DOI: https://doi.org/10.32782/2524-0072/2024-70-179

UDC 005.932:663.2/.3(477)

WINE DISTRIBUTION IN UKRAINE UNDER CONDITIONS OF UNCERTAINTY AND CONSTRAINTS

ДИСТРИБУЦІЯ ВИНА В УКРАЇНІ В УМОВАХ НЕВИЗНАЧЕНОСТІ ТА ОБМЕЖЕННЯ

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The article is dedicated to analysing the current state, challenges, and prospects of wine product distribution in the Ukrainian market. It examines the key factors influencing the formation of wine supply chains, including economic, political, social, and regulatory constraints. Particular attention is given to the application of the Theory of Constraints (TOC), developed in the 1980s by Eliyahu Goldratt. The article demonstrates how this theory has been adapted to the modern context, including the wartime conditions in Ukraine, which have significantly impacted logistics chains, production processes, and consumer behaviour. In the article, the author also explores the differences and commonalities between the Theory of Constraints (TOC) and Uncertainty Theory, analysing their approaches to problem-solving under conditions of constraints and uncertainty. In times of war, TOC helps address issues in supply chains and resource management, contributing to the improvement of wine distribution efficiency. It allows for a better understanding of the prospects for the functioning of the Ukrainian wine market in conditions of uncertainty and restrictions, as well as the development of practical tools for its sustainable development even in challenging circumstances. The article also discusses the key indicators in the wine distribution system according to TOC.

Keywords: wine distribution, Ukraine, uncertainty, constraints, Theory of Constraints, Uncertainty Theory, wine market, logistics, online sales, martial law.

Стаття присвячена аналізу сучасного стану, викликів та перспектив дистрибуції вина на українському ринку. У роботі розглядаються ключові фактори, що впливають на формування ланцюгів постачання вина, зокрема економічні, політичні, соціальні та регуляторні обмеження. Особливу увагу приділено використанню Теорії обмежень (Theory of Constraints), розробленої у 1980-х роках Еліяху Голдраттом і заснованої на пошуку та управлінні ключовим обмеженням системи, яке визначає успіх та ефективність усієї системи в цілому, як методологічної основи дослідження. У статті представлено, як ця теорія була адаптована до сучасної ситуації, включаючи військовий стан в Україні, що суттєво вплинув на логістичні, виробничі процеси та споживчі настрої. Розглядаються основні виклики, з якими стикаються учасники ринку, зокрема порушення ланцюгів постачання, зростання витрат на транспортування, зміна митного та регуляторного середовища, а також зниження купівельної спроможності населення. У статті досліджуються відмінності та спільні риси між Теорією обмежень (ТОС) та Теорією невизначеності (Uncertainty Theory), аналізуючи їх підходи до вирішення проблем в умовах обмежень і нестабільності. Використовуючи принципи ТОС, проаналізовано зміни у споживчих настроях, логістичних процесах та регуляторному середовищі, які формують нові виклики для учасників винного ринку. Основна увага приділена ключовим принципам ТОС, які спрямовані на покращення ефективності дистрибуції вина через виявлення та усунення обмежень, що заважають досягненню цілей. Умови війни створили унікальні виклики для сектору винної продукції, а ТОС може відігравати важливу роль у стабілізації та розвитку ринку. В умовах постійних ризиків і змін ТОС допомагає вирішувати проблеми в ланцюгах постачання та управлінні ресурсами, сприяючи підвищенню ефективності дистрибуції вина. Також у статті розглядаються основні показники, що визначають ефективність дистрибуції вина відповідно до ТОС, включаючи швидкість обігу товару, рівень запасів, гнучкість логістичних процесів та адаптивність до змін у попиті. Визначено перспективи розвитку українського винного ринку в умовах невизначеності та окреслено можливі сценарії його подальшого функціонування. На основі проведеного аналізу пропонуються практичні рекомендації: представлено узагальнену модель, яку необхідно адаптувати до специфічних умов воєнного

стану та особливостей українського винного ринку. Така модель допомагає оптимізувати ланцюг постачання та дистрибуції, враховуючи обмеження та ресурси, з якими стикаються підприємства під час війни.

Ключові слова: дистрибуція вина, Україна, невизначеність, обмеження, Теорія обмежень, Теорія невизначеності, винний ринок, логістика, онлайн-продажі, військовий стан.

Statement of the problem. The Ukrainian wine industry has long been an important part of the country's agricultural and economic sectors, with a significant role in the production, export, and distribution of high-quality wines. However, recent global crises and local challenges, including the ongoing war, have severely disrupted traditional supply chains, production capabilities, and consumer behaviour. These disruptions have created unprecedented uncertainty and constraints for wine producers, distributors, and buyers operating within and beyond Ukraine's borders. The military situation in particular has placed immense pressure on logistical networks, including transportation routes, infrastructure, and cross-border trade operations. Producers in regions directly impacted by the conflict face additional challenges, such as damage to facilities, displacement of labour, and volatile demand from both domestic and international markets.

Analysis of Recent Research and Publications. Wine distribution in Ukraine and foreign experience, especially during periods of uncertainty and constraints, has become an increasingly important subject in both academic and practical discussions. Recent research delves into several aspects of this issue, including the effects of geopolitical instability, economic difficulties, and logistical disruptions resulting from ongoing conflicts. These factors have a profound impact on the entire wine distribution chain, affecting everything from production and warehousing to the final delivery to consumers. Global Perspectives on Wine Distribution

Eugenio Pomarici, Flavio Boccia, and Daniela Catapano (2012) conducted an extensive survey on wine distribution systems worldwide. Their research highlights the different structures and strategies used across various markets, analyzing key factors influencing wine supply chains globally. This study provides a comparative perspective on distribution channels, regulatory environments, and market dynamics in different countries. Noa Ohana-Levi and Yishai Netzer (2023) focused on long-term trends in the global wine market, examining the evolving nature of wine consumption, production, and distribution. Their research delves into macroeconomic trends, the impact of globalization, and shifts in consumer preferences that shape the modern wine industry. Shymanovska-Dianich L. M., Pedchenko N. S., Lozova O. V., Kucher M. M., Steblyuk N. F., and Vyshnikina O. V. (2024) analyzed the development of Ukraine's wine industry during wartime, emphasizing the challenges and risks associated with distribution and sales. Their work discusses how war-induced disruptions affect supply chains and the necessary adaptations businesses must make to maintain market stability and operational efficiency. Alla Meish and Sergey Yadukha (2023) explored the formation of logistics subsystems in product distribution, presenting models for optimizing wine distribution processes. Their study integrates logistics strategies that improve efficiency, reduce risks, and ensure stable supply chain management – critical factors in uncertain economic conditions.

These studies collectively offer a comprehensive understanding of wine distribution, from global trends to specific regional challenges, particularly in Ukraine. They highlight the importance of adaptive logistics, market resilience, and strategic distribution planning in the wine industry [1–4].

Formulation of the article's objectives (problem statement). The primary objective of this article is to analyse the current state, challenges, and prospects of wine distribution in Ukraine, focusing on the effects of uncertainty and constraints. The study aims to explore the key factors influencing the formation of wine supply chains in Ukraine, including economic, political, social, and regulatory limitations. Additionally, the article seeks to apply the Theory of Constraints (TOC), a methodology that identifies and manages the most critical bottlenecks within a system, to understand how these constraints affect wine distribution in Ukraine. This theoretical framework will be adapted to the specific challenges presented by the current situation, such as disruptions in logistics, changes in production processes, and shifting consumer behaviour.

Presentation of the main research material. The Ukrainian wine market has encountered significant challenges over the past several years, shaped by a confluence of economic, geopolitical, and structural factors. These challenges have disrupted traditional

supply chains, constrained market growth, and demanded adaptation from producers, distributors, and other industry stakeholders (Figure 1).

Geopolitical Instability and ongoing war has severely impacted the wine industry in Ukraine. Key wine-producing regions have faced destruction of infrastructure, loss of vineyards, and displacement of skilled workers. The war has also disrupted supply chains, hindered exports, and led to market fragmentation, with producers struggling to reach both domestic and international consumers. The economic downturn caused by the war and its associated costs has diminished domestic purchasing power and reduced consumer spending on non-essential goods, including wine. Inflationary pressures and currency devaluation have further strained both producers and consumers, increasing production costs and reducing profitability. Regarding the transportation and logistics networks have been heavily disrupted due to damaged infrastructure, restricted access to occupied territories, and shifting trade routes. These disruptions have delayed deliveries, increased costs, and complicated the movement of goods both domestically and internationally. The constraints caused by the war and economic instability as well has shifted consumer priorities, with many focusing on essential goods over luxury items like wine. This has led to a contraction in domestic demand, further challenging the sustainability of the wine market. Ukrainian winemakers, as a part of distribution system, have also faced challenges associated with climate change, including erratic weather patterns, droughts, and extreme temperatures. These factors have affected grape yields and quality, making it difficult for producers to maintain consistency in their products. The pandemic accelerated the shift to e-commerce and digital marketing, yet many Ukrainian wineries as well as wine distributors and retailers were unprepared to fully capitalize on these trends. Limited technological infrastructure and expertise have posed challenges for producers

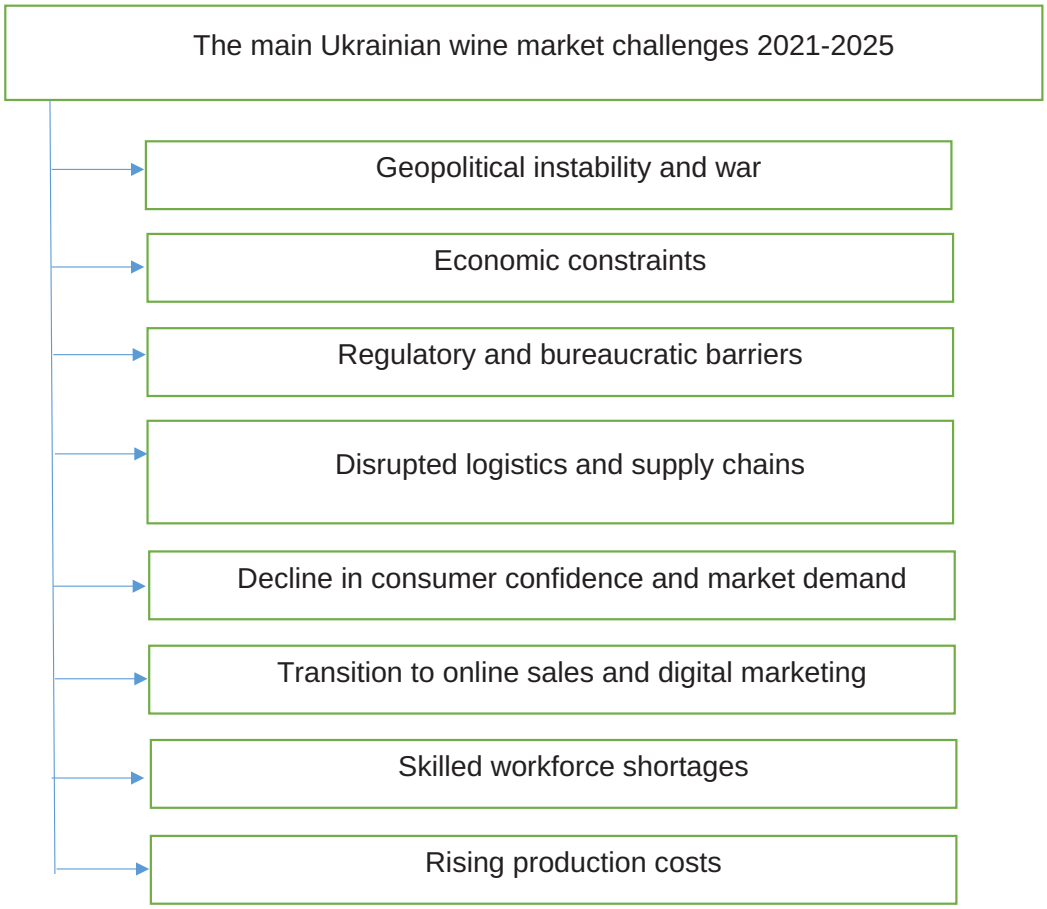

Figure 1. The main challenges Ukrainian wine market has encountered over the past several years

Source: developed by the author

attempting to establish a robust online presence and reach a broader audience. The ongoing war has resulted in the displacement of a significant portion of the labour force, including skilled vineyard workers and winemakers, sommeliers, cavists and wine specialists. This shortage of expertise has impacted the production in the country as well as the wine import and its support in distribution system process. Increasing prices for raw materials, energy, and transportation have also placed financial pressure on wine market.

Given the above, the application of the proposed key business process management theories is becoming increasingly relevant – the Theory of Constraints (TOC) and Uncertainty Theory. Let us examine the main principles of these theories highlighting their similarities and differences. The author of the TOC is Eliyahu M. Goldratt, an Israeli physicist, author, and business consultant. He introduced his theory in 1984 in the book "The Goal." The main idea of the TOC is that every system has at least one constraint (bottleneck) that limits its productivity. Therefore, to achieve maximum efficiency, it is necessary to identify this constraint, make the most of its potential, subordinate all other processes to the constraint, and eliminate it. Afterward, the process should be repeated to find new bottlenecks. The TOC theory is applied in many areas, including business process management, manufacturing, logistics, and strategic planning [5].

Uncertainty Theory was introduced by Baoding Liu, a Chinese mathematician and professor, in 2007. The main idea of the theory is to mathematically model situations where subjective judgment and incomplete information play a significant role. Unlike classical probability theory, Uncertainty Theory is used in cases where uncertainty cannot be quantitatively assessed using standard statistical methods. The core principles of this theory include an axiomatic approach, where the theory is built upon axioms similar to those in probability theory. It also involves the concept of uncertainty functions, which define the degree of confidence in different events, and uncertainty expectation, which allows for evaluating outcomes while considering the subjectivity of the data [6]. Uncertainty Theory is widely applied in fields such as finance, risk management, and decision-making under uncertainty.

In the Table 1, the comparison of commonalities and differences between the Theory of Constraints (TOC) and Uncertainty Theory are represented.

After examining the key aspects of theories such as their foundational principles, methodologies, and areas of application, it is proposed to consider the wine distribution system and its improvement using the Theory of Constraints (TOC), where the main problems are based on process efficiency (e.g., optimization of warehouses, logistics, supply).

As previously mentioned, the Theory of Constraints (TOC) aims to improve efficiency within organizations by identifying and eliminating constraints that hinder the achievement of goals. In times of war, TOC is focused on addressing issues in supply chains and resource management, thus improving the efficiency of wine distribution. The key step in applying TOC is identifying constraints, which can be physical, economic, technological, or administrative, such as: logistical constraints (infrastructure destruction, limited routes due to military actions, transport shortages); raw material supply problems issues with the supply of raw materials, packaging, and labels (domestic market) or goods (foreign market); security constraints threats to warehouses and transport, costs associated with ensuring security; economic constraints, the fluctuations in exchange rates, changes in demand due to financial difficulties faced by consumers; personnel and workforce constraints like mobilization of workers or lack of labour; information and administrative limitations, which consist in the instability of communications and access to data.

Identifying constraints is a critical step for ensuring the sustainable development of wine distribution in wartime conditions, and identifying weak points in the supply chain helps minimize delays and losses. To eliminate constraints, it is suggested to:

– conduct a systematic analysis of the supply chain, identifying weak links where delays or disruptions occur;

– assess risks and strategically manage stock levels, ensuring reserves of wine products;

– improve communications and planning, including clear communication between all participants in the wine supply chain;

– diversify wine supply channels to reduce risks through alternative suppliers and routes.

The next key principle is optimizing and increasing the throughput of the constraint (Exploiting the Constraint). Once the constraint is identified, the next step is to maximize the

Table 1

The comparison of commonalities and differences between the Theory of Constraints (TOC) and Uncertainty Theory

Aspect	Common	Different
Core Focus	Both address decision-making and optimization under constraints or lack of clarity.	TOC focuses on identifying and resolving bottlenecks in processes; Uncertainty Theory focuses on managing uncertainty in systems.
Approach	Both aim to improve system performance by addressing key factors impacting outcomes.	TOC is deterministic and relies on cause-effect logic; Uncertainty Theory deals with probabilistic and uncertain variables.
Scope of Application	Both can be applied across industries like manufacturing, logistics, and project management.	TOC is more operational, emphasizing productivity and throughput; Uncertainty Theory is theoretical and focuses on modelling and predicting uncertainty.
Decision-making	Both emphasize prioritizing decisions based on criticality or impact.	TOC uses methods like the Five Focusing Steps to identify bottlenecks; Uncertainty Theory uses axioms and probability models.
Tools Used	Both involve frameworks to manage complexity in processes.	TOC uses tools like Current Reality Trees, Critical Chain; Uncertainty Theory relies on mathematical probability and fuzzy logic.
Underlying Philosophy	Both aim to create clarity in complex or constrained environments.	TOC assumes constraints are the limiting factor; Uncertainty Theory assumes uncertainty is inherent in all systems.
Goal	Both seek to enhance the predictability and efficiency of outcomes.	TOC optimizes system flow; Uncertainty Theory reduces risks associated with incomplete knowledge.

Source: developed by the author using [6; 7]

effectiveness of this constraint. This may include improving logistics to reduce delivery time and costs, as well as finding alternative suppliers or distribution partners.

The next important step is to support the constraint with other resources (Subordinate Everything Else to the Constraint). All other resources and stages of the process should be aligned with the constraint. For example, if the identified constraint is logistics, production processes and warehouses should be set up to ensure timely delivery of the wine. It is important to synchronize production, warehousing, and transportation stages to avoid delays and ensure the availability of the required volumes of product for sale. If, after optimizing the process, the constraint still remains, the next step is to elevate the constraint (Elevating the Constraint). This may involve expanding warehouse capacities or implementing new technologies for faster order processing, improving logistics processes such as warehouse automation or establishing new contracts with transport companies, as well as increasing wine orders or diversifying offerings, and hiring additional staff.

To ensure continuous improvement of the process, it is important to maintain constant improvement (Repeat the Process). Once one constraint is eliminated or reduced, the process is repeated to identify the next constraint that is hindering wine distribution. This allows for continuous improvement of the entire supply chain and ensuring the highest efficiency.

Inventory management is another important aspect within the Theory of Constraints (TOC). Effective wine distribution requires optimal stock levels. If there are constraints at certain stages, the system should adapt to prevent excess or shortage of goods. It is also important to consider the demand for specific types of wine in different regions to be able to respond flexibly to changes. TOC is focused on a systemic approach (Systemic Thinking), which means that all elements of the wine distribution process should be considered as part of a larger system. Changes in one part of the process, such as inventory management, can affect other parts, such as delivery time or customer service levels [8].

Let's consider the main indicators in the wine distribution system according to Goldratt's TOC during the war such as Throughput capacity, Inventory Holding Costs, Lead Time, Total Cost

of Distribution, Customer Satisfaction, Order Fulfilment Rate, Flexibility and Adaptability.

Throughput capacity, which is a key indicator of the TOC, determines the amount of wine that can be delivered to consumers, considering physical, logistical, and administrative barriers. In wartime, it is essential to optimize all stages of supply to ensure maximum delivery volumes. Inventory holding costs include storage, processing, packaging, and risks related to damage or loss of wine. To reduce costs, companies need to decrease their inventory while maintaining an adequate level to meet demand. Lead time - the time from receiving an order to its delivery to the consumer – becomes critical during the war as logistics face significant challenges due to destroyed infrastructure, transport shortages, and supply disruptions. Reducing lead time is vital for effective distribution. To decrease lead time, it's important to use alternative logistics routes, diversify suppliers and warehouses, and automate internal processes. Expanding warehouses and preparing for emergencies allow quick responses to crisis situations. Continuous monitoring and flexibility in adapting to changing conditions help maintain distribution effectiveness. Proper supply chain management and process optimization can minimize the impact of war on wine distribution in Ukraine.

The total cost of distribution includes all stages of wine distribution – from procurement, production, and storage to transportation. The importance of this indicator during the war lies in the necessity to control costs amid increased uncertainty and changes in transport tariffs, customs procedures, and supply chains. Organizations must optimize costs to maintain competitiveness and the ability to deliver in challenging conditions. To reduce wine distribution costs during the war, it is recommended to optimize logistics processes by seeking alternative delivery routes and supply channels, which will help reduce transportation and storage costs. Implementing modern technologies for automating warehousing, packaging, and order processing, as well as creating an efficient inventory management system, will help reduce storage costs and avoid product shortages. An important aspect is the reorientation to the domestic market, specifically reducing dependence on international suppliers, which will lower customs fees and transportation costs. Additionally, flexible price adjustments and marketing strategies will help increase sales volumes and attract customers.

Customer satisfaction indicator is important for maintaining customer loyalty, especially during wartime when changes in consumer preferences may occur. Customer satisfaction is measured through surveys or feedback from clients.

During wartime, the ability to ensure a proper level of service becomes even more crucial. So that the Order fulfilment rate indicator measures the company's ability to fulfill customer orders according to their requirements. And the ability of the distribution system to quickly adapt to changes in external conditions is a critical factor for effective operations during the war. It is important to assess the time and resources required to adjust distribution processes according to Flexibility and Adaptability of the System indicator. [9]

Finalizing the research, we have developed a proposal for using TOC in mathematical models. We present a generalized model that needs to be adapted to the specific conditions of martial law and the characteristics of the Ukrainian wine market. Such a model helps optimize the supply and distribution chain, taking into account the constraints and resources businesses face during wartime.

Formula for Wine Distribution according to TOC:

$Distro_{wine}$(System) = min(Transport constraints, Resourses, Market Needs, Safety)

Identification of Constrainti:

Constraints = min (Transportation capabilities, raw material supplies, market availability, productivity) (1)

Optimization:

Maximization of utilization =

$$= \left(\frac{\text{Market demand}}{\text{Transportation constraints}}\right)$$

Engaging additional resources:

Resources = Investment in infrastructure + Expansion of supplies + Redistribution of demand

Review and improvement:

Dynamic optimization = Analyzing changes in constraints and adjusting plans

Conclusions. The application of the discussed TOC principles enables wine distributors to efficiently organize their supply chain, reduce costs, improve customer service, and quickly adapt to changes in demand and market conditions. In the context of the war in Ukraine, for effective wine distribution according to TOC methodology, it is crucial not only to focus on traditional metrics such as throughput

and costs but also to adapt them to the realities of war – specifically, by reducing risks, optimizing inventory and expenses, and swiftly responding to changes in demand and delivery conditions. Implementing TOC approaches allows organizations to remain competitive even in crisis situations.

The overall cost efficiency of wine distribution during the war increases due to damaged infrastructure, demand instability, and logistical challenges. However, by optimizing logistics, ensuring flexibility in inventory management, and automating processes, costs can be reduced, and stability in distribution can be maintained even under challenging conditions.

In this context, applying the principles of TOC helps ensure the stability of wine distribution, reduce the negative impact of crisis situations, and adapt business strategies for effective operation in wartime conditions.

REFERENCES:

1. Eugenio Pomarici, Flavio Boccia, Daniela Catapano (2012). The wine distribution systems over the world: An explorative survey. URL: https://www.researchgate.net/publication/281632240_The_wine_distribution_systems_over_the_world_An_explorative_survey

2. Shymanovska-Dianich L. M., Pedchenko N. S., Lozova O. V., Kucher M. M., Steblyuk N. F., Vyshnikina O. V. (2024). Development of food industry enterprises (wine industry) of Ukraine in the conditions of war: challenges and risks in improving the business processes of distribution and sale of products [Rozvytok pidpryiemstv kharchovoi promyslovosti (vynorobnoi haluzi) Ukrainy v umovakh viiny: vyklyky ta ryzyky u pytanniah udoskonalennya biznes-protsesiv dyistrybutsii i realizatsii produktsii]. *Akademichni Vizii – Academic Visions*, no. 29. (in Ukrainian)

3. Noa Ohana-Levi and Yishai Netzer (2023). Long-Term Trends of Global Wine Market. DOI: 10.3390/agriculture13010224 URL: https://www.researchgate.net/publication/367177351_Long-Term_Trends_of_Global_Wine_Market

4. Alla MEISH, Sergey YADUKHA (2023). Formation of the logistics subsystem of product distribution [Formuvannya lohistychnoyi pidsystemy dystrybutsiyi produktsiyi]. https://doi.org/10.31891/2307-5740-2023-324-6-69 URL: http://journals.khnu.km.ua/vestnik/wp-content/uploads/2024/01/324-69.pdf

5. Seven key trends that will shape the global wine industry in 2024. IWSR assesses the performance and outlook for the global wine market. URL: https://www.theiwsr.com/seven-key-trends-that-will-shape-the-global-wine-industry-in-2024

6. Eliyahu M. Goldratt. Theory of Constraints. URL: https://www.academia.edu/7095271/Theory_of_Constraints_Eliyahu_M_Goldratt

7. Baoding Liu (2007). Uncertainty Theory. URL: https://www.researchgate.net/publication/220688350_Uncertainty_Theory

8. Zeynep Tuğçe (Şimşit) Kalender, Noyan Sebla, Günay, Özalp Vayvay (2014). Theory of Constraints: A Literature Review. URL: https://www.researchgate.net/publication/272392183_Theory_of_Constraints_A_Literature_Review

9. Victoria J. Mabin, Robert Y. Cavana (2024). A framework for using Theory of Constraints thinking processes and tools to complement qualitative system dynamics modelling. URL: https://onlinelibrary.wiley.com/doi/full/10.1002/sdr.1768

СПИСОК ВИКОРИСТАНИХ ДЖЕРЕЛ:

1. Еудженіо Помарічі, Флавіо Бочча, Даніела Катапано (2012). Системи дистрибуції вина у світі: дослідження. URL: https://www.researchgate.net/publication/281632240_The_wine_distribution_systems_over_the_world_An_explorative_survey

2. Шимановська-Діанич Л. М., Педченко Н. С., Лозова О. В., Кучер М. М., Стеблюк Н. Ф., Вишнікіна О. В. (2024). Розвиток підприємств харчової промисловості (виноробної галузі) України в умовах війни: виклики та ризики у питаннях удосконалення бізнес-процесів дистрибуції і реалізації продукції. *АКАДЕМІЧНІ ВІЗІЇ,* № 29.

3. Ноа Охана-Леві та Ішай Нетцер (2023). Довгострокові тенденції світового ринку вина. DOI:10.3390/agriculture13010224 URL: https://www.researchgate.net/publication/367177351_Long-Term_Trends_of_Global_Wine_Market

4. Алла МЕЙШ, Сергій ЯДУХА (2023). Формування логістичної підсистеми дистрибуції продукції. https://doi.org/10.31891/2307-5740-2023-324-6-69 URL: http://journals.khnu.km.ua/vestnik/wp-content/uploads/2024/01/324-69.pdf

5. Сім ключових тенденцій, які формуватимуть світову виноробну індустрію у 2024 році. IWSR оцінює показники та перспективи світового ринку вина. https://www.theiwsr.com/seven-key-trends-that-will-shape-the-global-wine-industry-in-2024

6. Еліяху М. Голдратт. Теорія обмежень. URL: URL: https://www.academia.edu/7095271/Theory_of_Constraints_Eliyahu_M_Goldratt

7. Баодін Ліу (2007). Теорія невизначеності. URL: https://www.researchgate.net/publication/220688350_Uncertainty_Theory

8. Зейнеп Туче (Шимшіт) Календр, Ноян Себла, Гюнай, Озалп Вайвай (2014). Теорія обмежень: Огляд літератури. URL: https://www.researchgate.net/publication/272392183_Theory_of_Constraints_A_Literature_Review

9. Вікторія Дж. Мабін, Роберт Й. Кавана (2024). Рамкова структура для використання процесів Теорії обмежень та інструментів для доповнення якісного моделювання системної динаміки. URL: https://onlinelibrary.wiley.com/doi/full/10.1002/sdr.1768