Vol. 13 No. 3 / 2022
ISSN: 1847-9375

Business Systems Research

A Systems View accross Technology & Economics

Impressum

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Business Systems Research Journal (BSR) is an international scientific journal focused on improving the competitiveness of businesses and economic systems. BSR examines a wide variety of decisions, processes, and activities within the actual business setting and the systems approach framework. Theoretical and empirical advances in business systems research are evaluated regularly. Special attention is paid to educational, social, legal, and managerial aspects of business systems research. In this respect, the BSR journal fosters the exchange of ideas, experience, and knowledge between regions with different technological and cultural traditions, in particular in transition countries. The journal also publishes case studies describing innovative applications and critical reviews of theory.

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Language Editors

Managing Editors

Publisher

IRENET, Society for Advancing Innovation and Research in Economy

ISSN

Business systems research (Online) = ISSN 1847-9375

Editorial Office

e-mail: ***bsreditors@gmail.com***
Web: http://www.bsrjournal.org; http://hrcak.srce.hr/bsr; https://sciendo.com/journal/BSRJ

Business Systems Research

A Systems View across Technology & Economics

Special issue in Novel Solutions and Novel Approaches in Operational Research

Special issue Research Articles

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Editorial for the Special Issue: "Novel Solutions and Novel Approaches in Operational Research"

*co-published with the **Slovenian Society INFORMATIKA – Section for Operational Research (SSI-SOR)***

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Abstract

This special issue of Business Systems Research (SI of the BSR) is being co-published by the Slovenian Society INFORMATIKA – Section for Operational Research (SSI -SOR). It focuses on recent advances in Operations Research and Management Science (OR / MS), with a particular emphasis on linking OR / MS with other areas of quantitative and qualitative methods in the context of a multidisciplinary framework. The ten papers that were chosen for this Special Issue of the BSR present advancements and new techniques (methodology) in the field of Operations Research (OR), as well as their application in a variety of fields, including risk management, mathematical programming, game theory, gravity, spatial analysis, logistics, circular economy, continuous improvement, sustainability, e-commerce, forecasting, Gaussian processes, linear regression, multi-layer perceptron, and machine learning.

Keywords: interdisciplinary research, operations research, risk management, mathematical programming, game theory, gravity, spatial analysis, logistics, circular economy, continuous improvement, sustainability, e-commerce, forecasting, Gaussian processes, linear regression, multi-layer perceptron, machine learning.

Citation: Drobne, S., Zadnik Stirn, L., Žmuk, B. (2022). "Editorial for the special issue: "Novel solutions and novel approaches in Operational Research", Vol.13, No. 3, 1-7.
DOI: https://doi.org/10.2478/bsrj-2022-0020

Editorial process

Operations research (OR), often known as management science (MS), is a scientific approach to decision-making that aims to figure out how to build or operate a system most effectively, typically in situations that require the allocation of resources (Winston, 2003, Boucherie et al., 2021). OR is a field that focuses on decision support, and as such, its main purpose is to develop tools and methods that can help decision-makers solve problems and form judgments. Data analysis, simulation, modelling approaches and software tools are all part of the decision-support themes of OR (Mladenić et al., 2003; Rubio and Jiménez-Parra, 2014).

The use of OR in real-world problems can be found in various contexts, including industrial engineering, management, business, manufacturing, government, health care, transportation, geographic information systems, scheduling, marketing, inventory, and other fields (Cochran et al., 2011). The applications of OR enable complicated issues to be articulated clearly and flexibly in the context of a real-world environment, incorporating quantitative (e.g., financial ratios) and qualitative factors into the review process (Figueira et al., 2005).

The use of OR has had a significant impact on increasing organisational efficiency, leading to an increase in both production and social welfare. Both the International Federation of Operational Research Societies (IFORS) and the Association of European Operational Research Societies (EURO) are umbrella organisations for OR societies worldwide. Together these two organisations represent more than 50 national societies, including the Slovenian Society INFORMATIKA - Section for Operational Research (SSI-SOR). The main focus of SSI-SOR is the planning and coordination of international symposia. The 16th International Symposium on Operations Research, often called SOR'21, was held in Bled, Slovenia, from September 22nd to September 24th, 2021. SOR'21 was a scientific event in the field of Operations Research. It was another in the usual series of international OR conferences held every two years and hosted by SSI-SOR in Slovenia. The main goal of SOR'21 was to promote the knowledge, interest and education of OR in Slovenia, Europe, and worldwide. In addition, it was agreed at SSI-SOR to collaborate with other disciplines to find a middle ground between the breadth of theoretical knowledge in OR and the understanding of theory, techniques, and problems in other disciplines, both within and outside OR. SOR'21 was attended by 125 individuals from different research institutes, universities, government agencies, private and public companies, and 19 countries worldwide, both in person and online. 118 articles were presented, with 240 authors and co-authors contributing to their production. After a blind peer review process conducted by two independent reviewers from the SOR'21 Programme Committee and reviewers nominated by SSI-SOR, the articles were finally approved for publication.

As a result of the decision taken at SOR'21 to publish the special issue (SI) of the BSR, the call for papers for this SI was already published at this conference in Bled in September 2021. The invitation was addressed to all those who had registered for SOR'21 and to other researchers from the field of OR. The submitted papers should present current breakthroughs and novel approaches in OR methodologies and models and their practical applications in economics, business, finance, organisation, management, social sciences, environment, and transport, among others.

Fifteen contributions were received. Some are extended versions of short articles presented at SOR'21 and published in the Proceedings of SOR'21 (Drobne et al., 2021). The submissions to the BSR's SI were first blindly evaluated by the guest editors and then by two experts. This special issue of the BSR contains ten different contributions from different authors. They have consistently focused on model formation and modelling, contributing to their practical orientation. Moreover, they are more than just a presentation of algorithms; they amplify them to the latest advances in optimisation, simulation, and decision analysis.

The selected contributions deal with developments and techniques in OR and their practical application in business, economics, spatial science and location, environment, and social sciences. The topics covered in the selected papers represent interdisciplinary research. From a methodological point of view, they include risk management, mathematical programming, game theory, gravity, spatial analysis, logistics, circular economy, continuous improvement, sustainability, e-commerce, forecasting, Gaussian

processes, linear regression, multi-layer perception, and machine learning. The case studies are from four countries: Portugal, Croatia, Slovenia, and Spain.

The achievements of the BSR's SI are due to the collective work that has been done. The guest editors would like to thank the authors for their thoughtful and well-written contributions and the reviewers for their careful consideration of the contributions and their insightful and helpful comments. Last but not least, the guest editors would like to express their sincere gratitude and appreciation to the Editor-in-Chief, Professor Mirjana Pejić Bach, PhD, for asking us to serve as guest editors of the BSR's SI.

Contributions

The purpose of the papers that are published in BSR, following the objectives and editorial policy of BSR, is to present original theoretical and empirical advances in the field of business and economic systems using a wide range of methodological approaches, mainly from the fields of operations research/analytics, management science, and statistics. This is done to fulfil BSR's mission and to comply with BSR's editorial policy. These objectives have been achieved with ten papers BSR has accepted for this SI.

In the first paper, entitled "The Risk and Return of Traditional and Alternative Investments Under the Impact of COVID-19", *Aljinović, Marasović, and Miličević* provide risk and returns analyses and compare various traditional and alternative investments with special reference to the crisis COVID-19. The assets included in the analysis are stocks, bonds, commodities, real estate, foreign exchange, cryptocurrencies, renewable energy sources, gold, and oil. The risk measures of standard deviation, Value at Risk (VaR), Conditional Value at Risk (CVaR), and Sharpe ratio are used to compare the representatives of each asset class. This research shows that stocks won against all other assets, including gold and cryptocurrencies, during the COVID-19 crisis. The good features of a new alternative investment – renewable energy sources – with excellent earning potential are shown.

In the second paper, entitled "Possible Impact of Risk Management Strategies with Farm Model on a Mixed Farm Type", *Brečko and Žgajnar* present a mathematical model whose main objective is to evaluate the effectiveness of production and various possible agricultural holdings strategies by reducing risks. The applied model is based on linear programming and was extended with QRP for risk analysis. The approach was tested on a medium-sized mixed agricultural holding, which often faces challenges in light of the structural changes taking place in Slovenia. The results suggest that such a farm could improve its financial results through a more efficient risk management strategy. The authors conclude that diversification has a positive potential for a mixed farm that could achieve better financial results. With flexibility in management, the farmer could also achieve higher efficiency in risk management and better farm results.

In the third paper, "Conflict and Corporate Social Responsibility in Duopoly", *Vrankić* analyses the duopoly model in which firms decide on optimal social investment and production in two phases. The basic research question is how the significance of the conflict affects social investments, market shares, production quantities, profits, and social welfare. Game theory, optimisation, and comparative statics are used in the analysis. The conditions for the existence of equilibrium and its characteristics are described. The conflict harms the inefficient firm's profits while it has a positive effect on social welfare. The impact of conflicts on the profit of an efficient firm depends on the marginal cost difference. The author concludes that it is cheaper for firms not to invest in socially responsible activities if there is no significant cost difference, which affects social welfare. When the difference in marginal costs is significant, corporate social responsibility increases an efficient firm's profit and positively impacts social welfare.

In the fourth paper, "Migration Flows through the Lens of Human Resource Ageing", the

authors *Drobne and Bogataj* are motivated by the fact that the ageing and shrinking of the European population influences the shrinking of central places and the surrounding areas of cities in a spatial structure. The authors use data on internal migration between Slovenian municipalities in 2018 and 2019 to develop a cohort-based spatial interaction model to estimate future inter-municipal migration. In a spatial interaction model, we analysed differences in the attractiveness and stickiness of municipalities for different cohorts, focusing on those over 65 who may wish to prolong their working status. The authors also tried to answer the question of how to mitigate shrinkage processes in spatial units by investigating the potential to contribute to the social value of communities. The study results show that the over-65s do not have the same preferences regarding attractiveness and stickiness factors as younger migrants.

In the fifth paper, entitled "Boosting Regional Socioeconomic Development through Logistics Activities: A Conceptual Model", authors *Vieira, Ângela, Jorge Esparteiro and Wellington* are motivated by the trend that regional development allows countries to level out regional disparities by providing economic and social benefits to communities. Their research highlights the importance of logistics activities for regional social development, and a framework for assessing these linkages is proposed. Their paper aims to explore how regional socio-economic development can be promoted through logistics. The contributions of logistics to socio-economic development are analysed based on the previous research, and the case of the Alto Minho (AM) region in Portugal was used to illustrate the connection between logistics and regional development. Results showed that logistics had created jobs, increased company turnover and exports, and increased GDP growth in several regions. For the AM region, the results suggest that many companies are active in this sector and help to support municipalities in reducing regional imbalances. A framework for assessing regional logistics performance is proposed along with several logistics performance indicators. This approach is essential for future developments that incorporate logistics into socio-economic development.

In the sixth paper, entitled "Circular Economy and Consumer's Engagement: An Exploratory Study on Higher Education", authors *Alves, Silva, and Rodrigues* emphasise that the circular economy (CE) is considered one of the most important principles of modern society. Concerns about rising resource consumption have led governments and businesses to consider circular models as a hedge against resource scarcity and a driver of innovation and growth. This paper aims to bring together the CE and the consumer's perspectives to perceive the impact of their choices on CE initiatives. The authors surveyed consumer engagement with circular economy concepts. The results show consumer awareness and readiness to transition from the linear to the circular production model, which offers added value to consumers in reducing environmental impacts. The authors conclude that consumer behaviour can lead to creating a best practice guide for companies, designers, and consumers to consider when implementing circular economy initiatives.

The seventh paper, entitled "Internal Logistics Process Improvement using PDCA: A Case Study in the Automotive Sector", is based on the plan-do-check-act (PDCA) cycle methodology for implementing a continuous improvement project. Authors *Amaral, Ferreira and Ramos* aim to quantify the gains from waste reduction resulting from the application of the PDCA cycle as a tool in the implementation and optimisation of a milk run in an assembly line of a company in the automotive sector by determining the optimal cycle time of supply and the standardisation of the logistical supply process and material flow. The study was conducted through on-site observation and data collection and included two main phases: planning and implementation. According to the phases of the PDCA cycle, the process was analysed, and tools such as the SIPOC matrix, process stratification, 5S, and visual management were introduced. It was possible to reduce

waste by establishing concise flows and defining a supply pattern, which reduced movements. Transport waste was reduced by defining the position of more than half of the materials in the logistic trailers. The Excel simulator developed provided the optimal cycle time for the logistic train. The authors conclude that the assembly line supplied by milk-run was fundamental in demonstrating several improvements in the process of internal supply, such as better integration of stock management systems, greater application of quality or the introduction of better communication systems between the different areas and staff.

In the eighth paper, entitled "Dashboard for the Management and Acceptance of Customer Orders", authors *Nascimento, Frazão, Teixeira, and Ribeiro* focus on the activities related to customer orders management within an auto components plant in the Automotive Industry. The main challenge was highlighted: customers do not always adhere to the flexibility rules agreed with the company. Therefore, the planners must decide whether deviations in the order quantity can be accepted in the forecast period or whether an adjustment is necessary. The aim was not only to streamline the decision-making process in the planning team but also to provide important tools for carrying out their daily tasks – a visual and interactive dashboard to assess whether deviations in customer orders are within limits agreed with the company. Following lean information management and business intelligence principles, a thorough process analysis was conducted, centralised and standardised reports were created to serve as databases, and the dashboard was developed. The proposed tool reduced time from 3.5 hours per week, spent mainly on collecting data, calculating variations, and selecting and adjusting flexibility limits, to 0.2 hours a day per planner. In addition to streamlining the daily activities of planners, the main contributions are the promotion of digital transformation, data-driven decision-making, and an automated record of customer order variations that can be easily adapted to suppliers.

In the ninth paper, entitled "Using EPP Boxes in a Dark Store: A New Approach to Simplify Food Retail E-Commerce Deliveries", authors *Pintado, Coelho de Oliveira and Esparteiro Garcia* emphasise that e-commerce has emerged as a good response to the COVID-19 pandemic. However, the cost of providing a service that includes a driver and a vehicle is very high in a regular vehicle that can transport goods that require positive cold (0°C to 5°C). This paper investigates how a large Portuguese retail company can reduce its dependence on refrigerated vehicles by simplifying operations and reducing the cost of positively and negatively refrigerated food. This research was conducted in a Portuguese food retailer company, specifically in a Dark Store dedicated to the online channel. The study was developed based on the AS-IS/TO-BE process analysis method, which starts with analysing the current situation and produces the so-called AS-IS model. The results show that reducing costs associated with transporting positive refrigerated goods was possible. The result is that the cost of transporting orders could be reduced by 30%. The cost of transporting positive and negative refrigerated food was reduced, and the need for refrigerated vehicles was reduced by substituting room temperature transport vehicles.

In the tenth paper, entitled "A Machine Learning Approach to Forecast International Trade: The Case of Croatia", authors *Jošić and Žmuk* present a machine learning approach to forecasting Croatia's international bilateral trade. This paper aims to evaluate the performance of machine learning algorithms in forecasting international bilateral trade flows related to imports and exports in the case of Croatia. The dataset on Croatia's bilateral trade with over 180 countries worldwide from 2001 to 2019 was compiled using the main variables from the gravity trade model. Machine learning algorithms (Gaussian processes, linear regression and multi-layer perceptrons) were used to predict the values of Croatian bilateral exports and imports for one year (the year

2020). Each forecasting algorithm was evaluated by calculating the mean absolute percentage errors (MAPE). The authors found that the machine learning algorithms have the very good predictive ability in forecasting Croatia's bilateral trade, with the multi-layer perceptron of the neural network having the best performance among the other machine learning algorithms.

It can be concluded that the high quality and timely topics of the SI of BSR Papers are of interest to both the scientific and professional audiences, as there is a possibility that they will influence both theory and applications.

Ljubljana, Zagreb, December 2022

Guest Editors of SI BSR

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The Risk and Return of Traditional and Alternative Investments Under the Impact of COVID-19

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Abstract

Background: In making investment decisions, asset risk and return are two crucial criteria on which investors base their decision. **Objectives:** This paper provides risk and return analysis and compares different traditional and alternative investments with special emphasis on the COVID-19 crisis. Assets included in the analysis are stocks, bonds, commodities, real estate, foreign exchange, cryptocurrencies, renewable energy sources, gold, and oil. **Methods/Approach:** The risk measures of standard deviation, Value at Risk (VaR), Conditional Value at Risk (CVaR), and Sharpe ratio are used to compare the representatives of each asset class. **Results:** The crisis had the highest impact on the risk of crude oil, renewable energy sources, real estate, and stocks, a slightly lower impact on the risk of commodities and gold, and a very low impact on the risk of bonds, foreign exchange, and cryptocurrencies. The order of assets regarding earning potential during the crisis, compared to the period before the crisis, changed significantly for commodities in a positive way and for gold and bonds in a negative way. **Conclusions:** This research shows that stocks won against all other assets, including gold and cryptocurrencies, during the COVID-19 crisis. The good features of a new alternative investment – renewable energy sources – with excellent earning potential are shown.

Keywords: risk; return; traditional investments; alternative investments; crisis

JEL classification: C10, G15, D81
Paper type: Research article

Received: 31 Jan 2022
Accepted: 16 Oct 2022

Citation: Aljinović, Z., Marasović, B., Kalinić Milićević, T. (2022), "The Risk and Return of Traditional and Alternative Investments Under the Impact of COVID-19", Business Systems Research, Vol. 13 No. 3, pp. 8-22.
DOI: https://doi.org/10.2478/bsrj-2022-0021

Introduction

Investors are always looking for higher earnings, more fruitful portfolio diversification, portfolio hedging, and, especially in crises, safe havens. In fulfilling these goals, various forms of alternative assets are considered. In addition, the long period of historically low interest rates led to an intensification of the search for more fruitful investments. In this sense, cryptocurrencies represent one of the most intriguing investment classes in recent times. Up to now, research shows that of the possible roles for cryptocurrencies, that of being an investment instrument is predominant, Baur et al. (2018), Bouri et al. (2017). Li et al. (2021), Ma et al. (2020), and Petukhina et al. (2021) demonstrate the benefits of cryptocurrency inclusion in portfolios.

Research regarding influences on cryptocurrency prices shows that attractiveness or popularity is the variable with the highest influence, Goczek and Skliarov (2019). This finding can be employed to explain the early spring 2021 sharp rise of primarily the Bitcoin price but also of other cryptocurrencies. Baur and Dimpfl (2018) found that in the case of cryptocurrencies, an asymmetric effect appears - positive shocks tend to increase volatility more than negative shocks, which is the opposite of what usually happens in stock markets. In explaining that appearance, they use the FOMO – Fear of Missing Out concept: uninformed investors without sufficient knowledge and financial literacy buy for fear of missing earnings at a time of rising cryptocurrency value. In addition, the existence of "pump and dump schemes" contributes to such an effect. Researching the impact of peoples' intention to hold Bitcoin based on their perception of its value and risk, Huang (2019) finds that most individuals do not understand either the values or the risks of Bitcoin.

As shown by the CRIX (Cryptocurrency Index) value and Bitcoin prices, market capitalization, and trading volumes from the CoinMarketCap, a more noticeable movement in their values started in 2017. Next, 2018 is the year of intensification of trading, and continuous value fluctuations and high volatility characterize all the time that follows. The monotonous period regarding price movements and trading until 2017 is excluded from further calculations. Therefore, the beginning date for further investigation is January 1, 2017. The closing date is November 11, 2021, the date of data collection. In that period, the COVID-19 pandemic happened - the first strong and deep crisis in the "life of cryptocurrencies". It allows for testing different features of cryptocurrencies in crisis and the possibility of retesting and redefining the role of traditional and alternative assets in a period of extreme uncertainty and volatility in world financial markets. Unfortunately, no one can say that challenging times are not ahead, and it is important to know how certain assets behave in a crisis, whether they recover, and how quickly. January 1, 2020, was taken as the starting date of the pandemic crisis in our research since the first case of Covid-19 in the US was recorded on January 21, 2020.

Regarding the consulted literature and data availability, besides cryptocurrencies, calculations and analyses are carried out for stocks, bonds, commodities, real estate, foreign exchange, gold, and oil, all assets that are rather common for research. Since there is recognition of renewable energy as the fastest-growing source of energy, as well as an industry with constant value growth (Lisin et al. 2021), it was decided to include also this alternative investment in the analysis.

However, in the world of investments, the focus should never be only on the rate of return. Along with this variable, the volatility of prices or risk is highly important. This paper aims to investigate the accompanying volatility of prices of observed assets and asset groups and to put it concerning returns, thus gaining earning potentials of observed investments, especially during the Covid-19 crisis. Together with the standard deviation and Sharpe ratio, the Value at Risk (VaR) and Conditional Value at Risk

(CVaR) are employed, which represent the common measures for the purpose, Pradhan et al. (2021), Takada et al. (2019).

Many questions intrigue us: How do certain types of assets behave in a crisis; should one remain faithful to traditional investments; is the popularity of an asset a good sign for investment; is it profitable to accept a higher risk of an asset in a crisis? Finally, a research hypothesis can be defined: The Covid-19 crisis has affected the prices and risk values, measured by different measures, of all observed assets and asset classes, but not in the same manner. Some assets and/or asset classes are more resistant and, despite the expected higher volatility, show quite satisfactory, if not better, earning potential in the crisis.

To investigate the research hypothesis, calculations were performed using the historical data of assets' closing prices taken in the observed, almost 5-year-long period, with the majority falling into the time of crisis. Using the rolling window of daily returns for 126 days, with a shift of 21 days, standard deviations, VaR, CVaR, and Sharpe ratio are calculated. VaR and CVaR are calculated for 90% and 95% significant levels. The total number of calculations is 52 per measure. In addition to insight into the movement of the absolute values of each of the measures, relative positions – ranks of all assets regarding risk measures and Sharpe ratio – are calculated and analyzed for the total observed period and the pre-crisis and crisis sub-periods.

The remaining paper is structured as follows. The Literature Review follows the Introduction. In the section Data and Methodology, the presentation of the sample of assets and asset groups (asset portfolios) is followed by descriptive statistics for asset returns and the correlation matrix. A short presentation of the risk measures closes this section. In the section Results and Discussion, the exposition of results and appropriate analysis and discussion are given. The study is closed with concluding remarks.

Literature Review

The Covid impact on cryptocurrencies, stocks and other assets has garnered the attention of researchers lately. The research of Aljinović et al. (2021) has confirmed the risky character of cryptocurrencies. During the COVID-19 crisis, along with the high and growing levels of risk, a higher earning potential has been recorded.

Bilka et al. (2021) investigate and conclude that cryptocurrencies improved portfolios' risk-return performance during the COVID-19 pandemic. Although, as expected, cryptocurrencies reported higher volatility values, their role as effective diversifiers remains in the pandemic crisis period. From the mean returns and standard deviations analysis, cryptocurrencies outperform traditional assets from January 1, 2020, to March 15, 2021.

Caferra et al. (2021) examine cryptocurrencies and stock markets during the COVID-19 pandemic using the wavelet coherence approach and the Markov switching autoregressive model. The authors show that financial contagion at the beginning of the COVID-19 crisis strongly affected cryptocurrency and stock markets since their prices fell steeply. While cryptocurrencies quickly recovered, stock markets did not. In addition, there is a finding about the correlation between these two markets over time, though at low frequencies. Aysan et al.'s (2021) study of cryptocurrency volatility confirmed their resilience concerning the pandemic.

Considering the data on the two cryptocurrencies, stock indices, and industry groups (30 industry portfolios), Maasoumi et al. (2021) examine possible similarities and connections before and after the COVID-19 pandemic outbreak. During the pre-COVID period, the highest similarity was found between NASDAQ and Bitcoin return distributions. A strong similarity was also found between Bitcoin and the coal, steel, and mining industries. With the beginning of the COVID-19 crisis, the distances

between all observed assets have decreased by 75% or more. The highest similarity was observed between Bitcoin and six different industry groups during the crisis period.

Yousaf et al. (2021) study explored the return and volatility spillovers between the cryptocurrency and US stock markets, using the VAR– BEKK–AGARCH model on hourly data in the pre-and COVID-19 periods. While insignificant spillovers were noticed in the pre-COVID period, in the COVID period, the return spillover from S&P 500 to the cryptocurrency market (represented by Litecoin, Bitcoin, and Ethereum) was recorded.

Farid et al.'s (2021) research focused on intraday volatility transmission between different assets and asset groups/markets in the pre-and COVID-19 period. The observed assets were gold, silver, oil, natural gas, and stocks. The research showed a significant pandemic impact on the volatility transmission between the observed assets, with the spillover peaks during the spread of the virus.

Yousaf (2021) examines the direction and significance of risk transmission from COVID-19 to markets of different metals and energy markets by introducing a "global fear index" and applying the multivariate BEKK-GARCH model. There is significant negative risk transmission for gold, palladium, and Brent oil markets, which suggests these markets' safe-haven properties. In contrast, transmission is positive in the WTI oil market case, and in the case of the industrial metal market, the transmission is insignificant.

All the studies have shown the big influence of the COVID-19 pandemic on different assets and asset classes, noticing differences in terms of periods, directions, and intensities.

Data and Methodology

In this paper, different types of assets are included in the analysis: stocks, bonds, commodities, real estate, foreign exchange, cryptocurrencies, renewable energy sources, gold, and oil. Table 1 shows the representatives of each asset class.

Table 1
Selected Assets

Asset Class	Representative
Stocks	S&P500
Bonds	Vanguard Total Bond Market Index ETF (BND)
Commodities	The Bloomberg Commodity Index (BCOM)
Real Estate	Dow Jones Real Estate Index (DJUSRE)
Foreign Exchange	The US Dollar Index (USDX)
Cryptocurrencies	Bitcoin (BTC)
Renewable Energy Sources	WilderHill Clean Energy Index (ECO)
Gold	Gold Continuous Contract futures (GC00)
Oil	West Texas Intermediate (WTI) crude oil

Source: The author's work.

The well-known and widely used S&P 500 index covers stocks of 500 leading US companies, representing about 80% of the market capitalization (S&P Global, 2022). The Vanguard Total Bond Market Index ETF (BND) is a market value-weighted index, which includes a wide spectrum of US dollar-denominated, investment grade, taxable, fixed-income securities with at least one-year maturities (ETF.com, 2022).

The Bloomberg Commodity Index (BCOM) represents a diversified and liquid benchmark for commodities investments. The index contains 23 exchange-traded contracts on physical commodities such as natural gas, oil, soybeans, corn, gold, silver,

aluminium, etc. (Bloomberg, 2020), in a way that no single commodity or commodity sector dominates the index (Bloomberg, 2016).

The Dow Jones Real Estate Index (DJUSRE) tracks the performance of real estate investment trusts (REIT), companies, and agencies involved in the real estate sector, either as owners, managers or developers (S&P Global, 2022b). The index covers parts of the US market with large, medium, and small capitalization (Holovatiuk, 2020).

The US Dollar Index (USDX) measures the US dollar value relative to the value of currencies of the US most significant trading partners. Currently, the index is calculated by factoring in the exchange rates of the Euro at 57.6%, the Japanese yen at 13.6%, the British pound (11.9%), the Canadian dollar (9.1%), Swedish krona (4.2%), and Swiss franc in 3.6% (Chen, 2022).

The WilderHill Clean Energy Index (ECO) covers the clean energy sector. Comprises companies involved in renewable energy supplies, energy storage and conversion, power delivery and conservation, greener utilities, and cleaner fuels (WilderShares, 2022). Together with Brent and Dubai Crude, West Texas Intermediate (WTI) crude oil is one of the three main benchmarks in oil pricing. It is considered one of the best oils in the world and is regularly included as the underlying commodity of the NYMEX (New York Mercantile Exchange) oil futures (Chen, 2020).

As a cryptocurrency representative, the most famous cryptocurrency – Bitcoin, is used. As emphasized in Aljinović et al. (2021), Bitcoin performs almost the same as the Cryptocurrency Index – CRIX, regarding all measures and variables, showing the prevailing professionals' opinion and use of Bitcoin as a benchmark of the world of cryptocurrencies is correct. Due to this feature of Bitcoin, research on Bitcoin's issues can be generalized to a large extent.

For each asset, daily close prices were collected from marketwatch.com on November 11, 2021. The observed period is from January 1, 2017, to November 11, 2021. Working days in which the price of one or more assets is unknown are excluded from the final dataset. The characteristics of the final dataset are summarized with descriptive statistics, which include the calculation of the minimum value (Min), first quartile (q1), median (Me), third quartile (q3), maximum value (Max), the expected value (μ), standard deviation (σ), variance (σ^2), skewness (α_3), and kurtosis (α_4) for each asset class. An overview of the descriptive statistics for returns of assets, along with the Jarque – Berra (JB) test for normality, is given in Table 2.

Table 2
Descriptive Statistics for Assets Returns

	S&P500	USDX	BND	BCOM	DJUSRE
Min	-9.99%	-1.70%	-5.59%	-5.58%	-10.97%
q1	-0.29%	-0.24%	-0.13%	-0.41%	-0.46%
Me	0.09%	0.00%	0.01%	0.07%	0.08%
q3	0.57%	0.21%	0.14%	0.48%	0.60%
Max	8.97%	1.68%	5.18%	3.37%	8.07%
μ	0.06%	-0.01%	0.00%	0.02%	0.03%
σ	1.13%	0.37%	0.34%	0.82%	1.30%
σ^2	0.0001	0.0000	0.0000	0.0001	0.0002
α_4	17.60	4.19	116.89	7.31	19.89
α_3	-0.69	0.10	-1.62	-0.78	-1.18
JB	10877.9***	73.71***	656589.58***	1063.21***	14706.93***

Note: *** indicate significance at the 0.01 level
Source: The author's calculations in MATLAB

Table 2
Descriptive Statistics for Assets Returns (continued)

	GC00	ECO	BTC	WTI
Min	-6.75%	-14.13%	-43.37%	-132.42%
q1	-0.37%	-0.85%	-1.80%	-1.03%
Me	0.06%	0.20%	0.34%	0.23%
q3	0.49%	1.18%	2.71%	1.27%
Max	5.78%	13.40%	28.71%	72.25%
μ	0.04%	0.13%	0.33%	0.04%
σ	0.92%	2.22%	5.15%	5.37%
σ^2	0.0001	0.0005	0.0027	0.0029
α_4	10.30	9.44	10.33	336.89
α_3	-0.40	-0.49	-0.67	-10.33
JB	2727.28***	2147.10***	2809.05***	5660722.63***

Note: *** indicate significance at the 0.01 level
Source: The author's calculations in MATLAB

Bitcoin has the largest expected return. The asset class with the second largest expected return, 2.5 times lower than the BTC expected return and greater than 0.1%, is renewable energy sources. Expected returns of all other assets are between 0% and 0.1%, while the USDX has a negative expected return. The standard deviation is the largest in the case of the oil asset class. This is followed by the standard deviation of BTC, which is only 0.22 percentage points lower, and the standard deviation of ECO, which is 2.4 times lower than the standard deviation of oil. From Table 2, at 1%, 5%, and 10% significance levels, it can be concluded that returns are not normally distributed for all assets. All assets are negatively skewed except the USDX, meaning the left tail is longer and fatter. WTI has the most negative skewness. At the same time, WTI has the largest kurtosis, equal to 336.89, which indicates leptokurtic distribution, meaning that the tails are heavier than those of a normal distribution, indicating a higher degree of risk and a higher probability of extreme values. The kurtosis of all other assets is significantly lower than WTI kurtosis but still greater than 3, also indicating leptokurtic distributions.

In addition, an analysis of the correlation between asset classes is made. Table 3 shows the correlation matrix computed based on Pearson's coefficient that measures the linear dependence of assets.

Table 3
Correlation Coefficients

	S&P500	USDX	BND	BCOM	DJUSRE	GC00	ECO	BTC	CrudeOil WTI
S&P500	1.0000	-0.0890	-0.0076	0.3643	0.7396	0.0954	0.6895	0.1807	0.1917
USDX	-0.0890	1.0000	-0.2077	-0.2377	-0.1442	-0.3858	-0.1108	-0.0543	-0.0244
BND	-0.0076	-0.2077	1.0000	-0.0376	0.0804	0.2019	0.0018	0.1035	-0.0162
BCOM	0.3643	-0.2377	-0.0376	1.0000	0.2816	0.3482	0.3660	0.0870	0.4553
DJUSRE	0.7396	-0.1442	0.0804	0.2816	1.0000	0.1742	0.5251	0.1274	0.0903
GC00	0.0954	-0.3858	0.2019	0.3482	0.1742	1.0000	0.1378	0.0838	0.0904
ECO	0.6895	-0.1108	0.0018	0.3660	0.5251	0.1378	1.0000	0.1619	0.1720
BTC	0.1807	-0.0543	0.1035	0.0870	0.1274	0.0838	0.1619	1.0000	0.0341
CrudeOil WTI	0.1917	-0.0244	-0.0162	0.4553	0.0903	0.0904	0.1720	0.0341	1.0000

Source: The author's calculations in MATLAB.

From the obtained correlation coefficients, it can be noticed that most asset classes are low correlated. Exceptions to this are stocks, real estate, and renewable energy

sources. A significant positive correlation is identified between stocks and real estate, where the correlation coefficient reaches 0.7396. Stocks and renewable energy sources are also highly positively correlated, with a correlation coefficient of 0.6895. Further positive correlation greater than 0.5 is found in the case of real estate and renewable energy sources. The asset class negatively correlated with all other asset classes is foreign exchange.

Traditional risk measures, the most popular and widely used in the literature, are considered for measuring the risk of assets. The first risk measure, standard deviation, represents Markowitz's classical approach. Considering that observed assets have non-normal distribution, our second and third choices are Value at Risk (VaR) and Conditional Value at Risk (CVaR). According to the fundamental Value at Risk definition, it is the maximum expected potential loss of a portfolio over a given time horizon for a given confidence interval under normal market conditions (Jorion, 2007). The Conditional Value at Risk, introduced by Rockafellar et al. (2000), quantifies the expected losses that occur beyond the VaR breakpoint. Three key elements are characteristic of both measures: time (period), confidence interval, and the specified amount of loss in value or percentage. Mathematical formulations of these three risk measures are given as follows:

$$StD(X) = \|X - E(X)\|_2, \tag{1}$$

$$VaR_\alpha(X) = \min\{-z : F_X(z) \geq \alpha\} = -F_X^{-1}(\alpha), \tag{2}$$

$$CVaR^-_\alpha(X) = E(-X : X \leq F_X^{-1}(\alpha)), \tag{3}$$

where E(X) stands for the average return of the asset, α represents the confidence level, and $F_X(z)$ stands for the cumulative distribution function of the daily returns.

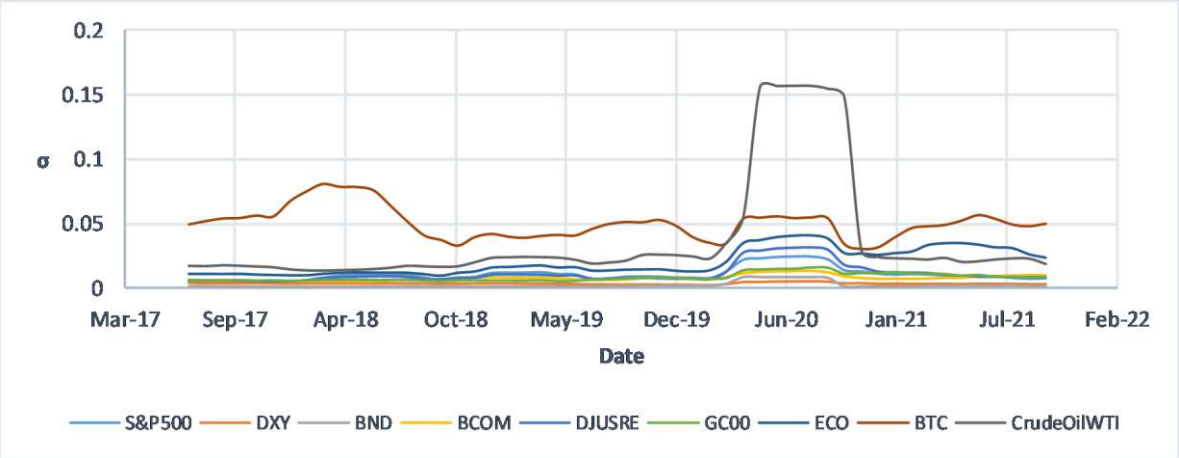
For analysis, we also use the Sharpe ratio that measures excess portfolio return over the risk-free rate R_f, relative to its standard deviation:

$$Sharpe\ ratio = \frac{E(R) - R_f}{StD(R)}. \tag{4}$$

Results and Discussion

The calculations are based on the historical data of assets' close prices. More precisely, for the observed period of January 2017 to November 2021, using the rolling window of daily returns for working days, for 126 days with the shift of 21 days, standard deviations, VaR, CVaR, and the Sharpe ratio are calculated. VaR and CVaR are calculated for 90% and 95% significant levels. The total number of calculations in the observed period is 52 per measure. The results are presented in Figures 1-6.

Figure 1
Results for standard deviation

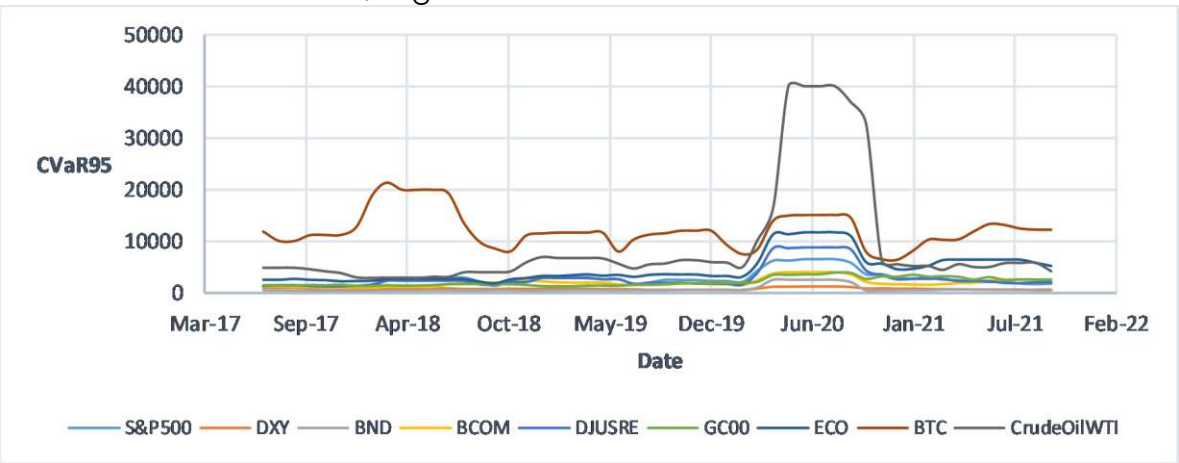


Source: The author's work in Excel.

Figure 2
Results for VaR with a 95% significant level

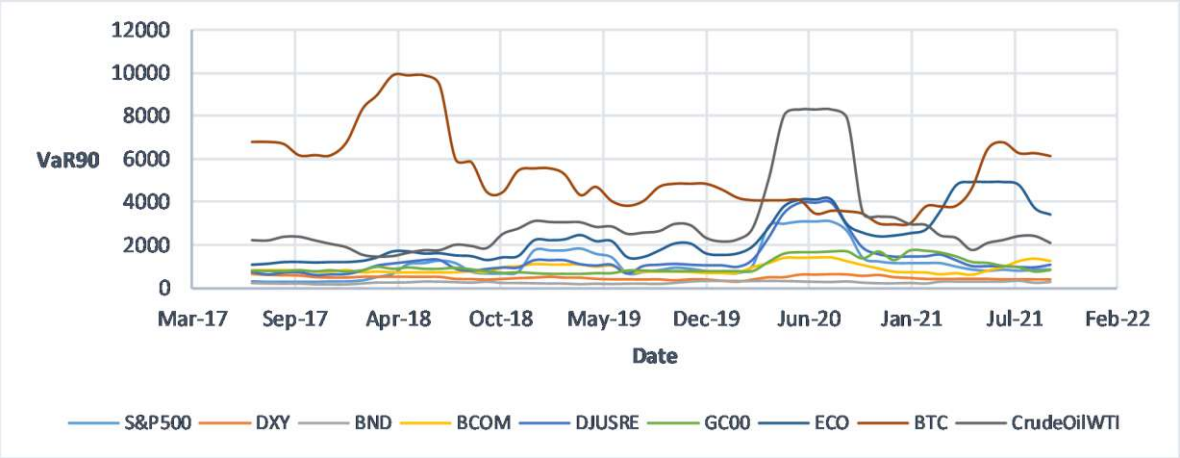
Source: The author's work in Excel.

Figure 3
Results for CVaR with a 95% significant level



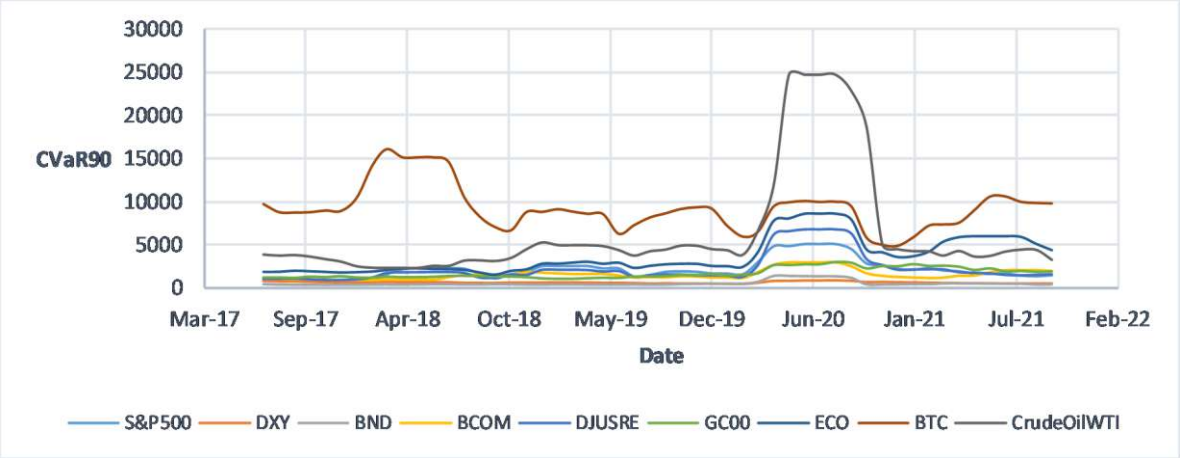
Source: The author's work in Excel.

Figure 4
Results for VaR with a 90% significant level



Source: The author's work in Excel.

Figure 5
Results for CVaR with a 90% significant level



Source: The author's work in Excel.

Figure 6
Results for the Sharpe ratio

Source: The author's work in Excel.

Figures 1-5 show that, regarding all risk measures, almost all assets had an increased level of risk between March 2020 and October 2020, which is the period of the onset of the pandemic crisis. In that period, crude oil had the largest risk values, while Bitcoin and the ECO index took the second worst position regarding risk measures. Out of that period, the largest risks are connected with Bitcoin, then with crude oil, and lately with renewable energy sources. If we look at Figure 6, the risk taken by investing in Bitcoin and renewable energy sources was periodically extremely well rewarded, which cannot be said so convincingly for crude oil. In addition to estimated risk values, it is important to observe the impact of the crisis on the riskiness of assets by observing the differences in the increase in risk values at the onset of the crisis compared to the period before the crisis. Thus, the highest increase in risk at the onset of the crisis, compared to the entire observed period before the crisis, was experienced by crude oil (WTI), renewable energy sources (ECO), real estate (DJUSRE), and stocks (S&P 500). Commodities (BCOM) and gold (GC00) have a relatively small increase in riskiness caused by the crisis.

In contrast, the riskiness of bonds (BND) and foreign exchange (USDX) is almost unaffected by the crisis. Bitcoin has a different risk trend concerning the remaining assets, whose highest risk value in the crisis did not exceed the highest risk value in the pre-crisis period. Although the risk rate increased during 2020 compared to the very end of 2019, this change in riskiness is not significantly different from the changes during the pre-crisis year of 2019. Therefore, although Bitcoin is among the first three riskiest assets in the crisis, it can be said that the crisis itself almost did not affect its increase in riskiness.

In addition to the individual analysis of the impact of the crisis on the risk of each asset class, it is interesting to analyze the mutual order of the observed types of assets regarding risk. Therefore, assets are ranked according to the average of 52 values for each of the five risk measures and the Sharpe ratio performance. Table 4 shows the ranks of nine different assets according to different measures and according to the entire observed period.

Table 4

Assets are ranked considering different measures from January 2017 to November 2021.

	VaR 95%	CVaR 95%	σ	VaR 90%	CVaR 90%	E(R)/σ
S&P500	5	5	5	5	5	9
DXY	8	8	8	8	8	1
BND	9	9	9	9	9	2
BCOM	7	7	7	7	7	3
DJUSRE	4	4	4	4	4	6
GC00	6	6	6	6	6	5
ECO	3	3	3	3	3	8
BTC	1	1	1	1	1	7
WTI	2	2	2	2	2	4

Note: In the case of standard deviation, VaR and CVaR rank 9 indicate the lowest risk level, while in the case of the Sharp ratio, rank 9 indicates the best proportion of expected return and risk.

Source: The author's calculations in MATLAB.

The results in Table 4 show that different risk measures rank assets equally according to their risk. Asset classes with a high average deviation from the mean (standard deviation) also have a high VaR and CVaR. Bitcoin has the highest risk level for all risk measures, but a good proportion of expected return and risk is presented with the

Sharp ratio. A similar and even slightly better situation is found with the ECO index. At the same time, crude oil is a risky asset, remaining a not very attractive investment regarding values, i.e., its rank by the Sharpe ratio. Bonds, the US Dollar Index, and commodities have the lowest levels of risk but also the lowest earning potential. Gold and Real Estate Index occupy the mid-ranks regarding observed risk values and the Sharpe ratio. Surprisingly, the best value from the Sharp ratio is found in stocks, which are accompanied by a middle level of risk and make them the most favourable asset.

Given that the observed period includes the period of the pandemic crisis in which the risk of almost all assets has increased, it is interesting to observe the results separately for the pre-and-crisis periods. Accordingly, a special ranking was conducted for pre-crisis data and data during the crisis, shown in Table 5 and Table 6. In addition, for easier analysis of the impact of the crisis on the mutual order of assets regarding riskiness and earning potential, Table 7 is given.

Table 5

Assets are ranked considering different measures from January 2017 to December 2019 (pre-crisis period)

	VaR 95%	CVaR 95%	σ	VaR 90%	CVaR 90%	E(R)/σ
S&P500	4	4	4	5	4	9
USDX	8	8	8	8	8	2
BND	9	9	9	9	9	4
BCOM	6	6	7	6	6	1
DJUSRE	5	5	5	4	5	5
GC00	7	7	6	7	7	6
ECO	3	3	3	3	3	8
BTC	1	1	1	1	1	7
WTI	2	2	2	2	2	3

Note: In the case of standard deviation, VaR and CVar rank 9 indicates the lowest risk level, while in the case of the Sharp ratio, rank 9 indicates the best proportion of expected return and risk.

Source: The author's calculations in MATLAB.

Table 6

Ranking assets considering different measures from January 2020 to November 2021 (crisis period)

	VaR 95%	CVaR 95%	σ	VaR 90%	CVaR 90%	E(R)/σ
S&P500	5	5	5	5	5	9
USDX	8	9	9	8	9	1
BND	9	8	8	9	8	2
BCOM	7	7	7	7	7	6
DJUSRE	4	4	4	4	4	5
GC00	6	6	6	6	6	3
ECO	3	3	3	3	3	8
BTC	1	2	2	1	2	7
WTI	2	1	1	2	1	4

Note: In the case of standard deviation, VaR and CVar rank 9 indicates the lowest risk level, while in the case of the Sharp ratio, rank 9 indicates the best proportion of expected return and risk.

Source: The author's calculations in MATLAB.

Table 7
Comparison of assets ranking according to risk before the crisis and risk during the crisis

Rank	Risk before crisis	Risk during crisis	Earning potential before the crisis	Earning potential during the crisis
9	BND	USDX	S&P500	S&P500
8	USDX	BND	ECO	ECO
7	GC00	BCOM	BTC	BTC
6	BCOM	GC00	GC00	BCOM
5	DJUSRE	S&P500	DJUSRE	DJUSRE
4	S&P500	DJUSRE	BND	WTI
3	ECO	ECO	WTI	GC00
2	WTI	BTC	USDX	BND
1	BTC	WTI	BCOM	USDX

Note: Rank 9 indicates the lowest risk level and highest earning potential.
Source: The author's calculations.

Tables 5-7 show that the COVID-19 crisis has affected ranks differently, i.e., risks and the return over risk ratio of some assets. Commodities (BCOM) keep their lower levels of risk in both periods, but with a significantly large difference in the Sharpe ratio ranking from the worst in the pre-crisis period to the fourth best in the crisis period. A significant impact is also obvious for gold (GC00). In the crisis, it became a slightly riskier asset and a less attractive investment regarding earning potential. From the fourth-best position in the Sharpe ratio ranking in the pre-crisis period, it sank to the third worst in the COVID-19 period. Due to the "episode" of high returns in the mid of 2019, bonds (BND) took a mid-position regarding the Sharpe ratio in the period before the crisis. For the crisis period, despite constant low-risk levels, they remained at the bottom of the Sharpe ratio ranking, together with the US Dollar Index (USDX). There were no changes in Sharpe ratio rank for the Real Estate Index (DJUSRE), although a slight risk increase happened. The always-risky Bitcoin (BTC) gains a slightly better risk rank position in the crisis period, with a consistently good expected return and risk ratio. The crisis did not affect the ECO Index rank positions at all. It stays a rather risky but profitable investment despite the spotted highest risk values during the first quarter of the COVID-19 crisis and worse risk rankings in the crisis period, the position of crude oil (WTI) regarding the Sharpe ratio improved by one place. Thus, crude oil was one place ahead of gold during the crisis.

Finally, stocks (S&P500) constantly have the best value of the Sharp ratio, accompanied by acceptable risk levels and a better risk ranking in the crisis period. This finding is surprising if we consider the results of recent studies, which had shown the priority of some other assets, primarily cryptocurrencies, in the observed context. Although stocks stayed trapped in the bear market for some time in 2020, it seems that stocks recovered very well over time and came to occupy a favourable position.

Conclusion

The presented research fulfilled the goal of risk measurement and comparing a wider set of different assets and asset groups. Risk is placed concerning the observed returns, thus indicating earning potentials of observed investments. In particular, the COVID-19 impact is considered. The study's possible limitation is that each asset class's representatives were chosen according to data availability. So, they are not necessarily the best representatives of classes. There are some interesting results from this study in which earning potentials are observed in parallel with risks. From the analysis of the individual impact of the crisis on the increasing risk levels of the different assets, it can be concluded that the crisis had the highest impact on the risk of crude

oil, renewable energy sources, real estate, and stocks, a slightly lower impact on the risk of commodities and gold, and a very low (almost none) impact on the risk of bonds, foreign exchange, as well as cryptocurrencies.

Although the crisis had a different impact on the riskiness of certain assets, it is interesting that the order of assets regarding risk did not change significantly during the crisis compared to the order before the crisis. In contrast, the order of assets regarding earning potential during the crisis, compared to the period before the crisis, changed significantly for commodities, from assets with the lowest earning potential to assets with the fourth-best earning potential. The crisis negatively affected the earning potentials of two more assets, gold and bonds. Surprisingly, and not in line with previous research, good old stocks won against all other assets and asset groups as the best-positioned asset according to earning potential before and during the crisis while having a middle level of riskiness. Furthermore, the study has shown the good features of a new alternative investment – renewable energy sources – with its second-best earning potential. On the third place on the list of earning potential is a new star on investors' horizon – cryptocurrencies.

The fact that most asset classes are low correlated, together with some specific correlation results, can be significant for investors. With the proper methodology, exploring the observed assets' diversifying, hedging, and/or safe-haven properties might be useful now that the crisis has continued.

Acknowledgements: The Croatian Science Foundation (CSF) under Grant [IP-2019-04 - 7816] supports this work. This paper is an extension of the paper "An evidence on risk and return of cryptocurrencies", presented at the 16th International Symposium on Operational Research in Slovenia SOR'21.

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Possible Impact of Risk Management Strategies with Farm Model on a Mixed Farm Type

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Abstract

Background: Farm-level models have become an important tool for agricultural economists as there is a growing demand for microsimulation and analysis of farms at the individual level. **Objectives:** In this paper, we present a mathematical model with the main objective of assessing the effectiveness of production and various possible strategies for agricultural holdings by reducing risks. At the same time, we were also interested in the environmental impacts of such strategies. The latter was measured using the indicator of GHG emissions. **Methods/Approach:** The model applied is based on linear programming and upgraded with QRP for risk analysis. The approach was tested on medium size mixed agricultural holding, which often faces challenges in light of the structural changes taking place in Slovenia. **Results:** The results suggest that such a farm could improve financial results with a more efficient risk management strategy. With a slightly modified production plan, the expected gross margin (EGM) can be increased by up to 10% at more or less the same risk. However, if the farmer is willing to diversify the production plan and take a higher risk (+23%), the farm's EGM could increase by up to 18%. This kind of change in the production plan would also generate 17% more GHG emissions in total, calculated as kg equivalent of CO_2 at the farm level, as both BL and C scenarios have the same relative ratio at 3.12 GHG CO_2 eq. /EUR. **Conclusions:** Through this research, we concluded that diversification has a positive potential on a mixed farm, and the farm could achieve better financial results. With flexibility in management, the farmer could also achieve higher risk management efficiency and better farm results.

Keywords: mathematical programming, farm model, greenhouse gas emissions, medium size farm type

JEL classification: O3, O33
Paper type: Research article

Received: 1 Mar 2022
Accepted: 11 Jun 2022

Citation: Brečko, J., Žgajnar, J. (2022), "Possible Impact of Risk Management Strategies with Farm Model on a Mixed Farm Type", Business Systems Research, Vol. 13 No. 3, pp. 23-35.
DOI: https://doi.org/10.2478/bsrj-2022-0022

Introduction

In the last decade, the development and use of farm-level models have become an important activity of agricultural economists (Ciaian et al., 2013). Decision makers at various levels urgently need data, models, and knowledge products that provide user-friendly data collection and analysis capabilities. The cases developed range from farm-level decision support to decision support for policymakers whose goal is sustainable management of natural resources management (Antle et al., 2017). Agricultural models are appropriate for assessing the impact of various farm-level policies and monitoring developments in individual sector segments (Reidsma et al., 2018). Most applied models are implemented at an aggregate level (regions, countries). Thus are unable to fully capture the impact of new policies at the farm level (Louhichi et al. 2015). Namely, there are obvious changes toward more outcome-oriented agricultural policies and a clear dedication to policies based on evidence and proven intervention logic (Lovec et al., 2020), which is linked to the increasing demand for micro-level policy analysis tools and methods and a better understanding of farm-level decision-making (Ciaian et al., 2013).

The reasoning for the farm-level model is primarily based on the growing demand and need for a microsimulation tool to design and analyze various policies at the level of each farm, thereby capturing the heterogeneity of farms (Louhichi et al., 2015) and the capabilities of farms in the aspect of risk management. At the same time, the possibility of environmental impact assessment is becoming increasingly important.

Despite its relevance, the calculation of GHG emissions in agriculture remains one of the most challenging studies in the field. As a typical example of nonpoint source pollution, agricultural GHG emissions must be calculated indirectly (Coderoni and Esposti, 2018). Most agricultural policies to reduce greenhouse gas emissions have largely been based on aggregate-level evidence without adequately accounting for farm heterogeneity. Recently, attempts have been made to obtain GHG data at the farm level (Stetter and Sauer, 2022).

In agriculture, greenhouse gas (GHG) emissions account for about one-tenth (10.1% in 2019) of total GHG emissions in Slovenia and are the second largest sector after transport. The main source of GHG emissions in agriculture is methane (68.4%), produced during the fermentation of feed in the digestive tract of domestic animals, especially in the rumen of ruminants and during the storage of livestock manure (Verbič, 2021). Of course, the impacts are different across different farms and types of production.

Assessing farm diversity and typology is also becoming increasingly important in the past few years. Farm typology is important for its utility in effective agricultural policy planning and for discussion and support in finding appropriate solutions for developing multifunctional and sustainable agricultural and rural areas (Mądry et al., 2016). Numerous operational models based on different techniques have been developed to answer various questions in agricultural systems (Ciaian et al., 2013). Various approaches have been used for this purpose. The most commonly used is mathematical programming (MP), including linear programming (LP), positive mathematical programming (PMP), mixed integer programming (MIP), and nonlinear programming (NLP), as well as models based on an econometric approach, and also agent-based models (ABM) (Ciaian et al., 2013). The type and quality of available data, as well as the scope of the research, usually determine which approach is best suited for farm-level modelling (Ciaian et al., 2013). In agriculture analyses, gross margin (GM) is predominantly used economic indicator (Reidsma et al., 2018), mainly due to large differences in fixed costs by farms, which is especially true if the analysis is performed on farm types.

Risk is becoming a significant factor in agricultural production. Several sources of risk threaten agricultural operations (Hardaker et al., 2015). An important source of risk is production risk, which reflects a change in the quantity and quality of crops and production, mainly due to adverse weather conditions and pests (Hardaker et al., 2015). There are also unstable prices, which have been increasingly volatile over the past decade. Common Agricultural Policy reforms have resulted in a market-oriented agricultural sector increasingly exposed to market price volatility (Tangermann, 2011). In addition, inappropriate risk management decisions, in general, can lead to the sale of assets, which reduces savings and decreases employment. Farmers are forced to reduce their investments to mitigate risk due to the inefficiency of inadequate risk management, which can have several unpleasant effects on production, which is relevant for farms facing structural challenges such as the one included in the analysis of this paper. Adopting an appropriate risk management strategy is essential for farmers to reduce the negative impacts (Hardaker et al., 2015). First and foremost, diversification of the production plan could be the first measure to mitigate risk.

Most farmers are risk-averse when faced with risky outcomes (Rosa et al., 2019). A risk-averse person is willing to accept a lower average return for less uncertainty, with the trade-off depending on the individual's level of risk aversion. Knowing farmers' risk preferences is essential for farmers themselves, for advisory services, for industry (which provides production and food processing inputs), and for policymakers. They can better manage their farms with a better knowledge of their risk preferences (Iyer et al., 2020). Risk must be factored into decision-making; farmers' strategies cannot be evaluated solely based on average or expected return. Knowing farmers' attitudes toward risk is important for picking the appropriate strategies. There are several challenges in organizing production effectively, and what activities should be selected to reduce risk or achieve better financial results at a given level of risk (Žgajnar et al., 2016). Such analyses have been done on different cases, from horse farms with different equestrian activities (Žgajnar, 2017) to berry fruit production in Bosna and Herzegovina (Žgajnar and Bećirović, 2019). Of course, the results obtained are specific to individual farm types and cannot be simplified and generalized.

There are several approaches to risk management analysis. This paper is about a possible reduction of risk at the farm level, especially the options available to the farmer in the area of production planning which is an issue of the production plan diversification, taking into account the normal risks that the farm should be able to deal with.

The expected value and variance model (E, V) is used to model this problem based on Markowitz's risk-balancing hypothesis. The mathematical concept of variance is used to quantify risk, and it is assumed that the decision-maker relies only on the mean and variance. Several variants of such approaches can be found in the literature (Hardaker et al., 2015), including quadratic risk programming (QRP), which minimizes the sum of the total variance while parameterizing the safety equivalent (e.g., expected gross margin) over the feasible region. The biggest advantage is that only information on the expected value and variance of the outcome distributions is needed to allow at least a partial ordering of the alternatives, which explains the usefulness of the E, V approach. Different states of nature defined by different sources of instability (yield, price, variable costs, subsidies, etc.) is how variability is measured (Hardaker et al., 2015).

There is a growing interest in understanding the linkages between agricultural production, especially livestock production, and climate change, which has led to a significant amount of research (Rojas-Downing et al. 2017). Increasing importance is based on the need to produce high-quality estimates of greenhouse gas (GHG)

emissions and the impacts of mitigation strategies at the livestock farm level for different decision-makers (Schils et al., 2012). To date, most research provides information on how GHG emissions are estimated and their incorporation into the sustainability assessment of a farming system. The role of GHG-based decision support systems is becoming increasingly important in this context (Ahmed et al., 2020). Thus, the question arises about how we influence this aspect by reducing risks.

The paper is organized as follows. In the first part, we briefly summarize the methodological aspect of the analysis. Next, we describe the analyzed farm and its different options regarding production planning and scenarios to mitigate risk and change economic results. We conclude the paper with results and discussion.

Methodology

The objective of the study is to i) analyze the efficiency of different possibilities of risk reduction through diversification of a production plan on a hypothetical semi-size farm and also ii) to measure the effects from the viewpoint of GHG emissions. It is a case of a farm with a typical mixed production plan, and it includes different livestock activities, fodder production as well as cash crops.

GHG emission is an indicator that shows the intensity of greenhouse gas emissions in animal production, especially from dairy and beef production. It shows emissions of methane released from the gastrointestinal tract and manure storage and nitrogen oxides released from fertilizer storage, on pasture, and due to fertilization with manure from dairy cows (including indirect emissions). Methane and nitrous oxide are converted to carbon dioxide equivalents and expressed in kg per unit of milk/beef meat produced or in kg CO_2 eq. Per animal. The reduction in emission intensity is mainly due to improvements in dairy farming efficiency (higher milk yield, improved milk production, reproductive characteristics, etc.) and partly to improved farming practices (e.g., more pasture). For other animal production (poultry, pigs, goats, etc.) GHG emissions were estimated based on uniform emission factors per animal per year. For this purpose, a farm model based on mathematical programming has been developed. It is an example of a spreadsheet model developed in Microsoft Excel and supported with VBA macros. Mathematical programming using Solver to solve linear and nonlinear models is used for solving such models (Chandrakantha, 2014).
The farm model is based on mathematical programming and enables production plan optimization. The model enables the integration of various production activities (livestock, crop, and vegetable/fruit products), different production intensity levels, and technological parameters change. To identify individual production activities' technological coefficients, the farm model is developed by the Agricultural Institute of Slovenia (AIS, 2020). The basic set of constraints deals with the available production resources, describing the characteristics of the analyzed farm. The basic constraints include labour requirements, tillage area, crop rotation, conservation technologies for grassland, nutrition and ration balance, and stable capacity (number of places for different categories of animals). The developed farm model consists of three sub-models.

The *first sub-model* is a simple static simulation model. It calculates the economic and technical parameters for all production activities that could enter the farm's production plan. It generates technological cards for each production activity and calculates revenues, variable costs, and gross margins for different states of nature, considering various integrated production functions. We assumed that technologies remain fixed; however, prices and costs change through different periods (2011 - 2020). The data is collected and obtained from the Agricultural Institute of Slovenia (AIS, 2020).

The *second sub-model* is based on *linear programming (LP)*. The main purpose of it is to find the optimal solution that provides the highest expected gross margin (EGM), which represents the starting point for the parametric constraint in the third sub-model that also considers risk. The objective function of the EGM is subjected to maximization. On that basis optimal production plan is determined, considering the price-cost ratios of the ten years (2011 - 2020).

$$EGM_f = max \left\{ \sum X_f EGM_{A,f} \right\} \quad (1)$$

$$s.t.$$

$$X_f TC_f \leq R_f \quad (2)$$

$$X_f \geq 0 \quad (3)$$

where X_f is the decision vector of activities and EGM_f is the scalar of the expected maximum gross margin per farm. TC_f represents the matrix of technical coefficients for the analyzed farm.

The *third sub-model* is based on *quadratic risk programming (QRP)*, which also considers production activities' riskiness. It enables optimal calculating solutions at a given risk level, forming an efficient production frontier. Thus, the basic idea for formulating the efficient E-V frontier is to minimize the variance as an argument of the objective function, achieved at a certain expected gross margin, which is expressed as a constraint in the model (Hardaker et al., 2015).

$$SD(GM_f) = min \left\{ \sqrt{X'_f (VARCOV(GM_{A_{ij}})_f) X_f} \right\} \quad (4)$$

s.t.

$$EGM_f \lambda = \sum_{A=1}^{i} X_f EGM_A, \qquad \lambda \text{ varied 1to n} \quad (5)$$

$$X_f TC_f \leq R_f \quad (6)$$

$$X_f \geq 0 \quad (7)$$

where SD (GM_f) represents the scalar of the standard deviations of the expected gross margins for a farm *f* and is computed as the square root of the sum product of the decision vector of solutions X_f and the variance-covariance matrix ($VARCOV(GM_{A_{ij}})_f$) of activities gross margins.

Analyzed farm

The farm model has been utilized on a typical semi-size farm. It is a mixed livestock and crop production farm, where the main economic activity is cattle breeding, dairy (18 dairy cows and five breeding heifers), and meat production (8 cattle for fattening). Besides cattle, hens (30 heads), pigs (3 heads), and goats (2 heads) are also kept on the farm. Given the structural changes in Slovenia, this type of farm often faces challenges in organizing production in the future. A certain share of such a farm type can increase production volume; there are enough areas in the surrounding area that can be rented, while others do not have this option. For some, the market is accessible; for others, it is not. So, we can face different challenges for the same general type of farm. However, we must address them to help such farms find the optimal strategy, as

confirmed by another study (Žgajnar et al., 2022). The main idea of those typical farms is that they should be representative of a group of farms and, in such a manner, also reflect the situation in the field. Therefore, the production plan is not necessarily economically optimal (regarding the given resources) but should reflect the situation in practice. A special calibration process has been applied, presented in Žgajnar et al. (2022). From the mathematical programming concept, an additional set of constraints is included in the model to fix mainly economical activities that define farm type (livestock in our case study).

The analyzed farm belongs in the less-favoured area (LFA), and among the agricultural land, meadows predominate with 10 ha of own meadows and the possibility to rent another 8 ha. The farm also has 2.5 ha of own fields with the possibility to rent an additional 4 ha of arable land in the vicinity of the farm if needed. Cereals, corn, clover-grass mixtures, and a small proportion of potatoes are grown in the fields. There is also an orchard of apple trees. The workload on the farm accounts for 1.7 full-time equivalents (FTE).

Analyzed Scenarios

However, since this is a typical farm and production plan in that sense is relatively fixed regarding the methodological concept (Baseline - BL), we tested some adjustments to the management strategy and possibilities in the analysis through different planning concepts. We analyzed different scenarios to analyze the possibilities of the farm's effective risk management strategies.

In the first stage, we were interested in i) what the farmer could do to increase financial results at the same level of risk (A) or ii) to reduce risk at the same level of EGM (B). Further, we analyzed two strategies of possible production plans to reduce risk. The first strategy was a minor change in current production capacity and assumed that it is impossible to increase animal production capacity over baseline values (NoAP – **No** increase in **A**nimal **P**roduction capacity), but only to decrease or reshuffle within given capacities. In the second strategy, we also assumed an eventual increase in animal production activities capacity (InAP – **In**crease in **A**nimal **P**roduction capacity). For both strategies, we calculated a series of production plans. In all of them, we gradually reduced the EGM with the described procedure of the farm model while minimizing the total risk (QRP). In doing so, we calculated various physical, economic, and environmental indicators.

Results

In this chapter, the main results for the analyzed farm are presented. In the first part, we present the summary of the production plan and economic indicators for the baseline (BL) and analyze different risk management strategies for achieving maximal EGM through the diversification of the production plan (Table 1). For main production activities, we also presented EGM (calculated as a ten-year average) and expected production intensity for the same period. Further, we present efficient frontiers in the E, V context (Figure 1) and for relative comparison of two different strategies (NoAP and InAP). For both (NoAP and InAP), we also include a percentage comparison for the decrease in EGM and risk (Figure 2). For all scenarios, GHG emissions for livestock breeding were also calculated and presented as a sum of kg equivalent of CO_2 for livestock on the hypothetical farm.

Basic indicators of different production plan scenarios

In the Baseline scenario (BL), the farm could reach total revenues of 65323 € and an EGM of 41289 € (Table 1). In such a case, it bred 18 dairy cows and needed several heifers, seven cattle for fattening and, as assumed, 30 laying hens, three pigs for fattening, and two goats. Needed fodder is produced mainly on grassland and corn, with cereals also on the arable land. As typical for such a farm, there is a small sale of cereals and a small apple orchard. In this scenario (BL), the farm produces 129.021 kg equ CO_2 in livestock production. For dairy production, cows on a farm produce 0,825 kg CO_2 eq./l of milk, which is not achieving the goal set for 2020 (0.789 kg CO_2 eq.) (Verbič et al., 2021). Reducing emissions can be achieved by increasing dairy and beef production efficiency, using different technologies of manure storage, and technological improvement (more pasture, etc.).

On the other hand, cattle for fattening are producing 5,062 kg CO_2 eq./kg gained, which is a good ratio, considering the average between 2005-2019 is around 5,8 kg CO_2 eq./kg. As shown in Table 1, the standard deviation (SD) in all scenarios is relatively low compared to the expected gross margin (EGM) level. Namely, economic conditions were relatively stable in the observed period. Such a plan in baseline has a coefficient of variation (CV) of 0.17; however, with increased animal production activities in scenario C, it increases (+0.72%).

Further, if the farm can diversify the production plan and expand the current barn and the number of animals in the herd (except dairy cows), this could improve the farm results. Scenario A shows that the farm can increase the EGM (+10.5%) with a change in the production plan. At the same time, the risk expressed as SD of EGM can remain almost the same, which can be achieved by retaining the exact number of dairy cows, reducing the number of breeding heifers by 1, and increasing the number of beef cattle by 2. However, the major influence is by including less risky production activities: laying hens (+20), fattening pigs (+7), and goats by three heads. With the diversification of the production plan, GHG emissions potentially increase by 3 %. Regardless of the slight increase, this also significantly improves the environmental efficiency of the farm production plan (2.913 kg CO_2 eq./EUR of EGM) measured as GHG emissions per EGM.

In the second example (B), we present how the farm can reduce risk while maintaining the same level of EGM, which can be achieved by reducing the number of cows (–2) and heifers (–2) while increasing the number of beef cattle by 2, laying hens (+20), fattening pigs (+7), and goats (+3), so that in this scenario the EGM remains at a similar level. In contrast, the farm has a lower risk. In this scenario, the farm has lowered its livestock GHG emissions by nearly 7%. However, this is an expected result. Namely, in this case, it is the main factor in reducing cattle stock, which is a key source of GHG emissions.

In the third option (C), we present an extreme: what the farm could achieve regarding the production resources if we only maximize EGM and don't consider risk. Also, we allow increasing the number of dairy cows. In such a case, the farm can increase its EGM by 18% while risk increases by 23%. The main binding constraints for further improvements in such a case are barn capacity (cattle), current market capacity (for laying hens, fattening pigs and goats), and availability of arable land. It is expected that within scenario C, with the highest revenue also, GHG emissions are the highest. The value of the indicator increases by 17%. However, if we consider improved economic indicators (EGM) in the context of emissions, the result is almost the same as efficient as the baseline (3.123 kg equivalent of CO_2/EUR of EGM).

Table 1
Optimal production plans for the hypothetical farm in different scenarios and economic and environmental indicators

Production Activities		Scenario					
Animal Production	**(unit)**	**Baseline (BL)**	**A**	**B**	**C**	**EGM of Activity (€)**	**Expected intensity (kg/head, kg/ha)**
Dairy Cows	**(heads)**	18	18	16	24	2161	6000
Breeding Heifers	**(heads)**	5	4	3	5	-60*	550
Cattle for Fattening	**(heads)**	7	9	9	4	1298	700
Laying Hens	**(heads)**	30	50	50	50	39	270
Pigs for Fattening	**(heads)**	3	10	10	10	117	150
Goats	**(heads)**	2	5	5	5	196	67
Crop Production – Fields							
Triticale	**(ha)**	0.6	0	0	1.0	-181	5000
Potatoes	**(ha)**	0.2	0	0.1	0.2	2808**	35000
Corn	**(ha)**	2.0	1.9	1.6	1.6	-854	9000
Corn for Sillage	**(ha)**	1.4	1.4	1.2	1.8	-809	50000
Barley	**(ha)**	0.6	1.5	1.3	0.7	-241	5500
Wheat	**(ha)**	0.2	0.3	0.3	0.3	54**	5500
Fruit Growing							
Apples	**(ha)**	0.5	0.5	0.5	0.5	452	7000
Crop Production – Grassland							
Grass silage	**(ha)**	7.3	7.0	6.3	9.7	-687	21857
Pasture	**(ha)**	0.2	0.2	0.2	0.3	-56	48971
Hay	**(ha)**	2.9	3.9	3.7	3.9	-405	8895
Economic Indicators at Farm Level							
Total Revenue	**(€)**	65323	70525	65808	80066		
Total Variable Costs	**(€)**	24034	24891	24543	31519		
EGM	**(€)**	41289	45634	41265	48547		
SD of EGM	**(€)**	6952	6943	6192	8525		
GHG Emissions	**(kg CO2 eq.)**	129021	132953	119395	151632		
GHG Emissions/EGM	**(kg CO2 eq./€)**	3.12	2.91	2.89	3.12		

* breeding heifers have a negative sign as they are raised for replacement; the cost of animal feed is not taken into account for livestock, as it is considered at the farm level
** potatoes and wheat are sold, and other crop production on fields and grassland used for fodder
Source: Authors' work

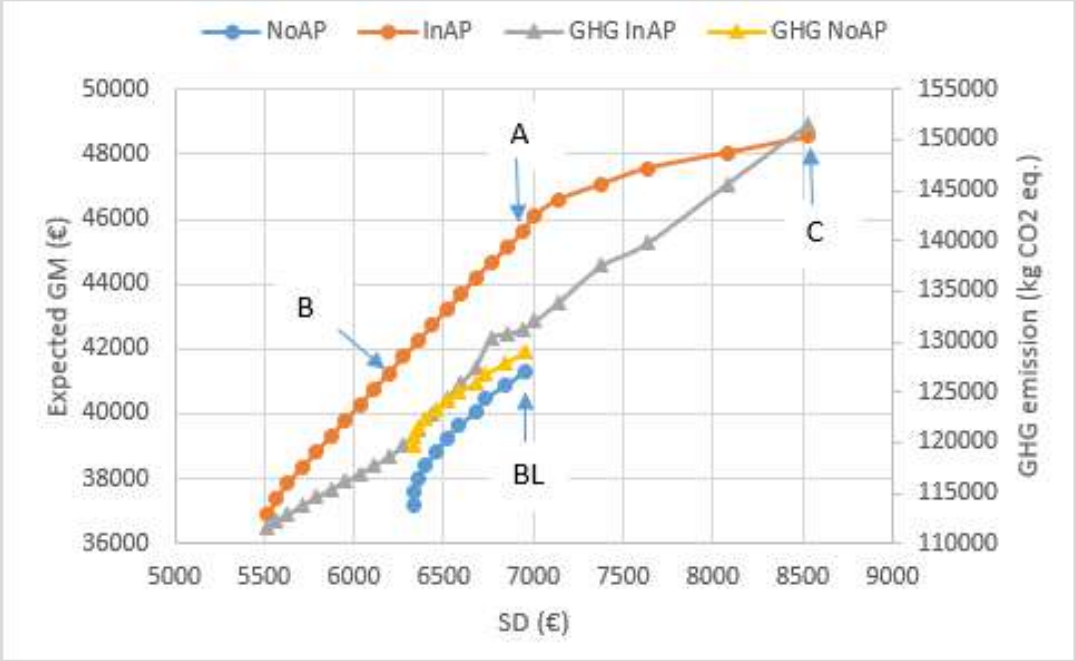
Risk-reducing strategies

For both strategies of reducing risk (**No**t possible to increase **A**nimal **P**roduction activities (NoAP) and eventual **In**crease of **A**nimal **P**roduction activities (InAP)), we have calculated a series of production plans, parameterizing EGM and minimizing risk (SD) (

Figure ***1***). As shown in Figure 1, NoAP has significantly minor possibilities of reducing risk and increasing EGM, indicating how important dairy is on such a farm from the risk management perspective. Both points (BL and C) in the upper right of Figure 1

represent an optimal LP solution that maximizes the EGM. Optimal solutions (BL and C) represent situations where the farmer would be indifferent to risk with the main objective of maximizing the EGM. As shown in Figure 1 and described above, by exploring the farm's potential and diversifying the farm's production plan, we can significantly (+10%) increase EGM with a similar level of risk.

Figure 1
E-V efficient frontiers for NoAP with baseline (BL) and InAP (Scenarios (A, B, C)) and GHG emissions for both NoAP and InAP

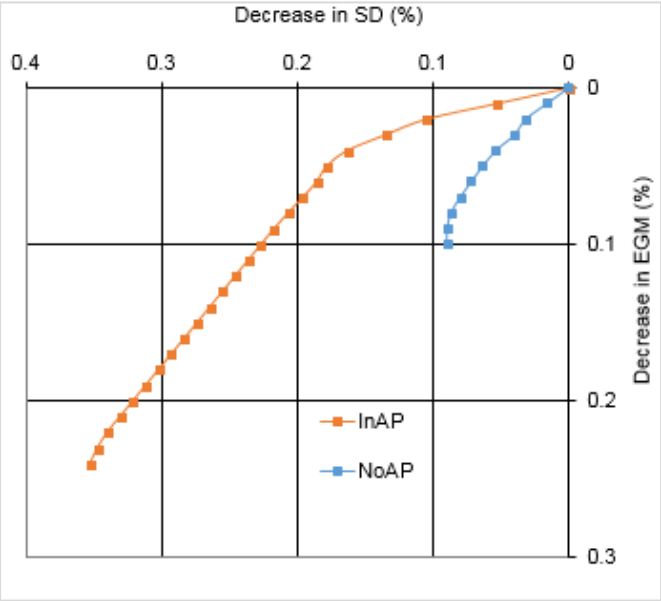


Source: Authors' work

For both strategies, NoAP and InAP we have also calculated how they affect GHG emissions. As apparent, the trend is similar to that of achieving the EGM. However, there is a more favourable impact of the InAP strategy, where the farmer is more flexible in production planning.

To analyze the efficiency a farm could have regarding circumstances at reducing risk, we show Figure 2. The steeper the curve, the less efficient the farm is at reducing risk, and the more EGM the farm must give up to reduce the risk for one unit. The results show that the NoAP is significantly riskier and less efficient than scenario InAP with possible diversification of the production plan with increasing animal production activities, mainly in favour of granivores. In the reduction of risk by 9%, we can see that NoAP has a decrease of EGM by 10%, while the same reduction in InAP scenario has only a 2% decrease in EGM. Results show that BL and C scenarios have the same relative ratio at 3.12 GHG CO_2 eq. /EUR. Scenarios A and B have a more favorable ratio at 2.91 and 2.89, which means that as we reduce risk on a farm, we also generate less GHG per unit of EGM.

Figure 2
Diversification efficiency for NoAP and InAP



Source: Authors' work

Conclusion

The paper presents a farm model for analyzing farm production plans considering different risk mitigation strategies. Numerous authors point out that overall risk can be significantly reduced through diversification (Paut et al., 2019) and that the efficiency of diversification strategies efficiency can be measured as risk reduction movement through whole farm planning. We present results for a typical mixed farm with a diversified production plan. The paper's goal was to present such a farm's possibilities concerning the current circumstances (production resources) and how much of the normal risks can be further managed through diversification. We were also interested in what would happen if we increased risk management efficiency with GHG emissions of the whole production.

Literature suggests that diversification of production plans can benefit economic indicators and improve risk management. Based on the results, we can conclude that the diversification strategy has a positive potential even in a mixed type of farm. The farm could achieve much better financial results and, above all, higher efficiency in risk management. If the farm can change the production plan and increase (slightly) its infrastructural potential, the results could indicate that it could increase the EGM by 10% with more or less the same level of risk. On the other hand, if the farmer is willing to take a higher risk, the farm's EGM could increase by up to 18%, based on the current situation. We can see that the environmental indicators (GHG emissions) vary depending on the scenario for livestock production. The highest EGM (scenario C) is associated with the highest environmental impact, 151632 kg CO_2 eq. (17% more than the baseline scenario). However, GHG/EGM ratio results show no distinction as both are at 3,12. Scenario B has the lowest environmental impact of keeping livestock on a typical farm, at 119395 (7% less than baseline). A farm's emissions and environmental impact can also be reduced by increasing the efficiency of livestock production (expected intensity of milk yield and cattle for fattening), but this was outside the scope of this paper. The results show that a little flexibility in management (possible expansion of the production plan on the farm), which would also mean that the

farmer has to make an effort and find an additional market (eggs, pig meat, and goat meat), he can significantly improve the efficiency of risk management. Results were presented for one typical mixed farm. In the future, similar work is to be done on other typical farms so that we will have a complete picture of the environmental indicators that individual farms produce and how risk can be mitigated in the context of improving environmental indicators on a farm in agriculture as a whole.

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Conflict and Corporate Social Responsibility in Duopoly

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Abstract

Background: Recent scientific research explains corporate social responsibility as an economic activity. This paper interprets social responsibility as a means of power to increase firms' market share in a duopoly. **Objectives:** This paper analyses the duopoly model in which firms decide on optimal social investments and production in two phases. The basic research question is how the significance of the conflict affects social investments, market shares, production quantities, profits, and social welfare. **Methods / Approach:** Conflict technology is described by contest success functions determining market shares. Game theory, optimization, and comparative statics are used in the analysis. **Results:** The conditions of equilibrium existence and its characteristics are described. Conflict adversely affects the profit of the inefficient firm while it favourably affects social welfare. Conflict's impact on an efficient firm's profit depends on the marginal cost difference. **Conclusions:** If there is no significant cost difference, it is more favourable for firms not to invest in socially responsible activities by agreement, which hurts social welfare. When marginal cost difference is significant, corporate social responsibility increases an efficient firm's profit, positively impacting social welfare.

Keywords: conflict, corporate social responsibility, contest success functions, mass effect parameter, game theory
JEL classification: D43, C72
Paper type: Research article

Received: Feb 2, 2022
Accepted: Sep 7, 2022

Citation: Vrankić, I. (2022), "Conflict and Corporate Social Responsibility in Duopoly", Business Systems Research, Vol. 13 No. 3, pp. 36-46.
DOI: https://doi.org/10.2478/bsrj-2022-0023

Introduction

Corporate social responsibility has social, environmental, and economic effects. Previously, it was thought that social responsibility resulted from altruism or social pressure, and modern scientific research views corporate social responsibility as an economic activity. Thus, in addition to consumer goods, companies also offer social goods for which there is a demand (Kaul et al., 2018). Social responsibility can be modelled so that firms maximize the sum of profit and part of consumer surplus (Fanti et al., 2017a, 2017b, 2018). This approach to corporate social responsibility modelling is dominant in the recent scientific literature and is followed by Planer-Friedrich et al. (2020, 2021).

In this paper, the problem of corporate social responsibility is approached from a different perspective. The company invests significant resources in socially responsible activities to encourage consumers to buy its products. Such activities include environmental action, donations of material resources, and the promotion of nature conservation awareness. In this way, companies strengthen their market position. This paper's basic idea is that companies' socially responsible activities are modelled as costs that companies make to increase their market share in conflict with other companies. The costs of socially responsible activities are measurable and visible in the company's financial reports. Hirshleifer (1989, 1991) describes the economic foundations of conflict theory. This paper analyses equilibrium in a duopoly when corporate social responsibility affects the firms' market shares. Production technology is described by the firm's costs, while conflict technology is summarised in the contest success functions. The analysis uses game theory, optimization, and comparative static methods.

The basic research question is how the importance of conflict and economic efficiency of the firm affects the firm's profits, investments in socially responsible activities, market shares, production quantities, and social welfare. Firms make decisions in two phases. In the first phase, they simultaneously decide on socially responsible investments, and conflict technology determines market shares. In the second phase, each firm decides on the production quantity that depends on the marginal costs and market share. The firm aims to maximize profit, and the model is solved by backward induction. Special research questions are under what conditions equilibrium exists in the duopoly of socially responsible firms and its characteristics. Equilibrium features include answers to questions about how increasing the importance of conflict for market sharing affects investments in socially responsible activities, market shares, production, firm profits, and social welfare.

The purpose of this paper is to analyze the duopoly model in which socially responsible firms compete for market shares. This paper explains in a new way the economic motives of socially responsible behaviour of firms that act selfishly and maximize their profits. This model is not known in the literature and combines the theory of corporate social responsibility and conflict theory. In this way, a theoretical framework is proposed to analyze corporate social responsibility as a means of power to increase the firm's market share.

After the introduction, the paper provides an overview of the literature that includes recent models of corporate social responsibility and the most important research on conflict theory; in the following chapter, the model of the duopoly in which firms make decisions on optimal investments in socially responsible activities and the optimal amount of production in two phases is presented. The model is solved by the backward induction method. The analysis of the results examines how the change in the significance of the conflict affects investments in socially responsible activities, market shares, production quantities, and the firm's profits. The special focus is on

analyzing the impact of conflict and the efficiency of technology on social welfare. Then follows a discussion and conclusion that answers the research questions, describes the model's limitations, and makes suggestions for future research.

Literature review

Recent economic literature explains corporate social responsibility in a variety of ways. A comprehensive review of the theoretical and empirical literature on corporate social responsibility is provided by Schmitz et al. (2015). Lundgren (2011) complements the microeconomic analysis of corporate social responsibility with a comparative static analysis and dynamics of the parameterized model and connects the derived results with empirical findings. Xu (2014) analyses the duopoly of hospitals competing for price and quality. The model is an extension of Hotelling's model of duopoly (Hotelling, 1929). In the first phase, hospitals determine the level of quality, and in the second phase, they determine prices simultaneously. Scenarios with and without social responsibility are compared. It is shown that the duopoly of a public and private hospital can be more efficient than the duopoly of two private hospitals. Xie et al. (2015) analyze corporate social responsibility by applying evolutionary game theory. Kaul et al. (2018) model the social and consumer goods market. In the social goods market, a company competes with a non-profit organization and shows how corporate social responsibility affects shareholders and social welfare. Fanti et al. (2017b) analyze the problem of corporate social responsibility in a duopoly with differentiated products and show that the equilibrium depends on the level of product differentiation and the degree of corporate social responsibility. The degree of corporate social responsibility describes the share of consumer surplus, and the socially responsible firm maximizes the profit and part of consumer surplus. The backward induction method can show how business owners determine the degree of social responsibility in an unionized duopoly with a homogeneous product and how the union determines wages (Fanti et al., 2019). The same authors using game theory show how socially responsible businesses can be a barrier to entering the industry (Fanti et al., 2017a). Planer-Friedrich et al. (2020) analyze the oligopoly in a similar theoretical framework and show how corporate social responsibility can increase market concentration. By this approach, they show that in the asymmetric Cournot duopoly model, a more efficient company chooses a higher degree of social responsibility, produces more, and makes a higher profit. When the cost difference is significant, the less efficient firm leaves the industry (Planer-Friedrich et al., 2021).

The approach to corporate social responsibility, which is based on the inclusion of part of the consumer surplus in the goal function of the firm, does not explain the firm's significant investments in socially responsible activities. Since investments in socially responsible activities of firms seek to attract customers and strengthen their market position, in this paper, the market shares of individual firms are described by conflict technology. Relative success in conflict is described by contest success functions (Hirshleifer, 1989, 1991), which represent the probability of success or a proportional share of the prize for which the subjects compete. Since the relative success depends on the funds invested in the conflict, the models based on quotient and difference differ. The mass effect parameter describes the significance of the conflict. Hirshleifer (1989) shows how the significance of conflict affects the shape of the contest success function in different models. It is usually assumed in the economic literature that economic activities are consumption, production, and exchange of goods. It is unjustifiably neglected that economic entities invest significant funds to strengthen their position concerning others. Hirshleifer (1991) describes the equilibrium of two rivals when the resources at their disposal can be invested in joint production or conflict

activity. This model explains the paradox of power according to which conflict is relatively more attractive to the poorer side. Experiments testing the theoretical results of an analytical model of power are explained by Durham et al. (1998).

Model

The market demand curve is assumed to be linear, $p = a - by$, where p is the price of the product, $y \in \left[0, \frac{a}{b}\right]$ refers to the demanded quantity, and a and b are positive real numbers. There are two firms in the market, p_i and y_i are price and quantity determined by the firm i and $c_i \in [0, a)$ are constant marginal costs of the firms, $i = 1,2$. The demanded quantity can be expressed depending on the price $y = \frac{a-p}{b}$. Firm's market shares ϑ_i are determined by contest success functions

$$\vartheta_i = \frac{s_i^m}{s_1^m + s_2^m}, i = 1,2, \quad (1)$$

where $s_i \geq 0$ are investments in socially responsible activities of the firm i, and $m > 0$ is the mass effect parameter. If firms do not invest in socially responsible activities, it is assumed that it is $\vartheta_1 = \vartheta_2 = \frac{1}{2}$. Therefore, firm i faces a demand curve

$$y_i = \vartheta_i \frac{a-p_i}{b} \text{ or } p_i = a - \frac{b}{\vartheta_i} y_i.$$

The profit of firm i is given by:

$$\pi_i = (p_i - c_i)y_i - s_i = \left(a - \frac{b}{\vartheta_i} y_i - c_i\right) y_i - s_i, i = 1,2. \quad (2)$$

In the first step, firms decide on optimal investments in socially responsible activities. They decide on the optimal quantity to maximize profits in the second step. The model is solved by the backward induction method. From

$$\frac{\partial \pi_i}{\partial y_i} = a - c_i - \frac{2b}{\vartheta_i} y_i = 0$$

follows

$$y_i = \frac{\vartheta_i (a-c_i)}{2b}. \quad (3)$$

It implies

$$p_i = \frac{a+c_i}{2} \text{ and } p_i - c_i = \frac{a-c_i}{2}. \quad (4)$$

Therefore, the profit of firm i is

$$\pi_i = \frac{a-c_i}{2} \frac{\vartheta_i (a-c_i)}{2b} - s_i = \frac{(a-c_i)^2}{4b} \vartheta_i - s_i. \quad (5)$$

$R_1(s_1) = \frac{(a-c_1)^2}{4b} \vartheta_1$ can be interpreted as income from socially responsible investments, and firm 1 chooses the optimal s_1 which for given s_2 maximizes profit. From the necessary condition for an interior solution $\frac{\partial \pi_1}{\partial s_1} = 0$ equality between marginal revenue and unit marginal cost of socially responsible investments is obtained

$$\frac{\partial R_1}{\partial s_1} = \frac{(a-c_1)^2}{4b} \frac{\partial \vartheta_1}{\partial s_1} = \frac{(a-c_1)^2}{4b} \frac{m s_1^{m-1} s_2^m}{(s_1^m + s_2^m)^2} = 1.$$

It is analogous to firm 2, and a system of equations describes Nash Equilibrium

$$4b(s_1^m + s_2^m)^2 = m(a - c_1)^2 s_1^{m-1} s_2^m,$$

$$4b(s_1^m + s_2^m)^2 = m(a - c_2)^2 s_1^m s_2^{m-1} \quad (6)$$

and non-negative conditions of profits $\pi_1 \geq 0$ i $\pi_2 \geq 0$. By dividing, it is obtained:

$$\left(\frac{a-c_1}{a-c_2}\right)^2 \frac{s_2}{s_1} = 1$$

and system (6) is solved by the substitution method. The following results are obtained

$$s_1 = \frac{m(a-c_1)^2}{4b} \frac{(a-c_1)^{2m}(a-c_2)^{2m}}{[(a-c_1)^{2m}+(a-c_2)^{2m}]^2} \quad (7)$$

$$\vartheta_1 = \frac{(a-c_1)^{2m}}{(a-c_1)^{2m}+(a-c_2)^{2m}} \quad (8)$$

$$\frac{(a-c_1)^{2m+1}}{2b[(a-c_1)^{2m}+(a-c_2)^{2m}]} \quad (9)$$

$$\pi_1 = \frac{(a-c_1)^{2m+2}[(a-c_1)^{2m}+(1-m)(a-c_2)^{2m}]}{4b[(a-c_1)^{2m}+(a-c_2)^{2m}]^2} \quad (10)$$

Analogous results are obtained for firm 2. Suppose $m \leq 1$ the conditions of non-negative profits are met. For $m > 1$, it is:

$$\pi_1 \geq 0 \Leftrightarrow (a - c_1)^{2m} \geq (m - 1)(a - c_2)^{2m} \Leftrightarrow \frac{a - c_1}{a - c_2} \geq (m - 1)^{\frac{1}{2m}}$$

and

$$\pi_2 \geq 0 \Leftrightarrow \frac{a-c_2}{a-c_1} \geq (m - 1)^{\frac{1}{2m}} \Leftrightarrow \frac{a-c_1}{a-c_2} \leq (m - 1)^{-\frac{1}{2m}}.$$

Therefore for $m > 1$, the profits of both companies are non-negative if and only if

$$(m - 1)^{\frac{1}{2m}} \leq \frac{a-c_1}{a-c_2} \leq (m - 1)^{-\frac{1}{2m}}. \quad (11)$$

It follows from inequality (11) that necessarily $m \leq 2$. If mass effect parameter $m > 2$, then Nash equilibrium does not exist.

Results

Previously calculated results can be presented in a simpler form after normalization $a = b = 1, c_1 = 0$ i $c_2 = c$, where without loss of the generality, it is assumed that firm 1 may potentially have lower costs. Then the description of Nash equilibrium for firm 1 is:

$$s_1 = \frac{m}{4} \frac{(1-c)^{2m}}{[1+(1-c)^{2m}]^2} \quad (12)$$

$$\vartheta_1 = \frac{1}{1+(1-c)^{2m}} \quad (13)$$

$$y_1 = \frac{1}{2[1+(1-c)^{2m}]} \tag{14}$$

$$\pi_1 = \frac{1+(1-m)(1-c)^{2m}}{4[1+(1-c)^{2m}]^2} \tag{15}$$

For firm 2 is:

$$s_2 = \frac{m(1-c)^2}{4}\frac{(1-c)^{2m}}{[1+(1-c)^{2m}]^2} \tag{16}$$

$$\vartheta_2 = \frac{(1-c)^{2m}}{1+(1-c)^{2m}} \tag{17}$$

$$y_2 = \frac{(1-c)^{2m+1}}{2[1+(1-c)^{2m}]} \tag{18}$$

$$\pi_2 = \frac{(1-c)^{2m+2}[(1-c)^{2m}+1-m]}{4[1+(1-c)^{2m}]^2} \tag{19}$$

It is important to note that the original results can be reconstructed from the normalized results if it is taken into account that it is $c = \frac{c_2-c_1}{a-c_1}$ whereby normalized y_i is multiplied by $\frac{a-c_1}{b}$, and normalized s_i and π_i are multiplied by $\frac{(a-c_1)^2}{b}$, $i = 1,2$. Given that it is for $m \in (1,2]$ satisfied $(m-1)^{\frac{1}{2m}} \leq 1 \leq \frac{1}{1-c}$ the condition of non-negativity of profits transforms to $\frac{1}{1-c} \leq (m-1)^{-\frac{1}{2m}}$. This condition can be written in equivalent ways

$$c \leq 1-(m-1)^{\frac{1}{2m}} \tag{20}$$

and

$$m \leq 1+(1-c)^{2m}. \tag{21}$$

The condition of non-negative profits (21) includes the case $m \leq 1$. The more significant the conflict for market sharing, the expression on the right in (20) is smaller, and the Nash equilibrium exists when the difference in firm costs is small enough.
From (15) and (19), it follows

$$\pi_1 - \pi_2 = \frac{1-(1-c)^{4m+2}+(1-m)(1-c)^{2m}[1-(1-c)^2]}{4[1+(1-c)^{2m}]^2}. \tag{22}$$

When there is a cost difference, and $m \leq 1$, the term (22) is positive. For $m > 1$ from the condition of non-negative profits (21), it follows $1-m \geq -(1-c)^{2m}$. Then it is

$$\begin{aligned} 1-(1-c)^{4m+2}+(1-m)(1-c)^{2m}[1-(1-c)^2] \\ \geq 1-(1-c)^{4m+2}-(1-c)^{4m}[1-(1-c)^2] = 1-(1-c)^{4m} > 0 \end{aligned}$$

and again, expression (22) is positive. A more efficient firm invests more in socially responsible activities, has a higher market share, produces more, and makes a higher profit.

When firms do not invest in socially responsible activities, $s_i = 0$ i $\vartheta_i = \frac{1}{2}$ from (3) and (5) follows $\overline{y_i} = \frac{a-c_i}{4b}$ i $\overline{\pi_i} = \frac{(a-c_i)^2}{8b}$, that is, after normalization

$$\overline{y_1} = \frac{1}{4}, \overline{y_2} = \frac{1-c}{4}, \overline{\pi_1} = \frac{1}{8} \text{ i } \overline{\pi_2} = \frac{(1-c)^2}{8}.$$

This relationship of firms in the market can be interpreted as a collusive equilibrium. Putting in (15) and (19) $m = 0$ implies

$$\pi_1(m=0) = \frac{1}{8} = \overline{\pi_1} \text{ and } \pi_2(m=0) = \frac{(1-c)^2}{8} = \overline{\pi_2}.$$

Therefore, collusive equilibrium can be interpreted as a marginal conflict equilibrium when the mass effect parameter *m* converges to zero.

If there is no difference in the efficiency of these firms, then their marginal costs are equal, $c = 0$. It follows from the description of equilibrium that firms divide the market into equal parts. Investments in socially responsible activities are equal, $s_i = \frac{m}{16}$, and each company supplies a quarter of the entire market. The profits of both companies are equal. The more significant the conflict is for market sharing, the greater the mass effect parameter m, and the more firms invest in socially responsible activities to maintain their market shares. Therefore, the conflict reduces the profits of both firms,

$$\pi_i = \frac{2-m}{16} = \frac{1}{8}\left(1 - \frac{m}{2}\right) = \overline{\pi_i}\left(1 - \frac{m}{2}\right).$$

When $c \in (0,1)$ from the equilibrium description, the market share and production of a more efficient firm increase when the mass effect parameter grows, while the market share and production of a less efficient company decrease. From (15) and (19) by derivation follows

$$\frac{\partial \pi_1}{\partial m} = \frac{(1-c)^{2m} V}{4[1+(1-c)^{2m}]^3}$$

where is $V = -2[\ln(1-c)] * [1 + m + (1-m)(1-c)^{2m}] - [1 + (1-c)^{2m}]$ (23)

and $$\frac{\partial \pi_2}{\partial m} = \frac{(1-c)^{2m+2} Z}{4[1+(1-c)^{2m}]^3},$$

where is $Z = 2[\ln(1-c)] * \{1 + (1-c)^{2m} - m[1-(1-c)^{2m}]\} - [1 + (1-c)^{2m}]$ (24)

As $m[1-(1-c)^{2m}] < m \leq 1 + (1-c)^{2m}$ due to the non-negative condition of profit (21), the expression in curly braces in (24) is positive and $Z < 0$. Therefore $\frac{\partial \pi_2}{\partial m} < 0$, and the conflict is economically unfavourable for the less efficient firm 2. The profit of firm 2 is smaller the more significant the conflict is. Term (23) can take on both signs, and for a more efficient company 1 conflict can be economically unfavourable

$$\pi_1\left(m = 1, c = \frac{1}{4}\right) = \frac{64}{625} < \frac{1}{8} = \pi_1\left(m = 0, c = \frac{1}{4}\right),$$

$$\pi_2\left(m = 1, c = \frac{1}{4}\right) = \frac{729}{40000} < \frac{9}{128} = \pi_2\left(m = 0, c = \frac{1}{4}\right),$$

or economically favourable

$$\pi_1\left(m = 1, c = \frac{1}{2}\right) = \frac{4}{25} > \frac{1}{8} = \pi_1\left(m = 0, c = \frac{1}{2}\right),$$
$$\pi_2\left(m = 1, c = \frac{1}{2}\right) = \frac{1}{400} < \frac{1}{32} = \pi_2\left(m = 0, c = \frac{1}{2}\right).$$

Conflict affects a more efficient company depending on the cost difference and the mass effect parameter. This numerical example shows that conflict attracts a more efficient company only when the cost difference is large enough. It is confirmed that the conflict is economically unfavourable for a less efficient company 2, regardless of the cost difference.

The social welfare function is the sum of companies' profits, investments in socially responsible activities, and consumer surplus. The consumer surplus from buying the product from the firm i is

$$CS_i = \int_0^{y_i}\left(a - \frac{b}{\vartheta_i}y_i\right)dy_i - p_i y_i = \frac{1}{4}(a - c_i)y_i = \frac{(a-c_i)^{2m+2}}{8b[(a-c_1)^{2m}+(a-c_2)^{2m}]}.$$

Total consumer surplus is:

$$CS = CS_1 + CS_2 = \frac{(a-c_1)^{2m+2}+(a-c_2)^{2m+2}}{8b[(a-c_1)^{2m}+(a-c_2)^{2m}]}$$

and the social welfare function is given by:

$$W = \pi_1 + \pi_2 + s_1 + s_2 + CS,$$

$$W = \frac{3\left[(a-c_1)^{2m+2}+(a-c_2)^{2m+2}\right]}{8b[(a-c_1)^{2m}+\ (a-c_2)^{2m}]}.$$

After normalization, it is obtained

$$W = \frac{3\left[1+(1-c)^{2m+2}\right]}{8[1+(1-c)^{2m}]}. \tag{25}$$

If the conflict does not affect market share, follows $W(m=0) = \frac{3\left[1+(1-c)^2\right]}{16}$. The derivation of the social welfare function by the mass effect parameter is positive when there is a difference in the costs of the company,

$$\frac{\partial W}{\partial m} = \frac{3\{(1-c)^{2m}[\ln(1-c)]\left[(1-c)^2-1\right]\}}{4[1+(1-c)^{2m}]^2} > 0.$$

Social welfare function, *W*, is increasing in m, and conflict favourably affects social welfare when there is a difference in company costs. When there is no difference in the efficiency of the firms, $W(c=0) = \frac{3}{8}$ is obtained, and the conflict has no impact on social welfare. Then social welfare is maximal, and higher investments in socially responsible activities compensate for lower company profits. From (25) follows $W(m=1) = \frac{3[1+(1-c)^4]}{8[1+(1-c)^2]}$, and

$$W(m=1, c=0) = 0.375 \geq W(m=1, c=0.4) = 0.311 \leq W(m=1, c=0.9) = 0.371.$$

This numerical example shows that increasing the marginal cost difference can affect social welfare differently. It is interesting to note that increasing the marginal cost of production of a technologically inefficient firm can benefit social welfare.

Discussion

Corporate social responsibility can be a tool for businesses to attract consumers. A firm's market share is described by conflict technology, where firms can have different production costs. The more significant the conflict is for market sharing, the Nash equilibrium exists for the smaller cost difference. Suppose the marginal cost of production is equal. In that case, firms invest equally in socially responsible activities, divide the market into equal parts, have equal profits, and each firm supplies a quarter of the entire market. The more significant the conflict for market sharing, the fewer profits firms make because they invest more in socially responsible activities to maintain their market shares.

When there is a difference in production technology, a firm with lower marginal costs invests more in socially responsible activities, has a larger market share, produces more, and makes a higher profit. As the significance of the market-sharing conflict increases, the market share and production of the more efficient company increase, while the market share, production, and profit of the less efficient company decrease. How a change in the significance of the conflict affects the profit of a more efficient firm depends on the difference in marginal costs. When this difference is large enough, the profit of a more efficient firm increases, and the conflict is economically attractive for the more efficient firm. When the difference in the marginal costs is small, the conflict has an economically unfavourable effect on both firms. In this case, companies should act collusively, divide the market into equal parts and not invest in socially responsible activities.

When there is no difference in the efficiency of the firms, the conflict has no impact on social welfare. Then social welfare is maximal, and higher investments in socially responsible activities compensate for lower company profits. When there is a difference in the efficiency of the firms, the conflict positively affects social welfare. The more significant the conflict for market sharing, the greater the social welfare. An increase in the marginal cost of production of a technologically inefficient firm can benefit social welfare. In this paper, the analysis is limited to a duopoly in which companies make decisions on investments in socially responsible activities simultaneously. In reality, more firms in the industry may make decisions on investments in socially responsible activities sequentially.

Conclusion

This paper's basic idea is to interpret socially responsible businesses as a means of power to increase market share. In this way, a new duopoly model is presented, in which firms decide on optimal investments in socially responsible activities and production in two phases. Contest success functions describe market shares. In contrast, the mass effect parameter describes the importance of conflict for market sharing, and the model is solved by the backward induction method. This approach combines socially responsible business and conflict theory. Suppose there is no significant difference in production technology. In that case, it is more favourable for firms not to invest in socially responsible activities by agreement, negatively affecting social welfare. When the marginal cost difference is significant, corporate social responsibility is a means of power to increase the profit of an efficient firm, which reduces the profit of an inefficient firm and positively affects social welfare.

This model assumes that two companies are operating in the market and that decisions on investments in socially responsible activities are made simultaneously. Future research includes an analysis of corporate social responsibility in the oligopoly and the possibility of sequential decision-making.

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Migration Flows through the Lens of Human Resource Ageing

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Abstract

Background: Ageing and shrinking of the European population influence the shrinking of central places and the hinterland of cities in a spatial structure. Migration also influences the shrinking or growing of spatial units. Various factors influence migration and, thus, spatial units' demographic, social and economic stability. The age structure of citizens in a spatial unit may change not only due to population ageing but also because these factors influence the migration flows of different cohorts differently, which has not been studied so far. **Objectives:** We used data on internal migration between Slovenian municipalities in 2018 and 2019 to develop a cohort-based spatial interaction model to estimate future inter-municipal migration. **Approach:** In a spatial interaction model, we analyzed differences in the attractiveness and stickiness of municipalities for different cohorts, focusing on those over 65 who may wish to prolong their working status. We also tried to answer the question of how to mitigate shrinkage processes in spatial units by investigating the potential to contribute to the social value of communities. **Results:** The study's results show that the 65+ cohorts do not have the same preferences regarding the attractiveness and stickiness factors as younger migrants. **Conclusions:** The results of our study could contribute to better decisions at the national, regional, and/or local level when designing strategies for regional, urban, and/or rural development, exploring the best solutions for long-term care, and investing in appropriate networks, or considering the revitalization of rural municipalities.

Keywords: attractiveness, stickiness, ageing, gerontology, social value, migration, gravity model, shrinking regions, human resources

JEL classification: A13; C10; J11; J26
Paper type: Research article

Received: 30 Dec 2021
Accepted: 16 Oct 2022

Citation: Drobne, S., Bogataj, M. (2022), "Migration Flows through the Lens of Human Resource Ageing", Business Systems Research, Vol. 13 No. 3, pp. 47-62.
DOI: https://doi.org/10.2478/bsrj-2022-0024

Introduction

Ageing Europe and shrinking regions

European cities and regions are depopulating (ESPON, 2017). The change in population density in regions is not only an important issue in terms of land consumption, the environment, and related health problems but also has an impact on the economy, as shrinking areas have fewer human resources and consume less production output, which also brings the challenge of creating social value from the activities in a region. Therefore, it also influences changes in urban and regional planning. The decline in residential density in cities is often seen as a consequence of urban sprawl as part of urbanization. However, if we look at the whole region in which an urban area occupies its central place, we see that urban shrinkage is not only the result of urban sprawl and that, in many cases, as the city shrinks, the whole region shrinks.

ESPON (2017) confirmed the thesis of Angel et al. (2010) that shrinkage dynamics are lower for larger cities (> 100,000 residents) than for small and medium-sized cities. Older studies have shown that urban sprawl is closely related to increasing land consumption per capita, i.e., higher spatial standards driven by GDP and income growth (Patacchini and Zenou, 2009), which are assumed to increase more than land prices (Angel et al., 2011). But urban sprawl is not the only case where urban areas are shrinking. The industrial transition to I4.0 and I5.0, lower fertility, and ageing human resources are also changing demographic trends (Bogataj et al., 2019a, 2019b, 2020a, 2020b; Calzavara et al., 2020). The relative number of shrinking Local Administrative Units at the LAU2 level in the EU Member States and other European Economic Area (EEA) countries over the period 2001–2011 is shown in Figure 1.

From Figure 1, we can conclude that there are nearly 41% (thirteen of the thirty-two) EU and other EEA countries where more than 40% of urban LAUs are shrinking in population, 25% (eight of the thirty-two) countries where 40% and more of medium LAUs are shrinking in demographic data. There are more than 62% (twenty of the thirty-two) EU and other EEA countries where 40% and more of rural areas are losing population. From Figure 1, we can see that the percentage of depopulated LAUs is increasing from west to east. The detailed data is aslo presented in Table 1.

In the journals indexed by the Web of Science, the keyword "shrinking city" is relatively new and was first mentioned in 2005. In the first decade of this millennium, there were only six articles with this keyword; in the second decade, another 159. The authors focus more on the renewal of industrial areas and the increase in residential areas, which is developing much faster than the demographic dynamics (Rienow et al., 2014). As pointed out in these articles, the trend towards lower population density for small, medium, and larger urban LAUs is noteworthy, considering that urban sprawl and the expansion of low-density settlements are costly for municipalities to provide public transport and other services, including care for the elderly, to affect the increase of the carbon footprint and to develop more and more land and other natural resources (Nuissl et al., 2009; Wolff et al., 2018). Wolff et al. (ibid.) also pointed out that the population has been shrinking faster in the last two decades in the post-socialist countries of Eastern Europe and the post-industrial states of Western Europe due to falling birth rates and negative net immigration, while ageing is expected to continue in the coming decades in both East and West (European Commission, 2020, 2021).

Figure 1
The relative number of shrinking Local Administrative Units on LAU 2 level in European countries (EU) and other European Economic Area (EEA) countries, 2001–2011.

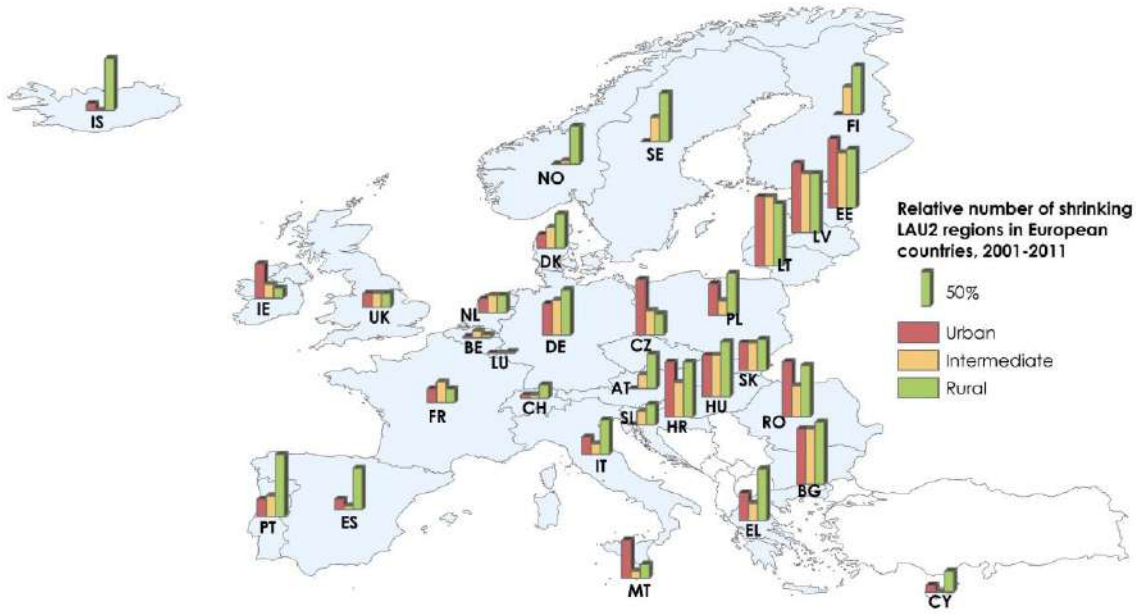


Table 1
Classification of Local Administrative Units on LAU 2 level in European countries (EU) and other European Economic Area (EEA) countries, 2001–2011

Classification	Under 20%	[20%–40%)	[40%–60%)	[60%–80%)	[80%–100%]
Urban	FI, SE, NO, AT, SI, CY, CH, BE, LU, LI IS, ES, NL	EL, PT, DK, IT, UK, FR	HU, DE, PL, SK, MT, IE	BG, RO	HR, LT, EE, LV, CZ
Number	13	6	6	2	5
%	40.6	18.8	18.8	6.3	15.6
Intermediate	IS, ES, NO, CY, CH, BE, LU, LI, IT, MT	EL, FI, PT, SE, AT, DK, SK, CZ, SI, NL, UK, FR, IE, PL	HR, RO, DE	BG, HU,	LT, EE, LV
Number	10	14	3	2	3
%	31.3	34.7	9.4	6.2	9.4
Rural	BE, LU, LI, IE	MT, CZ, SI, CY, NL, UK, FR, CH	PL, ES, NO, AT, DK, SK, IT	RO, EL, FI, DE, IS, SE	LT, EE, BG, LV, HU, HR, PT
Number	4	8	7	6	7
%	12.5	25	21.9	18.7	21.9

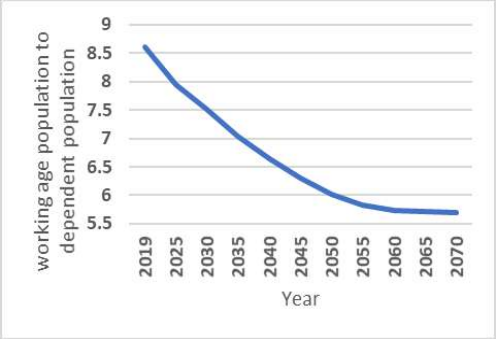
Source: Authors' calculation, ESPON (2017), Eurostat (2020b).

According to the baseline (BSL) of the EU population projection, the number of people in employment in Europe will fall from more than 288 million to 242 million - or even below 200 million if the no migration scenario is adopted - over the next 40 years; see Figure 2b. But it is not only the working population that is shrinking; other cohorts are shrinking too. Urban Audit - a European database for the comparative analysis of EU cities (Eurostat, 2020b) - shows that between 1996 and 2001, we lost 57% of the population of 220 large and medium-sized European cities. In addition to the almost 81% of cities in Central and Eastern European countries, many German, Italian and Spanish cities, among others, are also on the list of shrinking cities. Moreover, this

dynamic has increased in the second decade of the 21st century. As Wiechmann and Pallagst (2012) noted, urban shrinkage was, for years, considered a phenomenon of suburbanization. But as already mentioned, this phenomenon should not be seen primarily as a consequence of suburbanization.

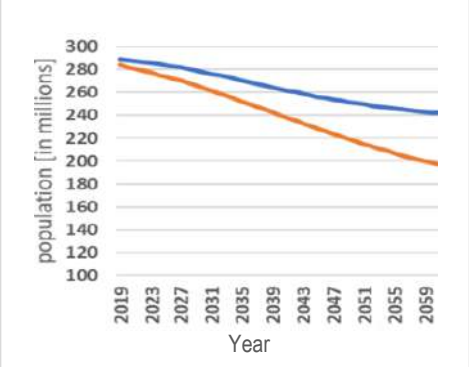
This shrinking city and region phenomenon should be analyzed in a wider spatial scope that considers migration between regions and countries and between central places and their surrounding areas. The basic idea of our approach is thus that we should look at the total number of municipalities in the analyzed area when we examine the shrinkage of their central places (see Figure 1, which shows the shrinkage of LAU2 regions, i.e., municipalities in %). As a result of the shrinkage of urban and rural areas, the EU should also consider the population outside the Schengen borders; otherwise, the difference between the blue and the orange line in Figure 2b could look like it does. The ratio between the working-age population and the dependent population in the EU is shown in Figure 2a. Figure 2b shows the projected working-age population in the EU according to two scenarios.

Figure 2a
Projection of the ratio between the working-age and cared-for populations in the EU.



Baseline scenario:
Source: Eurostat (2020a)

Figure 2b
EU Projection of the working-age population.



No Migration Scenario:
Base Line Scenario:
Source: Eurostat (2020a)

The law of spatial gravity

To consider how to curb the shrinkage of LAUs, the methodology of our research relies on the gravitational modelling approach. Initial attempts to understand regularities and patterns of spatial population flows began with the observation that this flow of people between central places and the hinterland, and at a higher level of spatial units, is analogous to the gravitational attraction between solid bodies. More migrants move between larger urban areas than smaller rural settlements. This movement is more intense between areas closer together than between areas further apart, ceteris paribus, which led to a simple mathematical model for predicting migration flows based on Newton's gravitational approach. Based on this idea, Wilson (1967, 1969) derived the family of spatial interaction formulae from entropy maximizing principles, followed by many studies.

The law of social gravity is widely applicable in population migration and commuting. However, this simple law is still being studied in many other and more complex social systems. Recently, for example, Wang et al. (2021) presented a model of free utility that helps us understand the spatial interaction patterns in complex social

systems and provides a new perspective for understanding the potential function also from the perspective of spatial games where regions compete for human resources and other inhabitants. The fact is that cities and settlements increasingly have to compete for new immigrants, new human resources, and consumers of their services. Therefore, they also try to retain the old population to whom they offer services and care and expand their silver economy. Residents are looking for prospects in the municipalities they want to move to, and municipalities can compete for them to avoid unwanted shrinkage. Among the values of factors as decision variables that influence attractiveness and stickiness, the level of wages and taxes, the availability and cost of housing units, amenities, and other social infrastructure are often cited as factors that make communities more attractive (Janež et al., 2016; et al., 2019b). But recently, these have not been the most important factors in Slovenia.

Our study focuses on town centres and their retail cores to understand their role as places of consumption and employment and their ability to attract residents to come and stay in their LAU2 (community) area. As the proportion of older adults is rapidly increasing, we should consider the potential multiple roles of older people in revitalizing and rejuvenating town centres and their surrounding areas, as places are central to health and safe living for all generations (Phillips et al., 2021). Age-friendly cities as community environments also for older adults is a concept often used in gerontological studies and strategies to describe the extent to which cities and their centres, as well as their surroundings, are suitable places to grow old, i.e., 'ageing in place. The findings are increasingly stimulating debate about the silver economy of a city or region. Our research assumes that more care and investment in housing and public spaces are needed to support community and social participation for 'ageing in place, as social and environmental gerontology puts it, and that the social value of such a focus on the silver economy also needs to be assessed (Rogelj and Bogataj, 2018a, 2018b, 2020a, 2020b). For these purposes, we need to distinguish between the needs of younger and older cohorts.

Objective

We should introduce the methods to study the attractiveness and stickiness of municipalities and evaluate the strong enough factors to attract residents of different ages to the shrinking areas to achieve the desired population dynamics. It is particularly important to study the factors that significantly influence the flows of missing human resources.

The fact is that cities and other settlements are increasingly competing for new immigrants from other regions of EU countries. They must try to retain old residents and their tax revenues to invest in these municipalities' social infrastructure to increase their social value areas. While municipalities compete for the younger cohorts with better jobs and schools, better health and social services are key influencing factors for the older ones. Since these factors vary in strength for different cohorts, we should examine each separately and consider their interrelationships. This is not the case in the long list of articles dealing with the law of social gravity in academic journals. It is advisable to examine these flows and make a comparative analysis. For this purpose, we will use the same model of socio-economic gravity separately for different cohorts.

Further, since the attractiveness and stickiness factors have different values for different cohorts, we wanted to study and compare the migration flows of the three main resident cohorts separately, which is also not the case in the long list of articles dealing with the law of social gravity in academic journals. In this study, we will use inter-municipal internal migration data in Slovenia for 2018-2019 to develop a cohort-based spatial interaction model to estimate future migration between municipalities

and consider policies to change trends by introducing public investment, wage, housing, and tax policies (Janež et al., 2016) and new education programs at the required levels (Grah et al., 2019, 2021; Colnar et al., 2019, 2020). To this end, it is recommended to use one of the social gravity models based on previous research findings as described in Drobne (2014), Drobne and Bogataj (2014), and Bogataj et al. (2019b), as well as in some other papers of this research group.

The spatial interaction models work empirically quite well. Many authors (Fotheringham and O'Kelly, 1989; Sen and Smith, 1995; etc.) have shown that they provide reasonable conclusions about the spatial behaviour of commuting or migration flows. They have been developed to provide a generally accepted theoretical derivation of spatial interactions and bases for local, regional, or national decision-making. Thus, by studying the variation of factors affecting migration intensity, we can find measures to mitigate the depopulation of regions and cities, which is our main objective.

In this paper, we specifically address the following research questions: How can municipal revenues, which are largely invested in the social infrastructure of the municipality, retain and/or attract human resources across different cohorts?

Methodology

The extended spatial interaction model

We study the gravitational characteristics, attractiveness, and stickiness of Slovenian municipalities separately, based on the general spatial interaction model (SIM) previously developed by Cesario (1973, 1974) and later extended by many authors, e.g., Drobne and Bogataj (2014), Drobne et al. (2019). The model is extended to include economic, housing, ageing, and municipal revenue factors, mainly used to finance social infrastructure. These factors influence the flow of three cohorts: residents under 65, between 65 and 74, and the 75+ cohort. The model helps us to answer the question of how to evaluate the influence of these factors on the shrinkage of LAU2 regions. Finally, the measures that need to be taken to achieve population sustainability in LAU2 regions are presented.

As suggested by Drobne (2014), we have introduced the normalized spatial interaction model, NSIM, (1) to estimate the influence of the factors analyzed:

$$M_{ij}^{(t)} = k\, K(d_{ij})^{\beta} \prod_r K(r)_i^{\gamma(r)}\, K(r)_j^{\alpha(r)}, \qquad (1)$$

where $M_{ij}^{(t)}$ is the number of migrants in age cohort t from an origin municipality i to a destination municipality j; the age cohorts are defined as follows: t = 0–65, 66–74, 75+ is the cohort of *t-year*-old residents; k is the constant of proportionality; $K(d_{ij})$ is the coefficient of the fastest time distance over the state road network between the centre of origin municipality i and the centre of destination municipality j; $K(r)_i$ and $K(r)_j$ are coefficients of factors r in origin municipality i and destination municipality j, respectively, defined as the value of the factor in municipality i and municipality j, divided by the average value of this factor in Slovenia, as explained in Table 2; β, $\gamma(r)$ and $\alpha(r)$ are regression coefficients defined in the regression analysis.

Table 2
Migration and factors are analyzed in the normalized spatial interaction model (definitions, descriptions, and sources).

Notation	Definition	Description	Source
$M_{ij}^{(t)}$	The number of migrants of age cohort t from the municipality of origin i to the municipality of destination j.	The number of migrants of age cohort t for 2018 and 2019.	SORS (2021a)
$K(d_{ij})$	Coefficient of the fastest time-spending distance between the origin municipal centre i and the destination municipal centre j.	The ratio between the time distance for a pair of municipal centres i and j and the average time distance for all pairs of municipal centres in Slovenia for the year 2019.	SIA (2021) and authors' calculation
$K(POP_{\circ})$	Coefficient of the number of residents of the municipality.	The ratio of the number of residents in the municipality to the average factor value for Slovenia for the year 2019.	SORS (2021b) and authors' calculation
$K(UEMP_{\circ})$	Coefficient of registered unemployment rate in the municipality.	The municipality's unemployment ratio to the average factor value for Slovenia for the year 2019.	SORS (2021c) and authors' calculation
$K(GEAR_{\circ})$	Coefficient of gross earnings per capita in the municipality.	The municipality's gross earnings per capita ratio to the average factor value for Slovenia for the year 2019.	SORS (2021d) and authors' calculation
$K(NDWE_{\circ})$	Coefficient of the number of dwellings per number of residents in the municipality.	The ratio of the number of dwellings per number of residents in the municipality to the average factor value for Slovenia for 2018.	SORS (2021e) and authors' calculation
$K(PDM2_{\circ})$	Coefficient of the average price per m^2 of the dwelling in the municipality.	The ratio of the average price per m^2 of the dwelling in the municipality to the average factor value for Slovenia for the years 2018 and 2019.	SMARS (2021) and authors' calculation
$K(MREV_{\circ})$	Coefficient of the municipal revenue per capita.	The municipal revenue per capita ratio to the average factor value for Slovenia for the year 2019.	MFRS (2021) and authors' calculation
$K(AGEI_{\circ})$	Coefficient of the ageing index of the municipality.	The ratio of the ageing index of the municipality to the average factor value for Slovenia for the year 2019.	SORS (2021f) and authors' calculation
$K(HELD_{\circ})$	Coefficient of the capacity of older people's homes in the municipality.	The ratio between the capacity of nursing homes in the municipality and the average factor value for Slovenia for 2019.	Breznik et al. (2019) and the authors' calculation

Source: Author's elaboration.
Note: $\circ$ *denotes the separate consideration of the variable in the municipality of origin* i *and the municipality of destination* j.

Considering the factors analyzed in the NSIM for three cohorts of migrants, model (1) can be formulated in detail as in (2).

$$M_{ij}^{(t)} = k\,K(d_{ij})^{\beta} K(POP)_i^{\gamma(POP)} K(POP)_j^{\alpha(POP)} K(GUEMP)_i^{\gamma(UEMP)} K(UEMP)_j^{\alpha(UEMP)} \cdot \\ \cdot K(GEAR)_i^{\gamma(GEAR)} K(GEAR)_j^{\alpha(GEAR)} K(NDWE)_i^{\gamma(NDWE)} K(NDWE)_j^{\alpha(NDWE)} \cdot \\ \cdot K(PDM2)_i^{\gamma(PDM2)} K(PDM2)_j^{\alpha(PDM2)} K(MREV)_i^{\gamma(MREV)} K(MREV)_j^{\alpha(MREV)} \cdot \\ \cdot K(AGEI)_i^{\gamma(AGEI)} K(AGEI)_j^{\alpha(AGEI)} K(HELD)_i^{\gamma(HELD)} K(HELD)_j^{\alpha(HELD)} \quad (2)$$

The notations in model (2) are described in Table 2. Model (2) was linearized and solved by IBM SPSS using ordinary least squares (OLS) regression analysis.

Empirical study

In Slovenia, the migration of residents between LAU2, i.e., municipalities, was studied, and data was collected for 2018 and 2019. The description and sources of the factors can be found in Table 2.

We considered three main cohorts of residents: age cohorts 0-65, 66-74, and 75+ years, wherein the first group (0-65) is employed. In the second group, their children who migrate with their parents are mainly retired but whose retirement age may increase if a new pension system is introduced, and in the 75+ group are retired persons. Many of them also need the help of others due to physical or mental functional impairment. Data on migration between Slovenian municipalities were collected by the Statistical Office of the Republic of Slovenia (SORS, 2021a) based on the Central Population Register. The SORS also provided us with data on the number of residents (SORS, 2021b), the registered unemployment rate (SORS, 2021c), gross earnings per capita (SORS, 2021d), the number of dwellings (SORS, 2021e) and also the ageing index (SORS, 2021f). Data on the delimitation of municipalities were obtained from the Surveying and Mapping Authority of the Republic of Slovenia (SMARS, 2021). Data on the revenues of municipalities that can be invested in social infrastructure, which can increase the attractiveness and social value of these investments, were provided by the Ministry of Finance (MFRS, 2021).

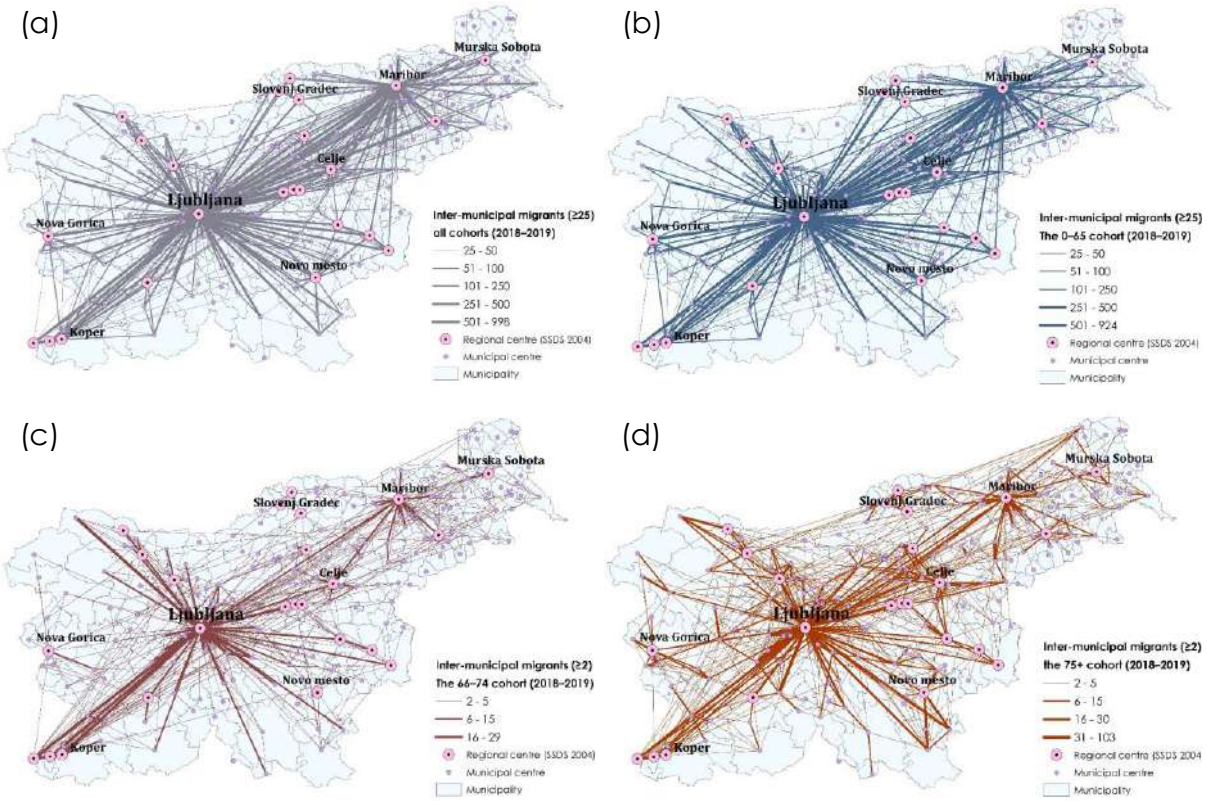
Results

In 2018-2019, 162,222 migrants changed their permanent residence between Slovenian municipalities. Broken by age cohorts, there were 150,670 inter-municipal migrants in the 0-65 cohort, 3951 migrants in the 66-74 cohort, and 7601 migrants in the 75+ cohort. Figure 3 shows the migration interactions for all migrants and the three cohorts analyzed (note that not all interactions are shown for better readability).

The results of the regression analysis can be found in Table 3, which shows the values of the regression coefficients of the linearized models for three age cohorts (0–65, 66–74, and 75+ years) that are significant for the change in migration flows between municipalities in Slovenia for at least one age cohort. Where the p-value is greater than 0.05, the values are in parentheses (detailed statistics are available from the authors upon request).

In the right part of Table 3, we see how the flows change when a factor increases by 10%. Let us take an example to understand the right side of the table. Let us calculate what the net migration would be for municipality j were previously the annual inflow of cohort 0–65, IF(0–65), was 30% less than the outflow, $OF(0-65) = a = 2000, IF(0-65) = 0.7a = 1400$; therefore the net migration for the cohort is negative, $NM(0-65) = IF(0-65) - OF(0-65) = -600$, therefore the municipality shrinks.

Figure 3
Internal migrants between Slovenian municipalities in 2018–2019: (a) all cohorts, (b) the 0–65 cohort, (c) the 66–74 cohort, (d) the 75+ cohort.



Source: Authors' work, SORS (2020), SMARS (2020).
Note: Only flows with 25 or more migrants are shown for all cohorts and the 0–65 cohort, and only two or more migrants for the 66–74 and 75+ cohorts.

The local government plans to invest in social housing to increase the availability of housing units per capita by 10%. How would the new flows - IFN is the new inflow, OFN the new outflow - and the new net migration, NMN, change? From Table 3, we can see the values of the factors for inflows and outflows. Suppose there are 500 residents of the 66-74 cohort in the inflow and 400 residents of this cohort in the outflow, while there are 300 residents in the outflow and 100 residents in the inflow in the 75+ cohort. What is the expected net migration, NMN, in the next two years?

Table 3 shows that the values of the standardized regression coefficients of the linearized model, which assess the strength of the impact of individual factors on migration flows, vary between cohorts. Older people aged 66–74 are more likely to opt for longer migration distances than 75+ ($\beta = -0.475 > -0.56$) and also more likely than the youngest population group (0-65), where $\beta = -0.649$. At the 10% longer time distance, the proportion of those willing to migrate is 6% lower if they belong to the 0–65 cohort, 4.4% lower if they belong to the 66–74 cohort, and 5.2% lower for the oldest population group (75+).

Table 3
Regression coefficients of the linearised model and their statistics for the age cohorts 0–65, 66–74, and 75+ years (inter-municipal migration in Slovenia in 2018–2019).

Regression coefficient	Value of standardized regression coefficient			Expected change of flow intensity in %, if the value of factor increases by 10%		
β	-0.649	-0.475	-0.56	-6.0	-4.4	-5.2
$\gamma(POP)$	0.464	0.401	0.445	4.5	3.9	4.3
$\alpha(POP)$	0.448	0.181	-0.03	4.4	1.7	-0.3
$\gamma\ (UEMP)$	0.016	-0.001	-0.054	0.2	0.0	-0.5
$\alpha(UEMP)$	0.025	0.056	-0.022	0.2	0.5	-0.2
$\gamma\ (GEAR)$	0.057	-0.011	-0.003	0.5	-0.1	0.0
$\alpha(GEAR)$	0.043	-0.026	-0.036	0.4	-0.2	-0.3
$\gamma(NDWE)$	0.13	0.122	0.068	1.2	1.2	0.65
$\alpha(NDWE)$	0.147	0.128	0.06	1.4	1.2	0.57
$\gamma\ (PDM2)$	-0.027	-0.012	(-.027)	-0.3	-0.1	NA
$\alpha(PDM2)$	(-.007)	-0.049	(-.003)	NA	-0.5	NA
$\gamma(MREV)$	0.037	0.054	0.074	0.4	0.5	0.7
$\alpha(MREV)$	0.016	(-.002)	-0.02	0.2	NA	-0.2
$\gamma(AGEI)$	0.029	-0.023	0.086	0.3	-0.2	0.8
$\alpha(AGEI)$	-0.015	-0.017	-0.038	-0.1	-0.2	-0.4
$\gamma\ (HELD)$	-0.015	-0.005	-0.06	-0.1	0.0	-0.6
$\alpha(HELD)$	0.018	0.131	0.282	0.2	1.3	2.7
R	0.786	0.6	0.622			
R^2	0.617	0.36	0.387			
Adjusted R^2	0.617	0.354	0.383			
Standard error	0.776	0.531	0.666			
No. of observations	14,096	1920	2481			
ANOVA stat. F	1336.89	62.84	91.46			
ANOVA p-value	0.0000	0.0000	0.0000			

Source: Authors' work.
Note: γ-factors are for the origin, and α-factors are for the destination.

The size of the municipality influences the out-migration of the 66–74 cohort less than that of the older and/or younger cohorts ($\gamma(POP) = 0.401 < 0.445 < 0.464$ in Table 4). In comparison, the size of the municipality attracts them less than younger cohorts. For those 75 or more, this factor is almost insignificant when choosing a municipality to emigrate to ($\alpha(POP) = -0.03$). It is interesting to see how unemployment affects emigration. While it has a positive effect on out-migration for cohorts 0–65 ($\gamma\ (UEMP) = 0.016$), where young families live, older persons tend to stay in municipalities with higher unemployment, $\gamma(UEMP)$ is even negative. We can also easily explain that the influence of salary level is positive for the youngest cohort, while it is not positive for the older ones. Still, for detailed conclusions, we need to perform the same operations as in Table 4. In the same way, as in Table 4, we can calculate each factor whose values are given in Table 3 and conclude.

Table 4 shows the response in new net migration if the availability of housing units per capita is increased by 10% ($K(NDWE_j) = 1.1$): total net new migration, NMN, will increase by 6.69% over the next two years.

Table 4
A numerical example of the change in the coefficient for the number of dwellings per resident in a municipality, $NDWE_j$

$NDWE_j$	0–65 years		66–74 years		75+ years		
$K(NDWE_j)$=1.1	Initial flow	RC	Initial flow	RC	Initial flow	RC	Sum of flows
Outflow (OF)	2000	1.2	400	1.2	300	0.65	2600
Inflow (IF)	1400	1.4	500	1.2	100	0.57	2200
Net migration (NM)	-600		100		-200		-700
Next year	**Final flow**	**Growth in %**	**Final flow**	**Growth in %**	**Final flow**	**Growth in %**	**Sum of new flows**
New outflow (OFN)	2024	1.2	404.8	1.2	210	0.65	2638.8
New inflow (IFN)	1419.6	1.4	506	1.2	60	0.57	1985.6
New net migration (NMN)	-604.4	-0.73	101.2	1.2	-150	-25	-653.2

Note: RC – regression coefficient.
Source: Authors' work.

Discussion

Why is it important to know the orientation values in the chapter "Results"? To stop the shrinkage of cities and regions, the European Long-Term Investors Association in Europe has launched the "Investing in Social Infrastructures" initiative, which could encourage residents to stay in city centres (Fransen et al., 2018). The European Commission, the European Investment Bank, the Council of Europe Development Bank, and many national development banks support the initiative. It emphasizes the importance of focusing policy attention on the role of education, social infrastructure, and related services, intending to increase investment in education (Grah et al., 2019, 2021), health and affordable housing, smart solutions, as well as other social infrastructures that are essential for Member States' economic growth and people's well-being and could bring social added value to the community (Rogelj and Bogataj, 2018b, 2019, 2020b; Rogelj et al., 2019) and mitigate shrinkage. In the final report by Fransen et al. (2018), in this association, a comprehensive collection of facts and figures on social infrastructure and social services and related funding opportunities and needs are considered, and many recommendations are made on current funding instruments and future programmes, including for municipalities.

We have therefore examined how municipal revenues, most of which are invested in the social infrastructure of the municipality, can increase the attractiveness and retention power of municipalities. This answer can also be derived from the gravity model results, as in Tables 3 and 4. We have thus answered the research question of how municipalities can retain and/or attract human resources across different cohorts. According to our results in Table 3, municipal revenue retains the older people, the 75+ cohort, and the least young people, the 0-65 cohort, but significantly attracts only younger people between 0 and 65.

Conclusion

Using data on 150,670 migrants of cohort 0-65 in 14,097 inter-municipal interactions in Slovenia, 3,951 migrants of cohort 66-74 in 1,921 inter-municipal interactions, and 7,601 migrants of the oldest residents of cohort 75+ in 2,482 inter-municipal interactions in Slovenia in 2018-2019, we found that the coefficient of determination is much higher for cohort 0-65 than for the oldest residents. In addition to the influence of the distance

between municipalities on migration and the influence of the size of the municipalities themselves, the availability of nursing homes was found to be a very strong factor for the 75+ population. From this, we can conclude that the decisive influence on population growth in the municipalities is an investment in housing for the oldest cohorts. Such investments also impact new jobs for nurses, social workers, and other workers involved in services and care for older adults (Grah et al., 2019, 2021), which can significantly reduce area shrinkage. Such investments could have a significant impact on stopping the shrinkage of communities and their central places by ensuring a better quality of life for older people and jobs for young people.

The initiative to activate investments in European social infrastructure, which could encourage residents to stay in their municipalities, is crucial to mitigate the shrinkage of municipalities in Member States and increase the population's prosperity. Based on the gravity model developed and implemented for Slovenian municipalities, we can conclude that infrastructure for older adults, especially investments in their better housing, can contribute to the sustainability of population growth and the silver economy, which can also be seen in Table 4.

Municipal revenues have not had a sufficient impact on the attractiveness and stickiness of territories in the past, and their influence on sustainability is even negative. Therefore, we should know better what was done with these revenues in the past and what we should do in the future. We should find a better municipal investment policy, especially now that the new law on long-term care, which has just been improved in the Slovenian Parliament, puts more responsibility on Slovenian municipalities.

National authorities and local governments could use the findings of this study when devising strategies for regional and urban development, when exploring the best solutions for long-term care and investing in appropriate networks, or when considering the revitalization of rural communities. We propose to incorporate our findings and new extended models into future strategies, such as the SI4CARE project (the details can be found at https://socialinterreg.eu/projects/si4care) or to rethink educational programmes and infrastructures for what would answer the question of when to raise the retirement age and how to attract older workers in a region that is the subject of the MAIA - European Academy (Cordis, 2022). The answers should be considered at the regional level (NUTS2 or NUTS3) and municipal level (LAU2).

Acknowledgements: The authors acknowledge the financial support from the Slovenian Research Agency for research projects J5-1784 Creating Social Value with Age-Friendly Housing Stock Management in Lifetime Neighbourhoods, and L7-3188 Hierarchical Design and Financing of Social Infrastructure of Smart Silver Villages. Samo Drobne also acknowledges the financial support from the Slovenian Research Agency from research core funding P2-0406 Earth observation and Geoinformatics.

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Boosting Regional Socioeconomic Development through Logistics Activities: A Conceptual Model

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Abstract

Background: Regional Development (RD) allows countries to balance regional differences by providing economic and social benefits to communities. This research highlights the importance of logistics activities to regional social development, and a framework to assess these connections is proposed. **Objectives:** How to boost regional socioeconomic development through logistics. **Methods/Approach:** The contributions of logistics to socioeconomic development are analysed based on the previous research, and the case of the Alto Minho (AM) region in Portugal was used to illustrate the connection between logistics and regional development. Results showed that logistics had created jobs, increased company turnover and exports, and increased GDP growth in several regions. For the AM region, results indicate that many companies are operating in this area, contributing to supporting municipalities to reduce regional disparities. **Conclusions:** A framework for assessing regional logistics performance is proposed together with several logistics performance indicators. This approach is essential for future developments integrating logistics into socioeconomic development.

Keywords: Logistics; Regional development; Logistics Performance Index; Portugal.
JEL classification: L16
Paper type: Research article

Received: 02 Feb 2022
Accepted: 06 Nov 2022

Citation: Vieira, T., Ângela, S., Jorge Esparteiro, G., Wellington, A. (2022), "Boosting Regional Socioeconomic Development through Logistics Activities: A Conceptual Model", Business Systems Research, Vol. 13 No. 3, pp. 63-83.
DOI: https://doi.org/10.2478/bsrj-2022-0025

Introduction

Over the last decades, regional well-being has become a common concern for several countries worldwide. Regional Development (RD) allows countries to balance regional differences by providing communities with the means to prosper (Sági and Engelberth, 2018). According to OECD (2020), RD is a broad term. Still, it can be seen as a general effort to reduce regional disparities by supporting economic activities (employment and generating wealth) in the regions. This definition is corroborated by Bœrenholdt (2009), who states that RD is the effort to develop countries in a socioeconomic context.

The Council of Supply Chain Management Professionals (SCMP)defends that Supply Chain Management (SCM) encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities, including the coordination and collaboration with channel partners, namely suppliers, intermediaries, third-party service providers, and customers. In this context, supply chain management integrates supply and demand management within and across companies (CSCMP, 2013). The SCMP also defines Logistics Management as a "part of supply chain management that plans, implements, and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption to meet customers' requirements".

According to Karayun et al. *(*2012), logistics is considered one of the most important strategic sectors of the 21st century. This sector has contributed to RD by providing a competitive advantage to companies in their supply chains. In doing so, logistics can be considered activities that promote a region's development. In a simplified way, Chankov et al. (2014) state that logistics is about ensuring the availability of the right goods, in the right quantity, in the right conditions, in the right place, at the right time for the right customer, and at the right costs.

Economic globalisation and the social division of labour have transformed logistics into a sophisticated organisation and an increasingly important and strategic management technology in the region's economic development (Wang, 2010). Logistics is today an instrument for RD, allowing the synchronisation of various activities developed in different locations (Egler and Becker, 1993).

Thus, this work aims to answer the following research question (RQ1):

- RQ1: What are the key logistics indicators which can contribute to socioeconomic development?

This work aims to identify the key logistics aspects of socioeconomic development, resorting to the case of the Alto Minho region in Portugal. This paper is divided as follows. Literature Review presents the definition of RD and the connection of logistics to the regional context and its advantages for the competitiveness of local companies. Subsequently, it is described the methodological approach used in the development of this study. Afterwards, an overview of the Alto Minho Region is presented, followed by a description of the Regional Logistics Performance Analysis Model. Finally, the last section presents the conclusions and suggestions for future lines of research.

Literature Review

The emerging debate about developing policies and initiatives devoted to RD has been increasing over the years. It can be justified because available policies did not respond effectively to the current needs of different regions.

In this regard, it is imperative to consider the characteristics of each region as well as the goals to be achieved. According to Pike et al. (2007), economic development is not an objective but only a way to achieve well-being.

RD can be used as a prompt answer to achieving economic and social development. It can also contribute to well-being (Šabić and Vujadinović, 2017; Sági and Engelberth, 2018).

Regional Development: An Overview

As an attempt to define RD, Pike et al. (2007) refer to this concept as an establishment of conditions and institutions that promote the realisation of the potential of the capacities and faculties of the human mind in people, communities, and places.

However, the term region does not have a specific delimitation, nor can it be measured in terms of area, number of inhabitants, number of companies, wealth per capita, and turnover, among other indicators. The region can then be classified as a place where it has history, legacies, institutions, and cultural customs that distinguish it from those of other regions and where the population shares a set of values and social, economic, political, and ecological perspectives (Dawkins, 2003; Pike et al., 2007; Šabić and Vujadinović, 2017).

According to Shenoy (2018), regional development is important for a country's balance. RD can also be seen as the general effort to reduce regional disparities, supporting economic activities that generate wealth and employment in the regions. Nowadays, the current policies adopted by some regions have failed to reduce regional disparities. It can be justified because they are based only on the development of infrastructure and the attraction of domestic investments.

Šabić and Vujadinović (2017) suggest that RD is closely linked to endogenous capacities and that the challenge for each region is to use its resources to remove competitive advantage and be attractive to the market. For the region's prosperity, cooperation between public and private institutions, universities, local industry, and government and local companies to take full advantage of the region.

In summary, RD can be defined as a joint effort between people, companies, and educational and research institutions. The government, who share the same cultural customs and the same concern for social, economic, ecological, and political values to enhance endogenous resources, enhancing and making the region attractive and competitive, reducing underdevelopment, without neglecting population well-being at a social and economic, cultural and environmental level (Pike et al., 2007, 2017; Bœrenholdt, 2009; Karayun et al., 2012; Šabić and Vujadinović, 2017; Sági and Engelberth, 2018).

Supply Chain Management and Regional Development

Supply chain sustainability has been receiving growing attention, especially for supply chains operating in emerging economies; however, the emphasis is given to supply chains that are composed of large multinational focal companies. To complement the existing literature, Silva et al. (2021) investigate the driving factors that support micro and small enterprises (MSE) supply chains to achieve sustainability, resilience, and regional development. Their results demonstrate that MSE supply chains have enhanced resilience to crises because they often focus on long-standing economic activities within the regional ecosystem.

The question of why one region is more vulnerable to economic shock than another impelled Palekiene et al. (2015) to analyse the resilience notion in the regional development context, and their research revealed that regional resilience is dependent on multidimensional aspects such as government capacity, strategic

insights capacity, knowledge, and innovation capacity, learning capacity, networking, and cooperation capacity and regional infrastructure and natural resources development capacity, which are directly related with resilient supply chains.

Recently, the interest in developing green supply chains has emerged in literature, and their impact on social, human, and environmental areas is analysed globally (Wang et al., 2022; Le et al., 2022). The research developed by Wu et al. (2022) analysed the economic impact of inland ports on regional development. It concluded that there exists a positive economic impact of the inland port on regional development, providing the basis for the policy of investing in these infrastructures.

As a springboard to economic development, logistics can be considered an important activity for regions' development. It can be justified that these activities have easy access to various modes of transport, economical transport services, and efficient logistics are essential to enhance the comparative advantages of the regions (Kumar et al., 2017). According to Egler and Becker (1993), logistics is also vital for economic restructuring, increasing flows, and reducing inventories in a spatial dimension that goes beyond the factory's location.

In the industrial sector, logistical clusters have several advantages, for instance, creating jobs, improving labour accessibility and mobility, providing greater access to intermediate goods and commodities, external and internal economies of scale, and to some extent, increasing productivity (Sheffi, 2010). According to Kumar et al. (2017), logistical clusters allow an improvement in accessibility and mobility of the workforce, which contribute to the increase in labour markets employment, greater access to goods and merchandise, and increased productivity, allowing companies in the cluster to benefit from economies of scale and grouping. Sheffi (2010) also adds knowledge sharing and the creation of knowledge centres, such as universities and consulting companies, to the importance of logistics clusters.

Logistical activities allow companies to have access to a range of different services, such as third-party suppliers, transporters, distributors, stockists, truck terminals, railways, ports and airports, allied manufacturing specialised information technology, high-quality workforce, and low qualification (Gafurov et al., 2014; Heijman et al., 2017), allowing the creation of auxiliary companies to their activities, such as truck maintenance companies, software suppliers, specialised law firms, financial service providers, among others (Heijman et al., 2017). The work developed by Gafurov et al. (2014) indicates that the creation of inter-regional logistics centres leads to reductions in transport costs of 7 to 20%, a reduction of 15 to 30% in the cost of handling and storing resources and final products, and accelerates the turnover of material resources by about 20 to 40%.

Logistics plays an important role in developing business worldwide as an industry's strategic sector. This sector can benefit companies through a rapid movement of goods and services, favouring the region in its development since they serve the various sectors of activity (Kumar et al., 2017).

Although logistics activities have several positive effects, it also has negative impacts, such as increasing environmental pollution, changing quality of life, road accidents, and noise pollution (Efimova and Gapochka, 2019). These aspects have drawn attention to the need to develop new strategies for both companies and governments to reduce these negative impacts related to logistics, providing a territorial ordering and a balance of all the activities involved. In this sense, Šabić and Vujadinović (2017) defend that each state must be concerned with balanced development, as it contributes to political and social stability and creates conditions

for dynamic and sustainable economic development at economic, social, and ecological objectives.

Logistics and Regional Development – Case Studies

As previously described, logistics can be a driver for RD (Egler and Becker, 1993; Kumar et al., 2017). However, despite bringing numerous positive aspects, its activities also have negative aspects (Efimova and Gapochka, 2019).

The experience discussed by Gafurov et al. (2014) shows that the creation of an interregional logistics centre in the interior of Russia, in Sviyazhsky, has provided the development of the industries of the region and strengthened the ties of cooperation between Russia's interregional strategy for the country's economic development, as well to a series of strategic objectives to improve the socioeconomic development of the regions.

Also, the work developed by Efimova and Gapochka (2019) highlights that Port activities also have an important role in the development of coastal regions. These activities positively influence job creation and gross regional product, accelerate RD, and create links between transport and logistics service providers, shipping operators, and authorities.

According to Kumar et al. (2017), transportation and logistics clusters in the US in 2014 provided 5.7 million jobs. They concluded that transportation clusters and logistics could benefit metropolitan and non-metropolitan regions.

The creation of clusters leads to the agglomeration of companies and people, which may bring social and economic development to the regions. Sheffi (2010) refers that the clusters offer a variety of jobs from executive positions, information technology, and other professionals and make economically viable the development of physical infrastructures (roads, bridges, wastewater systems), the energy system (generation and transmission of energy); information and communication infrastructures (broadband, mobile network, satellite), legal system and the development of all the infinity of basic and advanced services such as health, entertainment, culture, and education. In their work, the author suggests a set of examples of logistical clusters that boosted the development of different regions in the world, such as the ports of Singapore and Rotterdam, Memphis as a major logistics centre, the Panama Canal as a major logistics centre and the passage of large cargo ships and the logistics hub of Zaragoza in Spain, which functions as an inland port connecting the ports of Barcelona, Tarragona, Valence, Bilbao, Gijon and Sines, being connected to the European cargo rail network.

According to Heijman et al. (2017), there is a strong dependence on port activities and RD in the global business cycle near the port of Rotterdam, estimating for the period from 2011 to 2020, an increase in production by 20%, while GDP and employment increase by 10% and 7%, respectively.

The city of Memphis in the USA is an example of the contribution of logistics to regional development. This city is designated as "Aerotrópolis" with a huge airport logistics centre, where Memphis International Airport is responsible for more than 220154 jobs. Its surrounding area specialises in transport and storage, where it concentrates a series of commercial activities around the airport, such as shopping malls, hotels, hospitals, conferences, and exhibition centres, among other activities (Antipova and Ozdenerol, 2013).

According to Martinez et al. (2016), the Panama Canal is an important logistical centre for the passage of large cargo ships, reducing the maritime distance between the east and west coast of the USA. The Panama Canal is an important route for

transporting goods by container from Asia to the east coast of the United States of America.

In terms of global logistics performance, the Logistics Performance Index (LPI) ranking developed under The World Bank is a well-known benchmarking tool that provides measures for more than 160 countries (WorldBank, 2018). The World Bank encourages countries to use the LPI database to compare countries of their choice to identify weak areas for improvement (Su and Ke, 2015).

The LPI ranking brings together six dimensions, namely: efficiency and customs and border management; the quality of infrastructure related to trade and transport; the ease of arranging international shipments at competitive prices; the competence and quality of logistics services; the ability to track and track shipments and the frequency with which shipments reach consignees within the scheduled or expected delivery time (WorldBank, 2018).

According to Su and Ke (2015), national logistics performance benchmarking can fill the gaps in logistics performance and build stronger connectivity between nations to facilitate efficient international trade flows.

Methodological Approach

This research used a qualitative approach to achieve the proposed objective. The work is divided into four main stages.

- *Stage 1*

The work began with a literature review considering two main areas: logistics and regional development. For this stage, reports and scientific publications related to the AM region in Portugal were used as the main data source for this research. Nevertheless, after a comprehensive search for this region (Logistics in AM region) in this region through the current literature, few works were found, revealing the lack of research in this field.

- *Stage 2*

Then, the case of the AM region was used to illustrate the relationship between logistics and RD. In this stage, key aspects related to logistics and RD were analysed.

- *Stage 3*

This stage focuses on developing a framework for analysing regional logistics performance. A set of regional logistic indicators is proposed to assess regional logistical performance, which is the first attempt to develop a methodology that will allow the future to evaluate logistics performance at a regional level. This work aimed to identify the key logistics indicators contributing to socioeconomic development from the scarce literature available. A case study was adopted as a research strategy to study logistics and RD within AM region context.

- *Stage 4*

Finally, the main conclusions of the work and suggestions for future research are presented, aiming to capture the key aspects of logistics to regional and socioeconomic development; the case of AM region in the northern region of Portugal was taken as an example.

This work focused on this region due to its strategic location and contribution to logistics activities in Portugal. The sample consists of ten municipalities that are part of AM region. This region's characterisation will be summarised and discussed in the section where the results are presented. A picture of socioeconomic aspects, logistics indicators, and their contributions as a springboard to RD will be highlighted.

An Overview of the Alto Minho Region

In this work, an analysis of the logistics of socioeconomic development was conducted addressing the Alto Minho region in Portugal. The first attempt to study this relationship showed key indicators to be considered when searching for logistics benefits to RD. Furthermore, the main aspect to ensure logistics activities in this region were pointed out, namely logistics infrastructure and the exportation of goods.

AM region comprises ten municipalities, which run 22 industrial business zones spread across these municipalities. These industrial zones have been operating in different markets through international contracts, producing and delivering export-led products for many countries worldwide. From the research conducted, Table 1 presents the results that highlight the number of business zones for each municipality. According to data from PORDATA 2018, AM represented around 1.45% of the turnover generated in Portugal, which represented 5.14% of the turnover of the entire North region.

These industrial zones connect countries through logistics infrastructures, transporting different goods through railways, ports, airpofrts, and highways. Table 1 illustrates sea and wind activities, electronic machines and devices that stand out in the municipality of Viana do Castelo and common metals in Valença and Monção. The automobile industry cluster is also very important, mainly in Ponte de Lima, Paredes de Coura, and Vila Nova de Cerveira.

Table 1
Technical records from municipalities of the Alto Minho region

Alto Minho	***Turnover***	**Enterprise Category**		
	1.45%	**Number of Companies (sum)**	**Large**	**SMES**
		30089	21	30068
Municipality	***Industrial business zone (n)***	**Cluster (activities)**	**Turnover**	
Arcos de Valdevez	3	Plastic	286115	
Caminha	1	Fish	198902	
Melgaço	1	Rubber and Tires	139548	
Monção	1	Common Metals	238725	
Paredes de Coura	2	Automobile Components	164729	
Ponte da Barca	2	Plastic and Rubbers	100956	
Ponte de Lima	2	Automobile Components / Agrifood and Viticulture	1033091	
Valença	2	Common Metals	363011	
Viana do Castelo	5	Wind Activities / Sea Activities / Electronic Machines and devices	2647080	
Vila Nova de Cerveira	3	Automobile Components / Mechanics and Metallomechanics	585965	
Viana do Castelo	5	Wind Activities / Sea Activities / Electronic Machines and devices	2647080	
Vila Nova de Cerveira	3	Automobile Components / Mechanics and Metallomechanics	585965	

Source: (PORDATA, 2020b)

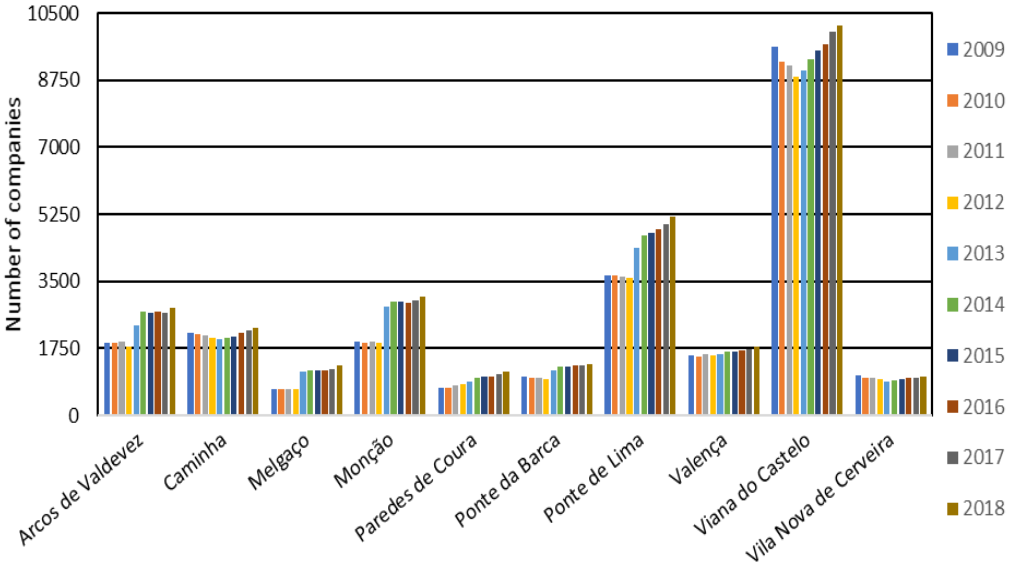
As outlined in Table 1, AM presents a total of 30089 companies, which correspond to 6.98% of the total companies in the North region of Portugal and 2.35% of the total

number of companies operating in Portugal. Regarding the company size, results showed that 21 were considered large companies, with the rest being (30068) considered SMEs (PORDATA, 2020b).

As shown in Figure 1, the municipality of Viana do Castelo has the largest number of companies, with 10185, followed by Ponte de Lima, with 5186. The municipality with the lowest number of companies is Vila Nova de Cerveira, with only 1008 companies, existing four municipalities with less than 1500 companies based.

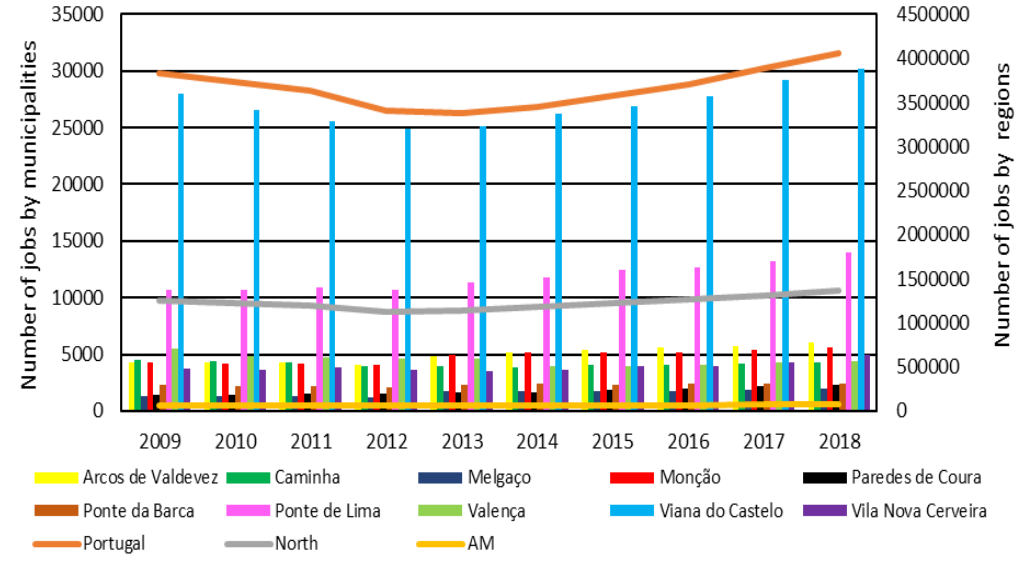
Regarding the contribution of this region to employment, the region is responsible for about 76 thousand jobs in the region. Fig.2 presents the evolution of the created jobs in the region over the last few years.

Figure 1
Evolution of the number of companies in the Alto Minho



Source: (PORDATA, 2020b)

Figure 2
Created jobs by the municipality in the AM region

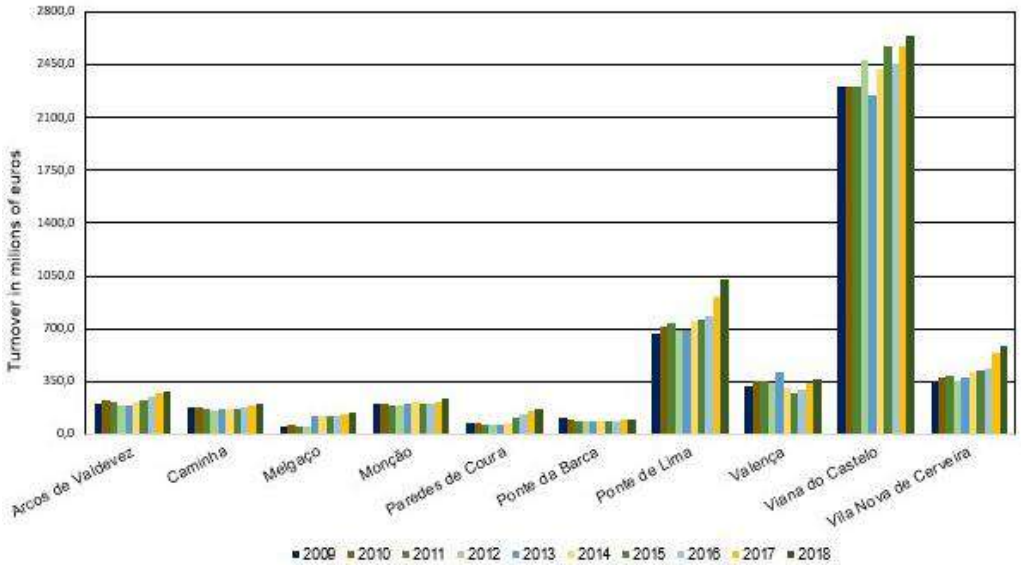


Source: (PORDATA, 2020a)

The results in Figure 2 showed that in 2018, the AM employed 76221 people, corresponding to 1.88% of the total number of people employed in Portugal and 5.56% of the entire North region. The results showed that the industry in Alto Minho alone employs around 59 thousand people (Sociedade de Consultores and Associados, 2013). Of all municipalities analysed, Viana do Castelo was the one with the largest number of people employed, accounting for 30140, followed by Ponte de Lima with 14030, it can be justified since these two municipalities have the largest number of companies based.

Regarding the potential contribution of AM companies to the region's turnover, Figure 3 shows the turnover for the last years for each municipality. Results showed that Alto Minho municipalities performed in a similar way to the North region and Portugal, meaning a decrease in values until 2012 followed by increases (Minho-Lima, 2019), with few exceptions such as the municipalities Paredes de Coura and Viana do Castelo, which registered the lowest value is 2013, and Valença in 2015. Apart from Ponte da Barca and Valença, all municipalities had the highest turnover in 2018.

Figure 3
Turnover of AM municipalities



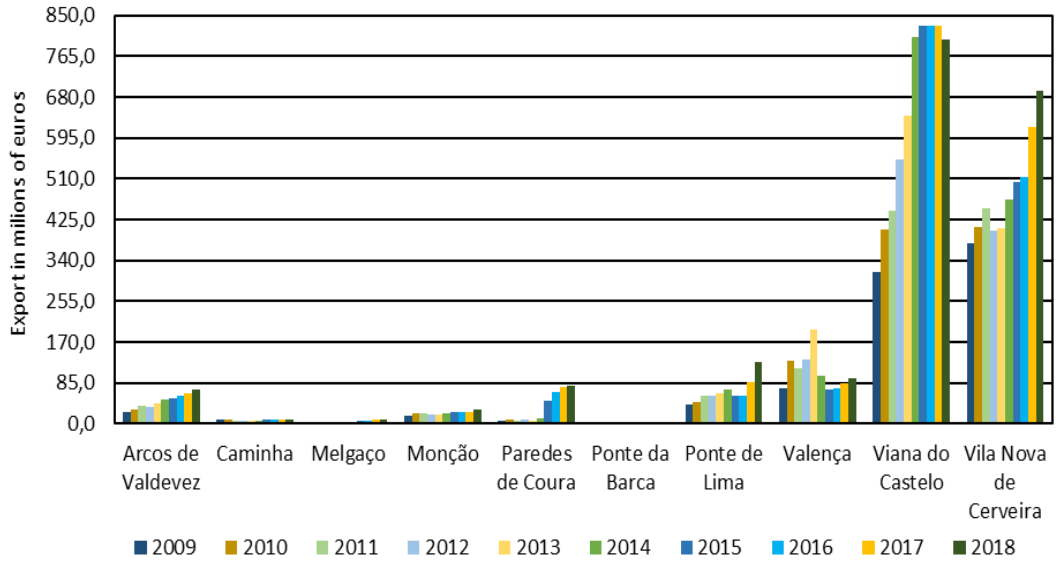
Source: (PORDATA, 2020d)

Despite the positive economic benefits previously mentioned in this research, the role of logistics activities was focused on as a key aspect of bringing RD. As such, AM region in Portugal was used as a case to illustrate this relationship (Logistics-RD); the region was chosen due to its strategic location and economic importance to Portugal.

Data related to the exportation of all municipalities from AM region was used to address the importance of logistics activities to the region. It can be seen as the first picture of logistics contribution to the region since the total values of exportation may reflect the number of transported goods by each municipality.

Figure 4 presents the exportation values from the municipalities from the period between 2009 and 2018. The results showed that the main destination of goods produced in Spain is justified due to the border proximity and the existence of more than 70% of Spanish companies which operate in the industrial parks in the municipalities of Valença and Vila Nova de Cerveira, the results also showed that the United Kingdom, France, and Germany are the biggest export destinations after Spain (Consulting and Consulting, 2018).

Figure 4
The export share of goods by municipalities



Source: (PORDATA, 2020c)

From the reports consulted, emerging markets such as Morocco, Algeria, Ghana, and Iran also play an important role in exporting goods produced in this region. Fig. 4 shows that since 2009 the number of exportations has fluctuated in most municipalities, with the exceptions of Arcos de Valdevez and Paredes de Coura, with continuous growth. The results also revealed that although Portugal has a higher value of imports than exports, the North and AM region are considered one of the main players for all countries, with higher export values than imports.

The results showed that in 2018, the ratio between exports and imports from Portugal was 78.68%, while in the North, it was 130, 45% and in Alto Minho, 150.67%, which indicates that the AM is above the North region average (Minho-Lima, 2019). The results corroborated with data presented in Fig. 4, confirming the municipalities of Ponte de Lima, Valença, Viana do Castelo, and Vila Nova de Cerveira as the main players in the region.

The results presented in Fig. 3, 4, and 5 bring to light two main aspects of the AM region: economic growth and the increasing demand for logistics activities to support companies in delivering goods to different countries. Yet, from the analyses conducted, few works highlighting the contribution of logistic activities to the economic growth of this region were found. To address this concern, the main logistics infrastructures, which have been supported by companies operating in this region on the production and exportation of goods, as well as the main logistics indicators, can be used as tools to identify the contribution of logistics to RD, were analysed. As previously mentioned, AM region is a strategic area for the country since it's a border region with access to key logistics infrastructures. Table 2 summarises a set of potential logistical benefits for each municipality from the research conducted.

Although AM region is well-known as an important economic region for Portugal, the results presented in Table 2 showed that the quality and access to logistics infrastructure persist as a barrier. For the municipalities consulted, the only ones with direct access to railways were Valença, and Viana does Castelo, which means that for the rest of the municipalities, the transport of goods is mostly carried out by highways, contributing to this way to increase economic and environmental concerns.

The results showed that the infrastructure presented in Table 2 connects through export activity Viana does Castelo in the North to Vila Nova de Gaia in the south by the coastal strip and the interior of municipalities such as Braga-Guimarães-Vila Nova de Famalicão. On the other hand, Vila Nova de Cerveira in the North of Viana do Castelo and Bragança in the eastern part of the North stand out in the export activity outside this western exporting block (Consulting, 2018).

Table 2
Logistic infrastructures available in AM region

	Access to infrastructure/distance (km)								Access to foreign infrastructures
Municipality	***Ports***	**Km**	**High way**	**Km**	**Air port**	**Km**	**Rail way**	**Km**	
Arcos de Valdevez	Yes	47.6	Yes	17.3	-	-	-	47.6	
Caminha	Yes	24.1	Yes	6.6	-	-	-	28.6	
Melgaço	Yes	92.7	Yes	40.3	-	-	-	39.6	Port and Airport of Vigo
Monção	Yes	70.7	Yes	18.0	-	-	-	17.3	Port and Airport of Vigo
Paredes de Coura	Yes	50.0	Yes	12.5	-	-	-	23.0	
Ponte da Barca	Yes	47.7	Yes	17.4	-	-	-	48.1	
Ponte de Lima	Yes	30.8	Yes	4.5/3.2	-	-	-	31.6	
Valença	Yes	52.8	Yes	0.75	-	-	Yes	1.0	Port and Airport of Vigo
Viana do Castelo	Yes	0	Yes	5.0/5.0	-	-	Yes	5.1	
Vila Nova de Cerveira	**Yes**	**37.1**	**Yes**	**4.7**	**-**	**-**	**-**	**16.2**	Airport of Vigo

Source: CIM, 2013)

Regarding the ports infrastructure, the results from the administration of Porto do Douro, Leixões, and Viana do Castelo (APDL) showed that the port of Viana do Castelo mainly handles solid bulk and also showed that exports represent 74% of the port's global movement and that Kraft paper remains the main exported commodity (APDL, 2019). At this time, new road access is also under construction for the commercial sector of the port of Viana do Castelo, which can improve accessibility to the port infrastructure, reinforcing its competitiveness and expanding its hinterland. In terms of infrastructure, the port of Viana do Castelo has a new crane with the capacity to transport loads of up to 100 tons and allows the scale of ships with 190 meters in length and 30,936 GT (gross tonnage) (APDL, 2018, 2020).

Regarding the type of goods exported, data from 2018 showed that the most exported items were transport materials (car parts, among others) which account for 752€ million, followed by machines, devices, and electronic materials worth 319€ million, and pulp of wood or other fibrous cellulosic material; accounting to 239€ million, corresponding to more than 68% of all material exported in 2018 by AM (Minho-Lima, 2019).

Over the last few years, logistic activities have played an important role in economies worldwide. Yet, as previously mentioned, few works have discussed its importance to RD, configuring a gap in the current literature. This gap can be justified

due to the lack of indicators to measure RD through logistics activities; the LPI developed an attempt; the methodology proposed a set of indicators, such as infrastructure, imports/exports services, international shipments, and track and trace, to analyse the role of logistics economic performance across countries worldwide. In this research, some of these indicators were analysed in the regional context, aiming to understand the applicability of logistics indicators to evaluate logistics performance in economics and RD.

The results indicate that due to continuous economic growth of AM region and the potential of companies that operates in this region to promote RD leads to a call to increase investments in logistics capabilities in the region, which may also create conditions to support companies to produce and deliver goods as well to increase economic and RD for municipalities and AM region.

Regional Logistics Performance: Analysis Model

As its main objective, this chapter has to present a framework that allows analysing and discussing aspects of regional logistics performance and propose a set of logistics indicators at a regional level. This framework aims to present a model to support logistics performance in different regions.

Framework for Regional Logistics Performance Assessment

The literature analysis made it possible to identify a gap in logistics performance indicators at the regional level. Considering this gap, this research proposes a framework for selecting logistical indicators to be used at the regional level.

The framework proposed is based on a combination of different approaches and methodologies. The development of the framework structure contains three distinct phases divided into several sequential steps that encompass the following topics:

- Literature review.
- Survey of logistics indicators.
- Definition of criteria for the selection of indicators.
- Preliminary list of selected indicators.
- Selection of a set of companies to validate the previously selected indicators.
- Validation of indicators.
- Analysis of regional logistics performance.

As shown in Figure 5, the first phase is based on research of scientific works and publications; it serves as the basis for phase 2, which focuses on LPI indicators. In this second phase, through the information obtained in the previous phase, interviews, questionnaires, and focus groups can be designed to identify the logistics performance indicators that will be part of the framework. After identifying and classifying the indicators, the third and last phase, the logistics performance analysis, begins, focusing on the indicators previously identified in the development phase.

Based on the Framework, the intention is to identify the main gaps found at the level of regional logistics. Then, the evaluation tool can be used to validate the performance of the indicators. The dimensions of the logistical indicators were constructed based on the LPI questionnaire adapted to the regional dimension.

Finally, the third and last phase of the framework presents the analysis of logistics performance. In this last stage, after obtaining the answers to the questionnaires, the value of each logistic indicator for each dimension will be calculated, allowing the analysis of the logistical performance of the region. As previously mentioned, the framework is divided into 3 phases, as summarised in Figure 5:

Phase 1: Literature review

- Analysis of scientific literature focusing on performance indicators and regional development.

Phase 2: Identification of indicators for logistics performance

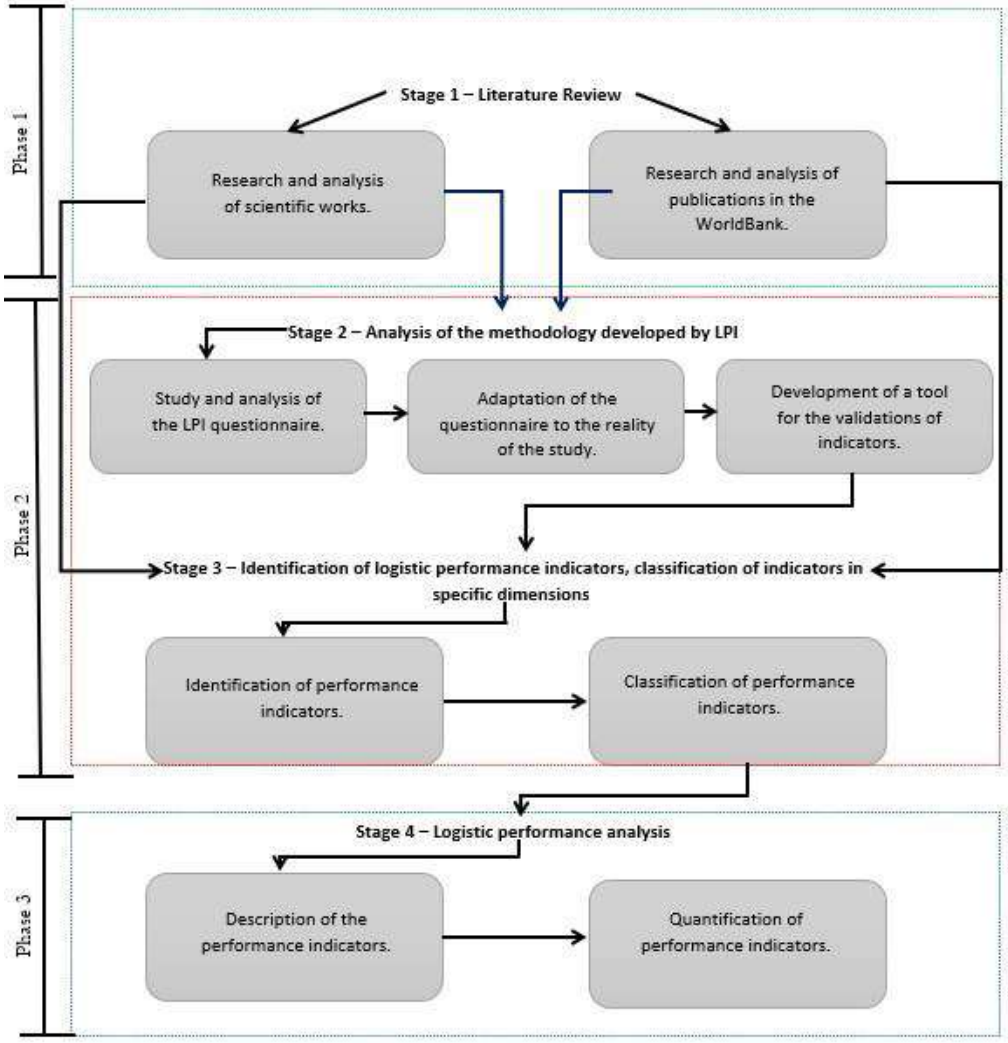
- Analysis of the methodology of the LPI (Logistic Performance Index).
- Selection of a set of performance indicators that can be used and adapted to the reality of the work context (based on the previous phase).
- Classification of performance indicators by dimension.
- Development of the questionnaire adapted to the regional context, considering the indicators selected in the previous phase.

Phase 3: Logistic performance analysis

- Description of performance indicators by dimension and its way to measure.
- Analysis of regional logistics performance, transforming the answers obtained in questionnaires on a Likert scale from 1 to 5 and making their average.
- After the development of the framework, the next topic addresses the assessment tool used in developing performance indicators.

Figure 5

Framework for analysis of logistics performance



Source: Author's illustration

Logistics Performance Indicators

Based on the phases presented in the previous section, a set of indicators was selected and grouped into six dimensions. The indicators presented in this section serve as an initial proposal to assess regional logistics performance. The tables presented below are based on the methodology proposed by the LPI. It was used due to the methodology has already been validated and used in an international context.

The selection of indicators has considered the context in which the companies are inserted; namely, the advantages of applying this type of methodology in the regions and the potential that a set of indicators can do in favour of the development of the companies and the regions where they are located are inserted.

Tables 3, 4, 5, 6, 7, and 8 present the dimensions for each set of indicators: infrastructures, tracking and tracing of goods, customs aspects, punctuality and logistics competence, regional and international shipping, and quality of logistics services.

For the infrastructure dimension, six indicators were selected. Table 3 shows the indicators selected for this dimension. The objective of this dimension is to analyse the conditions of the companies' infrastructures at the regional level and to evaluate whether the companies evaluate parameters such as breaks and obsolescence and the customers' complaints.

Table 3
Infrastructure Indicators

Item	Infrastructure indicators	Measurement
I1	Percentage of companies with implemented logistics performance indicators.	(Number of companies with performance indicators implemented / Total number of companies) * 100
I2	Percentage of companies with industrial management software (Ex .: PR, WMS).	(Number of companies with industrial software implemented / Total number of companies) * 100
I3	Percentage of companies that have established loading and unloading schedules.	(Number of companies with loading and unloading hours / Total number of companies) * 100
I4	Percentage of companies with implemented reverse logistics initiatives.	(Number of companies with implemented reverse logistics initiative / Total number of companies) * 100
I5	Percentage of companies that measure breaks and obsolescence	(Number of companies that measure breaks and obsolescence / Total number of companies) * 100
I6	Percentage of companies that measure customer complaints	(Number of companies that measure customer complaints / Total number of companies) * 100

Source: adapted from (World Bank, 2018)

For the tracking and tracing dimension, four indicators were selected. Table 4 shows the indicators selected for this dimension. This dimension aims to analyse whether companies in the region track their goods shipped as received goods and identify the main modes of transport that companies handle and which are the main markets in which they operate.

Table 4
Goods Tracking and Tracing indicators

Item	Tracking and Tracing Indicators	Measurement
TT1	The average distance of shipments/receipts	Up to 20 km; Up to 100 km; Up to 700 km; More than 700 km
TT2	Export activities	(Number of companies with international shipments / Total number of companies) * 100
TT3	Tracking of shipments by the company	(Number of companies that track / Total number of companies) * 100
TT4	Number of companies using other means of transport than road	(Number of companies using other means of transport than road / Total number of companies) * 100

Source: adapted from (World Bank, 2018)

For regional and international shipping dimensions, six indicators were selected. Table 5 shows the indicators selected for this dimension that aim to assess the competence and quality of the different logistical services provided in the region and the country at the level of regional and international shipments and infrastructure.

Table 5
Regional and International Shipping Indicators

Item	Regional and international shipping indicators	Measurement
RIS1	Quality assessment of regional road, rail, sea, air, storage, and ICT infrastructures.	Very weak; Weak; Satisfactory; Good; Very good
RIS2	Quality assessment of road, rail, sea, air, storage, and international ICT infrastructures.	Very weak; Weak; Satisfactory; Good; Very good
RIS3	Number of documents needed to receive merchandise internationally	0 to 2; 3 to 5; 6 to 10; More than 10
RIS4	Number of documents needed to receive goods domestically	0 to 2; 3 to 5; 6 to 10; More than 10
RIS5	Number of documents needed to send goods domestically	0 to 2; 3 to 5; 6 to 10; More than 10
RIS6	Number of documents needed to send goods internationally	0 to 2; 3 to 5; 6 to 10; More than 10

Source: adapted from (World Bank, 2018)

For the dimension of customs aspects, four indicators were selected. Table 6 shows the indicators selected for this dimension that aim to assess the main difficulties that companies face in releasing goods at customs and borders and how they evaluate the services these logistics agents provide.

Table 6
Customs indicators

Item	Custom Indicators	Measurement
C1	Efficiency in transparency in customs clearance	Never; Rarely; Sometimes; Oftentimes; Ever
C2	Efficiency in transparency in the release of goods at the border	Never; Rarely; Sometimes; Oftentimes; Ever
C3	Classification of the competence of customs brokers	Never; Rarely; Sometimes; Oftentimes; Ever
C4	Classification of the competence of customs agencies	Never; Rarely; Sometimes; Oftentimes; Ever

Source: adapted from (World Bank, 2018)

For the timeliness dimension, five indicators were selected. Table 7 shows the indicators selected for this dimension to assess whether companies experience delays in receiving and sending goods.

Table 7
Timeliness indicators

Item	Timeliness Indicators	Measurement
T1	Import shipments shipped and delivered on schedule	Never; Rarely; Sometimes; Oftentimes; Ever
T2	Export shipments shipped and delivered on schedule	Never; Rarely; Sometimes; Oftentimes; Ever
T3	Delays due to pre-shipment inspection	Never; Rarely; Sometimes; Oftentimes; Ever
T4	Delays due to sea transhipment	Never; Rarely; Sometimes; Oftentimes; Ever
T5	Delays due to mandatory storage/transhipment.	Never; Rarely; Sometimes; Oftentimes; Ever

Source: adapted from (World Bank, 2018)

For the dimension of quality of logistical service, 5 indicators were selected. Table 8 shows the indicators selected for this dimension, which aim to assess whether companies receive timely information about changes in regulations, experience control load theft, how service providers classify and the times they are charged fees for logistical services.

Table 8
Indicators of quality of logistical service

Item	Quality indicators of logistical services	Measurement
QILS1	Receiving timely information on regulations	Never; Rarely; Sometimes; Oftentimes; Ever
QILS2	Experiencing criminal activities (stolen cargo)	Never; Rarely; Sometimes; Oftentimes; Ever
QILS3	Percentage of companies that evaluate the quality of logistics services.	(Number of companies evaluating the quality of logistics services / Total number of companies) * 100
QILS4	Classification of road, rail, sea, air, and storage and transport service providers.	Very low; Low; Satisfactory; Good; Very good
QILS5	A monthly collection of port and airport taxes; highways; railway; service, and agent service.	0 to 5 times; 6 to 12 times; 13 to 20 times; 21 to 30 times; More than 30

Source: adapted from (World Bank, 2018)

After selecting the indicators referred to in tables 3 to 8, an evaluation tool should be carried out, which will be used as an initial attempt at validation using a set of

companies in the Alto Minho region. A questionnaire designed for the regional dimension will be used as an evaluation tool. This questionnaire was based on the LPI methodology. This tool aims to verify whether companies have difficulties answering questions and will make it possible to validate the proposed logistical indicators. In this work, the questionnaire will be a first attempt to assess the logistics performance of the Alto Minho region.

Conclusions

In this research, logistics activities and RD were discussed behind economic and social aspects while considering the AM region in the North of Portugal. The study was conducted addressing this region due to the strategic location in the country as well as the economic importance of the region for the country.

The positive economic benefits of AM region were summarised, and its contribution to RD was analysed. Furthermore, logistic activities were analysed as a key driver for socioeconomic development in the region.

The work was based on a review of the scarce literature concerning logistics and RD. Due to the lack of research matching these topics, the research attempted to analyse data from governmental reports and scientific literature.

Industrial activities in AM region have been growing in different sectors over the last few years. The results indicate that, after the economic crisis in 2008, this region has been increasing its numbers, both level of companies and job creation. Also, in terms of business volume and goods exported, the region has experienced positive gains, making AM one of the regions of Portugal with the highest volume of exports. Results also showed that SMEs mainly characterise this region, the municipalities of Viana do Castelo and Ponte de Lima, with the highest number of companies, goods exported, and jobs created.

Additionally, although Viana does Castelo is the municipality with the highest number of exportations, in second place comes Vila Nova de Cerveira, the municipality with the fewest companies, and on the opposite is the one that most contributes to the value of exports. Yet, the strategic position of the region, namely the border region with Spain, fast access to highways, ports, and railways, bring logistics activities as an instrument to support companies from this region to overcome challenges related to bringing together suppliers and customers in the international market.

In line with previous research published by the LPI, the findings presented in this work describe a set of logistic indicators that can be used to evaluate logistics performance from different countries, namely infrastructure, imports/exports services, turnover, and jobs created, providing the answer to the first research question of the paper (RQ1), about the key logistics indicators which can contribute to socioeconomic development. Different countries largely use these indicators to justify their logistics performance. In this research, they were used as a first attempt to access the logistic performance in a regional context.

The results also indicate that municipalities such as Viana do Castelo, Valença, and Vila Nova de Cerveira were the ones that present the faster access to highways, ports, and railways, it has been reflecting the positive gains in terms of exportation and the number of jobs created in the region. Logistics plays an important role in supporting these regions in production and distribution.

On the other hand, the municipalities of Arcos de Valdevez, Paredes de Coura, Caminha, Ponte da Barca, Ponte de Lima, Monção, and Melgaço fail to access logistics infrastructures. For instance, despite the importance of municipalities such as Paredes de Coura, Arcos de Valdevez, and Ponte de Lima, this region (AM) has no

easy access to railways and ports, which difficult the connection between suppliers and customers, configuring a challenge to be faced by these municipalities.

In summary, regardless of the potential contribution of logistics to regional and socioeconomic development in AM region in Portugal, it becomes evident that actions and strategies for a better discussion about the role of logistics activities need to be disseminated by researchers and stakeholders from AM region. This research showed that faster access to logistics infrastructures such as ports, highways, and railways should be considered key to socioeconomic development for the AM region in Portugal.

As a main result, a framework for assessing regional logistics performance is proposed together with several logistics performance indicators to assess the impact of logistics on regional development. The results presented here are part of ongoing work aiming to demonstrate the benefits of logistic activities to RD. Although initial research, the approach used here is essential for future developments integrating logistics into socioeconomic development. The authors are now proceeding to develop a model resorting to a set of logistic indicators to be used in a real case with a set of companies from AM region, aiming to understand their logistics behaviour in the region. In this work, the questionnaire is a first attempt to assess the Alto Minho region's logistics performance.

Acknowledgements: ERDF, ref: BI1-_ALTOMINHO4.0_2020 - reference POCI-02-0853-FEDER-041192, FCT - project UIDB/04728/2020 (Alves) and UIDB/00319/2020 (Silva).

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Circular Economy and Consumer's Engagement: An Exploratory Study on Higher Education

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Abstract

Background: Circular Economy has been considered one of the most powerful principles of modern society. The concerns about increasing resource consumption have forced governments and companies to look at the circular models as a hedge against resource scarcity and an engine for innovation and growth. **Objectives:** This research aims to bring together the Circular Economy and the consumer's perspective to perceive the impact of its choices on CE initiatives. **Methods/Approach:** A survey was conducted considering the consumer's engagement with the circular economy concepts. **Results:** The results pointed out the awareness and willingness of consumers for the transition from the linear to the circular production model, providing an added value to consumers for reducing environmental impacts. **Conclusions:** Consumers' behaviour can have a forefront role in building a guide with best practices to be considered by companies, designers, and consumers on implementing initiatives in the field of Circular Economy.

Keywords: Logistics, Circular Economy, Sustainability, Consumers

JEL classification: JL16
Paper type: Research article

Received: 05 Feb 2022
Accepted: 06 Nov 2022

Citation: Alves, W., Silva, Â., Rodrigues, H.S. (2022), "Circular Economy and Consumer's Engagement: An Exploratory Study on Higher Education", Business Systems Research, Vol. 13 No. 3, pp. 84-99.
DOI: https://doi.org/10.2478/bsrj-2022-0026

Introduction

Over the last decades, sustainability has been considered one of the most powerful principles of modern society. This principle has contributed to society's increased place on the value of sustainable technologies, processes, and products that either have zero impact on ecosystems or function within the limits of their carrying capacity. Also, society is increasingly sensitive to issues related to sustainable values (George et al., 2015; Kirchherr et al., 2017; Korhonen et al., 2018).

From the industrial perspective, this sector faces significant economic and environmental challenges toward a sustainable process. Challenges such as the lack of non-renewable resources have culminated in a prompting call for disseminating initiatives aiming to develop sustainable business models in the industrial sector (Minunno et al., 2020; Brydges, 2021; Tseng et al., 2020).

To achieve sustainability, Circular Economy (CE) has emerged as an alternative for both industries and governments. According to Ellen MacArthur Foundation (2013), which presents the first attempt to define CE, it can be defined as an industrial system that can be seen as a vital system if the concept of the end of life is replaced and shifted towards a business model which considers waste elimination from the design to a disposal of a product or service, in all stages of production.

Logistics activities can be seen as a decisive element for the supply chain since it is directly associated with two main aspects: the consumption of resources by customers and the possibility of serving as a bridge to manage the waste generated by customers in the product's end-of-life. In the supply chain, each stage could obtain raw materials for end-of-life; when well-managed, these products can contribute to the overall circularity of products (Jain et al., 2018; Julianelli et al., 2020).

Although CE has attracted the attention of researchers and practitioners, few studies have investigated the possibility of integrating CE with other approaches, which can also contribute to sustainability. As such, the engagement of companies, governments, and consumers in initiatives toward CE, can be considered the key element to closing the loop in the traditional linear economy model (Geiger et al., 2018; Wu et al., 2018).

When performed, it can also empower consumers to provide cost-saving and opportunities to force companies to build a sustainable product policy. It is in this direction, enhancing the participation of consumers in the CE, that the European Commission proposes a revision of EU consumer law, aiming to ensure that consumers receive trustworthy and relevant information on products at the point of sale, including on their lifespan and the availability of repair services, spare parts, and repair manuals (European Commission, 2020). The European Commission's strategy should strengthen consumer protection against greenwashing practices and premature obsolescence, setting minimum requirements for sustainability labels/logos and information tools (Chen, 2013; Zou et al., 2019).

From this perspective, this research aims to understand the impact of consumers' choices on CE initiatives focusing on the younger bits of society, identifying then CE aspects such as general behaviour, environmental attitudes, the durability and reparability of products, and also the main barriers and drivers faced by consumers from higher education.

This paper is divided as follows. Literature Review presents concepts related to CE and the importance of the consumer's behaviour related to embracing CE initiatives. Subsequently, it is described the methodological approach used in the development of this study. Afterwards, the results are presented and discussed. Finally, the last section presents the conclusions and suggestions for future works.

Literature overview

According to Özkan et al. (2020), the linear economy is based on the traditional model of extraction, consumption, and disposal of resources, resulting in the disorder and destruction of the ecosystems on which we depend. To stay within our planet's boundaries, companies and all society have been called to think together about the urgency to redesign the current economic model, focusing on ecological principles. The CE is a production and consumption approach that focuses on the circularity of raw materials sustainably, closed then cycles, energized by renewable sources, regenerating ecosystems, and ensuring social progress. The fundamental principles of a CE are: 1) Eliminate waste and retain value; 2) Ecological regeneration; 3) Systemic perspective (Hanumante et al., 2019).

If considered, the transition from linear to CE can reduce pressure on natural resources and achieve sustainable growth, considering, for instance, climate neutrality targets and halting biodiversity loss. It targets how products are designed, promotes CE processes, and encourages sustainable consumption, ensuring that waste is prevented and that resources used are kept in the EU economy for as long as possible (European Commission, 2020).

Morseletto (2020) defends that as an economic model, CE can be seen as an efficient approach to use resources through waste minimization towards a closing loop of products, contributing then to environmental protection as well as delivering social benefits. In doing so, this approach aimed at reducing the negative impacts of the linear economy through building long-term resilience in business and economic opportunity, providing environmental and social benefits.

As a sustainable approach, initiatives related to CE have been increasing in developing and developed economies. It has been supporting different economic sectors, such as the industrial, touristic, and service, to emphasize the importance of waste reduction from the design to disposal in all stages of their production, contributing to both sustainability and the closure of the supply chain's loop (Hartley et al., 2020; Gazzola et al.,2020; Tobler et al., 2012).

For society, CE can contribute to providing high-quality, functional, and safe products that are efficient and affordable, last longer, and are designed for reuse, repair, and high-quality recycling. Nonetheless, to enhance the participation of consumers in the CE, the policies developed by European Commission (2020) propose a revision of EU consumer law to ensure that consumers receive trustworthy and relevant information on products at the point of sale, including on their lifespan and the availability of repair services, spare parts, and repair manuals.

In doing so, companies and consumers can work together towards analyzing (the end of life of products beyond recovery at the product level, the material and parts that can be recovered through recycling and reusing parts, according to (Islam et al. (2021), researcher which investigates the consumer behaviour can support both companies and academics to identify suitable methods to achieve CE. This strategy can also be important to understand better consumers' needs and awareness regarding aspects such as consumption, disposal, recycling, and repair. The authors also defend that there is a considerable knowledge gap in the current literature when trying to understand consumer behaviour around the link between consumer behaviours and CE.

Also, Arman & Mark-Herbert, (2021) reinforce the importance of responsible consumption by consumers. According to these authors, this practice is important for reducing waste in a different type of production process, which is also one of the Sustainable Development Goals, namely Responsible Consumption and Production (SDG 12). It can be reached when postponing product life in a cradle-to-cradle

structure as part of CE. Nonetheless, it is necessary to understand if the consumers are willing to delay the products' life by reusing them.

Yet, the research developed by Testa et al. (2022) defends that number of green consumers behaviours has been increasing over the last few years. In this context, the consumer's behaviours can be linked to green consumption. Nevertheless, the emergent environmental awareness forces companies and researchers to develop further research to investigate how consumers deal with consumption from a CE perspective.

As such, this research is oriented to consumer behaviours. This opportunity to investigate this theme from a CE perspective becomes relevant since the design of these aspects is the basis of CE concepts. Designers also can create enabling preconditions for prolonged product lifetimes. However, whether products designed for prolonged lifetimes will be used for longer and/or more frequently utilized depends on the people using them (Selvefors et al., 2019; Chi et al., 2021).

Aiming to understand the antecedents of CE engagement and green buying, Morais et al. (2021) developed a conceptual model exploring the effects that the need for social status and competitive altruism play as drivers of those. The objective was to contribute knowledge for elaborating strategies and public policies for enhancing and stimulating CE acceptance from a consumer's perspective.

Also, Islam et al. (2021) performed a global review of consumer behaviour toward e-waste and its implications for CE research. In the same direction, Kuah and Wang (2020) developed a study to examine consumers' acceptance of three CE practices in East and Southeast Asia: using shared platforms, buying recycled goods, and purchasing remanufactured products. The authors concluded that Asia generates a large amount of e-waste, but the level of awareness of CE facilities and programs is limited; although consumers are willing to try sharing platforms, they are concerned about being exploited or tricked; consumer acceptance of recycled and remanufactured products in Asia is low because of their concern of reliability and quality, and consumers are still willing to buy these products in the future because of their environmental- and cost-consciousness.

From the research conducted, Kuah and Wang (2020) recommended that policymakers and companies work on promoting CE practices, such as targeting certain demographic groups, managing consumers' trust, easing their concerns, improving offerings, and appealing to innovation-minded consumers.

For the case of end users or consumers, these concerns are not well-known; however, some examples, such as e-waste, start in a journey into several paths within the CE, such as repair, reuse, remanufacturing, and recycling, are available. E-waste often ends up in landfill due to improper disposal of e-waste with household waste by consumers. Studying consumer behaviour allows for identifying appropriate approaches to achieve CE (Islam et al., 2021).

From the consumer's perspective, CE can be considered a key element to support them when buying goods with quality and at an affordable price; it can be justified due to the linkage between optimal lifetime and durability of products and the easy repair, upgrade, disassemble and recycling of products (Nyadzayo et al., 2020). It is also possible due to the potential to give products a second life by selling them in the second-hand market.

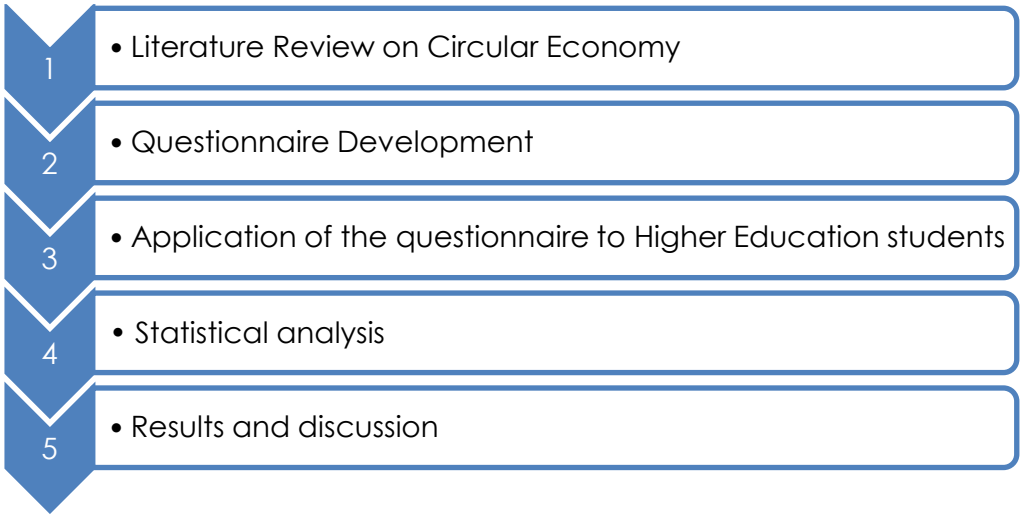
Methodology

This section presents an overview of the main steps carried out in this research to achieve the objective proposed. The work was designed to assess CE in terms of consumers' value, considering logistics activities as a strategic player to CE. Figure 1

presents the main stages developed in this work, namely: (1) The research began with an initial screening of scientific studies on the CE topic, focusing on its challenges and benefits; (2) Then, a questionnaire was developed to understand consumers' willingness to embrace CE practices; (3) The questionnaire was then applied among the selected sample, namely 123 young students from High Educations institutions in Portugal. (4) A statistical analysis was developed resorting to IBM SPSS version 27; (5) Based on the achieved results from the questionnaire, the linkage between Logistics and CE was established, focusing on aspects such as reparability, availability to spare parts, and repair.

The undertaken steps presented in this section were used as a strategy to capture consumer behaviour towards moving on to an alternative over the traditional linear economy; then to draw suggestions regarding the role of logistics activities in this shift.

Figure 1
Methodological approach



Source: Authors' work

The questionnaire developed was inspired by the previous report published by European Commission. This report was chosen due to the importance of this research, which aimed to offer relevant insights to support implementing an Action Plan for CE in the European Union. Also, due to the application and validity of the study, which focused on a qualitative and quantitative analysis, resorting to a survey as a research strategy, linking different countries from the EU (see: Implementing Framework Contract – _CHAFEA/2015/CP/01/LE) (European Commission, 2018).

The questionnaire is composed of four parts: the first one is related to general information about the respondents; the second is associated with CE behaviour and environmental attitudes; the third is concerned with the durability and reparability of the products; finally, the last part uses some category product to observe the barriers and drivers to repair or reuse products. Table 1 describes the items analyzed on the questionnaire, namely the second and the third part.

Table 1
Items related to CE, durability, and reparability information

Item	Description
Agreement Level on Circular Economy Behavior	
CE1	I always keep things I own for a long time
CE2	I always recycle my unwanted possessions
CE3	I always repair my possessions if they break
CE4	I buy second-hand products
CE5	I always buy the latest fashion clothes
CE6	I always buy new the newest electronic goods and gadgets
Agreement Level on Environmental Attitudes	
EA1	It is important to be environmentally friendly
EA2	I want my friends to know that I care for the environment
EA3	When I buy things, I know the expected lifespan of the product
EA4	I am aware of repair services for the products I own
EA5	Second-hand products are usually good quality
EA6	I much prefer possessions that are brand new
EA7	I want my friends to know I own the latest trends or fashion
EA8	I trust claims made by companies about their products
EA9	I am usually very busy and lack free time
Agreement Level About Durability and Reparability Information	
DR1	I always search for information on how long a product will last
DR2	I always search for information on how easy it is to repair a product
DR3	I would like to receive better information on how long a product will last
DR4	I would like to receive better information on how easy it is to repair a product
DR5	It is difficult to find information on how long a product will last
DR6	It is difficult to find information on how easy it is to repair a product

Source: Authors' work

Table 2
Drivers and barriers to the reparability of products

Item	Description
Thinking about the last time these products broke down or became faulty, did you repair these products?	
R1	No. I did not repair it or have it repaired
R2	Repaired the product myself
R3	Had the product repaired for me by a friend or relative
R4	Had the product repaired for me by a professional repair service
R5	Had the product repaired for me by the manufacturer (including via a retailer)
Reasons for not repairing the product	
B1	I preferred to get a new one
B2	It would have been too expensive
B3	The product could not be repaired
B4	The product was obsolete or out of fashion
B5	I did not know how to repair it/where to get it repaired
B6	It would have been too much effort
B7	The parts/materials required weren't available
Reasons for having repair the product	
D1	It was cheaper than buying a new one
D2	I am good at repairing things myself
D3	It was easier than buying a new one
D4	It is better for the environment than buying a new one
D5	I was particularly fond of my current product
D6	My preferred product was no longer in production

Source: Authors' work

In the last part of the questionnaire, inquiries were asked to think about some products from different categories, such as technology (mobile phones and TV), other applications (vacuum cleaners and dishwashers), and clothes (jackets). The goal is to understand the consumer's behaviours when these products break down (repair or buy a new one) and the reasons for that attitude. Table 2 describes the items considered for this research.

Results and discussion

This section aims to provide an overview of the main findings of this research. The results presented here are inspired by the European Commission, which aimed to analyze the general population of some European countries bringing CE and Consumer behaviours. In the meantime, this research aimed to assess the perception of the young population with some education level and access to information about CE.

Sample characteristics

As presented in Table 3, in this research, both genders were considered; all of them are young, and some have some knowledge in the logistics field. The awareness in the logistics area was evident because some of them are enrolled in courses in this area, meaning they have some knowledge regarding concepts and tools presented in the questionnaire.

Table 3
Summary of the Sample

Gender	%	Age	%	Student status	%	Training in logistics	%
Female	66.7	**<25**	75.6	**Student (only)**	82.1	**Yes**	**44.7**
Male	**33.3**	**[25;50]**	**24.4**	**Student worker**	**17.9**	**No**	**55.3**

Source: Authors' work

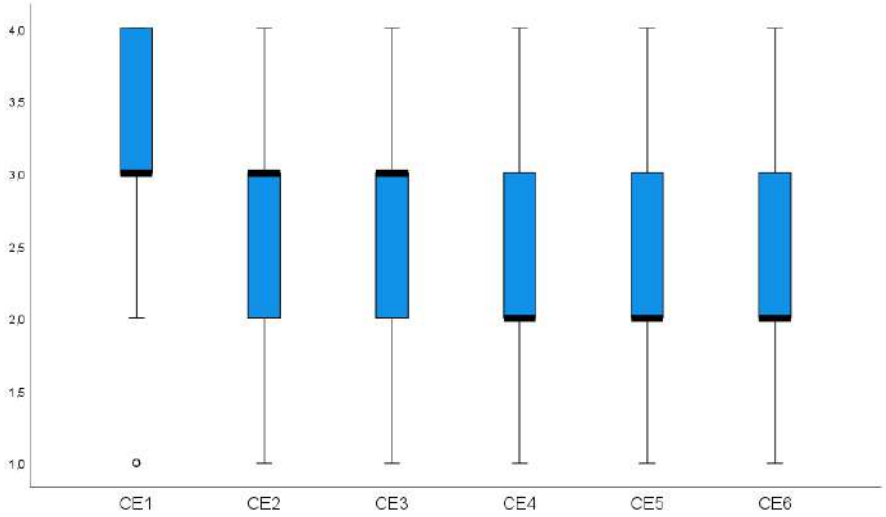
This characterization aims to understand if some training areas or work experience could influence the opinion about CE. As summarized in Table 3, most of them are students and have some knowledge of logistics.

This section highlights that the sample was selected randomly but focused on students from Polytechnic Schools in Portugal. This strategy was chosen due to the willingness of the students to participate in the research. Due to the sample size, this research does not intend to generalize the results but gets important insight from the achieved results.

Circular economic behaviour

Regarding a generic analysis of CE statements, a Likert scale of four points was used, where one means "Strongly disagree" to 4 has the significance of "Strongly agree". Figure 2 presents the level of agreement for each sentence. Despite the answers using all scales' amplitude, there is a strong response on the positive end of the scale. The results showed that most positive answers were given items CE1 to CE3, where the median (the black line in bold) is on level 3 of agreement.

Figure 2
Boxplots related to General Behavior about CE



Source: Author's illustration

The results presented in Figure 2 show that the respondents considered it important to keep goods as long as possible, and they are also concerned about the possibility of repairing the products when needed. These results showed that the concerns are in line with the CE approach.

Table 4 scrutinizes the graphical analysis. Compared with the EU report, the inquiries adopt similar behaviour, increasing the purchase of second-hand items. Additionally, a non-parametric Mann-Whitney U test (Maroco, 2007) was performed to compare the differences between the two independent groups. It was used to test the null hypothesis that two non-normally distributed samples come from the same population, i.e., have the same median. The significance level used was 0.05. For this research, the answers were analyzed by gender, student status, and training in logistics.

The results evidence the opinion's difference regarding the gender factor on the items CE1 and CE2. After carefully analyzing the answers, it was possible to confirm that there is a higher dispersion of agreement level for men's answers. At the same time, the female inquiries tend to choose the positive agreement levels of the items. There is no significant difference between groups for status students; when logistic training is considered, only item CE4 stands out. In this case, students with no training in logistics tend to disagree more with the sentence.

Table 4
Descriptive Statistics and Non-parametric Man-Whitney tests regarding General Behavior of CE

Item	Descriptive Statistics				Mann-Whitney U test		
	Min	Max	Mean	St. Dev.	By gender (sig.)	By student status (sig.)	By logistics training (sig.)
CE1	1	4	3.2	0.68	0.004***	0.947	0.847
CE2	1	4	2.8	0.76	0.019**	0.968	0.218
CE3	1	4	2.7	0.67	0.288	0.702	0.476
CE4	1	4	2.3	0.91	0.402	0.980	<.001***
CE5	1	4	2.2	0.74	0.479	0.540	0.481
CE6	1	4	2.6	0.96	0.632	0.192	0.568

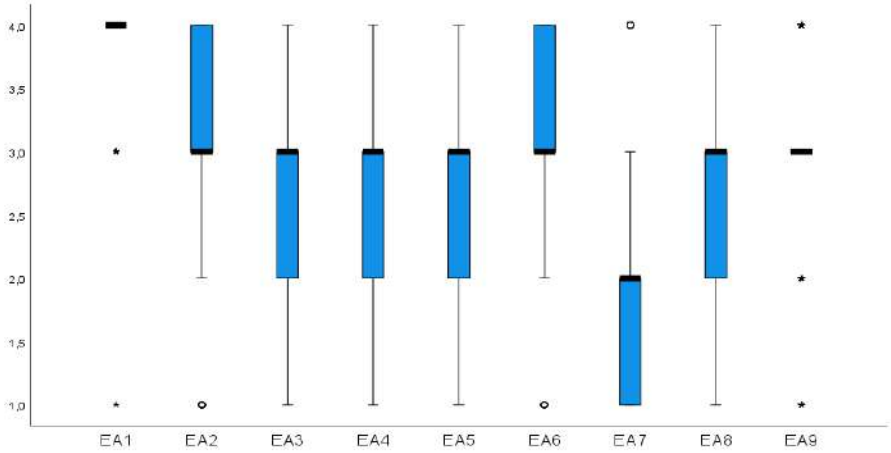
*Note: *** stastically significat at 1%; ** 5%*
Source: Authors' work

Circular economy and environmental concerns

The current environmental trends emerged in a closed-loop situation, and there is a growing demand for environmentally friendly and ecological products. Following this sense, Figure 3 shows the boxplots related to the level of agreement with some environmental attitudes. The results showed that the respondents tend to agree with the environmental attitudes described, especially EA1 (be environmentally friendly), EA2 (care about the environment by themselves and friends), and EA6 (buy fashion brands).

Figure 3

Boxplots related to Environmental Attitudes



Source: Author's illustration

This behaviour is corroborated by the descriptive statistics presented in Table 5. The results showed that the standard deviation is similar for all items. However, when the mean is analyzed, it is possible to observe that item EA7 has a disagreement level average, and the highest level of agreement is item EA1 (the importance of being environmentally friendly).

Additionally, when the Mann-Whitney test was applied, the results showed no differences when the education qualifications factor was considered. Nonetheless, when gender is the factor of comparison, items EA1, EA2, and EA6 are distinct and dig into the answers. This means that women tend to agree with the importance of caring about the environment and the possibility of buying fashion brands. Students' status also revealed differences between items EA8 and EA9.

Table 5

Descriptive Statistics and Non-parametric Man-Whitney tests regarding Environmental Attitudes

Item	Descriptive Statistics				Mann-Whitney U test		
	Min	Max	Mean	St. Dev.	By gender (sig.)	By student status (sig.)	By logistics training (sig.)
EA1	1	4	3.9	0.40	0.022**	0.857	0.616
EA2	1	4	3.2	0.76	0.006***	0.693	0.980
EA3	1	4	2.7	0.77	0.051	0.853	0.777
EA4	1	4	2.9	0.79	0.100	0.550	0.760
EA5	1	4	2.6	0.64	0.561	0.134	0.265
EA6	1	4	3.0	0.75	0.012**	0.424	0.503
EA7	1	4	1.6	0.72	0.990	0.349	0.503
EA8	1	4	2.5	0.69	0.065	0.018**	0.089
EA9	1	4	3.0	0.71	0.540	0.042**	0.900

*Note: *** stastically significat at 1%; ** 5%*

Source: Authors' work

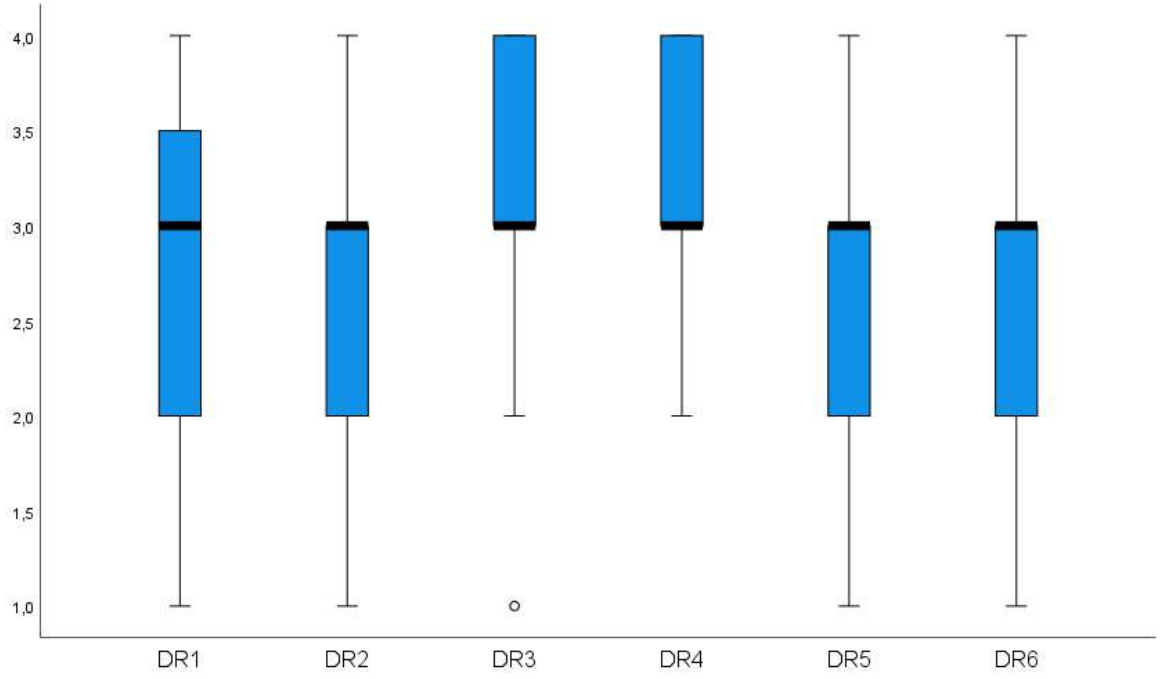
Durability and reparability of products

Thinking in CE is changing the mindset, shifting the concept of "consumer" to "user"; thinking not only to buy but also to lease, rent, or share wherever possible can be a great opportunity to close the production cycle. Additionally, if the consumer could obtain more information regarding a product's durability and/or reparability, this correct choice can reduce consumption.

The results presented in this section are discussed in light of the durability and reparability of the products. Figure 4 shows that more than 50% of the respondents agree or strongly agree with the sentences related to the importance of considering the durability and reparability of goods. Although searching for information is real, finding it is not always easy.

Figure 4

Boxplots related to Durability and Reparability Information



Source: Author's illustration

After analyzing the mean values presented in Table 6, it is possible to conclude that the results align with those inquiries that tend to agree with the statements of the need to get information access about the possibility of repairing goods and their durability. Concerning the Mann-Whitney tests, women strongly agreed, compared to men, with sentence DR3 (possibility to get additional information about durability and reparability of goods). Nonetheless, it is important to highlight that this result is supported not only by the non-parametric test but also by the graphics generated by factors' answers that were omitted in the paper due to the extension of this section. Regarding the students' status, meaning the students working, only DR3 and DR4 have significant differences in answers, with student workers who tend to have higher levels of agreement. The results point out the same behaviour when measuring the students who do not have training in logistics.

Table 6
Descriptive Statistics and Non-parametric Man-Whitney tests regarding Durability and Reparability Information

Item	Descriptive Statistics				Mann-Whitney U test (significance level 0.05)		
	Min	Max	Mean	St. Dev.	By gender (sig.)	By student status (sig.)	By logistics training (sig.)
DR1	1	4	2.9	0.78	0.565	0.074	0.595
DR2	1	4	2.7	0.81	0.093	0.786	0.676
DR3	1	4	3.2	0.68	0.026**	0.034**	0.059
DR4	1	4	3.3	0.61	0.130	0.032**	0.032**
DR5	1	4	2.7	0.79	0.694	0.420	0.080
DR6	1	4	2.7	0.82	0.575	0.808	0.098

*Note: ** stastically significat at 5%*
Source: Authors' work

Barriers and drivers for considering the reparability of products

Reusing and extending the product's life can be important to achieving CE. Repairability can be considered a key strategy to increase the time use of the products, increasing their lifetime. Yet, consumers face several barriers when they need to repair goods. Due to this challenging task, in this research, an analysis of the consumer's experience with repairing products was carried out, following the original EU report, and a set of product categories were considered for this analysis, namely mobile phone, TV, dishwasher, vacuum cleaner, and jacket.

Table 7 presents the results and an overview of consumers' experiences regarding reparability as an option used over the years. The results showed that not all respondents have selected any answer, probably because they do not know or do not remember the last situation when the product broke down. From the respondents that answered, it is possible to check that both applications, mobile phones, and jackets were the items with the highest values regarding R1 (Products that are not repaired). In the meantime, for those products considered by respondents to repair, mobile phones, TV, and dishwasher on repair services or manufacturers (R4 and R5), while vacuum cleaners and jackets were repaired most by themselves or a friend/relative (R2 and R3). A possible explanation for these choices could be related to the cost of the service or even the technology involved.

Table 7
Experience with Repairing Products by Category (in %)

Item	Mobile phone	TV	Dishwasher	Vacuum cleaner	Jacket
R1	36.6	30.3	19.3	32.1	41.0
R2	7.5	6.1	4.5	15.4	24.0
R3	11.9	15.2	19.3	28.2	23.0
R4	26.1	21.2	38.6	10.3	9.0
R5	17.9	27.3	18.2	14.1	3.0

Source: Authors' work

Regarding the respondents that do not repair the product, Table 8 shows a set of barriers pointed out as justification for not considering the repair as an option. In the case of mobile phones, the barriers are related reparation price of the service (B2), followed by the fact that they cannot be fixed (R3). For TV, several barriers were listed, such as difficulties in finding components to replace, the cost of its components, and the amount of time to repair were the main aspects pointed out. The dishwasher

stands out in the effort to repair, while the vacuum cleaner is pointed to the lack of knowledge (B5) and materials to replace (B7). Finally, regarding the category of clothes – jacket – the main reason indicated is the possibility of getting a new one (B1) for pleasure or because it is out of fashion (B4).

Table 8
Barriers to not repairing the product category (in %)

Item	Mobile phone	TV	Dishwasher	Vacuum cleaner	Jacket
B1	20.5	20.0	2.9	29.0	46.8
B2	37.0	30.0	37.1	22.6	2.1
B3	24.7	30.0	22.9	12.9	23.4
B4	6.8	10.0	8.6	9.7	19.1
B5	4.1	7.5	2.9	9.7	4.3
B6	4.1	0.0	20.0	6.5	2.1
B7	2.7	2.5	5.7	9.7	2.1

Source: Authors' work

To figure out what motivates self-repair, the respondents were asked to indicate the most important reason to be considered to repair a product themselves. The results presented in Table 9 showed that, for the case of a jacket, it drivers the consumer's skills needed to repair (D2) or the affective value given to that model (D5). Yet, technology items have different drivers, such as the price of the mobile phone (D1) and the attachment for the model (D6). In the case of TV, it is related to the fact that self-repair is easier to find a solution. The environmental concerns (D4) were just considered important for dishwashers; it can be justified due to the facility to find repair stores and because it is cheaper to repair than buy a new one.

Table 9
Drivers to self-repair by category of products (%)

Item	Mobile phone	TV	Dishwasher	Vacuum cleaner	Jacket
D1	37.5	16.7	50.0	22.7	14.0
D2	12.5	16.7	12.5	13.6	30.2
D3	4.2	33.3	6.3	31.8	16.3
D4	4.2	5.6	25.0	9.1	9.3
D5	29.2	16.7	0.0	13.6	25.6
D6	12.5	11.1	6.3	9.1	4.7

Source: Authors' work

Conclusion

The transition from Linear to CE is an ongoing movement changing production and consumption paradigms. This research has sought out aspects related to CE and its contribution from the consumer's side, focusing on a young audience. Due to the importance of these target audiences regarding consumer behaviour, it can be considered an important path toward the transition from the consumer perspective.

This research intended to investigate young students' understanding of the circular economy initiatives, considering aspects such as behaviour, barriers, and drivers on adopting environmental awareness when consuming goods. From the research conducted, the results presented here are aligned with the current literature, which discusses the need to disseminate the benefits of adopting circular economy initiatives among consumers, especially the young generation. It can be a powerful strategy to better understand consumers' role in the linear transition.

The results also highlight the importance of bringing together topics such as the possibility of reusing and better-designing goods; having the consumers as part of its end-use can contribute to this transition and, simultaneously, reduce the material used and take care of its disposal.

These results indicate the importance of using a young sample of students attending Higher Education as a key element to incentivize both companies and consumers to move from a linear to a circular economy. The findings also align with the work developed by the EU report (EU report, 2018), which aimed to identify barriers consumers face when purchasing goods produced through a circular approach. From this perspective, the results showed that from the consumer's outlook, to decide to buy new goods considering the concept of circularity, there is a need for further information regarding aspects related to the repair of the products and higher accessibility to pieces of the appliances.

In this research, the sample size can be considered a limitation, yet, for future work, the extension of this survey to a wider audience is considered an important task. Also, the need to better understand concerns about CE aspects from the different public to verify the European Union's understanding. It can be used as a forefront approach to building a guide with best practices to be considered by companies, designers, and consumers.

From an academic perspective, the journey of unleashing the potential CE is just at the beginning. This research calls attention to the need for future industries to provide new solutions to promote CE to consumers, especially your generation. At this moment, this research shined from the young consumers' point of view, and the results showed that there is already environmental awareness for these consumers. With a few exceptions, the answers given do not have significant differences between gender, student status, or even training qualification. The fact that only students of Higher Education have been considered in this research is a limitation of this work due to the challenge of reaching different audiences. Yet, the possibility of extending the sample will be considered for future research.

Acknowledgements: This research was supported by CAPES and Science without Borders scholarship, BEX Process 10.190-13-9 (Alves) and FCT - UIDB/04728/2020; ADiT-LAB, Instituto Politécnico de Viana do Castelo, and FCT through R&D Unit Project Scope UIDB/00319/2020 (ALGORITMI) (Silva); and UIDB/04106/2020 (CIDMA) and UIDP/04106/2020 (Rodrigues).

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Internal Logistics Process Improvement using PDCA: A Case Study in the Automotive Sector

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Abstract

Background: The Plan-do-check-act (PDCA) cycle methodology for a continuous improvement project implementation aims for the internal logistics upgrade, which is especially important in the industrial context of a component manufacturing company for the automotive sector. **Objectives:** The goal is to quantify the gains from waste reduction based on the usage of the PDCA cycle as a tool in the implementation and optimisation of a milk run in an assembly line of a company in the automotive sector by determining the optimal cycle time of supply and the standardisation of the logistic supply process and the materials' flow. **Methods/Approach:** The research was conducted through observation and data collection in loco, involving two main phases: planning and implementation. According to the phases of the PDCA cycle, the process was analysed, and tools such as the SIPOC matrix, process stratification, 5S, and visual management were implemented. **Results:** Using Lean tools, it was possible to reduce waste by establishing concise flows and defining a supply pattern, which resulted in a reduction of movements. The transportation waste was reduced by fixing the position of more than half of the materials in the logistic trailers. The developed Excel simulator provided the logistic train's optimal cycle time. **Conclusions:** The assembly line supplied by milk-run was fundamental to highlight a range of improvements in the process of internal supply, such as better integration of stock management systems, greater application of quality, or the adoption of better communication systems between the different areas and employees.

Keywords: PDCA, Continuous improvement, Logistics, Milk-run, Automotive sector.
JEL classification: L6 Industry Studies: Manufacturing (L60 General)
Paper type: Research article

Received: 25 Jan 2022
Accepted: 06 Nov 2022

Citation: Amaral, V. P., Ferreira, A. C., Ramos, B. (2022), "Internal Logistics Process Improvement using PDCA: A Case Study in the Automotive Sector" Business Systems Research, Vol. 13 No. 3, pp. 100-115.
DOI: https://doi.org/10.2478/bsrj-2022-0027

Introduction

Developed between 1940 and 1950, Lean quickly became a strong and dominant management reference in the industrial context (Garza-Reyes et al., 2018). It represents a philosophy focusing on value creation by employing continuous improvement tools and waste elimination (non-added value) of the production system along the supply chain (Boateng, 2019). Lean practices allow the continuous flow of a company's processes in an integrated way, contributing to its higher performance. The concept of Lean reflects the idea of 'creating more with less, enabling cost reduction, increased quality, and improved delivery times (Abreu et al., 2017).

Lean thinking is associated with the Toyota Production System (TPS). The automotive industry was a pioneer in applying this system, which originated in Japan, at the Toyota car plant, just after the Second World War. At that time, the Japanese industry had very low productivity and a considerable lack of labour, which prevented the adoption of the mass-production model (Chiarini et al., 2018; Ohno, 1988). The goal is to make it right the first time, seek effectiveness in the production process, use the minimum necessary resources, reduce lead times, improve productivity and meet the customer requirements (Santos et al., 2015). Since value creation requires pressure on processes over time, the quality of services and products is a derivative of the quality of processes.

In contrast, improvement cannot be regarded as a one-time project. Thus, systematic attempts to seek opportunities to eliminate defects' causes and use new ways to conduct and introduce changes actively must be preconised (Brajer-Marczak, 2014). The Lean approach focuses on reducing or eliminating waste, mainly overproduction, overprocessing, transport, movements, waiting, defects, and stock, which leads to product quality and productivity improvement (Oliveira et al., 2019). This methodology is supported by theoretical and empirical evidence from increasing the competitiveness of organisations through the application of tools such as Kaizen, Kanban, 5 S methodology, Poka-Yoke and Andon systems, visual management tools, value stream mapping, supply flow balancing of parts and products, and many others (Bragança et al., 2013; Garza-Reyes et al., 2018; Puchkova et al., 2016; Randhawa & Ahuja, 2017; Veres et al., 2018).

In the manufacturing environment, internal logistics is essentially responsible for the operations that affect the performance of assembly lines (Alnahhal et al., 2014) and guarantee efficient material flow (Goldsby & García-Dastugue, 2003). This requires important decisions due to the need to predict what, how much, by whom, where, when, and how to transport the materials, considering the supply and demand requirements (Kluska & Pawlewski, 2018).

Several logistic solutions can be implemented to ensure the internal supply of materials in factories. The Milk-run system is a profitable management strategy that uses a logistic vehicle (or logistic train) to meet supply demands in a supply chain. It is a solution commonly used in production systems due to its successful results in providing waste reduction and transport efficiency (Kluska & Pawlewski, 2018; Nemoto et al., 2010). It's a relatively easy and cost-effective solution to minimise the covered distances between the storage locations and the workstations (Gyulai et al., 2013). When these vehicles' capacity is maximised, their application's advantages directly contribute to implementing one-piece flow production systems (Gotthardt et al., 2019; Kluska et al., 2018).

For its implementation, it is required to study the supply process, defined by the production cycle time and materials management. It is necessary to determine how often and in what quantity is necessary to transport the materials from the warehouse

(or a storage place, e.g., an intermediate supermarket) to a different point in a factory, attending the routes that provide consumable items in time to production.

Following the idea that only consumed materials can be replaced, the principal goal of the milk-run process is to make materials flow faster through the production area, making deliveries in different locations within the same route and the same service period. Thus, milk-run systems are aligned with implementing Lean tools, contributing to reducing the seven wastes, mainly in transport, waiting for time, and stocks (Ivanov et al., 2018; Vicente et al., 2016).

There are several methodologies that, when implemented in an integrated way, lead to increased performance outcomes. One of those methodologies is the Plan-do-check-act (PDCA) cycle. Developed by Edwards Deming in the 1950s, the PDCA cycle is a quality tool, especially useful for promoting continuous improvement (Isniah et al., 2020). It has been used to improve production systems and work management applications and to enhance business organisation. It has also offered the steps as drivers of continuous improvements and the key to a learning culture (Lerche et al., 2020).

Four steps define the method - *Plan*, *Do Check,* and *Action*. In the *Plan* phase, the improvement opportunities are identified and then prioritised. Also, the goals are established, and the processes to achieve specific results are planned (Isniah et al., 2020; Realyvásquez-Vargas et al., 2018). In the second phase (*Do*), the action plan previously developed is implemented, putting in action all the data collection, measurement techniques, and tools for data analysis. Afterwards, all the results are analysed (*Check*) through a before-and-after comparison to verify the achieved gains. The last step is the *Action* stage, where the plan is created to improve and standardise the achieved results (Isniah et al., 2020; Realyvásquez-Vargas et al., 2018).

According to Jagusiak-Kocik (2017), the PDCA cycle is a very adaptable methodology. It can be successfully used In continuous improvement processes, during the implementation of changes and innovative solutions, or even during a process improvement review. Mantay de Paula & Feroni (2021) applied the PDCA cycle and a milk-run system in a reverse logistics project in the food industry sector. According to the authors, the PDCA methodology reduced the customers' dissatisfaction with reverse logistics processes, facilitating the identification of the problem's root causes. The study describes the milk-run system efficiency as a solution in the goods returning process. The application of PDCA methodology and the milk run conduced to a faster process with increased levels of customer satisfaction since the product reuse rates and reverse costs of freight were optimised (De Paula & Feroni, 2021). In the automotive sector, for example, Rahim *et al.* (2016) used the PDCA cycle to improve the quality of the electrodeposition painting process, to reduce operating costs and lead time. By applying the PDCA cycle, the authors identified the most frequent defects and the implemented tools to improve the method quality. The cycle time was reduced by reducing the duration of a few work processes, resulting in less than 33% of direct person-hours and less than 50% in material consumption and consequent cost savings (Rahim et al., 2016). PDCA methodology is usually applied with the resort to visual management practices, 5S methodology, standard work, checklists application, and Six Sigma tools. With this approach, supplier–input–process–output–customer (SIPOC) matrices and control charts can be generated for further analysis (Oliveira et al., 2019; Realyvásquez-Vargas et al., 2018; Uluskan, 2019).

The PDCA cycle has proven efficient in many industrial processes (Aichouni et al., 2021). This allows structuring the problem in several steps, making it possible to analyse the root causes of the problem in more detail and create corrective measures to mitigate them.

In the literature, several processes are used to study the PDCA cycle with the continuous improvement process. These case studies are reported in a wide range of industrial areas. Antunes Junior & Broday (2019) applied the PDCA cycle in a food company in southern Brazil to solve the problem of excessive waste of sauce used in frozen meals. It was possible to reduce waste by 86.75% by implementing improvements in the operation and sauce dispensing equipment.

The PDCA was applied in a company's case study that assembles a set of keys, locks, and handles (Malega et al., 2021). The authors introduced measures to correct the long-term problems and made changes to individual and production control documents. Through the statistical analysis, the authors confirmed the effectiveness of the continuous improvement processes implemented in the first month. Milosevic et al. (2021) implemented the PDCA cycle with Lean tools to ensure the sustainability of the production process of welded excavator frames. The authors refer that the process had a significant performance improvement (10.67%).

Due to a growing demand for electronic components, a manufacturing company in Mexico began to detect defects in the electronic board welding process (Realyvásquez-Vargas et al., 2018). The PDCA cycle was applied to three double production lines of the boards, where defects decreased by 65%, 79%, and 77%.

The case study presented in this article represents the need to improve an internal process within the company, so it cannot be directly compared with other cases in the literature. However, similar to this case study, the studies above highlight the positive aspects of applying the PDCA cycle and using continuous improvement tools. This way, it is possible to normalise work processes, minimise waste that does not add value to the product, and allow for more efficient and healthy production workflow management.

The main purpose of this paper is to explore the use of the PDCA cycle as a tool in the implementation and optimisation of a milk run in the assembly line of a company in the automobile sector by determining the optimal cycle time of supply and the standardisation of the logistic supply process and the materials' flow. Also, it aims to demonstrate that Lean and Logistics can contribute to improving the internal supply process with simple and cost-effective approaches. The present research is in line with the work reported in the referred literature: applying continuous improvement tools to an industrial context, aiming to reduce cycle times and minimise labour and resource wastes. In addition to the PDCA approach, this paper is focused on applying current tools such as the SIPOC, milk-run systems, and simulators to identify the material needs in industry 4.0. Therefore, this paper falls within the field of applied research. Despite the particular context of the paper application, the study provides an important scientific contribution since the methodology and the developed simulator can be easily adapted to other assembly lines, not only in the electronic components production for the automotive sector.

The paper was organised into six sections. After the introduction, section two describes the methodology framework, and section three characterises the case study. The Lean logistics tools implemented in the project were described in section four, mainly milk-run, Kanban, and visual management. The results validation and main conclusions are presented in sections five and six.

Research Methodology: PDCA

This study is classified as a case study and developed through observation and data collection in loco (Saunders et al., 2007). The continuous improvement project was developed within a company dedicated to producing electromechanical components for vehicles.

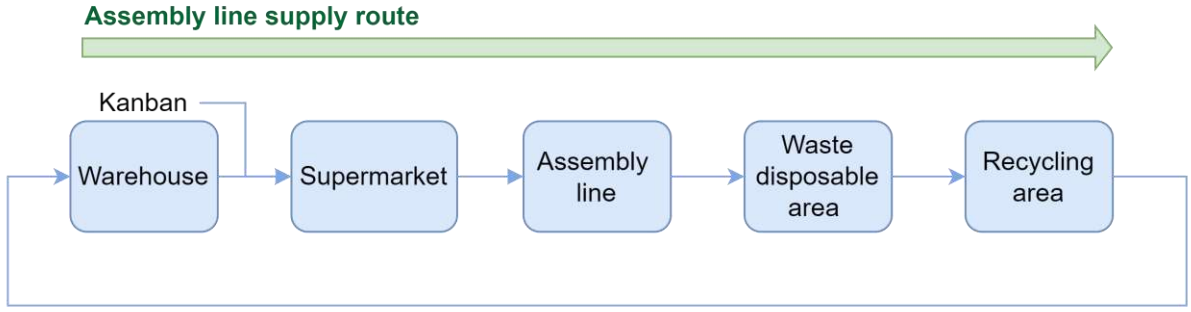
PDCA cycle was used as the reference method for the continuous improvement project implementation, which included different Lean tools: SIPOC matrix, Chart Control, 5S, and Visual Management. Thus, the wastes from the materials' flow of the assembly line were effectively identified and measured to formulate and undertake suitable methods to optimise the supply strategy.

In the Plan phase, the assembly line was selected as the study object (called from now on line Y), and the supply processes were assessed to identify improvement opportunities. The main problem was the lack of an adjusted cycle time for the internal supply process of the line. Thus, strategies were defined for the optimisation of the milk-run process. In the second stage, phase Do, the data needed to estimate the optimal cycle time were collected, and the defined strategies were developed to improve the milk-run supply process. In the Check phase, the milk-run supply process was again analysed to confirm and evaluate the results obtained by implementing the previous phase's improvements. To validate the implementations, a brief satisfaction survey was developed to evaluate the impact of the changes from the operators' perspective and the assembly line productivity. In the last PDCA stage, the Act phase, an action plan was created to maintain the obtained results regarding the continuous improvement of the supply process for assembly line Y.

Case Study Description

The case study was carried out for seven months, focusing on analysing the company's internal supply process (Figure 1). The company uses a milk-run system for the internal supply to deliver different materials in small batches from a central warehouse to the assembly lines, with standard routes and predetermined cycle times.

Figure 1
Milk-run supply process circuit



Source: Authors' work

The assembly line supply process occurs continuously during the three 8 hours shifts. The logistic operators are responsible for supplying the train and the assembly lines, ensuring that the required components are provided following the production orders. Material management is attained through a Kanban system between the warehouse and the supermarket.

Only the materials that have been consumed are replaced. This enables higher vehicle loading rates, low inventory levels, and delivery accuracy, maximising the efficiency of manufacturing continuous flow.

The logistic train is also responsible for properly collecting and disposing of wastes from the assembly line and forwarding reusable materials to the recycling area. Thus, the milk-run system is simultaneously used to supply the assembly line and, in the reverse logistic processes, transport materials, such as plastic boxes and other

packaging items, as well as reusable materials that have an internal flow (e.g., injected plastic parts trays). Despite the well-defined logistic train route and the use of the supply vehicle, a detailed analysis of the line Y supply process showed discrepancies between the theoretical and effective cycle time.

Implementation of Continuous Improvement Tools

Different Lean tools were applied during the project development, according to the PDCA cycle steps and considering a continuous improvement approach.

Milk-run supply process optimisation

The strategy was to effectively identify improvement opportunities for optimising the milk-run process. To do so, a SIPOC matrix was developed. As shown in Table 1, two main improvement opportunities were identified: (1) the methodology to supply the logistic train and the assembly line; and (2) the management of both waste and reusable materials.

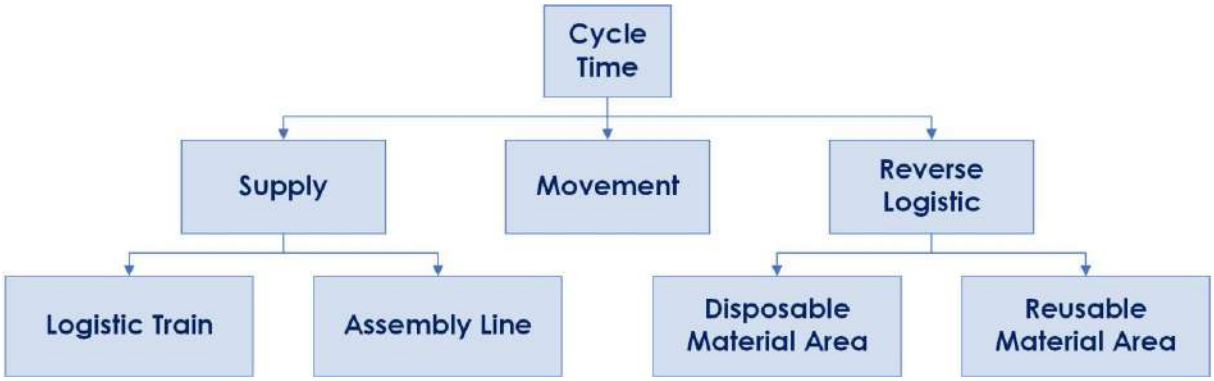
Table 1
SIPOC matrix to identify improvement opportunities

Suppliers	Inputs	Process	Outputs	Customers
Supermarket	Materials to transport	Supply the logistic train with material	Stocked logistic train	Logistic train
Logistic train	Availability of materials to the assembly line	Supply the assembly line	Stocked assembly line	Assembly line
Assembly line	Residual materials and reusable materials	Supply the logistic train with residual and reusable materials	Logistics train loaded with residual and reusable materials	Logistic train
Logistic train	Residual materials and reusable materials	Discard residual materials and return reusable materials	Discarded waste materials and returned reusables	Availability of waste and reusable materials

Source: Authors' work

To determine the optimal cycle time for the milk run, it was decided to stratify the process by dividing the cycle time into supply activities, reverse logistic activities, and movements (Figure 2). The assembly line operations' data were collected using a Radio-Frequency Identification (RFID) controller. Data collection was based on a sample of 30 observations, randomly performed during the morning and afternoon shifts.

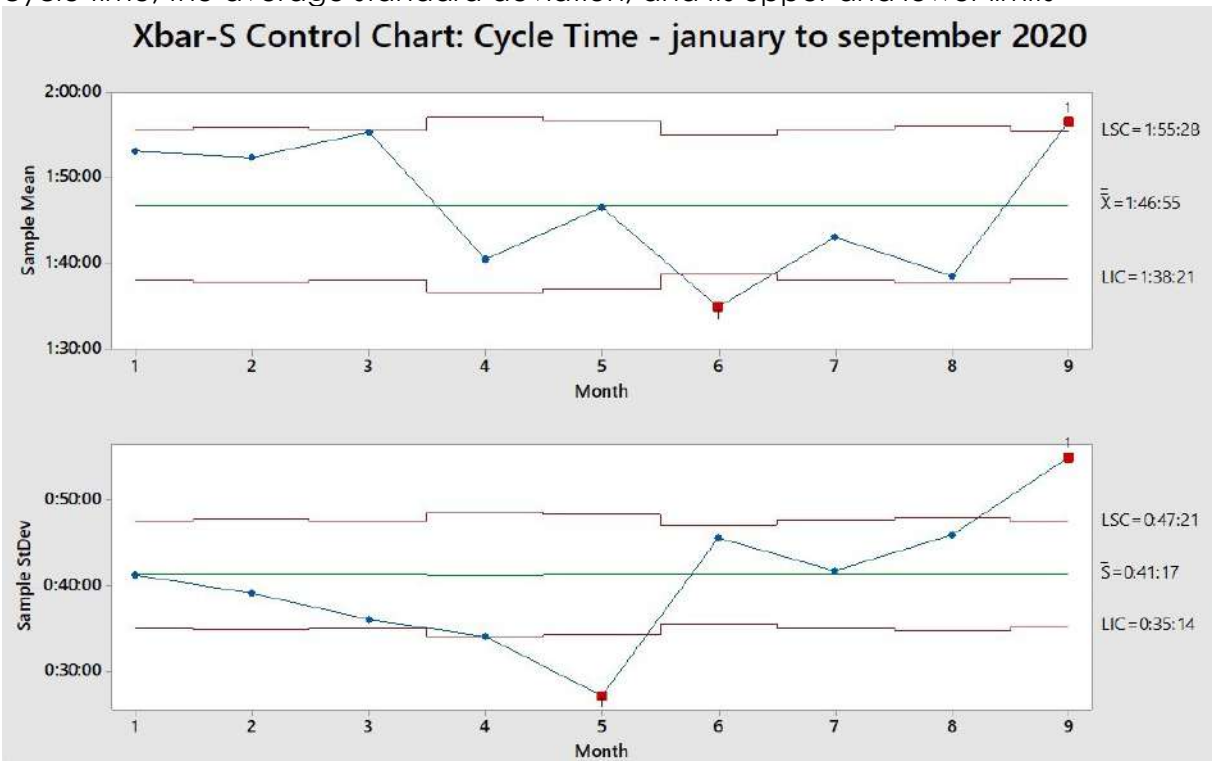
Figure 2
Stratification of cycle time in the milk-run supply process



Source: Authors' work

With the collected data, a control chart was prepared (Figure 3) to compare the monthly average cycle times with the theoretical value predetermined by the company managers, a cycle time of 1 hour. The control chart was developed with the historical data from the nine previous months, providing insight into the instability of the milk-run process. There is a discrepancy of 76.7% between the theoretical cycle time (1 hour) and the average calculated value, which corresponds to approximately 1 hour and 47 minutes. This assessment reflects the complexity of the assembling process and the urgent need to study the supply method because different products require managing between 40 to 70 different materials per cycle.

Figure 3
Control chart of the milk-run process before improvements, considering the average cycle time, the average standard deviation, and its upper and lower limits



Source: Authors' work

It was also necessary to perform a motion study analysis based on the movement diagram of the assembly line to identify possible wastes during the supply process. With this data, a simulator in MS Excel was developed (Figure 4). This simulator considered the assembly line settings, specifying the batches of materials transported by logistic train at each cycle. To do so, several steps were taken into account:

1) Separate materials that are supplied in bags but must be supplied in tubes or carton boxes on the logistic train and assembly line;
2) Sum of all the different materials quantities that are supplied per cycle by the logistic train;
3) Calculate the time for milk run and assembly line replenishment, indicating the daily average restocking activity time.

From the simulation program and the defined cycle time, a new work pattern could be determined according to the line needs, promoting process normalisation and movement waste reduction. In addition, labels were developed to identify packaging materials, respecting the quantities necessary for the assembly line to minimise reverse logistics flows.

Figure 4

Representation of MS Excel simulator interface for 10 of the 24 simulated cycles for the logistic train

Logistic Train:			Cycles										Average
			1	2	3	4	5	6	7	8	9	10	
Tube	Bag	Roll	10	4	11	14	3	11	11	13	0	12	9
Plastic Box (1)	Plastic Box (2)		1	7	2	2	3	5	2	4	1	5	4
Plastic Box (3)			3	3	2	5	3	3	4	3	2	5	4
Carton Box ESD (1)			4	5	3	4	4	5	3	5	5	4	5
Carton Box ESD (2)			1	0	1	0	1	0	1	0	1	0	1
Batch	Blister (2)		6	8	5	5	7	7	4	6	7	7	7
Tray (1)	Blister (1)		35	34	35	34	35	35	34	35	35	34	35
Blister PCB			31	30	31	30	32	29	31	30	32	29	31
Bag		00:24	04:01	01:36	04:25	05:37	01:12	04:25	04:25	05:13	00:00	04:49	03:34
Plastic Box (1)		00:14	00:14	01:42	00:29	00:29	00:43	01:13	00:29	00:58	00:14	01:13	00:46
Plastic Box (3)		00:26	01:20	01:20	00:53	02:14	01:20	01:20	01:47	01:20	00:53	02:14	01:28
Carton Box ESD (1)		00:25	01:40	02:05	01:15	01:40	01:40	02:05	01:15	02:05	02:05	01:40	01:45
Carton Box ESD (2)		00:25	00:25	00:00	00:25	00:00	00:25	00:00	00:25	00:00	00:25	00:00	00:12
Blister (2)		00:17	01:43	02:18	01:26	01:26	02:00	02:00	01:09	01:43	02:00	02:00	01:46
Blister (1)		00:03	02:14	02:11	02:14	02:11	02:14	02:14	02:11	02:14	02:14	02:11	02:13
Blister PCB		00:10	05:10	05:00	05:10	05:00	05:20	04:50	05:10	05:00	05:20	04:50	05:05
Time to supply - Logistic Train			16:49	16:13	16:19	18:38	14:57	18:09	16:52	18:35	13:14	18:58	16:52
Movement			6:19	6:19	6:19	6:19	6:19	6:19	6:19	6:19	6:19	6:19	6:19
TOTAL:			**23:09**	**22:32**	**22:38**	**24:57**	**21:16**	**24:28**	**23:11**	**24:55**	**19:33**	**25:17**	**23:12**

Source: Authors' work

Visual management

Visual management and 5S methodology were applied to the assembly line and the logistic train to guarantee process standardisation.

On the assembly line, the excess material that contributed to waste was removed through the implementation of 5S. When implementing this methodology, the maximum batch quantities of materials can be estimated by considering the requirements of each workstation. Also, different positions were defined for support material in the assembly line.

In the logistic trailers, the 5S was implemented to facilitate visual management and vehicle restocking, resulting in a more agile shift change, reducing wastes of overproduction, transport, movements, and the stock itself.

The most used materials in the production line and the necessary quantities per supply cycle were then allocated in fixed positions for those most frequently used. The materials allocation in the milk-run trailers and the different fixed positions were validated with the operators, so the last trailer could always be available for transporting disposable and reusable materials. Considering the new specifications of the line supply process, the operators received specific training to absorb the new procedures and practices to meet the expected cycle time. The new procedures were properly documented to instigate standardisation.

Results and Discussion

The development of this project brought direct contributions to the company. The results from the line supply cycle standardisation, implementation of 5S, and visual management tools are presented.

Milk-run supply process optimisation

First, developing a simulation tool to define the cycle time for milk-run supply processes allowed us to determine the optimal cycle time of 1h10min for supplying the assembly line Y. The tool was based on the assembly line configurations, identifying which parts and the respective quantities the milk run should transport per cycle. Thus, the time cycle considered the average time spent on the assembly line supply, waste disposal, and recycling tray filling. The picking time for all materials was also included.

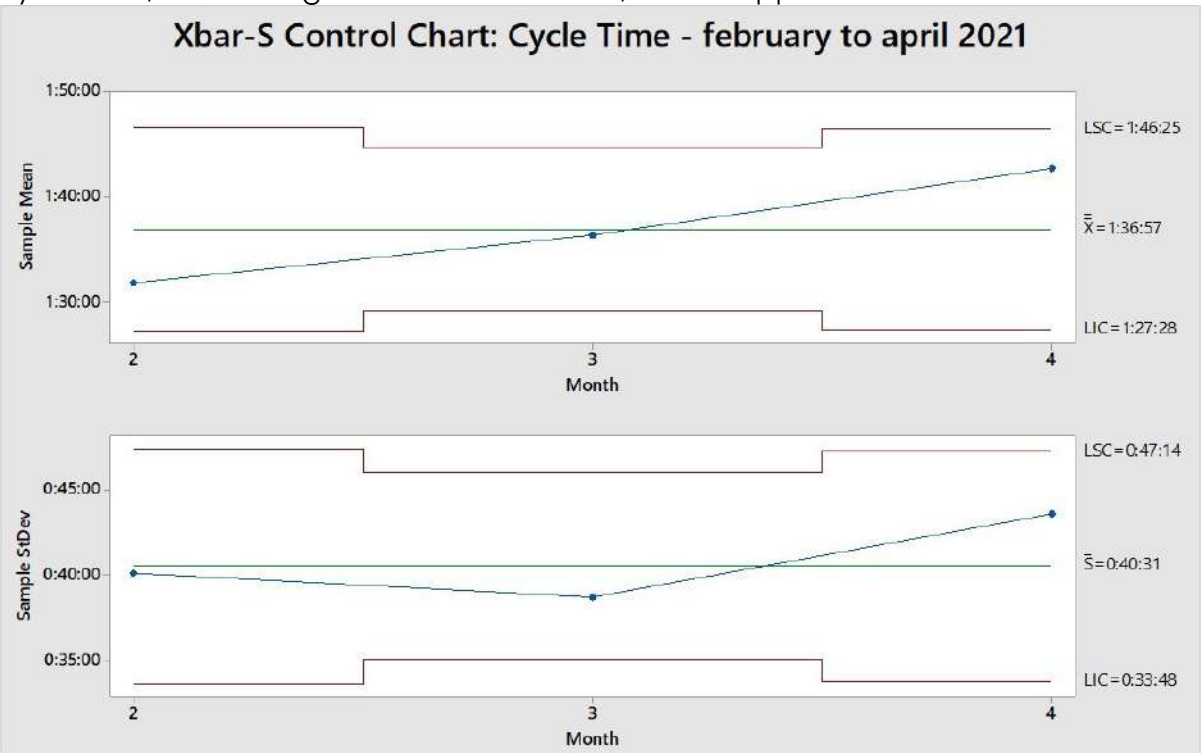
The standardisation of the supply process and the development of documentation for operators' training have represented a reduction of 9%, on average, of the cycle time practised by the milk run (new average calculated value of 1 hour and 37 minutes). This result can be observed by comparing the control chart of Figure 5 for the milk-run process after the continuous improvement tools implementation with the one presented in Figure 3. The control chart was developed with the data collected three months after the improvement tools implementation. Results showed that reducing the cycle time and keeping the average standard deviation within the lower and upper limits is possible.

In this study implementation, it was observed that there were differences in the time of carrying out the supply activities between the different work shifts. Generally, the morning shift had longer cycle times when compared to the afternoon shift. On average, the cycle time of the morning shift was 5.6% higher than the afternoon shift time cycle.

The activities where there is a greater discrepancy are: supplying the train according to Kanban, line supplying at stop 1 (P1), and line supplying at stop 3 (P3). To overcome these differences, training was prepared for the line supply employees of both shifts to standardise the internal logistic process.

Some critical points were raised during the new work plans implementation. One of them is related to production plan change since such change can cause variable supply time cycles and consequent lack of available materials. In addition, without an effective exchange of information between the production planning and the logistic sectors, the production orders may not be concluded.

Figure 5
Control chart of the milk-run process after improvements, considering the average cycle time, the average standard deviation, and its upper and lower limits



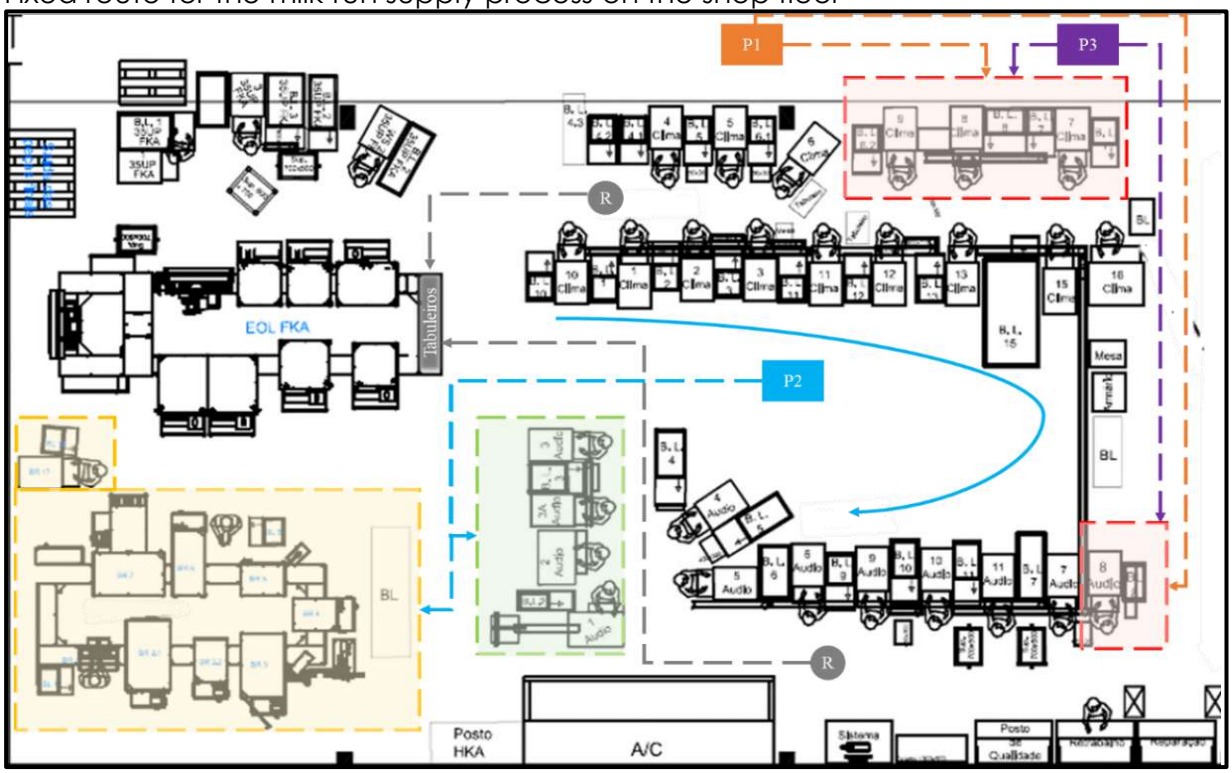
Source: Authors' work

To ensure adequate working conditions for logistics train operators, it was defined that the exchange of references must be communicated to logistic workers at least one hour in advance, giving them time to complete the current logistic cycle and prepare to fully meet the needs of the line when it starts to produce another product reference. After defining the cycle time, a fixed route for the milk run was proposed according to the assembly line needs. The fixed route proposal also aimed the movement reduction.

The supply route was defined considering the optimisation of materials flow and using tags and Kanban cards for visual management. The proposed route includes three stops (Figure 6) because some workstations require two supplies per cycle. At the first (P1) and third stops (P3), the operator must supply the line, picking and returning electronic boards whenever necessary. During the second stop (P2), the operator must proceed with the trays recycling and return to replenish the line that presents such a need. The picking of electronic boards and other parts must be carried out whenever necessary. The maximum quantities to directly fill up the supply bays were delimited.

It was verified a reduction of transportation and stock waste, mostly due to the enhanced visual management provided by new guidelines for managing materials in the milk run. Also, the excess material that contributed to extra processing, unnecessary movements, and transportation was removed from the supply area.

Figure 6
Fixed route for the milk-run supply process on the shop floor

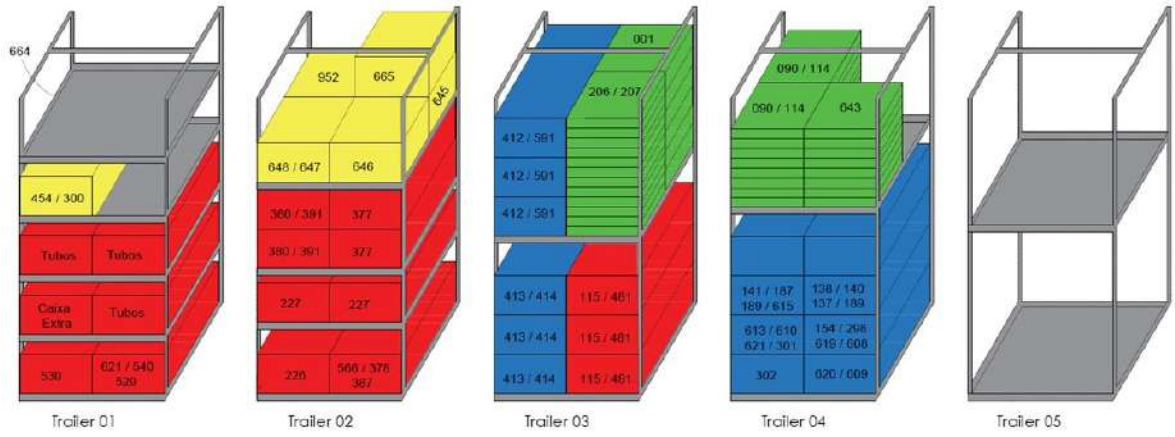


Source: Authors' work

Visual management

As can be observed in Figure 7, the employment of fixed storage positions allowed the release of storage capacity for trailer five. Assuring a maximum occupancy of 80% of the milk run, materials in the logistic trailers represent 68%, and remaining space for the waste transport (12%), thus reducing the movement and transport on the factory floor. The colour coding establishes the different dimensions of the boxes in which different materials are placed. The free spaces of the milk run are intended for materials that are not frequently used, and the last trailer is reserved for the collection of waste produced on the line and for materials of reverse logistics flows.

Figure 7
Fixed positions on milk-run



Source: Authors' work

In the assembly line, the application of 5S resulted in the reduction of stock waste by eliminating 2 856 parts in intermediate stock, which corresponded to 9 220 € savings and a gain of 1.92m² in the available supply area, as well as improvements in the visual management level and other packing materials. The comparison between the initial state and the state after implementing these visual management tools can be seen in Figure 8.

Figure 8
Comparison between the initial state (a) and after (b) the implementation of visual management tools to the logistic train

(a) (b)

Source: Authors' work

It was also estimated a reduction in terms of wasted movements on the production floor, which corresponded to a decrease of about 24%. In addition to the consequent improvement in productivity, this outcome had implications for minimising the impacts of excessive movements on the operator's health.

To guarantee the organisation and maintenance of the established supply procedures, through the reduction of the time cycle, the weekly control of the process via RFID was defined, as well as the implementation of regular audits of the line and logistic train.

Discussion and Final Considerations

Lean and quality tools allow a broader view of internal logistics by applying simple, economical, and efficient solutions to improve the process, generating direct and indirect gains for the company.

The objective of the current research was to optimise a milk-run supply system from one of the assembly lines of an automotive sector company by implementing the PDCA methodology. In this sense, an optimal time for the supply cycle was determined, and the internal logistics process was standardised. The different phases of the PDCA approach were used to implement the materials flow and provide better project management. The goals of this study were achieved after collecting data in loco, analysing the supply process, combining quality tools with Lean tools, and following the project according to the phases: Plan, Do, Check, and Action.

A simulator was developed to determine the optimal cycle time for the assembly line supply process, and the ideal time for the milk-run cycle was calculated as 1h10min. Integrating the simulation in MS Excel, 5S, and the visual management was decisive for the good results obtained in the milk-run supply process. With the implementation of 5S and visual management, it was possible to reduce waste, optimise materials supply and adjust the reverse logistics within the company by defining a fixed position for the materials and a fixed route for the milk run.

Implementing new supply rules reduced wasted movements, freed up the storage area capacity, and avoided unnecessary intermediate stocks. This better organisation, both in the assembly line and in the logistics train, resulted in a total occupancy rate of 80% in the production area and less movement of the operators. At managerial levels, the PDCA cycle for continuous improvement reinforced the benefits of staying on the factory floor, teamwork, and a good relationship between managers and employees. These aspects significantly contributed to the project's success and the full internal logistics chain's development, with positive impacts outside the assembly line. These results agree with (Garza-Reyes et al., 2018; Gyulai et al., 2013). Both works used prototypes and software to solve the milk-run planning problem considering real-life industrial data and obtaining the reduction of cycle times.

In addition to the direct gains, the project made it possible to demonstrate the potential of using Lean Logistics methodologies, showing improvements in working conditions, standardising internal processes, and creating procedures or work instructions within the company.

For the automotive company, the study represented a learning mechanism that generated know-how for future projects in the company's internal supply processes. The assembly line supplied by milk-run was fundamental to highlight a range of possible improvements in the process of internal supply, such as better integration of stock management systems, greater application of quality, or the adoption of better communication systems between the different areas and employees.

Due to the size of the company under study and the quantity and complexity of the production lines, it was necessary to focus the research work on a single line that presents several points of similarity with the other production lines of the company. This can be considered a limitation of the work since (at the moment) the developed simulator only works for the line mentioned in the case study. However, adopting this simulator to other lines is relatively easy, having to parameterised the characteristics that are variable between different lines of production.

As a future work, and to overcome these limitations, it would be interesting to adapt the simulator to all production lines, carrying out a quantitative study that would allow an economic evaluation of the milk-run implementation in the global context of the company's production lines. Through a preliminary theoretical analysis, it is predicted that the impact will be even more significant. It is also suggested to implement studies that aim to extend the use of logistic trains so that tasks such as the internal supply of packaging for final products (activity until then performed by line assistants) might be covered by the improved supply chain methods.

Finally, ensuring the continuous analysis of the processes, the PDCA approach can be used to identify other problems and new opportunities in the context of Lean Logistics.

Acknowledgements: This work has been supported by FCT within the R&D Unit Project Scope UIDP/04077/2020 (METRICS), R&D Units Project Scope UIDB/00319/2020 (ALGORITMI) and R&D Units Project Scope UIDP/04005/2020 (COMEGI).

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Dashboard for the Management and Acceptance of Customer Orders

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Abstract

Background: This paper focuses on activities related to Customer Orders Management withing an auto components plant in the Automotive Industry. The main challenge was highlighted: customers don't always regard the flexibility rules agreed with the company. Hence, planners must decide if variation in ordered quantity can be accepted in the forecast period or if adjusting is necessary. **Objectives:** The purpose was not only to streamline the decision-making process in the planning team but also to provide essential tools for the execution of their daily tasks – a visual and interactive dashboard to assess whether variations in customer orders were within the limits agreed with the company. **Methods/Approach:** Following Lean information management and business intelligence principles, a thorough process analysis was carried out, centralized and standardized reports were created that served as databases, and the dashboard was developed. **Results:** The proposed tool allowed reductions from 3,5h per week, spent mainly on collecting data, calculating variations, and selecting and adjusting the flexibility limits, to 0,2h a day per planner. **Conclusions:** Besides streamlining planners' daily activities, main contributions regard the promotion of digital transformation, data-driven decision-making, and an automated record of customer order variations that could easily be adapted to suppliers.

Keywords: Order variation calculation, flexibility rules, customer order management, dashboard development, data analytics, digital transformation

JEL classification: D240, D830, L620, M110, M150, O310
Paper type: Research article

Received: 30 Jan 2022
Accepted: 06 Nov 2022

Citation: Nascimento, J., Frazão, N. Teixeira, S., Ribeiro, A. C. (2022), "Dashboard for the Management and Acceptance of Customer Orders" Business Systems Research, Vol. 13 No. 3, pp. 116-129.
DOI: https://doi.org/10.2478/bsrj-2022-0028

Introduction

Over the years, the manufacturing industry has witnessed a steady increase in complexity and requirements, with digital transformation (DT) revolutionizing the industrial environment to an unprecedented degree, establishing a variety of new business potentials and opportunities for industries worldwide. DT is focused on business transformation, mainly motivated by "organizational, customer and technology-driven initiatives" (Tomičić Furjan, Tomičić-Pupek, & Pihir, 2020). The success of an industry essentially depends on how consistently and actively the DT is shaped and how the use of new opportunities is made, making it possible for industries to improve quality, costs, and delivery performance and thus increase customer satisfaction (Bosch, 2020).

The Lean logistics paradigm appeared with a focus on non-value-added logistics activities, as logistics operations are characterized by a high level of manual control which ultimately impacts the cost of operations (Pejić, Lerher, Jereb & Lisec, 2016). In administrative areas, the processes that add value to a product or service depend immensely, amongst other factors, on the overall flow of information and employee knowledge (Monteiro, Alves & Carvalho, 2017). Although there is a lack of current research on the application of Lean paradigms in administrative areas, this paper aims to study Lean practices to reduce non-value-added activities through improvements in information flow, automation, and digitalization.

This paper focuses on optimizing customer order management tasks performed by the planning teams within the logistics department at an automotive electronics components company. With a focus on task effectiveness and efficiency through automation, its main goal is to achieve waste reduction, structure adjustment, and capacity re-allocation to where it is most beneficial for profitable growth.

After introducing the theme, the second chapter reviews the existing literature on the themes surrounding the subject, and the diagnosis of the analyzed processes and description of the identified problems are presented, formulating the research hypothesis. The fourth chapter describes the development and implementation of the proposed improvements, and the fifth chapter examines the improvements achieved. This paper is concluded with the sixth chapter, where a general balance of the project is made, and conclusions and possibilities to improve the work are developed continuously.

Theoretical Background

The application of Lean principles in administrative areas is denoted as Lean office and embraces "the improvement of administrative processes and information flows" (Freitas & Freitas, 2020). Monteiro, Pacheco, Dinis-Carvalho & Paiva (2015) improved lead times, process tasks, space organization, and work standardization by implementing Lean office in the public sector, eliminating non-value-adding activities and automating tasks that were performed manually to increase efficiency in data search and daily problem-solving requirements.

In modern days offices, it is vital to coordinate the development of information management capabilities and optimization of information flows, with emphasis on the advantages of electronic technologies and resources, guaranteeing information quality, reducing the use of paper with digitalization, and increasing the use of information systems (Freitas & Freitas, 2020). The focus on improving the flow of information and implementing a Lean approach to information management proves to be crucial to increase competitiveness, as it allows organizations to achieve

improvements over a short period with low resource investment (Bevilacqua et al., 2015).

According to Bittencourt, Alves & Leão (2019), the implementation of I4.0 is facilitated by Lean Thinking as "it simplifies processes and eliminates waste in a way that it is not repeated, reduces the possibility of compromising scarce resources, and increases the transparency of work processes/organization." The same authors highlighted the importance of controlling and optimizing a process before automating it, as "the automation of an inefficient process does not make it efficient." Hoellthaler et al. (2020) proposed a framework to classify and characterize digital technologies within ICT, identification technologies, and automation technologies, which allowed for more efficient information flows, declining trial and error rates, and improving overall process speed, thus increasing efficiency. In his study, they expected the proposed framework to offer "starting points and potential levers to improve information processes in the context of information logistics" and incentivize "to use digital technologies accordingly".

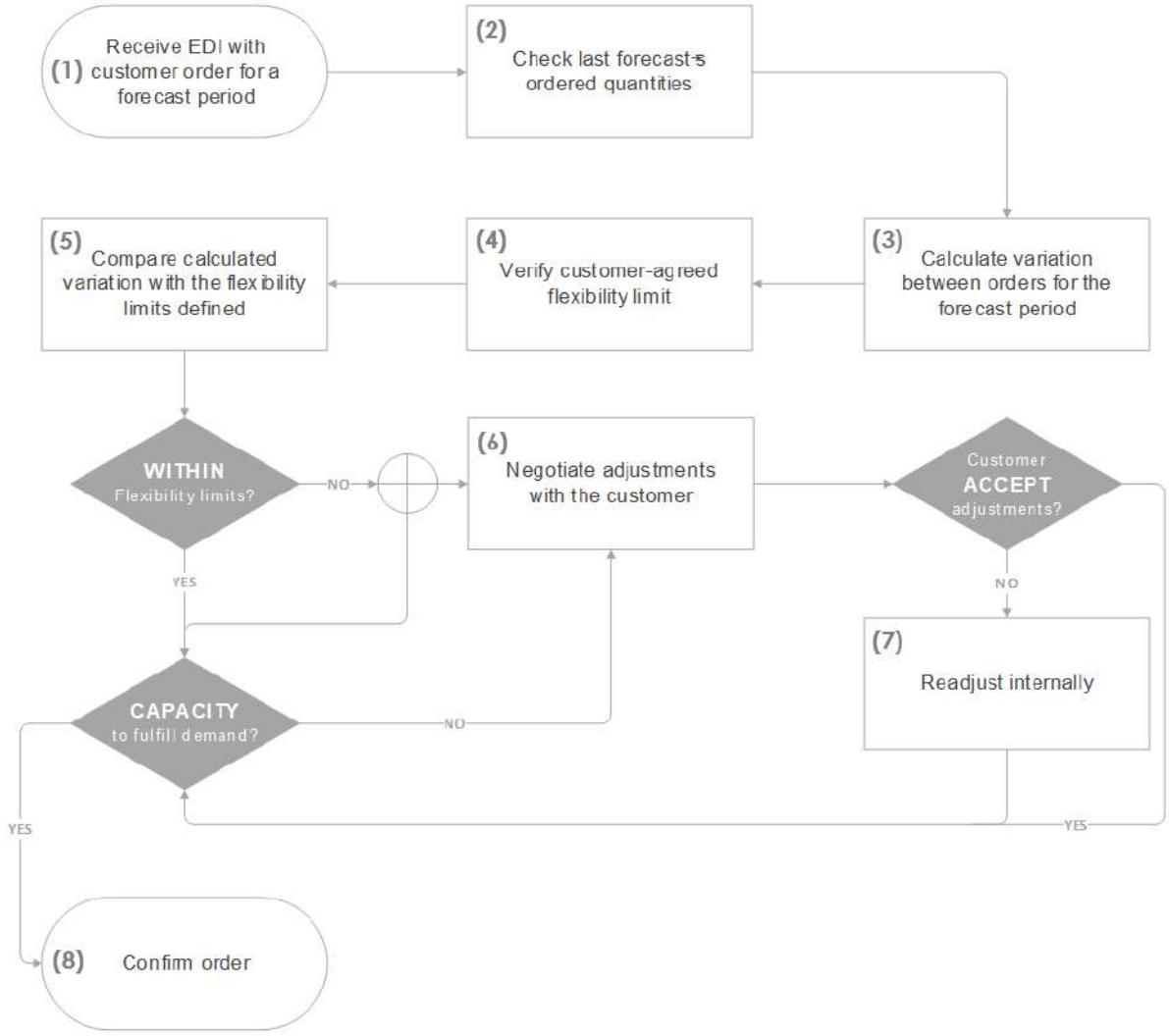
Good information management competencies to integrate, transform and access business data are fundamental to distinctive analytical capabilities. As Davenport & Harris (2007) noted, "it's better to know (…) than to believe or think or feel" as "most companies can benefit from more analytical decision making". Data quality is an essential characteristic that determines data reliability for organizational decision-making. Specifically, guaranteeing high-quality, reliable data is a competitive advantage for all industries (Salem & Abdo, 2016).

Through business intelligence (BI), it is possible to improve business analysis and support decision-making. Teixeira, Oliveira & Varajão (2019) demonstrated the importance of an area dedicated to BI within organizations as a way of increasing agility and quality in data processing since its deficiency made it "difficult to have access to data because there were no tools or software that allowed to have the information and the data on time". BI is characterized as the technologies and processes that take advantage of the extensive use of data to comprehend and analyze the performance of organizations. In contrast, business analytics (BA) makes statistical and quantitative analysis with explanatory and predictive models possible to achieve greater efficiency and drive smarter decision-making and better business actions (Davenport & Harris, 2007). Analytical applications range from a variety of tools and systems, including simple data analytics, manipulation, and visualization tools such as Excel and Power BI, to complex deep learning algorithms and predictive analysis, applicable in a wide range of techniques to assist organizations in forecasting, simulation, and optimization to streamline and improve decision making (Krishnamoorthi & Mathew, 2018). Silva, Cortez, Pereira & Pilastri (2021) added that, although BA has proven useful in optimizing resources and detecting customer needs, there are still few research application studies within this topic.

Problem Identification

Several types of waste arise from inadequate information management principles and the deficiency of digital and automated data analysis tools (Nascimento, Frazão, Teixeira & Ribeiro, 2021). These problems were identified in receiving and analyzing customer orders, mainly to verify if there were variations in the ordered quantities and if they are allowed in the customer's contracts (Figure 1).

Figure 1
Customer Order Variation Analysis



Source: Author's work

Customer orders are transferred via Electronic Data Interchange (EDI), and planners need to receive and analyze them to plan production according to customer needs (1). When examining new orders, the planners also check for any alteration in the demand quantity (2 and 3) and whether it is within the variation limits fixed with the customer (4 and 5). The order is accepted if the variation is within the flexibility rules (8); if not, adjustments need to be made with the customer (6), as long as it is within the reaction time or in the production plans for the forecast period (7). This analysis is crucial to determine whether the plant can fulfil the order or needs to renegotiate order quantity or reallocate production for the next forecast period.

The main issue identified is that planners waste too much time and manual effort on data searching, collection, and reporting tasks. To manage customer orders, it is necessary to generate several reports whose data sources have different origins. There is no common repository for all customers where flexibility rules are available, as well as a tool that consolidates the results for later analysis and action by planners. As a consequence of not fulfilling this task on time, planners have to accept the order leading to capacity problems in fulfilling the orders. This can result in negative impacts on service level and stock levels, from unfulfilled orders to customers, delays in

delivering the orders, shortage of raw materials in orders with large increases in variations, or wasteful accumulation of stocks with large decreases in ordered quantity. The main purpose of this paper is to assess whether the application of lean information management principles with digitalization reduces the planning team's time and manual effort.

Methodology

To define what procedures should be structured to accomplish the automation objective, the most important aspect was to ascertain what tool would best support the planners in their analysis, what data should be taken into consideration, and how that data should be displayed. The purpose of the tool would be to compare the current week's releases with snapshots of previous releases for a specific forecast period, clearly and visually indicating whether there is variation between the current release and the forecast release and whether this variation is permitted or restricted by the flexibility limits contractually defined with the customer. Furthermore, the tool should also be able to quantify the variation, as this information is necessary to report to the customer. The team of planners was already acquainted with dashboards, using them daily to support planning activities, examine stock levels, coordinate production backlogs, and occupation production lines. Therefore, it was decided to develop a new dashboard sheet for managing customers' orders and integrate it into the team's existing dashboard. This dashboard would be powered by reports that could also be consulted if planners needed a more detailed analysis. It would also report information regarding releases, forecasts, variations in quantities, and flexibility rules associated with each customer.

The first step in the project development was to analyze the planners' daily activities and how the tasks were currently performed, then automate these as possible tasks. Three main actions were established:

- Automate order variation calculation
- Analyze flexibility rules by the customer from the orders variation report
- Develop order variation dashboard

The first two actions identified consisted of creating the reports that would serve as the database for the dashboard, and the third act was the development of the dashboard itself.

Automation of Order Variation Calculation

To retrieve data relating to customer order volume analysis, traditional data sources and centralized manual data inputs were used. The report from the company's internal system contains the parameters of each customer order and quantities ordered by Calendar Week (W) – when the order is due – taking place in each Snapshot Week (SW) – when the customer places the order. Each order release is retrieved from the company's management software and characterized with predetermined parameters. Customers place an order for a final product associated with a project that can contain more than one final product. This means that each project can comprehend multiple products, but a product can only be associated with one project.

To automate the calculation of the variation of order releases, the first stage was to define which forecast period would be considered. The requirements for the forecast period selected and the time horizons to be compared were defined:

- The variation in releases would be calculated weekly, as there are no significant daily variations

- Relative order variation in releases is used in comparison with the flexibility rules, while absolute variation in quantity ordered is displayed as information for the planner
- To allow records comparison, the report would comprise information on releases from the snapshot of the current week (SW_n) up to snapshots of six weeks prior (SW_{n-6})
- Would only be considered variations in percentage in releases between the snapshot of the current week's releases (SW_n) and the two previous weeks' snapshots (SW_{n-2}) in a 60-week calendar horizon (W_{n-8} to W_{n+52})

For each calendar week, the variations of the ordered quantities (Q) are calculated as follows:

$$\Delta Q_{SW_{n,n-x}} = Q_{SW_n} - Q_{SW_{n-x}}, for\ x = \{1,2,3,4,5,6\} \quad (1)$$

$$\Delta_{SW_{n,n-1}}(\%) = \left(\left(Q_{SW_n}/Q_{SW_{n-1}}\right) - 1\right) * 100 \quad (2)$$

$$\Delta_{SW_{n,n-2}}(\%) = \left(\left(Q_{SW_n}/Q_{SW_{n-2}}\right) - 1\right) * 100 \quad (3)$$

Table 1
Description of the notations used in the equations

Symbol	Description
Δ	Variation
Q	Ordered quantities
SW	Snapshot date of customer order releases
n, x	Week

Source: Author's work

After identifying the parameters characterizing each release and the fields needed for the calculation, the order variation report was created (Table 2).

Table 2
Order Variation Calculation Report

Calendar Week	Order Release Parameters	SW_{n-6}	…	SW_n	$\Delta Q_{SW_{n,n-1}}$	…	$\Delta Q_{SW_{n,n-6}}$	$\Delta_{SW_{n,n-1}}$	$\Delta_{SW_{n,n-2}}$
W_{n-8}		PC	…	PC	PC	…	PC	%	%
…		…	…	…	…	…	…	…	…
W_{n+52}		PC	…	PC	PC	…	PC	%	%

Source: Author's work

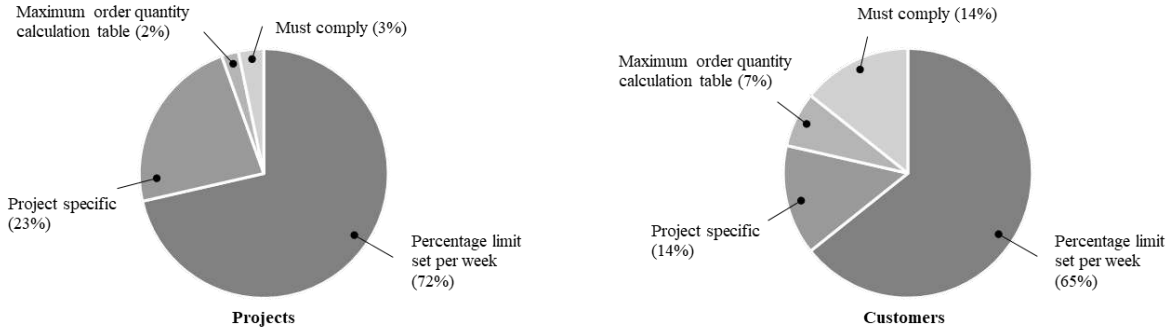
The report comprises information on order variations quantity, in pieces (PC) and percentage (%) per customer material, ship-to, plant, and total volume with data retrieved from various integrated systems.

Flexibility Rules Analysis

Following the completion of the orders, the variation report was the development of the flexibility rules report. It consisted of gathering the logistics analysis reports from the different customers, standardize the flexibility rules defined within the agreements, and grouping customers and projects by the standard. Each customer group has agreed on flexibility rules applied to all orders commissioned by that customer, consequently applied to the projects with which the products are associated. However, there are projects associated with multiple customers with different rule sets. Four standard rules were identified (Figure 2): Increase/decrease *percentage limit set per week*; *Project*

specific rules; *Maximum order quantity calculation tables*; *Must comply* with ordering quantity.

Figure 2
Project and Customer Distribution by Standard



Source: Author's work

The development of the report and dashboard mostly includes the most significant standard, the *percentage limit set per week* (72% of projects and 65% of customers), since there is no standard guideline for active projects with *specific rules* (23% of projects and 14% of customers) and customers with *must comply* rules (3% of projects and 14% of customers) are outside the scope of this analysis. For the *calculation tables* standard (2% of projects and 7% of customers), an adapted calculator (Figure 3) was developed and accessible through the dashboard. Entering specific parameters returns the maximum daily, weekly, and monthly quantities allowed to order. The calculator is based on data tables and calculation instructions provided by customers. Based on the periodic forecast, the average daily consumption of each product is compared with the flexibility tables provided by the customers to identify the maximum consumption quantities, which, multiplied by the consumption coefficient provided, allows the calculation of the maximum order quantities for each period (daily, weekly or monthly).

Figure 3
Example of Calculator Developed for *Calculation Tables* Standard

CALCULATOR - *CALCULATION TABLES* STANDARD

INPUT FIELDS	
Last Periodic Forecast	17600
Number of Worked Days	20,5
Consumption Coefficient	1
Packaging Unit	100
Volume Constraint	1000
Average Daily Consumption (ADC)	**858,54**

Maximum Quantity in Flexibility Tables	1070
w/ consumption coefficient	1070
Maximum DAILY Consumption	1000
Maximum Quantity in Flexibility Tables	4625
w/ consumption coefficient	4625
Maximum WEEKLY Consumption	4700
Maximum Quantity in Flexibility Tables	17958
w/ consumption coefficient	17958
Maximum MONTHLY Consumption	18500

Source: Author's work

The standard increase/decrease *percentage limit set per week* characterizes the limit as a percentage change defined in a predetermined time horizon in weeks (Table 3). This standard is known in 9 customers and more than 60 projects of the plant

Table 3
Flexibility Rule Standard General Example - *Percentage Limit Set per Week*

W	x%			y%				z%	
	0	+1	+2	+3	+4	+5	+6	+7	+8
	-x%			-y%				-z%	

Source: Author's work

This example characterizes a flexibility rule defined on a 9-week horizon. W_0 is considered the week the order is released, and the rule is applied over the next eight weeks. In this example, the first two weeks following the posting of the purchase order, W_0, and W_{+1}, have allowable quantity changes of ±x%. The next four weeks, W_{+2}, W_{+3}, W_{+4}, and W_{+5}, allow quantity changes of ±y%, and the last three weeks of the horizon, W_{+6}, W_{+7}, and W_{+8}, ±z% variation.

After identifying the fields characterizing the first flexibility rule standard, the flexibility rules report was created (Table 4). The report aims to centralize the manual data inputs and serve as a database for the dashboard.

Table 4
Flexibility Rule Standard General Example - *Percentage Limit Set per Week*

Calendar Week	Customer	Rule Description	$\Delta_{SW_{n,n-2}}$ Upper Limit	$\Delta_{SW_{n,n-2}}$ Lower Limit	$\Delta_{SW_{n,n-1}}$ Upper Limit	$\Delta_{SW_{n,n-1}}$ Lower Limit
W_{n-2}			%	%	-	-
W_{n-1}			%	%	%	%
…			…	…	…	…
$W_{...}$			-	-	%	%

Source: Author's work

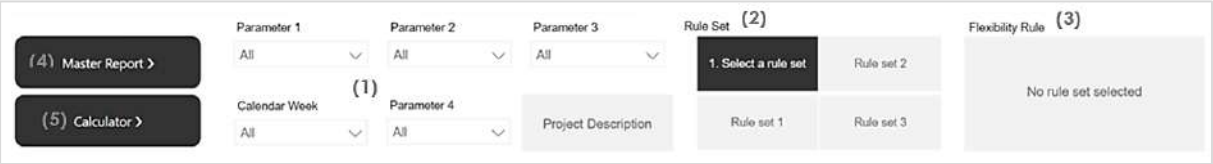
The report comprises information on percentage limits (%) per customer group with data retrieved from the requirements matrixes of customers.

Dashboard Development

After completing the reports that would serve as the database for the dashboard, the final action was to design an easy, visual, and interactive dashboard, with a graph comparison between order variation percentage and flexibility limits defined. Since planners have access to all the information detailed in the reports, it would be unnecessary to repeat data in the dashboard, displaying only the information that would be relevant in the comparison between order variation and flexibility rules in the dashboard.

The developed dashboard contains two charts representing variations in orders between snapshot weeks for the different calendar weeks and compares these variations with the limits set by the rules. The planner selects the parameters (Figure 4) concerning the order to be analyzed in the filters area (1) and selects the rule set corresponding to the customer for whom the order is placed (2). Descriptive information about each selected rule set is also provided (3). The centralized master report (4) is accessible through the dashboard, where the data is refreshed weekly, adding, modifying, or eliminating flexibility rules. The two reports created in the previous sections are also available in the master report. It is also through the dashboard that planners access the calculator for orders analyzed by the *calculation tables* standard (5).

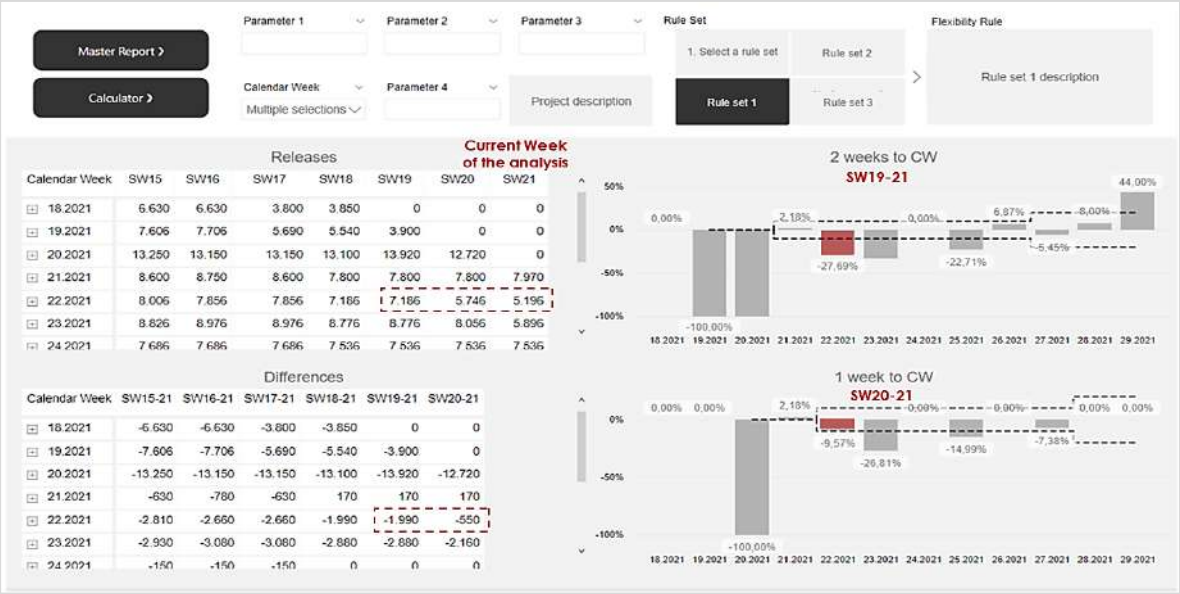
Figure 4
Order Variation Dashboard – Filter and Information Area



Source: Author's work

The dashboard represented in Figure 5 contains fictitious data reporting order releases for a product from weeks 13.2021 to 21.2022. In the current week of the analysis, 22.2021, the releases in the week's snapshot, SW_{21}, are compared with the releases of the previous two weeks, SW_{19} and SW_{20}. The values of the columns in both charts represent this variation. Line values represent the maximum percentage variations allowed.

Figure 5
Order Variation Dashboard – Analysis Example



Source: Author's work

In this example, when analyzing calendar week 22.2021, it is observed that:

- In the snapshot for the week two weeks before the current week, SW_{19}, the ordered quantity for week 22.2021 was 7 186 PC, while in the current week's snapshot, SW_{21}, the ordered quantity is 5 196 PC (equation 1). This decrease of 1 990 PC represents a variation of -27.69% (equation 3) in the ordered quantity that is outside the permitted limit of ±10% for that week
- In the previous week's snapshot, SW20, the order for week 22.2021 was 5 746 PC, and in the current week's snapshot, SW21, 5 196 PC. This decrease of 550 PC (equation 1) represents a -9.57% (equation 2) variation within the permitted limit of ±10%.

Based on the information synthesized in the dashboard, the final decision always depends on the planner. In the example, for week 22.2021, it is observed that the reduction compared to the amount ordered two weeks before is greater than the one allowed by the flexibility limits. Still, the reduction compared to the previous week is allowed. This means that, according to the flexibility rules, the planner must inform

the customer of the excess quantity and can reject the reduction that exceeds the allowed limits. However, depending on the plant's circumstances, the planner may not reject the order. Reliant on the quantity of product in stock, it may be in the planner's interest to reject the reduction and deliver the originally ordered quantity to the customer, avoiding keeping large accumulations of inventory. On the contrary, considering the crisis in electronic components affecting the industry, reducing the quantities ordered is beneficial for the planner, as it allows the relocation of critical raw materials to other orders and maintains the satisfaction of customer needs.

This design made it possible to achieve the main objective of this dashboard, understandable and easily interpreted by planners, providing an overview of customer orders and helping planners' decision-making. Ideally, the planner stops manually checking the comparison between order variation and customer flexibility rules, automatically obtaining the information to report to the customer.

Results and Discussion

By this time, the order variation dashboard is available and tested by the planners, whose response on its accuracy and suitability further improves customer order management and production planning. The customer order variation dashboard covers 72% of customers and 74% of projects within the plant, with over 18 000 customer orders being automatically evaluated weekly. To cover the entire range of projects and customers, guidelines for projects with the *specific rules* standard or *must comply* standard could be aligned with one of the two standards covered by the dashboard.

A study was carried out within the planning team, estimating that the planner took 2.5 hours per week on tasks like data searching, collection, and calculation of variations in orders and another 1 hour to prepare information to report to the customer. Automating this task with the proposed tool allows for potential savings of up to 1 337 hours per year in the department, reducing the time spent analyzing customer order variation and comparing flexibility rules to 1h per week per planner. More than 95% of the time spent would be saved with the automatic weekly refresh of the dashboard data, which loads the latest information from the internal system. In comparison, 7% is reflected by the data organization and added additional information displayed in the dashboard (Table 5).

Table 5
Implementation Results

	Initial Process		After Implementation		Variation
	weekly	daily	weekly	daily	weekly
Data Collection Variation Calculations Select & Adjust Limits	2.5 h	0.5 h	0.07 h	0.01 h	- 1.5 h **- 97.2 %**
Report variation to the customer	1 h	0.2 h	0.93 h	0.19 h	- 0.07 h **- 7 %**
Total	**3.5 h**	**0.7 h**	**1 h**	**0.2 h**	- 2.5 h **- 71.43 %**

Source: Author's work

Main Contributions & Limitations

Implementing a lean approach to information management can increase a company's competitiveness (Bevilacqua et al., 2015). Overall, it is possible to observe great improvements both in expended time and necessary manual effort in the

collection, cleaning, and use of information, allowing not only to streamlining the decision-making process of the planning team but also to provide essential tools for the execution of their daily tasks. Validating similar results obtained by Bevilacqua et al. (2015), "the specific focus on lean information management has enabled the company to increase the benefits already obtained by applying lean production principles", achieving substantial advantages in process lead times, task efforts, and reduction of waste in the form of non-value-added activities, in line with the results obtained in Monteiro, Pacheco, Dinis-Carvalho & Paiva (2015). Furthermore, the paper provides insights into the actual applicability of lean information management, from waste detection on manually performed tasks and data analytics to the flexibility and low cost of dashboard implementations. This paper also aims to give a reference for improving digitalization and information management practices within multiple industries.

In addition to saving 2.5 hours per week in the assessment of variations in customer orders, the developed dashboard could benefit the Planning and Fulfilment department and other areas within Logistics. Each customer group has stipulated flexibility rules applied to all projects associated with that customer, although there are projects associated with several customers with different rule sets. Selecting the flexibility rule and the project as two independent parameters presents the planner with the ability to evaluate one project by different rules and allows for better assessment in the analysis and decision support in reviewing the flexibility rules with the customer. Another contribution made possible by this dashboard concerns the response to demand fluctuations. Having an automated record of variations in customer orders allows the planning department to predict production plans better and the purchasing department to align this variation in orders with the variation in raw material purchases. In the future, based on the data provided by the dashboard, flexibility rules adapted to the plant's needs can be agreed upon with suppliers, and a new dashboard to inspect these variations can be created since the standard is already developed.

The integration of lean information management concepts allowed not only to take full advantage of the information that is continuously generated but also to transform and integrate it to satisfy the information needs of planners, providing them with the necessary information when required and guaranteeing its quality. Despite being available, the current circumstances of the crisis of electrical components make it impossible to use the order variation dashboard as intended. As there are shortages of various materials and insufficient quantities to satisfy all customer requests, the planners do not accept any changes to the ordered quantities. At the moment, planning is made according to the availability of raw materials and not according to customer requests. However, it is expected that active work will continue to improve this tool and allow greater agility and flexibility in the tasks performed by planners.

Enhancements can be developed in future work, such as the flexibility of reports and dashboards and a more detailed and real-time analysis of customer order launches. It was stated that the release variation would be calculated weekly as there were no significant daily variations. However, a variation to an already planned quantity would be registered once a week. Orders received the next days would only be considered the following week, substantial or not. A potential solution would be reducing the time between updates and replacing weekly snapshots with daily snapshots.

Furthermore, the calculation of variations always considers the current week of the analysis. To increase the flexibility of the analysis, another proposal for improvement

would be to allow the choice of weeks to be compared, regardless of the current week. Implementing these proposals will generate new opportunities for progress and trigger other challenges following an endless cycle of continuous improvement.

Conclusion

The development of the dashboard described in this paper allowed for accomplishing the proposed objectives, saving time, and streamlining the tasks of the planning and fulfillment department planners. Simultaneously, the project permitted additional contributions associated with the planners' responsibilities in the decision-making. In addition, to improve the effectiveness and productivity of the Planning and Fulfilment department, the contributions of this article aim mainly to help to fill a gap in the literature with the study of the implementation of Lean practices in digitalization and information management supported not only by similar results obtained within the industry but other administrative areas as well.

The contributions of this paper employ not only the improvements in the effectiveness and productivity of the planning team but also help to fill a gap in the literature with the study of the implementation of Lean practices in the context of lean office and information management. The results are in line with studies consulted that obtained similar and significant improvements, both in the automotive industry and in other areas focused on information management and administrative processes. It highlights issues of lacking usage of business analytics tools and managing information, vital to the continuous improvement of organizations. Continuous work needs to be followed within the subject to generate new opportunities for growth and continuous improvement, both in studying information-related processes and their applicability within the wide range of an organization's divisions.

Acknowledgements: This research was supported by the Portuguese Foundation for Science and Technology (FCT) within the Project Scope: UIDB/04005/2020 (COMEGI) and within the Project Scope UID/CEC/00319/2020 (ALGORITMI).

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Using EPP Boxes in a Dark Store: A New Approach to Simplify Food Retail E-Commerce Deliveries

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Abstract

Background: E-commerce has emerged as a good response to the pandemic of COVID-19. However, the costs of providing a service, which includes a driver and a vehicle, in a regular vehicle that can transport goods that need positive cold (0° to 5°C) are very high. **Objectives:** This paper aims to investigate how a big Portuguese retailer company can reduce its dependence on refrigerated vehicles, simplifying operations and reducing the costs of transporting positive and negative cold food. **Methods/Approach:** This research was carried out in a food retailer Portuguese company, more precisely in a Dark Store dedicated to the online channel. The study was developed based on the AS-IS/TO-BE process analysis methodology, starting with the analysis of the current situation, giving rise to the so-called AS-IS model. **Results:** It was possible to reduce costs associated with transporting positive cold goods. As a result, there are 30% fewer costs associated with order transportation. With an additional 10% in space optimization with the gain of space within the galley of each vehicle. **Conclusions:** The costs of transporting positive and negative cold foods were decreased, and substituting vehicles with room temperature transport reduced the need for refrigerated vehicles.

Keywords: E-commerce; Transportation; Sustainability; Dark Store; Food Retail; Case study

JEL classification: L81, L91, Q56, L16
Paper type: Research article

Received: 02 Feb 2022
Accepted: 16 Oct 2022

Citation: Pintado, E., Coelho de Oliveira, L., Esparteiro Garcia, J. (2022), "Using EPP Boxes in a Dark Store: A New Approach to Simplify Food Retail E-Commerce Deliveries" Business Systems Research, Vol. 13 No. 3, pp. 130-143.
DOI: https://doi.org/10.2478/bsrj-2022-0029

Introduction

In the last decades' food retail structures have evolved rapidly, initially transitioning from traditional stores to supermarkets and, in a second phase, from supermarkets to the online market (Lu & Reardon, 2018). This evolution did not invalidate the other structures' existence; it required organizations to find new models of managing their supply chains that would allow hybrid structures between offline and online food retail channels (Wuang & Ng, 2020). Traditional food retail has been changing a lot in recent years, and this is due to new technologies such as smartphones and tablets, software such as apps, digital coupons, and mobile payments. Technologies enable an optimized interaction between the customer and the company. With this new scenario, it has been seen that cross-channel and multichannel models have been moving towards an omnichannel model, in which the full integration of the various channels shapes the service interface and creates a perfect experience for consumers (Alves et al., 2021). More evident in Western Europe and the United States, this evolution has been driven by consumer characteristics and the need to reduce infrastructure costs, enabling the offer of more competitive prices, as described by Oliveira et al. (2023).

Nowadays, people have less and less time and want everything as immediate and simple as possible. The food retail industry responds to this reality with a continuous effort to reduce the complexity and the number of actions required by the consumer from the moment the need arises to the purchase (Martins et al., 2020; Cosimato & Troisi, 2015). According to Deloitte (2017) in the Global Powers of Retailing 2017 study, four trends are crucial for the food retail sector, namely the development of value-added digital skills, combining channels to make up for lost time, creating unique and engaging store experiences; the reinvention of food retail with new emerging technologies (Deloitte, 2017). The advantages of shopping online are numerous since you no longer spend your precious time doing other more productive tasks than daily going to a supermarket and being bombarded with stimuli to purchase items that are unnecessary or waste time to be with the ones you care about most. It is safer in times of pandemic. However, there is a need for robots that have an algorithm in your automation that allows you to understand the intensity of touch they should exert when choosing a particular food, nor the color to be easy to associate with the taste registered in the system by the customer (more mature or greener). Today, they work daily to meet the needs of several people, and sometimes the article may not come out in ideal conditions or according to expectations. Or it may not be dispatched at all. Supply chains face recovery from the disruption caused by the 2020 pandemic event. At the end of 2019, the world was exposed to an unprecedented pandemic crisis that has cost high human losses characterized by a frightening speed of propagation. As the scientific community developed an answer, the economic impact was quick. Supply chains were in crisis because of the government restrictions, like social distancing, remote work, and restaurants and schools closed, as measures to control COVID-19. Additionally, the need for isolation and new human behaviour quickly influenced the nature of business (Bhatti et al., 2020). As a result, online commerce has increased rapidly, triggering problems along supply chains that have faced operational difficulties and the capacity to respond. Within days, the food retail sector began to feel pressure, increasing delivery times, reducing supply, and overloading its technological systems (Lone et al., 2021). In the first phase of the COVID-19 pandemic, we witnessed the purchase associated with panic; then, due to scarcity, the idea emerged that it was necessary to create stock, combining contradictory information. As a result, it was not difficult to observe the disruption of supply chains worldwide. The stockouts created even more stress on consumers as

supply chains looked for new solutions and faced problems caused by COVID-19. Many suppliers even went into production disruption (Campisi et al., 2021). With the evolution of the pandemic, and the perception of its infectious severity, customers favored online channels for security reasons. In this scenario, E-commerce emerges as a good response to this reality, offering a wider range of products (including products that are not available in stores) and providing an unimpeded offer in terms of access without the consumer having to worry about the crowd, decisions transportation, weather conditions, and parking (Bhattim et al., 2020). Also, the technological advances witnessed in recent decades have led to a growing recognition of the possibility of online shopping (Jiang et al., 2013). Before the pandemic, the market was already expanding; it is evident that the convenience for the consumer to be able to buy what they need for their home online. For instance, with the growth of solutions such as Alexa or Siri, linked to the refrigerators and cabinets themselves, in the future, with just voice recognition, it may be even easier to order the items that are missing for the nearest dinner. However, purchasing fresh items that lack a visualization and touch on the product still suffer some resistance when buying them. The food retail sector was expanding in a structured manner with a focus on customer satisfaction and increasing the information spectrum throughout the supply chain. In 2019, the sector followed the growth trend of previous years with an EU-wide average of 10%, but 2020 exceeded all expectations with an average of 50%. (McKinsey Company, 2021). In this context of the evolution of e-commerce in the retail sector, the present investigation arises. For instance, the food retail case study presented in this paper increased by 80% in 2020 versus 2019, only accounting for e-commerce. This combines the need to increase the offer in the distribution channel (reduction of lead time) at the lowest possible cost in association with high levels of service. During the first confinement, operations and the site were unprepared for the surge due to the Covid-19 pandemic. However, the case study company saw an opportunity related to the distribution of products packaged in the positive cold (0° to 5°). This distribution requires refrigerated road vehicles, resulting in higher diesel consumption and lower availability. If the costs of providing a service, which includes a driver and a vehicle, are three times higher when comparing a regular vehicle that can transport goods that need positive cold (0° to 5°C) compared to a vehicle that can only transport goods that are at room temperature. The focus on sustainability has increased over the years; the company's strategic plan aligns with the 2011 White Paper (Kallas, 2011)for the reduction of CO_2 emissions. The integration of a zero-emission vehicle is expected in the short term.

This paper aims to analyse how retailer companies reduced their dependence on refrigerated vehicles, reducing the costs of transporting products from online orders in vehicles. In doing so, aspects such as Savings in service provision costs with vehicles with EPP (Expanded Polypropylene) boxes; Savings on diesel costs (in refrigerated vehicles, diesel consumption is higher); Ensuring better product quality; Reducing waste products when the delivery is not made; Cost savings in trading on a larger scale with non-refrigerated vehicles (the number of non-refrigerated vehicles increase, so the price per vehicle decreases) were analysed in the light of the replacement of these regular vehicles. To meet these needs, delivery vehicles should have at their rear a truck body capable of receiving a refrigeration system directly linked to the vehicle's energy consumption, which in turn implies a greater diesel consumption during the trip (Margaritis et al., 2016). And a project that promotes sustainability improvement does not require an increase in costs. On the contrary, Competitiveness and Sustainability are sides of the same coin; as society strengthens the power of consumers, this relationship is a powerful weapon for innovation and

value creation (Cosimato & Troisi, 2015). As is well known, transport is one of the heaviest items in monetary terms of a supply chain manager, which involves the physical movement of a product from one point to another.

For this reason, food retailers and online commerce struggle daily to reduce their costs per unit of movement without penalizing product quality. These cost savings must be higher than the investment costs in thermal plates, EPP (Expanded Polypropylene), and BLE (Bluetooth Low Energy) sensors, as well as the manual work of placing the products in these same boxes, associating, and disassociating orders from the respective sensors to obtain temperature tracking per order box. The properties of EPP include good heat resistance, good chemical resistance, and good characteristics as a thermal insulator. EPP does not absorb water but is nevertheless permeable to water vapor and other gases. (Maier & Haber, 1998).

In related work, Casson et al. (2021) proposed investigating the environmental performance of the expanded-polypropylene (EPP) box production process to improve sustainability in catering services. Their work quantified the environmental benefit of using the EPP box instead of conventional packaging. Furthermore, in another related work, Mohebi et al. (2015) highlighted an overview of existing commercial sensors for monitoring meat stability and its shelf-life, discussing sensors that have been applied to monitor different kinds of meat, such as pork, fish, beef, and shrimp. In addition, they also reviewed the integration of these sensors into the meat packaging technology and compared their advantages and disadvantages in the meat industry. Alberto Lopes et al. (2019) demonstrated that heat treatment of semi-crystalline polymeric food contact cups in EPP boxes could lead to changes in the degree of crystallinity. Physical changes were also observed on the surface of the material. The variation in crystallinity affected the specific migration of several substances. However, they were only observed at temperatures above 40 °C.

The document comprises an introduction that addresses the investigation's context, description, and objectives. Subsequently, it is presented the methodology used in this research paper. Afterward, the Main Findings are presented, where it is possible to discover more about the company's dynamics and what led it to discover that it could innovate to reduce its ecological footprint and costs in your operating account. Then, a discussion of the main findings obtained during the development and implementation of this research is made. Finally, the last chapter considers this investigation, and the next steps for implementing the project at the company are presented.

Methodology

This investigation was carried out in a food retailer Portuguese company, more precisely in a Dark Store dedicated to the online channel. In this structure, orders are delivered daily to meet the requests of your online store. In these orders, all items must be transported at the required temperature (ambient, refrigerated, or frozen) not to lose the characteristics that give them quality or, in certain cases, the possibility of being consumed.

The study was developed based on the AS-IS/TO-BE process analysis methodology, starting with the analysis of the current situation, giving rise to the so-called AS-IS model. After its study and identification of inefficiencies, a set of improvements (translated into actions) are presented, thus exposing the desirable situation for the process, conceiving the so-called TO-BE model.

The opportunity identified in the context of this research is linked to the fact that it is necessary to increase the level of customer service at the lowest possible cost in a short period, which is why the refrigerated transport replacement project was created,

which allows for a reduction in dependence on this type of vehicle, increasing fleet availability associated with cost reduction, on delivery to the final consumer, ensuring that the temperature is maintained throughout the supply chain (Cosimato & Troisi, 2015; Deloitte, 2017).

For reasons of confidentiality, no cost will be disclosed. In the next chapter, the logistical process within the Dark Store will be presented to understand the changes that had to be made to implement the efficiency project. The development and implementation of this project took place between the first and second waves of confinement caused by COVID-19, allowing the company greater flexibility in its supply chain to avoid the disruption experienced in the first wave.

Main Findings

The Dark Store used for this case study has 6 000 square meters. This distribution center is very similar to a supermarket but without clients.

In stock, this has high and medium rotation products arranged in a practical layout to ensure that everything is accessible to the operators, minimizing distances and times required during the picking operation. Three times per day, an offline store (the same company's supermarket) sends the fresh product (e.g., meat, vegetables, fruit) and the long-tail items needed for orders. To satisfy the daily demand, the layout of Dark Store has six departments: reception, picking, consolidation, shipping, replacement, and quality control. In the first phase, an AS-IS analysis was carried out to identify gaps in the operational process; we mapped the product flow from the arrival of the order to the return of the vehicle to the Dark store.

The most obvious bottleneck was in the dispatch process created by the vehicle typology and the inherent characteristics of the whole process. Thus, we proceeded to develop the desirable situation through a TO-BE analysis, presenting a set of improvements obtained through a set of actions.

AS-IS PROCESS

As mentioned above, Dark Store consists of 6 functional departments, whose functions will be described below:

- Reception – is responsible for ensuring the reception of items sent to the Dark Store from the Azambuja Distribution Center and the Support store. This department registers all stock or order movement entries (parts of orders) in the system.
- At the end of the flow, the reception also acts on the return of empty boxes and their respective cleaning near the loading/unloading docks. This department is also responsible for recording all products that return from the customer (e.g., the customer was not at home and did not receive the order).
- If it is a temperature-controlled food item, it is recorded as broken since its quality cannot be guaranteed (e.g., frozen food, yogurt, vegetables).
- In cases of non-food items (e.g., broom or shower gel), this item is moved back into stock.
- The quality department inspects the remaining cases before being returned to stock.
- Picking - is responsible for ensuring the preparation of orders per customer in the following circuits: Sweet and Savory Grocery; Drinks (juices, water, wines, and spirits); Milk and eggs; DPH (Drug shop, Perfumery, and Hygiene); Non-food (ironing boards, dishes); Fresh (Fruits & Vegetables, Delicatessen, Butcher and Fishmonger); Frozen.
- Each of these circuits has its team that alternates its area of action as needed.

- Consolidation - At the end of preparation, the boxes of a given order, the CHEP boxes (boxes used for preparing items), are stacked by customer and route (the trip number defined by the router that aims to optimize the delivery of orders by different postal codes), in an area called expedition marshaling.
- Shipping - is responsible for ensuring that orders are loaded in the correct order and that the number of boxes shipped is equal to the number of boxes prepared for that route (it's a manual process - still).
- Replacement - is responsible for ensuring the replacement of items in the defined locations to avoid stockouts or process inefficiencies (example: return from stockout - order preparer returns to the position where the item was missing at the end of preparation or goes to another location of over, but that wastes more time in moving).
- Quality Control is responsible for ensuring that the items sent to the customer are in the conditions defined by the central quality control, within the required validity period, and at what temperature the cold transport vehicles leave and return.

Based on the process mapping and analysis, the following opportunities for improvement were identified:

- During the picking process, the products had a temperature rise, although the process ensured fast movement between the cold rooms and the vans;
- The contracted transport vans were prepared for the transport of positive cold items, making it also possible to transport products that only need room temperature (unnecessary), being necessary to place frozen orders in boxes with lining and eutectic plates to ensure the temperature;
- During the distribution process, the inside temperature changes due to the consecutive openings of the vans' doors during the stops at the customer's homes, which causes the loss of cold, the loss of quality, and customer dissatisfaction;
- The consultation of the temperature of the vans required a manual request to the carrier to obtain the temperatures at which the vans were at the beginning and end of the trip, not being possible autonomy in the control or tracking of temperatures along the route.

TO-BE PROCESS

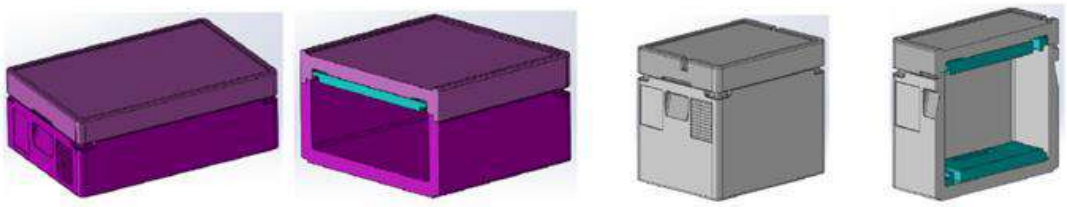
To reduce all costs inherent to the process, transport, and product quality inefficiencies, which includes the investment of two new tares (EPP boxes), it was necessary to create new functions/tasks within the Dark Store. Figure 1 shows the conceptual model of the EPP Boxes and the eutectic plate.

Figure 2 presents how the Dark Store layout is divided in a macro way, identifying the areas related to this new process. The final process this research implemented will be analyzed in detail throughout the explanation below. The processes presented will only refer to positive cold and negative cold goods.

These EPP Boxes are produced using expanded polypropylene (EPP). This material is resistant to touch, insulating, can be stacked on other boxes, and is extremely light. The characteristics that compose this product not only guarantee the quality required by the project at the insulation level but are also very useful in operational terms, being a light to facilitate handling. Resistant, because they will be transported on different types of equipment and platforms, and because they can be stacked on top of each other, they optimize the space between them throughout the logistic chain, as well as the possibility of being stacked on CHEP boxes (green boxes used for transporting fruits and vegetables), which are standard used worldwide through a pooling system. There

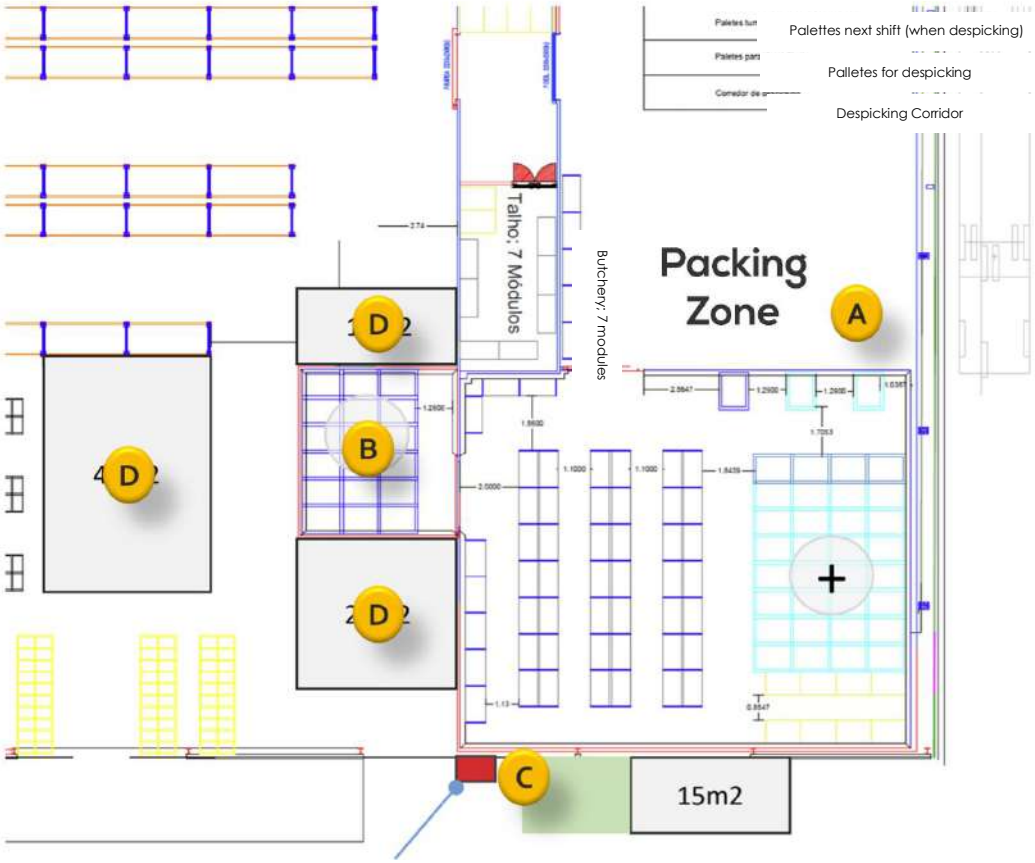
are two bins: EPP Refrigerated bins and EPP Frozen bins. The EPP Ref box measures 600x400x270mm, and the EPP Cong boxes measure 400x300x350mm. Each box allows the placement of 2 eutectic plates. One plate is fixed on the lid of the box, and the other box is on the base inside the box. The products are in the middle of the box. Eutectic plates contain a solution that mixes water with salts, whose melting point (or freezing point) is constant and lower than that of water. Two types of plates were purchased for this project.

Figure 1
EPP Boxes and eutectic plate



Source: self-elaboration

Figure 2
The layout of the process inside the Dark Store



Source: self-elaboration

An orange plate allows for reaching the freezing point at -12ºC (B- refrigerated), and a blue plate with a higher freezing point, -21ºC, for the frozen operation. The logistics of eutectic plates within Darkstore was one of the processes that were born with the implementation of this process. At the end of order preparation (positive cold), the orders are placed inside the respective EPP boxes together with the eutectic plates. This packaging is carried out in the identified zone A. The eutectic plates are supplied whenever necessary from zone B to zone A inside the Darkstore. In this packaging process, the process is as follows:

Step 1: Preparation of the EP Box - Opening the respective EPP box and place a eutectic plate corresponding to the box type at its interior and a plate on the lid.

As previously mentioned, these are very resistant to touch, are insulating, can be stacked, and are extremely light. The characteristics that make up this product not only guarantee the quality required by the project in terms of insulation but are also very useful in operational terms, being a light to facilitate handling. In the project, two types are used - Refrigerated and Frozen.

Step 2: Product Placement - Products from a particular order box (each order can have multiple order boxes) are placed inside the EPP box.

Step 3: Order Tag change location - The order box contains a label that identifies the respective order and associated route information in addition to its order box identification.

This label is taken from the old box where products are placed during preparation (green CHEP box) and placed in a plastic bag in the respective EPP box.

Step 4: Order Association to EPP box - The application created for this research follows the process of associating orders to the respective EPP boxes (using equipment ZebraZT57).

In this process, the employee must enter the cold box application, choose the option associate order, and then read the bar code of the EPP box (BLE Sensor) and prick the order box code.

After entering both codes, the employee must press the associate option.

Step 5: Shipping the boxes - Then, the boxes are taken to the dispatch marshaling to a position identified with its route number (see Figure 3). They are stacked in towers containing the three different temperatures for the same order (positive, negative, not refrigerated).

When leaving the Dark Store, the number of boxes is counted for future validation on its return.

This process also facilitates the driver's work when he arrives at the customer's house and must identify the respective order. Instead of visiting two spaces with different temperatures to collect order boxes, the same order is stacked in 1 or more columns. When the driver returns to the Dark Store with empty EPP boxes or with the product, they are placed in zone C.

Figure 3
EPP Boxes and eutectic plate

Source: self-elaboration

Now, at Zone C, it starts the inverse logistics process. The following steps are very important to support the daily supply of equipment and to reduce waste:

Step 6: Verification of number and exterior status - If any box is missing, an alert is triggered to inform the logistics partner.
Physical separation of Refrigerated EPP and Frozen EPP boxes to avoid storing different boxes in the same place.
Checking whether the box contains one or more undelivered items.

Step 7: Checking Current Temperature - If the box has a product, the employee carrying out this process must have a ZebraZT57 terminal with him to check if the temperature is within the correct temperature.
The app is used to perform this instant collection.

Step 8: Replacement of the item as in stock - In case it is at a temperature, according to this article, it returns to its stock position, avoiding food waste and breakdown costs.

Step 9: Placing the plates back into freezing - The eutectic plates are removed from the boxes and placed in the respective dolis of each type of plate. These, when full, are transported by the wheels that support them to the freezing chambers located in zone B.

Step 10: Disassociation of empty EPP boxes - the empty EPP boxes are stacked in EURO pallets and taken to a gantry equipped with Gateways that collect the temperature data (BLE Sensors), creating a history.
Afterwards they disassociate the box from the products it transported on the previous trip. These operations are triggered through a tablet at the entrance of the gantry (ZebraPriceChecker).
This pallet with the empty boxes is placed in one of the D zones for storage, depending on the type of tare.

This new process allows real-time traceability of any boxes transported, thus ensuring the legislative standards of health and hygiene in transporting perishable goods and controlled temperatures.

This is a cost-efficiency project, but it also has an innovation component for connecting several types of technological equipment to obtain the expected result. In Figure 4, it is possible to observe the several pieces of equipment mentioned above that allowed the process to be changed.

Figure 4
Process Equipment's

Source: self-elaboration

As mentioned in Step 1, the EPP boxes need the eutectic boards to ensure the correct temperature. Associated with these is a BLE sensor which consists of a Bluetooth low energy sensor (lower energy consumption and costs, ensuring similar communication and range) that allows autonomous temperature capture, being robust and waterproof.

This sensor is associated with the parcel at Step 4 to ensure information collection and disassociated at Step 10 with the help of Gateways. The sensors collect the temperature every 15 minutes. The Gateways collect the information from the sensors in 1 minute and can read 48 simultaneously. ZebraZT57 and Zebra Price Checker allow the insertion and access to the data in the developed app.

Discussion

The reduction in operational costs was achieved by reducing costs associated with transporting positive cold to customers' homes since it now only uses vehicles with room temperature transport. The macro estimate realized was 30% fewer costs associated with order transportation. With an additional 10% in space optimization (routes allocated to a given vehicle) with the gain of space within the galley of each vehicle.

The reduction in daily use from 30 refrigerated vehicles to normal vehicles directly impacts the ecological footprint reduction. However, the fact that more boxes requiring plates were purchased cannot be ignored, contributing to the increase in energy effort in the refrigeration chambers. Although the figures are lower, we do not have the ratio.

The Dark Store can now centralize over 300 more refrigerated and frozen items due to the loss of the need to ensure that the packaged product is inside the respective chambers. Today this product goes directly to the shipping marshaling without the

intervention of the supermarkets. This way, the intervention of the support stores was reduced, contributing to increasing the process's capacity and agility.

As explained in the definition of the receiving concept, the Dark Store, which continues to receive stock returning from orders that were not delivered for various reasons, now has a chance to check if the products conform (if the temperature and expiration date are met) and put them back in stock. This translates not only into an economic benefit, given the savings in the items that no longer go directly to the garbage, but also decreases the food waste index of the company.

Regarding the increase in food safety, this happens due to the tracking of the articles' temperature from the moment they leave the chambers until they arrive in the best conditions at the customer's house or return to stock.

This project involved an investment in the human process (packaging, association, disassociation, and management of containers), annual Capex of the project (amortization of technological devices), and increased consumption of consumables (boxes, plates) and electricity; however, in the end, the study proved that the direct economic benefits associated are greater than the costs and in the short term a different potential is expected due to the greater occupation of the routes.

Finally, it was possible to achieve a significant reduction in the loss of boxes and eutectic plates and a substantial reduction of losses with the recovery of refrigerated goods. In addition, with the elimination of distribution through refrigerated vehicles, there has also been a marked reduction in fuel consumption and much higher availability because refrigerated boxes are now used without the need for the specific use of this type of vehicle.

Conclusions and Future Research

The pandemic scenario we are currently experiencing has brought the acceleration of these types of solutions, not only because more online commerce is consumed in its chain with solutions identical to the ones we have seen throughout this paper but also in the backstage of the stores.

At the end of this research work and through the combination of new technologies that allow for collecting product information, it was possible to implement new products for Transportation (frozen and fresh). The replacement of vehicles was accelerated by the growth of the company's e-commerce channels, which allowed for a better level of service, increased operational capacity, and a reduction in financial and environmental costs. It is also possible to understand how products can be transported with quality and safety to all customers of the Dark Store.

This work allowed the identification and implementation of an opportunity for improvement in the distribution chain of the online store. With its implementation, it was possible to reduce operational costs, decrease the ecological footprint, increase the capacity and agility of processes, reduce food waste, and increase food safety.

This paper also presents a solution for monitoring temperatures during deliveries in a food retail supply chain to increase flexibility. The 80 percent growth in demand in the online market has created the need to implement new, more efficient processes. In this research was also possible to reduce costs associated with transporting positive cold to customers' homes since it now only uses vehicles with room temperature transport. The macro estimate realized was 30 percent fewer costs associated with order transportation. With an additional 10 percent in space optimization (routes allocated to a given vehicle) with the gain of space within the galley of each vehicle. Furthermore, because refrigerated boxes are now used instead of refrigerated vehicles, there has been a significant reduction in fuel consumption and a

considerably higher availability because of the elimination of distribution via this type of vehicle.

One of the limitations of this work was that it was not possible to use EPP boxes with all types of products, which would have allowed even greater cost savings. Due to the limitation of the box size, only some products can be transported in these conditions. In this study, it was also not possible to monitor all transports comprehensively, so it is expected in future studies that a more detailed analysis of cost reduction per delivery and type of product will be done.

As future work, we are investigating the possibility of integrating the temperature at which the item arrived at the customer's home to be visible on the order invoice. Also, it is intended to study how to print the boxes on a 3D printer to save the cost per EPP box further. Finally, we want to improve the Operational Efficiency (FTE Packaging and FTE Container) and pick directly from the EPP box.

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A Machine Learning Approach to Forecast International Trade: The Case of Croatia

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Abstract

Background: This paper presents a machine learning approach to forecast Croatia's international bilateral trade. **Objectives:** The goal of this paper is to evaluate the performance of machine learning algorithms in predicting international bilateral trade flows related to imports and exports in the case of Croatia. **Methods/Approach:** The dataset on Croatian bilateral trade with over 180 countries worldwide from 2001 to 2019 is assembled using main variables from the gravity trade model. To forecast values of Croatian bilateral exports and imports for a horizon of one year (the year 2020), machine learning algorithms (Gaussian processes, Linear regression, and Multilayer perceptron) have been used. Each forecasting algorithm is evaluated by calculating mean absolute percentage errors (MAPE). **Results:** It was found that machine learning algorithms have a very good predicting ability in forecasting Croatian bilateral trade, with neural network Multilayer perceptron having the best performance among the other machine learning algorithms. **Conclusions** Main findings from this paper can be important for economic policymakers and other subjects in this field of research. Timely information about the changes in trends and projections of future trade flows can significantly affect decision-making related to international bilateral trade flows.

Keywords: machine learning; WEKA; international trade; MAPE; Multilayer perceptron; Croatia.

JEL classification: B17, C45.
Paper type: Research article

Received: 21 Jun 2022
Accepted: 06 Nov 2022

Citation: Jošić, H., Žmuk B. (2022), "A Machine Learning Approach to Forecast International Trade: The Case of Croatia" Business Systems Research, Vol. 13 No. 3, pp. 144-160.
DOI: https://doi.org/10.2478/bsrj-2022-0030

Introduction

Artificial intelligence originated in the 1950s and has become a multidisciplinary field with applications in nearly every aspect of human life. Machine learning is an application of artificial intelligence for finding patterns and regularities in data (Kulkarni & More, 2016). Therefore, machine learning has many applications in the field of economics. One is forecasting macroeconomic variables, an important toolkit for many countries. It is important to recognise that artificial intelligence and machine learning have important implications for international macroeconomics and trade, Goldfarb and Trefler (2018). Previous investigations were oriented to a compare of machine learning methods with traditional ones, Mitrea et al. (2009), Zekić-Sušac et al. (2014), forecasting realized variance using high-frequency data, Arnerić et al. (2018), stock price prediction using neural networks, Medić et al. (2020), comparison of multivariate statistical analysis and machine learning methods in retailing, Ćorić (2016).

This paper presents the application of machine learning algorithms in forecasting bilateral international trade flows in the case of Croatia. Because trade influences production, prices, employment, and wages, it is important to correctly predict future trade patterns and flows. Batarseh et al. (2020) are almost a high priority for timely decision-making. The seminal paper in this field of research can be attributed to Nuroglu (2012), who analysed the bilateral trade flows of Turkey with its major trading partners. He used panel data models and neural networks on annual data from 1985 to 2010. In Turkey's bilateral trade flows analysis, neural networks were superior to the traditional panel data models.

This paper follows the research method introduced by Wohl and Kennedy (2018) and Quimba and Barral (2018), who forecasted international trade flows using neural networks. Wohl and Kennedy (2018) assembled a dataset using variables from the international trade gravity model. Input variables were the distance between countries, the importer's and exporter's GDP, and dummy variables (language, border, colonial relationship, and trade agreements). On the other side output variable was the value of bilateral trade flows. Quimba and Barral (2018) compare the gravity models (estimated with the OLS, PPML, and GPML estimators) with the neural networks using panel data to analyse the bilateral trade flows between APEC economies. The study's results pointed to neural networks' strong capacity to make the most accurate estimations and predictions of bilateral trade flows.

This paper aims to evaluate the performance of machine learning algorithms in predicting international bilateral trade flows related to imports and exports in the case of Croatia. The input variables in the analysis are GDP exporter, GDP importer variables, distance, and dummy variables (Language, Border, Landlocked, and WTO). In contrast, the output variables are the values of bilateral trade imports and exports. The data were collected for the period from 2001 to 2019. The software WEKA forecasts Croatian bilateral trade flows for a one-year-ahead horizon (the year 2020). It is an open-source machine learning software comprising its algorithms (Gaussian processes, Linear regression, and neural network Multilayer perceptron). According to Abirami and Chitra (2020), a Multilayer perceptron is an add-on to a forward neural network. In contrast, neural networks are the most used machine learning algorithms. All machine learning algorithms can be classified into two basic groups: supervised and unsupervised.

The precision of forecasting algorithms is inspected by calculating the mean absolute percentage errors (MAPE). The expected result is the good predictive capability of machine learning algorithms in forecasting Croatian bilateral trade flows. Therefore, the paper's hypothesis states that machine learning algorithms will have a good predictive capability in forecasting Croatian bilateral trade (the value of MAPE

is lower than 10). The paper contributes to the state-of-the-art by employing three machine learning algorithms in predicting bilateral trade flows in the case of one small country, Croatia.

The structure of paper consists of five sections. After the introduction, the literature review elaborates on bilateral international trade forecasting using neural networks. In the methodology and data section, the explanation of data, data sources, and research methods is presented. The paper's most important findings are displayed and discussed in the results and discussion section. The final chapter presents concluding remarks.

Bilateral international trade forecasting using neural networks

Table 1 is the chronological overview of studies on bilateral international trade forecasting using neural networks.

Table 1

Overview of studies related to bilateral international trade forecasting using neural networks

Authors (Year)	The goal of the paper	Data forecasted	Method/algorithm used	The best method
Nuroglu (2012)	Forecasting E15 bilateral trade flows	EU15, 1964 -2003	Panel data, neural networks	Feed-forward two layers network
Circlaeys et al. (2017)	Bilateral trade flows prediction	1.9 million data points, 1800s to 2014, 200+ countries	Six machine learning models	Feed-forward neural network
Baxter and Srisaeng (2018)	Prediction of Australia's export air cargo demand	Australia, from 1993 to 2016	Multilayer perceptron	Multilayer perceptron
Quimba and Barral (2018)	Prediction of bilateral trade flows of APEC countries	21 APEC countries, 8,329 observations, from 1996 to 2001	OLS, PPML, GPML, Neural networks	Neural network
Wohl and Kennedy (2018)	Forecasting bilateral trade flows	91,094 obs. for 68 partner countries from 1986 to 2006	OLS, PPML, Neural networks	Multilayer perceptron regressor
Almog et al. (2019)	Forecasting bilateral trade flows	200 countries, from 1950-2000	Gravity models, Enhanced Gravity Model (EGM)	EGM
Dumor and Yao (2019)	Estimating China's Trade within the Belt and Road Initiative	China's bilateral trade exports from 1990 to 2017	OLS, PPML, Neural network	Fully connected neural network
Nyoni (2019)	Forecast Zimbabwe's exports and imports	Zimbabwe, from 1975 to 2017	Neural networks	Neural network with Hyperbolic Tangent Function
Vidya and Prabheesh (2020)	Forecasting future trade after the COVID-19 pandemic	15 global trading countries, 2016Q4-2020Q1	Neural Networks	Recurrent neural network
Batarseh et al. (2021)	Forecasting global beef trade flows	Australia, Germany, Netherlands, France, US, from 1989 to 2018	ARIMA, GBoosting, XGBoosting, Light Gradient Boosting Machine (LightGBM)	LightGBM
Chan (2021)	Estimation of United States-Asia clothing trade	United States, China, and 15 South and Southeast Asian countries, 2012-2018	Multiple regression, Neural Network	Neural Network using a k-fold cross-validation procedure
Gopinath et al. (2021)	International agricultural trade forecasting	Seven major agricultural commodities, 1962-2016	LightGBM, XGBoost, Random forest, Extra trees regression, Neural network	scikit-neural network

Source: Authors' work

Nuroglu (2012) investigated bilateral trade flows among EU15 countries from 1964 to 2003 using a panel data analysis and neural network modeling. When comparing out-of-sample forecasting performances, neural networks produced much lower MSE, making them superior to the panel models. According to Circlaeys et al. (2017), neural networks are a promising approach to predicting bilateral trade flows. The results of the comprehensive study on 1.9 million data points from the 1800s to 2014 for 200+ countries and territories showed that feed-forward neural networks improved the gravity model's prediction performance by the test R^2 score of 0.15 using the same set of features.

Baxter and Srisaeng (2018) employed an artificial neural network to predict Australia's export air cargo demand. The observed period was from the year 1993 to the year 2016. The artificial neural network was based on multilayer perceptron architecture. It fed a multilayer feed-forward network with data randomly divided into three sets. Those are training, testing set, and model validation. Four goodness-of-fit measures were selected to find the best-fit model. Those metrics are mean absolute error (MAE), mean square error (MSE), root mean square error (RMSE), and mean absolute percentage error (MAPE). The results suggested that the artificial neural network correctly predicted Australia's annual export air cargo demand. Quimba and Barral (2018) explore neural network models in understanding bilateral trade in APEC. They compare different gravity model estimators, such as OLS, PPML, and GPML, with the neural network. The neural network estimation was found to be far superior to other estimations.

Wohl and Kennedy (2018) analyse bilateral international trade using neural networks (NN), constructing a dataset assembled from the variables belonging to the gravity trade model. The authors used test data to measure how different methods, such as an OLS estimator, a Poisson pseudo-maximum likelihood estimator (PPML), and a neural network generalise to the data. It was found that a neural network with country-fixed effects yields the most accurate out-of-sample predictions, as seen in a comparison of root mean squared errors. Almog et al. (2019) introduced the Enhanced Gravity Model (EGM) of trade, which combines the gravity trade model with the network approach within a maximum-entropy framework. China's trade with its trade partner countries within the Belt and Road Initiative was estimated using neural network analysis, Dumor and Yao (2019). It was found that neural networks performed better than the gravity model estimators of international trade flows.

Nyoni (2019) forecasted Zimbabwe's exports and imports by employing the neural network approach on annual time series of data over the period from 1975 to 2017. Neural networks were evaluated using the forecast evaluation statistics or error metrics; mean squared error (MSE) and mean absolute error (MAE). The results showed that neural networks yielded reliable forecasts of Zimbabwe's exports and imports over the observed period. The COVID-19 outbreak led to a drastic reduction in trade interconnectedness and density among countries changing the structure of trade-network, Vidya and Prabheesh (2020). The forecasted exports and imports declined in all observed countries until December 2020 due to the adverse impact of the COVID-19 pandemic. Batarseh et al. (2021) employed machine learning models (ARIMA, GBoosting, XGBoosting, and LightGBM) to predict future trade patterns. The accuracy of models presented in this paper was in the range of 69% to 88%. Chan (2021) estimated the United States-Asia clothing trade using multiple regression analysis and artificial neural networks. The analysis was conducted for clothing exports from 2012 to 2018, while the trade pattern prediction was estimated for 2019. The paper's main findings conclude that artificial neural networks had much more accurate predictions of bilateral trade flows than the standard basic gravity trade models. Gopinath et al. (2021)

forecasted the international agricultural trade of seven major agricultural commodities using machine learning tools. Results of the analysis pointed to the high relevance of the machine learning models in forecasting trade patterns relative to traditional approaches, with neural network approaches providing a better fit over the long term.

Methodology

Data

This paper observes Croatian bilateral trade (exports and imports) with other countries from 2001 to 2019, with forecasts for 2020. The input variables in the model are the GDPs of exporting and importing countries, the distance between countries, and dummy variables (language, border, landlocked, and WTO). The input, as mentioned above, variables are the main explanatory variables in the gravity model of international trade. So they are often used in the estimation of gravity models of trade. Therefore, we have used those variables as input variables for machine learning algorithms. The output variables are exports from Croatia and imports to Croatia. The full list of variables and their brief description and data sources is presented in Table 2.

Table 2
List of observed variables

Variable	Description	Source
Exports	Exported value, in US$ thousand	Trade Map (2021)
Imports	Imported value, in US$ thousand	Trade Map (2021)
GDP Exporter	Gross domestic product of the exporting country, current US$	World Bank (2021)
GDP Importer	Gross domestic product of importing country, current US$	World Bank (2021)
Language	Importer and exporter have the same language (0 = No, 1 = Yes)	CEPII
Border	Importer and exporter have the same border (0 = No, 1 = Yes)	CEPII
Distance	Importer and exporter distance, in km	CEPII
Landlocked	Importer/exporter is landlocked (0 = No, 1 = Yes)	CEPII
WTO	Importer and exporter are both members of the World Trade Organization in the same year (0 = No, 1 = Yes)	World Trade Organization (2021)

Source: Authors'

The data for the analysis are provided from various sources: Trade Map, World Bank, CEPII, and WTO. CEPII is the Centre d'Études Prospectives et d'Informations Internationales, main French institute for research into international economics. Both variables, Exports and Imports are expressed in thousands of US$. The Exports variable observes the value of exports from Croatia to other countries, whereas the Imports variable shows the value of imports to Croatia from a certain country worldwide. Variables GDP Exporter and GDP Importer give information about the gross domestic product value of a country that exports goods and services and the gross domestic product value of a country that imports them. Variable language is a binary variable that takes the value of one if both exporting and importing countries share the same language as an official in their country. An irregular border is also a binary variable. If exporting and importing countries are neighboring countries, an irregular border takes the value of one. Variable distance measures the distance between capital cities of

trade partner countries in kilometers. If a country does not have direct access to the open sea, the variable Landlocked is equal to one. When the importer and the exporter countries are both members of the World Trade Organization, the value of the variable WTO is equal to one.

Trend analysis and forecasting

The analysis will also use descriptive statistics to describe trends in Croatian exports and imports from 2001 to 2019. The analysis used 2,881 data values from Croatian export value records and 2,895 from Croatian import value records. However, in the analysis, yearly export and import averages were used.

Although Croatia has traded with more than 180 countries worldwide, only the most important trading partners in the paper will be emphasised. Croatia was analysed as a single country, although the analysis could be made for many more countries. The idea is to present a framework for analysis that could be implemented to forecast bilateral international trade flows comprehensively.

Different forecasting techniques and algorithms are applied to forecast the future values of Croatian bilateral exports and imports for 2020. For that purpose, a WEKA, which is an open-source machine learning software (University of Waikato (2021), and selected machine learning algorithms (Gaussian processes, Linear regression, and Multilayer perceptron), with default settings, will be applied.

The multilayer perceptron is a feed-forward artificial neural network that is mostly known and frequently used. The neurons in the Multilayer perceptron are trained with the backpropagation learning algorithm. Learning consists of adjusting perceptrons' weights, providing lower errors on the training data. The expression describing the predictive capacity of the Multilayer perceptron is:

$$f(x) = (\sum_{i=1}^{m} w_i * x_i) + b \quad (1)$$

where m is the number of neurons in the previous layer, w is a random weight, x is the input value, and b is a random bias, Data Science (2020). The strong predictive capability of neural network Multilayer perceptron comes from its networks' hierarchical (multi-layered) structure.

Gaussian processes have been developed by Rasmussen and William (2006) and have often been used for forecasting time-series phenomena, as well as Linear regression. A Gaussian process is a random process where any point $x \in \mathbb{R}^d$ is assigned a random variable $f(x)$ and where the joint distribution of a finite number of these variables $p(f(x_1), \ldots, f(x_N))$ is itself Gaussian:

$$p(f|X) = \mathrm{N}(\mathrm{f}|\mu, \mathrm{K}) \quad (2)$$

Given a training dataset with noise-free function values f at inputs X, a Gaussian process prior can be converted into a Gaussian process $p(f_*|\mathrm{X}_*, X, f)$, which can then be used to make predictions f_* at new inputs X_*, Kraser (2018). Linear regression supports regression-type problems and works most naturally with numeric attributes. It is fast to train and can have great performance if the output variable for your data is a linear combination of your inputs, Brownlee (2019).

$$x = w_0 + w_1 a_1 + w_2 a_2 + \cdots + w_k a_k \quad (3)$$

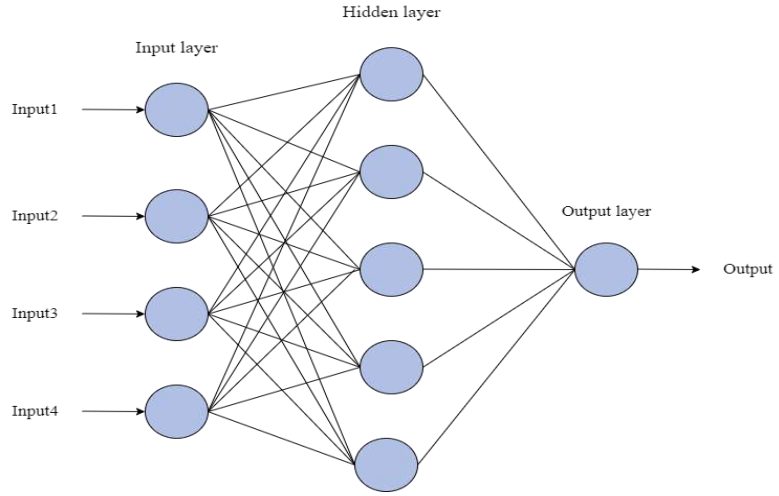
Then we calculate weights from training data and predict a value for the first training instance (a):

$$w_0 a_0^{(1)} + w_1 a_1^{(1)} + w_2 a_2^{(1)} + \cdots + w_k a_k^{(1)} = \sum_{j=0}^{k} w_j a_j^{(1)} \quad (4)$$

Finally, choose weights to minimize square error on training data, Hall et al. (2011).

$$\sum_{i=1}^{n} \left(x^{(i)} - \sum_{j=0}^{k} w_j a_j^{(1)}\right)^2 \quad (5)$$

Figure 1
The structure of Multilayer perceptron



Source: Authors' illustration

In Figure 1, the structure of the Multilayer perceptron is illustrated. It contains the input, visible, hidden, and output layers with fully connected weights between layers. The input layer receives the input signal to be processed. An arbitrary number of hidden layers is placed between the input and output layers, representing the computational engine of the Multilayer perceptron. For the hidden layer neurons, sigmoid functions are frequently used, leading to smooth transitions instead of hardline decision boundaries as when using step functions, Menzies et al. (2014). Prediction and classification tasks by the output layer, Abirami (2020). The preparation of Croatian export data for the *.arff file inputted into the WEKA interface is displayed in the following form (Figure 2).

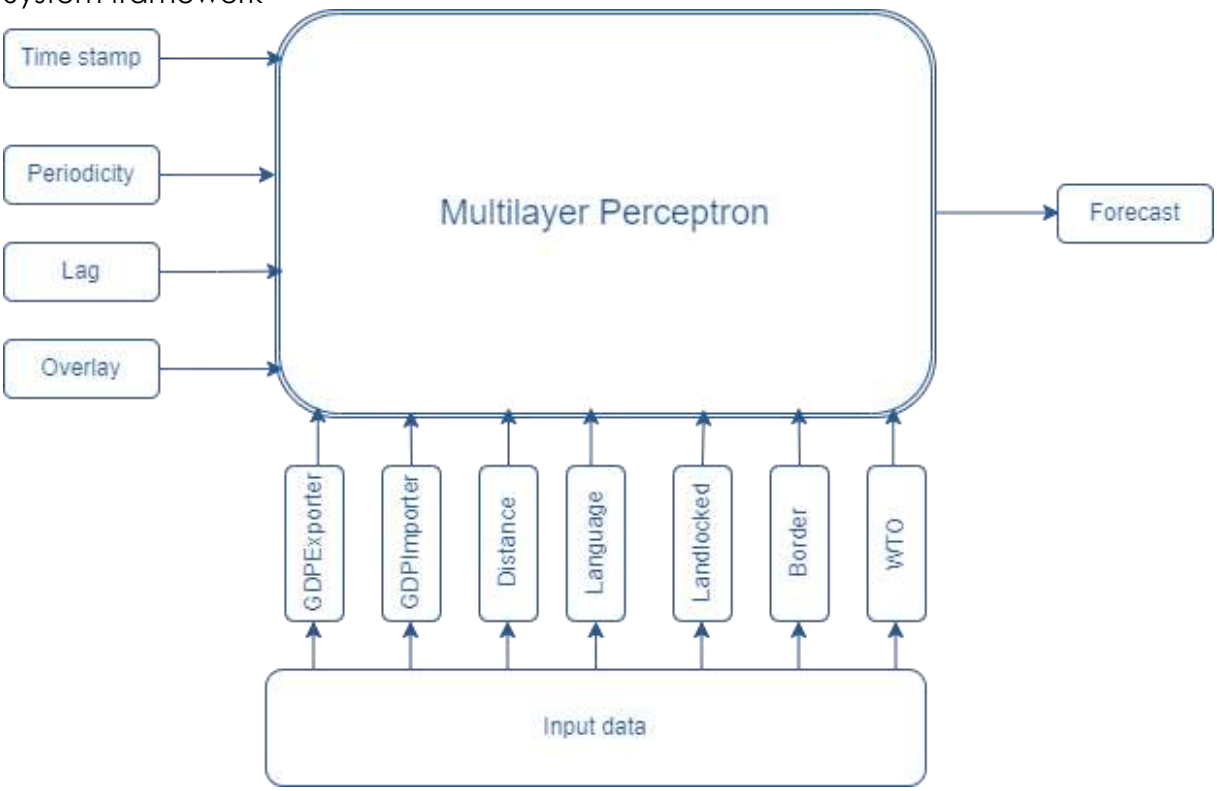
Figure 2
Structure of the Weka file for the Croatian exports

```
@relation 'Exports'
@attribute Year date "yyyy"
@attribute Exports numeric
@attribute GDPExporter numeric
@attribute GDPImporter numeric
@attribute distance numeric
@attribute language numeric
@attribute border numeric
@attribute Landlocked numeric
@attribute WTO numeric
@data
2001,1106529, 23054778851.2787, 1167012796420.58, 517.05, 0,0,0,1
2002,1114986, 26813968850.5192, 1270712309429.7,  517.05, 0,0,0,1
2003,1651020, 34682900712.6654, 1574145823927.77, 517.05, 0,0,0,1
2004,1834388, 41587470546.7946, 1803226967966.23, 517.05, 0,0,0,1
…
2016, 1864324, 51601147665.8089, 1875797463583.87, 517.05, 0,0,0,1
2017, 2140708, 55481644098.0495, 1961796197354.36, 517.05, 0,0,0,1
2018, 2511138, 61375222347.0256, 2091544955092.31, 517.05, 0,0,0,1
2019, 2382927, 60752588976.3175, 2003576145498.04, 517.05, 0,0,0,1
```

Source: Authors' work

In this example, the data for bilateral trade with Italy are presented. Figure 3 is the system framework for conducting the analysis (forecasting Croatian international bilateral trade). The system framework is constructed from input data related to gravity variables, WEKA's settings related to the time stamp, periodicity, lags, overlay, and a performing algorithm (in this case, Multilayer perceptron).

Figure 3
System framework



Source: Authors' illustration

Model validation

The evaluation of each forecasting algorithm will be made by applying and calculating the mean absolute percentage error (MAPE). Mean absolute percentage error is defined as follows:

$$MAPE = \frac{\sum_{t=1}^{T}\left|\frac{y_t - F_t}{y_t}\right| \cdot 100}{T}, y_t \neq 0 \quad (6)$$

where y_t is the value of time series at time t, F_t is forecast at time t, T is the number of pairs of actual values and forecasts. The lower the value of MAPE a certain forecasting algorithm will have, it will be more successful in forecasting the Croatian bilateral exports and imports. MAPE values will be interpreted according to the range of observed errors. "The value of MAPE lower than ten can be interpreted as highly accurate forecasting, the value of MAPE in the range of 10-20 can be interpreted as good forecasting, the value in the range of 20-50 is reasonable forecasting while the value of MAPE higher than 50 can be interpreted as inaccurate forecasting" Žmuk and Jošić (2020:477). Each forecasting algorithm will be observed and compared in general, as well. Finally, the recommendation about which forecasting algorithm should be optimally used in forecasting exports and imports could be brought.

Results

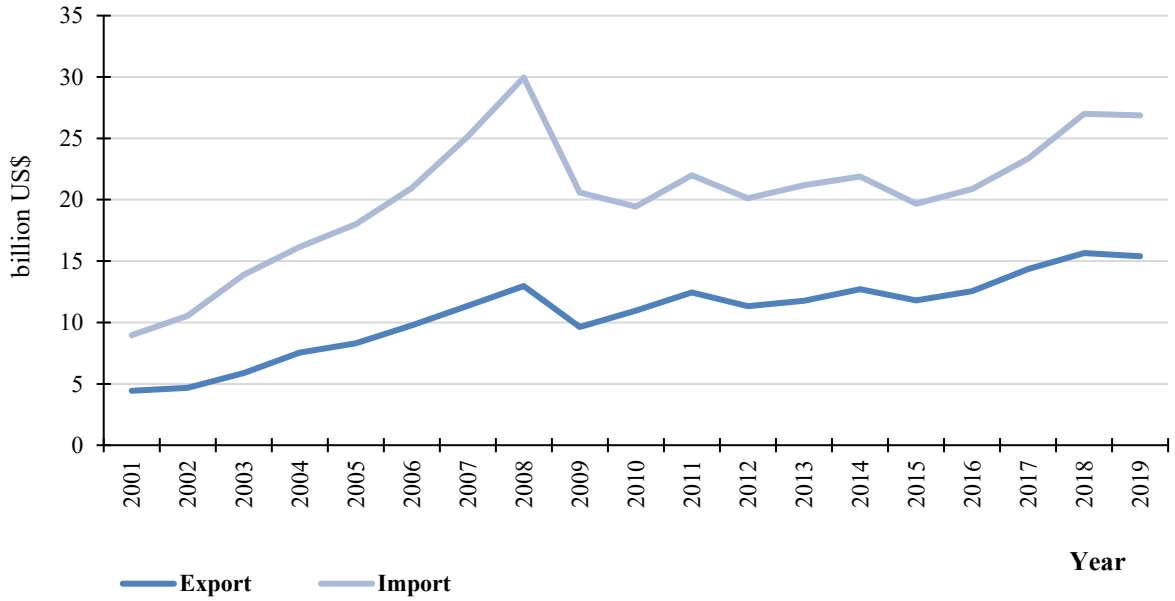
Trend analysis

Croatia maintains bilateral foreign trade in goods and services with more than 180 countries worldwide. The annual values of exports and imports in Croatia from 2001 to 2019 are presented in Figure 4. It can be seen that the volume of trade is rising throughout the observed period despite the sharp drop in 2008 and 2009.

The exports were constantly lower than the imports in the observed period, with imports increasing from 2001 to 2008. Due to the financial crisis in 2008, exports and imports decreased in 2009, but the drop in imports was larger than the drop in exports. After 2009 it seems that the absolute difference between exports and imports remained the same. Croatia has the largest share of trade in a few countries, so that they can be observed as its main trading partners.

Figure 4

Values of Croatian exports and imports, 2001 to 2019, in billions of US$



Source: Authors', Trade Map (2021).

In Table 3, the top 10 countries according to the share in average export value of Croatia in the period from 2001 to 2019 are displayed. Croatia mostly exports to Italy, Bosnia and Herzegovina, Germany, and Slovenia. Croatia had an average export value above 10% of total exports for each country individually, after which comes Austria with an average share of 7% in the total export value. All other countries had significantly lower exports share with 3% or lower. Croatian has a land and sea border with Italy, Slovenia, Hungary, and Bosnia and Herzegovina, and a common language with Bosnia and Herzegovina. All countries from the list are also members of the World Trade Organization.

In Table 4, the countries with the highest share in average imports value in the period from 2001 to 2019 are shown. Similar to the value of exports, the most important Croatian import trading partner countries are Italy and Germany. More than 30% of these two countries' imports to Croatia are combined.

Table 3
Top 10 countries according to the share in average exports value of Croatia, data from 2001 to 2019

Importer	Share in average export value (%)	Language	Border	Distance from Croatia (km)	Landlocked	WTO
Italy	18%	0	1	517	0	1
Bosnia and Herzegovina	13%	1	1	290	0	1
Germany	12%	0	0	912	0	1
Slovenia	10%	0	1	117	0	1
Austria	7%	0	0	271	1	1
United States of America	3%	0	0	6,909	0	1
Hungary	3%	0	1	302	1	1
France	3%	0	0	1,082	0	1
Russian Federation	2%	0	0	1,875	0	1
United Kingdom	2%	0	0	1,341	0	1

Note: Language (0-not common language, 1-common language); Border (0-no common border, 1-common border); Landlocked (0-No, 1-Yes); WTO (1-WTO member, 0-no member)
Source: Authors', Trade Map (2021), CEPII

Table 4
Top 10 countries according to share in the average imports value to Croatia, data from 2001 to 2019

Exporters	Share in average export value (%)	Language	Border	Distance from Croatia (km)	Landlocked	WTO
Italy	16%	0	1	517	0	1
Germany	15%	0	0	912	0	1
Slovenia	9%	0	1	117	0	1
Austria	7%	0	0	271	1	1
Russian Federation	6%	0	0	1,875	0	1
Hungary	5%	0	1	302	1	1
China	5%	0	0	7,649	0	1
France	3%	0	0	1,082	0	1
Bosnia and Herzegovina	3%	1	1	290	0	1
Netherlands	3%	0	0	1,085	0	1

Note: Language (0-not common language, 1-common language); Border (0-no common border, 1-common border); Landlocked (0-No, 1-Yes); WTO (1-WTO member, 0-no member)
Source: Authors', Trade Map (2021), CEPII

Forecasting

Croatian exports and imports are forecasted by applying Gaussian processes, Linear regression, and Multilayer perceptron algorithms. All three forecasting algorithms were applied to forecast bilateral trade flows to each country with whom Croatia exported or imported some goods and services from 2001 to 2019 separately. Consequently, over 500 forecasting procedures were conducted (separately for each partner country times three machine learning forecasters). The export forecasting process considered the following input variables: Exports, GDP Exporter, GDP Importer, Language, Border, Distance, Landlocked, and WTO. Also, each forecasting algorithm was evaluated by observing MAPE. For example, the results of the CRO-ITA bilateral exports forecast for the year 2020 were presented in Table 5, while the graphical

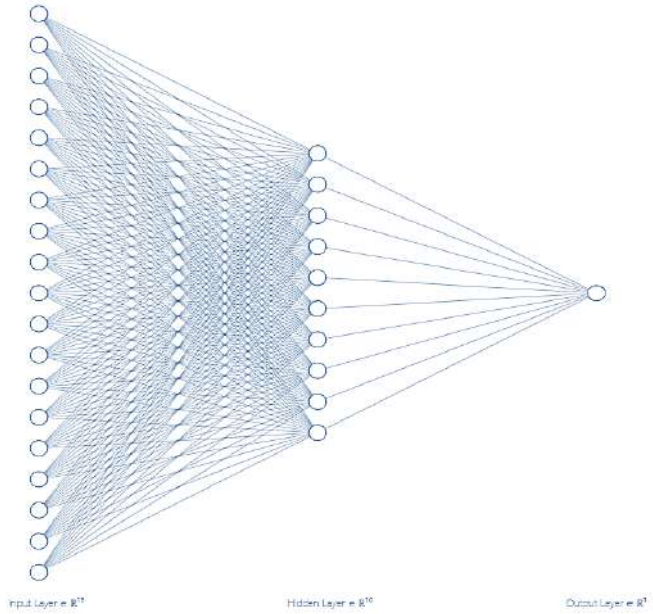
presentation of the Multilayer perceptron was displayed in Figure 5. The projection was made for 2020; in this case, the MAPE value was 14.69.

Table 5
The results of the CRO-ITA bilateral exports forecast for the year 2020, Multilayer perceptron, GDP in 000

Year	Exports	GDP_Exp	GDP_Imp	Language	Border	Distance	Landlocked	WTO
2001	1,106,529	23,054,778	1,170,000,000	0	0	517	0	1
2002	1,114,986	26,813,968	1,270,000,000	0	0	517	0	1
2003	1,651,020	34,682,900	1,570,000,000	0	0	517	0	1
2004	1,834,388	41,587,470	1,800,000,000	0	0	517	0	1
2005	1,860,237	45,376,744	1,860,000,000	0	0	517	0	1
2006	2,397,480	50,423,077	1,950,000,000	0	0	517	0	1
2007	2,360,141	60,073,426	2,210,000,000	0	0	517	0	1
2008	2,694,857	70,234,425	2,400,000,000	0	0	517	0	1
2009	1,993,759	62,600,093	2,190,000,000	0	0	517	0	1
2010	2,209,989	59,918,313	2,130,000,000	0	0	517	0	1
2011	2,111,687	62,537,851	2,290,000,000	0	0	517	0	1
2012	1,892,256	56,580,819	2,190,000,000	0	0	517	0	1
2013	1,851,904	58,194,069	2,140,000,000	0	0	517	0	1
2014	1,921,306	57,639,588	2,160,000,000	0	0	517	0	1
2015	1,717,513	49,525,747	1,840,000,000	0	0	517	0	1
2016	1,864,324	51,601,147	1,880,000,000	0	0	517	0	1
2017	2,140,708	55,481,644	1,960,000,000	0	0	517	0	1
2018	2,511,138	61,375,222	2,090,000,000	0	0	517	0	1
2019	2,382,927	60,752,588	2,000,000,000	0	0	517	0	1
2020*	2,629,761	59,497,585	1,870,000,000	0	0	517	0	1

*Note: Language (0-not common language, 1-common language); Border (0-no common border, 1-common border); Landlocked (0-No, 1-Yes); WTO (1-WTO member, 0-no member); *projections*
Source: Authors'

Figure 5
Graphical presentation of the Multilayer perceptron



Source: Authors using LeNail (2019).

Table 6 presents the aggregate results classified by the number of countries, and the sum of shares in average exports value from 2001 to 2019, according to the range of MAPE value for each applied forecasting algorithm. The more detailed analysis results for Croatian exports on an individual country level are available on request from the authors.

Table 6
The MAPE, according to the forecasting approach, is the sum of shares in average exports value, data from 2001 to 2019, forecasts for the year 2020

Mean absolute percentage error - range	Number of countries			Sum of shares in average exports value from 2001 to 2019		
	Gaussian processes	Linear regression	Multilayer perceptron	Gaussian processes	Linear regression	Multilayer perceptron
0-10	6	92	77	50.36%	47.11%	69.80%
10-20	16	4	25	29.73%	43.85%	26.24%
20-30	18	3	13	10.07%	3.04%	0.81%
30-40	13	3	4	2.87%	1.16%	0.17%
40-50	9	1	5	0.99%	0.06%	0.02%
50 and more	122	81	51	5.98%	4.78%	1.65%
Total	184	184	175	100.00%	100.00%	98.69%

Source: Authors' calculations

According to the research results, the most inappropriate forecasting algorithm is the Gaussian process. It has the lowest number of countries for which the MAPE value was lower than 50%. However, it excellently forecasts trade with main trading partner countries, as seen from the sum of shares in average export value. On the other hand, Linear regression has the highest number of countries for which the MAPE value was below 10%. In contrast, the Multilayer perceptron has the lowest number of countries with larger forecasting errors (50 and more). There are many countries in all three forecasting algorithms for which the MAPE is higher than 50%. It turns out that countries with MAPE higher than 50% generally have lower export shares than those with a MAPE lower than 50%. There are so many countries with large MAPE values because Croatia does not have equally large and continuous exports to all countries in the world. The total sum of shares in average exports value is not equal to 100% for Linear regression and Multilayer perceptron algorithms because the research procedure for some countries could not be applied due to technical limitations.

Using the same approach for the exports, Croatian imports are forecasted by applying the Gaussian process, Linear regression, and Multilayer perceptron algorithms. All three forecasting algorithms were applied for each country separately, from which Croatia imported some goods and services from 2001 to 2019. Again, over 500 forecasting procedures were conducted. In the forecasting process following variables were considered: Imports, GDP Exporters, GDP Importer, Language, Border, Distance, Landlocked, and WTO.

Table 7 shows the sum of shares in average imports value from 2001 to 2019, according to the MAPE of the certain forecasting approach. According to Table 7, the most inefficient forecasting algorithm again turned out to be the Gaussian process due to the lowest number of countries with MAPE lower than 50%. On the other hand, Multilayer perceptron achieved the highest accuracy among the three algorithms, resulting in the highest number of countries with MAPE lower than 50%. Multilayer perceptron achieved the highest accuracy (MAPE lower than 10%) for 89.86% of countries in the sample. The more detailed analysis results for Croatian imports on an individual country level are available on request from the authors.

Table 7
The MAPE, according to the forecasting approach, is the sum of shares in average imports value, data from 2001 to 2019, forecasts for the year 2020

Mean absolute percentage error - range	Number of countries			Sum of shares in average import value from 2001 to 2019		
	Gaussian processes	Linear regression	Multilayer perceptron	Gaussian processes	Linear regression	Multilayer perceptron
0-10	6	53	99	37.11%	17.63%	89.86%
10-20	29	5	11	53.58%	37.06%	0.56%
20-30	17	3	12	2.84%	0.88%	0.07%
30-40	15	5	5	2.70%	0.24%	0.13%
40-50	13	4	11	0.45%	0.02%	0.03%
50 and more	108	117	49	3.32%	44.13%	9.33%
Total	188	187	187	100.00%	99.97%	99.98%

Source: Authors' calculations

It can be concluded that machine learning algorithms have a very good predictive ability in forecasting Croatian bilateral international trade, with neural network Multilayer perceptron having the best performance. It has been noticed that the estimation techniques are more precise when forecasting trade for countries having a higher share in overall Croatian bilateral trade. The results obtained from this paper are comparable with other studies in this field of research, claiming that neural networks yield reliable forecasts of countries' exports and imports over the observed period. According to Wohl and Kennedy (2018), neural networks can generate fairly accurate predictions about international trade. They use a small number of economic, geographic, and historical variables in the prediction process. In certain cases, the neural network's estimations can be close to actual trade values, even ten years beyond the training period. Out-of-sample root means squared errors were the lowest for the neural network estimator using country-year fixed effects with a deviation of U$0.6 million, which explains 79 percent of export variability around its mean, Quimba and Barral (2018). The superiority of neural networks in predicting international trade can aid in better understanding the interregional freight distribution, commodities, specific trade sectors, and the impact of trade agreements on global trade.

In this paper, the value of MAPE metrics lower than 10 in a very high percentage of cases for exports and imports showed that the best or the most precise predicting algorithm is the neural network Multilayer perceptron. This is in line with previous research findings that neural networks outperform standard statistic and econometric algorithms and machine learning algorithms in projecting bilateral trade flows. Baxter and Srisaeng (2018) obtained a MAPE value of 2.44% for the artificial neural network in predicting Australia's export air cargo demand which was extremely good precision. Furthermore, Nyoni (2019) obtained a value of errors of 2.24% for Zimbabwe's bilateral exports and 1.56% for Zimbabwe's bilateral imports. It can be concluded that machine learning algorithms are a suitable tool for analysing and predicting bilateral international trade flows in Croatian settings, indicating that they could also be useful for other similar, open economies.

Conclusion

The paper aimed to forecast bilateral international exports and imports in Croatia for 2020 using machine learning algorithms (Gaussian processes, Linear regression, and

Multilayer perceptron). It was found that machine learning algorithms can precisely forecast Croatian international bilateral trade flows for a one-year horizon. The MAPE metrics showed that a Multilayer perceptron is the best or the most precise predicting algorithm. Therefore, the paper's hypothesis that machine learning algorithms have a good predictive capability in forecasting Croatian bilateral trade can be accepted as valid.

The limitation of the paper is related to the impossibility of machine learning algorithms to predict bilateral trade in a few cases, which can be observed as a technical limitation of the analysis. Generally, the limitation of neural network models is that it fails to describe causal relationships between the variables.

Further research could be made to compare the efficiency of machine learning algorithms with the trade gravity models, Pseudo Poisson Maximum Likelihood (PPML), and other estimators. Additionally, the analysis could be extended by forecasting the horizon larger than one year; however, in that case, the precision of machine learning algorithms in predicting bilateral trade flows is expected to be lower. Another approach to which special attention should be paid is the ensemble approach, Salama et al. (2022). The accuracy of machine learning algorithms and neural networks in predicting bilateral trade flows can be very beneficial for policymakers, researchers, and firms in making decisions related to international bilateral trade.

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