about Simulation
Volume: 9 2023 Issue: 2 Pages: 21-25 ISSN 1339-9640

13	**0**	**0**	**- α**
14	**0**	**0**	**+ α**
15	**0**	**0**	**0**
16	**0**	**0**	**0**
17	**0**	**0**	**0**
18	**0**	**0**	**0**
19	**0**	**0**	**0**
20	**0**	**0**	**0**
21	**0**	**0**	**0**
22	**0**	**0**	**0**
23	**0**	**0**	**0**

As can be seen from Table 1, the first stage of the CCD design is formed by a two-level design of type 23 (marked in yellow in Table 1). To this design, we add central and axial points (trials) in the second stage. Orange is depicted 6 axial points and blue 9 central points. The number α is determined based on the plan requirements, according to the relationship:

$$\alpha = \sqrt[4]{2^k} \qquad (1)$$

where the symbol k denotes the number of factors. The meaning of α is evident from Figure 3.

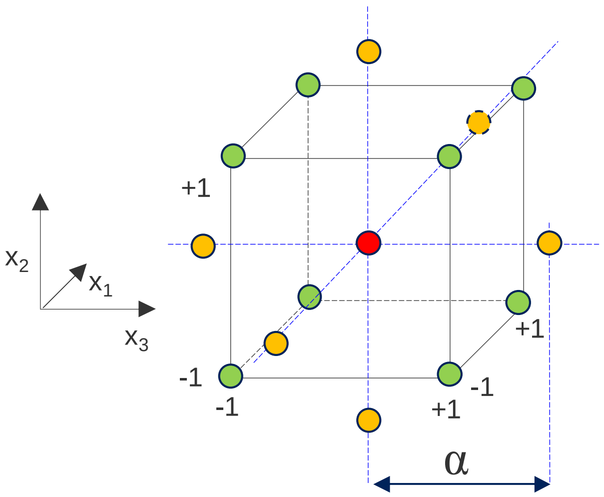


Figure 3 Meaning of the symbol α

The cube of the CCD design is always a two-level experiment design, usually with a resolution of IV or V. The star arises by varying individual factors such that we start from the middle point (so-called central point). The distance of the factor levels of this variation exceeds the distance of the cube levels in such a way that each factor is examined at 5 levels. A graphical representation of the experimental space for the CCD plan with three factors is shown in Figure 4.

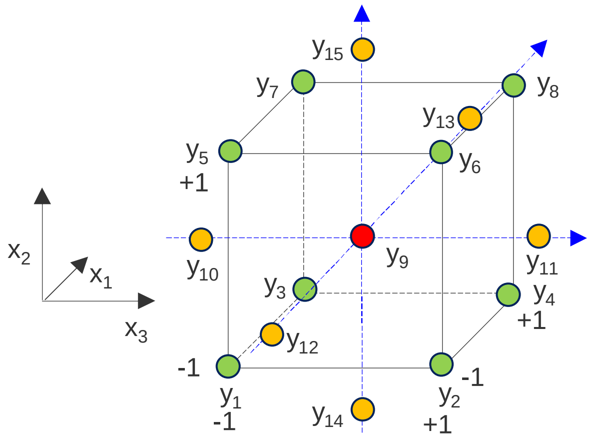


Figure 4 CCD design with three factors and two levels

As seen from Figure 4, in the first stage, a two-level design (cube) is created, to which additional trials (stars) are added in the second stage. This arrangement of the plan allows for the investigation of non-linear dependencies as well.

According to [8], we can create a CCD plan based on Figure 7-7, which is shown in Table 2.

Table 2 CCD design for 3 factors and 2 levels

Trial	x1	x2	x3	Response y
1	**- 1**	**-1**	**-1**	**y1**
2	**- 1**	**-1**	**1**	**y2**
3	**- 1**	**1**	**-1**	**y3**
4	**- 1**	**1**	**1**	**y4**
5	**1**	**-1**	**-1**	**y5**
6	**1**	**-1**	**1**	**y6**
7	**1**	**1**	**-1**	**y7**
8	**1**	**1**	**1**	**y8**
9	**0**	**0**	**0**	**y9**
10	**- -**	**0**	**0**	**y10**
11	**++**	**0**	**0**	**y11**
12	**0**	**- -**	**0**	**y12**
13	**0**	**++**	**0**	**y13**
14	**0**	**0**	**- -**	**y14**
15	**0**	**0**	**++**	**y15**

This design is initially created from a 2^3 design, so we carry out 8 trials. The ninth trial tests the central point (y9). The following trials test the variations, each for one factor, that exceed the cube's boundaries of the design. Therefore, when using a CCD design, 13 trials are sufficient to study 3 factors (see Table 3).

Various approaches are used to reduce the number of CCD design trials. The most well-known is the so-called Draper-Lin CCD design (also sometimes referred to as Face-Centered CCD), which differs from the classical CCD design in that none of its trials exceed the cube's dimensions. This allows for the reduction of trials to a theoretical minimum. An example of this type of experimental design is shown in Figure 5.

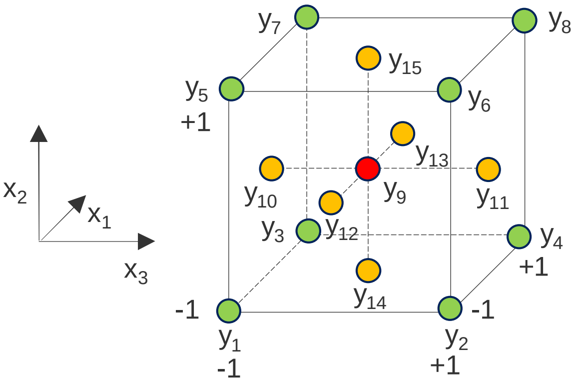


Figure 5 Draper-Lin CCD design

In Table 3, the number of necessary settings depending on the number of factors for CCD and Draper–Lin CCD is listed. As can be seen in Figure 5, the Draper-Lin CCD plan uses a cube, more densely populated with points (trials), in addition to the corner points, the center points of each surface have also been added.

Table 3 Number of necessary settings depending on the number of factors

Factor	Trial count	CCD	Draper-Lin plan
3	**10**	**13**	
4	**15**	**25**	**17**
5	**21**	**41**	**23**
6	**28**	**49**	**29**
7	**36**	**57**	**39**
8	**45**	**81**	**53**

It is typically necessary to use designs with three levels of factors when using second-order models that contain terms with higher powers (ax2). The disadvantage of designs that use 3 factors (3k) is the rapidly increasing number of necessary trials and at the same time it is necessary to determine a whole series of insignificant interactions. Therefore, in such a case, the CCD design is usually used. When using the CCD design, we use a 2k design and add the so-called central points and points called stars to it. By adding the necessary number of central points, the experimental design approximates an orthogonal design.

An example can be a simple experimental design with two factors that can take 2 levels of the type 2k, where k = 2.

Number of trials n = 22 = 4

To this design, a central point and star points are added:

- 1 central point
- star points

Then the total number of trials will be equal to 4+1+4 = 9.

Such a CCD experimental design, according to [9], is shown in Table 4.

Table 4 CCD plán experimentov

Trial	Factors	
	A	B
1	**-1**	**-1**
2	**+1**	**-1**
3	**-1**	**+1**
4	**+1**	**+1**
5	**0**	**0**
6	**- α**	**0**
7	**+ α**	**0**
8	**0**	**- α**
9	**0**	**+ α**

In Table 4, some rows contain the symbol α which, as Miller, I. (2010) states, has a value higher than 1 and its value is most often the square root of two, so it equals 1.41.

Krausova [7] provides the relationship and method of calculating the values of α (equation 1) and determining the number of zero points (their number approximates the design to the orthogonal design). Examples of such calculated values of α and the number of zero points are given in Table 5.

Table 5 Values α

Number of factors	α	Number of zero points
2	**1.414**	**8**
3	**1.682**	**9**
4	**2.000**	**12**
5	**2.378**	**16**

Based on the results of the CCD design, it is possible to create a second-order regression model, which will include interactions as well as the second powers of factors. An example of such type of models is the model:

$$y = b_0 + b_1x_1 + b_2x_2 + b_{11}x_1^2 + b_{22}x_2^2 + b_{12}x_1x_2 \quad (2)$$

Appropriate software for statistical analysis is used to solve more complex models of this type. An example of experiment results processed in the statistical software Minitab is shown in Figure 6.

Term	Effect	Coef	SE Coef
Constant	31,8928	0,0909	351,03
Čas	1,7815	0,8907	0,0909
Počet pracovníkov	3,7339	1,8670	0,0909
Počet AGV	3,8813	1,9407	0,0909
Čas*Počet pracovníkov	-0,0963	-0,0481	0,0909
Čas*Počet AGV	0,5740	0,2870	0,0909
Počet pracovníkov*Počet AGV	0,6943	0,3471	0,0909
Čas*Počet pracovníkov*Počet AGV	-0,0342	-0,0171	0,0909

Term	T-Value	P-Value	VIF
Constant	0,000		
Čas	9,80	0,000	1,00
Počet pracovníkov	20,55	0,000	1,00
Počet AGV	21,36	0,000	1,00
Čas*Počet pracovníkov	-0,53	0,613	1,00
Čas*Počet AGV	3,16	0,016	1,00
Počet pracovníkov*Počet AGV	3,82	0,007	1,00
Čas*Počet pracovníkov*Počet AGV	-0,19	0,856	1,00

Figure 6 Experiment results from the Minitab system

Using coefficients calculated with the least squares method in the Minitab system, it is possible to construct the desired regression model. The p-value determines the significance of the linear terms of the model and also their potential substitution in the model with quadratic terms.

The evaluation of how well the model explains the obtained variability is done using the adjusted coefficient of determination, RADJ. With the responses obtained, we can then graphically display the response surface in the form of a contour or isopleth diagram.

3 Conclusions

Central Composite Design (CCD) represents a comprehensive and flexible tool for planning simulation experiments. This approach has proven advantageous for research in a wide range of areas where it is necessary to solve complex problems with multiple factors. Thanks to its ability to effectively and reliably create second-order regression models, CCD allows researchers to better understand and interpret their data. Various types of CCD plans, including CCC (Central Composite Circumscribed), CCF (Central Composite Face centered) and CCI (Central Composite Inscribed), provide different options for tailoring the experimental planning process to the specific needs and constraints of individual research projects.

It is important to emphasize that CCD is not always the most suitable solution. There are situations when it might be better to use alternative methods, such as the Draper-Lin CCD plan. Regardless of which method is used, it is crucial to carefully and thoughtfully plan experiments to ensure accurate and reliable results.

Despite this article providing a detailed view of the theory and application of CCD, it is important to continue exploring and improving these methods. Success in research and development often depends on our ability to effectively and innovatively use available tools like CCD. In the future, with the ongoing development of technologies and computational capacities, new possibilities are expected to emerge for the refinement and expansion of CCD use in the field of simulation experiment design.

Acknowledgement
This work was supported by the Slovak Research and Development Agency under the contract no. APVV-21-0308.

References

[1] BIŇASOVÁ, V., BUBENÍK, P., RAKYTA, M., KASAJOVÁ, M., ŠTAFFENOVÁ, K.: Programmable Model of an Automated Warehouse, *Technológ*, Vol. 15, No. 2, pp. 110-113, 2023. https://doi.org/10.26552/tech.C.2023.2.20
[2] TREBUNA, P., MIZERAK, M., KLIMENT, M., SVANTNER, T.: Meaning and Functions of the Specialized Laboratory Testbed 4.0, *Acta Simulatio*, Vol. 8, No. 3, pp. 23-28, 2022. https://doi.org/10.22306/asim.v8i3.86
[3] KOPEC, J., PEKARČÍKOVÁ, M., KLIMENT, M.: 3D Printing Methods Used in Engineering, *Acta Tecnologia*, Vol. 9, No. 1, pp. 31-34, 2023. https://doi.org/10.22306/atec.v9i1.165
[4] SANCHEZ, S.M., SANCHEZ, P.J., WAN, H.: *Work Smarter, Not Harder: A Tutorial on Designing and Conducting Simulation Experiments*, In: RABE, M. et al. (ed.), Proceedings of the 2018 Winter Simulation Conference, pp. 237-251, 2018.
[5] KLEIJNEN, J.P.C.: *Experimental Design for Sensitivity Analysis, Optimization, and Validation of Simulation Models*, In: BANKS, J. (ed.), Handbook of Simulation, Principles, Methodology, Advances, Applications, and Practice, John Wiley & Sons, New York, pp. 173-223, 1998.
[6] LAWSON, J.: *An Introduction to Acceptance Sampling and SPC with R*, Chapman and Hall/CRC, 2021.
[7] KRAUSOVÁ, D.: Navrhovanie experimentov – DoE (Design of Experiments) 2, [Online], Available: https://slidetodoc.com/navrhovanie-experimentov-doe-design-of-experiment-2-as [13 Jan 2022], 2022. (Original in Slovak)
[8] SIEBERTZ, K., BEBBER, D., HOCHKIRCHEN, T.: *Statistische Versuchsplanung – Design of Experiments* (DoE), Springer Verlag, Berlin, 2010.
[9] MILLER, I.: *DOE - Návrh a analýza experimentu s pomocí MINITAB®*, Interquality, Praha, 2010. (Original in Czech)

Review process
Single-blind peer review process.

Acta Simulatio - International Scientific Journal about Simulation
Volume: 9 2023 Issue: 2 Pages: 27-31 ISSN 1339-9640

https://doi.org/10.22306/asim.v9i2.100

Received: 12 May 2023
Revised: 02 May 2023
Accepted: 14 June 2023

Optimization of the production process using simulation modelling

Matus Matiscsak
Technical University of Košice, Faculty of Mechanical Engineering, Department of Industrial and Digital Engineering, Park Komenského 9, 042 00 Košice, Slovak Republic, EU, matus.matiscsak@tuke.sk (corresponding author)
Peter Trebuna
Technical University of Košice, Faculty of Mechanical Engineering, Department of Industrial and Digital Engineering, Park Komenského 9, 042 00 Košice, Slovak Republic, EU, peter.trebuna@tuke.sk
Richard Duda
Technical University of Košice, Faculty of Mechanical Engineering, Department of Industrial and Digital Engineering, Park Komenského 9, 042 00 Košice, Slovak Republic, EU, richard.duda@tuke.sk

Keywords: optimization, production process, Tecnomatix Plant Simulation.

Abstract: The aim of this paper is to optimize the production process of graphics card assembly in an unnamed company. For the optimization of the production process, we will use the Tecnomatix Plant Simulation software from Siemens. The first and most important step to optimize the manufacturing process is to analyse the current process so that we can pinpoint where bottlenecks or downtime is occurring. For this reason, the first simulation is dedicated to the current production process. In the second simulation, we have successfully implemented all the proposed changes within the upgraded manufacturing process. These changes included replacing the human workforce with two robots in the tenth stage, which involves the assembly of large components. The implementation of the upgraded process allows 44 graphics cards to be assembled in one hour, an increase of 15 graphics cards compared to the current process. In an eight-hour shift, 353 graphics cards can be assembled, which is 118 graphics cards more than the current production process.

1 Introduction

With regard to maintaining their competitiveness, manufacturing companies are forced to constantly improve the quality of their processes with innovative tools. One such tool is simulation programs, which will be dealt with in this work. Simulations allow a wider range of companies to optimize their internal processes.

The article is divided into four interrelated parts. The aim of the first part is to introduce readers to the context of the issue and provide them with the necessary theoretical knowledge to understand the next part of the article. The second part of the article describes the used methodology, analysis of the current production process, simulation of the current production process and simulation of the innovative production process. In the third part of the article, we analysed the results in detail based on the statistical reports provided by the simulation software TX Plant Simulation. The last part summarizes the contribution of our research.

1.1 PLM

Product Lifecycle Management (PLM) is a concept aimed at managing all information about a product and related processes during its life cycle, from design and production to decommissioning. The main concept is quick access to the necessary and up-to-date information about the product, which is the basis for ensuring quality, reducing time and reducing costs. By PLM system, we do not mean one super product, but a set of software products (also from different suppliers) [1]. The system should exchange data with the project management system and, if necessary, with the customer's or company's information systems. The PLM system can be seen as the basis of Industry 4.0, in which there are several other systems that are mandatory for implementation in production. I will highlight the main systems [2]:

1. PDM system - product data management system.
2. CAD system - product design.
3. CAE system - engineering calculations.
4. CAPP system - development of technical processes.
5. CAM system - development of control programs for CNC machines.
6. MPM system - modelling and analysis of product production.

1.2 MPM system

Manufacturing Process Management (MPM) - production process management, digital production. As a rule, it is a set of technologies, methods and programs used in the production of products [3].

The MPM solution allows companies to create models of technological processes and then subject them to analysis. By combining knowledge management tools and optimizing assembly into a common open. Environments MPM systems reduce lead time, design capacity, and provide greater flexibility for product design changes [4-5].

Advantages of implementing MPM systems:

- Reduction of preparation time to produce new products.
- Reduction of commissioning and production time to achieve projected capacity.
- Optimization of production management.

2 Methodology

In this article, we analysed the manufacturing process of graphics card assembly and identified the key parameters that affect the current production. To evaluate the efficiency of this process, we used the simulation software TX Plant Simulation from Siemens [6]. Using simulation, we compared the current production process with the new, innovative graphics card assembly process.

In the current manufacturing process, we have identified a problematic bottleneck in the manual installation of large components that require special handling. This step is time consuming and can lead to errors and inefficiency [7]. To improve this process, we proposed an innovation that consists in replacing the manual installation of large components with two special robots. These robots will be operated by employees who have been engaged in manual assembly until now.

2.1 Analysis of the current production process

As part of this analysis, we focus on one specific process of assembling a graphics card within production. Throughout the production of graphics cards, there are several complex processes that require a high level of labour and demandingness on the part of the workers. The current production process is divided into thirteen steps, which we describe in detail:

1. Quality control by employees: The first step in the assembly process is quality control performed by employees. This inspection serves to ensure that all components and materials used in the assembly process meet the required standards and norms.
2. Applying the paste to the front side of the PCB: At the beginning of the assembly, the paste is applied to the front side of the PCB (Printed Circuit Board), which is the base plate on which the electronic components will be mounted.
3. Installation of components: Next is the installation of individual electronic components on the front side of the PCB. These components include integrated circuits, resistors, capacitors, and other components necessary for the proper functioning of the graphics card.
4. Soldering the components: After installing the components, a soldering process is performed where the electronic components are permanently joined to the PCB using heat and solder paste. This step ensures a reliable and permanent connection of the components to the board.
5. Second quality control by employees: After soldering is completed, a second quality control is performed, the purpose of which is to verify the correctness and quality of the connection of the components to the PCB. Employees check visually and by means of tests that all parts are correctly positioned and connected.
6. Applying paste to the back of the PCB: Paste is then applied to the back of the PCB, which will serve as a support for other components and ensure proper connection.
7. Component Installation: After applying the paste, other electronic components are installed on the back side of the PCB. These components may include smaller parts and fasteners.
8. Soldering the components: The components on the back side of the PCB are then soldered, which ensures their reliable connection to the board.
9. Third quality control by employees: After soldering, a third quality control is performed, where employees verify the correctness and reliability of the connection of the components on the back of the PCB.
10. Manual installation of large components: This phase involves manual installation of larger components such as connectors or larger parts that require special handling.
11. Installation of the cooler: The next step is the installation of the cooler, which ensures proper cooling of the graphics card and protection against overheating.
12. Testing: After the assembly is completed, thorough testing of the graphics card is carried out, where its functionality and correct functioning in various conditions and loads are verified.
13. Packaging and subsequent shipment: The last step is the packaging of the finished graphics card and its shipment to the destination where it will be distributed and sold to customers.

In the current production of graphics cards, a total of 15 workers works on one shift. These employees have different roles within the production process and their work is essential for the smooth running of production without downtime. Among the busiest and most important employees are inspectors and workers responsible for the manual installation of large components. Controllers have a key role in ensuring production quality. Their work consists in checking and verifying whether all parts and products meet the established standards and requirements. Their job is to ensure that each graphics card is manufactured with the highest possible quality and without errors. Employees responsible for manual installation of large components also have an important role. These workers perform the demanding work of precisely installing larger components that require special handling. Their task is to ensure the correct and reliable connection of these components to the graphics cardboard. Their work requires expertise, care and skill. Paste application, assembly and soldering of components is done using machines.

2.2 *Simulation of the current production process*

Using the TX Plant Simulation software, we simulated the current production process of graphics card assembly, which consists of 13 points, which are described in detail in subsection 2.1. Table 1 shows the times of individual production operations.

Table 1 Work of all machines in current production

Name of the operation	Process time [s]
Quality control 1	45
Paste application 1	20
Installing components 1	30
Soldering components 1	60
Quality control 2	45
Paste application 2	20
Installing components 2	30
Soldering components 2	60
Quality control 3	45
Installation of large components	200
Installing the heat sink	40
Testing	80
Packaging	20

Table 1 shows that the longest operation of the manufacturing process of graphics card assembly is the installation of large components. This operation takes 200 seconds.

In Figure 1 we can see the current production process in 3D.

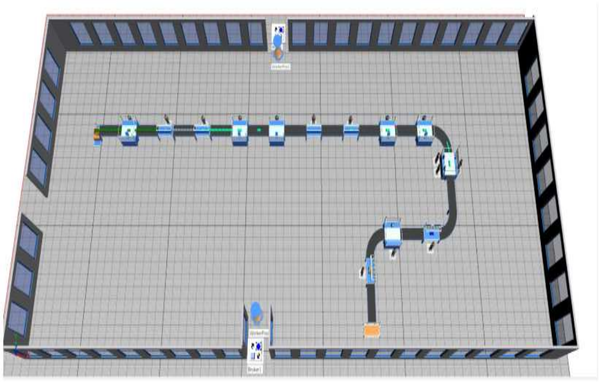


Figure 1 Simulation of current production in 3D

The simulation of the current production process is set up for one work shift that lasts 8 hours.

2.3 *Simulation of innovative production process*

In the framework of the fourth industrial revolution, the automation of processes is an important goal. In the case of this factory, it was decided to replace the human workforce with two robots for the improvement of the tenth phase, which involves the assembly of large components. This change has the potential to bring several benefits, such as increasing the speed and accuracy of assembly and reducing the risk of error. In Figure 2 we can see the innovative production process, simulated in the TX Plant Simulation software. The yellow rectangle marks the updated place in the manufacturing process of the graphics card assembly.

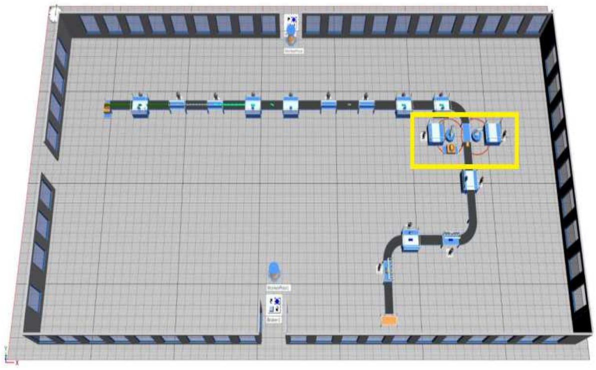


Figure 2 Simulation of innovative production in 3D

In Table 2, we can see the times of each production operation in the innovative production process.

Table 2 Work of all machines in innovative production

Name of the operation	Process time [s]
Quality control 1	45
Paste application 1	20
Installing components 1	30
Soldering components 1	60
Quality control 2	45
Paste application 2	20
Installing components 2	30
Soldering components 2	60
Quality control 3	45
Installation of large components	100
Installing the heat sink	40
Testing	80
Packaging	20

In Table 2, we can see that the process time for installing large components has been reduced to 100 seconds compared to the original 200 seconds in the current production process.

The simulation of the innovative production process is set up for one work shift that lasts 8 hours.

3 Results and discussion

We evaluate the efficiency results of the graphics card assembly production process using the statistical report offered by the Tecnomatix Plant Simulation software.

First, we evaluate the simulation results of the current production process. In both cases, the simulation time is set to 8 hours.

In Figure 3 we see the result of the current production process.

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Drain	PCB	30.0000	235	29	66.67%	33.33%	0.00%	0.28%	

Figure 3 Results of current production

Subsequently, in Figure 4 we see the result of the innovative production process of the graphics card assembly.

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Drain	PCB	30.0000	353	44	66.67%	33.33%	0.00%	0.19%	

Figure 4 Results of innovative production

Based on the above results, the innovative production process achieved a significant improvement in performance. The current production process allows for the assembly of 29 graphics cards in one hour and 235 graphics cards in an eight-hour shift. After the implementation of the innovative process, performance increased significantly. 44 graphics cards can be assembled in one hour, which is 15 more than in the current process. During an eight-hour shift, 353 graphics cards can be assembled, which is 118 more than at present.

These results indicate that the innovative production process with the use of automation with the help of robots brings a significant increase in efficiency and productivity.

4 Conclusions

When optimizing the production process, it is important to consider all the factors that affect our production process. We must analyse in detail the cause of the bottleneck, how we can remove it, whether removing it will not create a new bottleneck in production. For this reason, it is very important that we think about the smallest details so that we can avoid failure [8].

The implementation of the innovative process makes it possible to assemble 44 graphics cards in one hour, which represents an increase of 15 graphics cards compared to the present. During an eight-hour shift, 353 graphics cards can be assembled, which is 118 graphics cards more than in the current production process.

Such an innovative production process will bring several advantages. First, automating the installation of large components with robots will increase the efficiency and accuracy of this step. Robots will be able to perform tasks faster and with less error. Second, employees now involved in manual assembly will be freed up to attend to other important tasks that require human interaction and expertise.

Overall, the innovative manufacturing process using robots to install large components is expected to significantly improve the efficiency, quality and overall performance of graphics card manufacturing.

Acknowledgement
This article was created by the implementation of the grant projects: APVV-17-0258 Digital engineering elements application in innovation and optimization of production flows, APVV-19-0418 Intelligent solutions to enhance business innovation capability in the process of transforming them into smart businesses. VEGA 1/0438/20 Interaction of digital technologies to support software and hardware communication of the advanced production.

References

[1] KLIMENT, M.: Production efficiency evaluation and products' quality improvement using simulation, *International Journal of Simulation Modelling*, Vol. 19, No. 3, pp. 470-481, 2020. https://doi.org/10.2507/IJSIMM19-3-528
[2] TREBUŇA, P.: *Aplikácia vybraných metód modelovania a simulácie v priemyselnom inžinierstve*, 1st ed., Košice, TU, SjF, 2017. (Original in Slovak)
[3] TREBUNA, P., MIZERAK, M., KLIMENT, M., SVANTNER, T.: Meaning and functions of the specialized laboratory Testbed 4.0, *Acta Simulatio*, Vol. 8, No. 3, pp. 23-28, 2022. https://doi.org/10.22306/asim.v8i3.86
[4] GRZNÁR, P., MOZOL, Š., GABAJOVÁ, G., MOZOLOVÁ, L.: Application of virtual reality in the design of production systems and teaching, *Acta Tecnologia*, Vol. 7, No. 2, pp. 67-70, 2021. https://doi.org/10.22306/atec.v7i2.110
[5] STEFANIK, A., GRZNAR, P., MICIETA, B.: *Tools for Continual Process Improvement - Simulation and Benchmarking*, In: Annals of DAAAM for 2003 & Proceedings of the 14th International DAAAM Symposium: Intelligent manufacturing & automation: focus on reconstruction and development, Katalinic, B., ed., Daaam Int Vienna: Wien, 2003, pp 443-444, 2003.

[6] STRAKA, M., ŽATKOVIČ, E., SCHRÉTER, R.: Simulation as a means of activity streamlining of continuously and discrete production in specific enterprise, *Acta logistica*, Vol. 1, No. 3, pp 11-16, 2014. https://doi.org/10.22306/al.v1i3.22

[7] STRAKA, M., HURNA, S., BOZOGAN, M., SPIRKOVA, D.: Using continuous simulation for identifying bottlenecks in specific operation, *International Journal of Simulation Modelling*, Vol. 18, No. 3, pp 408-419, 2019. https://doi.org/10.2507/IJSIMM18(3)477

[8] SADEROVA, J., KAČMÁRY, P.: The simulation model as a tool for the design of number of storage locations in production buffer store, *Acta Montanistica Slovaca*, Vol. 18, No. 1, pp. 33-39, 2013.

Review process

Single-blind peer review process.

JOURNAL STATEMENT

Journal name:	**Acta Simulatio**
Abbreviated key title:	Acta Simul
Journal title initials:	AS
Journal doi:	10.22306/asim
ISSN:	1339-9640
Start year:	2015
The first publishing:	March 2015
Issue publishing:	Quarterly
Publishing form:	On-line electronic publishing
Availability of articles:	Open Access Journal
Journal license:	CC BY-NC
Publication ethics:	COPE, ELSEVIER Publishing Ethics
Plagiarism check:	Worldwide originality control system
Peer review process:	Single-blind review at least two reviewers
Language:	English
Journal e-mail:	**info@actasimulatio.eu**

The journal focuses mainly on the original and new, interesting, high-quality, theoretical, practical and application-oriented contributions to the field of science and research as well as to pedagogy and education in the area of simulation.

Acta Simulatio journal supports the San Francisco Declaration on Research Assessment (DORA). The primary directives include open access, reuse of outputs, diversity among authors and reviewers, peer review, description of provided services and related publishing charges.

Publisher:	**4S go, s.r.o.**
Address:	Semsa 24, 044 21 Semsa, Slovak Republic, EU
Phone:	+421 948 366 110
Publisher e-mail:	**info@4sgo.eu**

Responsibility for the content of a manuscript rests upon the authors and not upon the editors or the publisher.