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Advancing Circular Economy Through Waste Management: Pathways to Sustainable Development in Transition Economies

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Abstract

Environmental protection and resource preservation are key priorities for modern societies, and the European Union's Circular Economy Package sets ambitious targets for 2030. As an EU candidate country, Serbia faces significant challenges in aligning its waste management system with these requirements and in increasing the use of waste as secondary raw materials. In 2023, Serbia generated 3.1 Mt of municipal waste, of which nearly 80% was landfilled, with over 60% consisting of biodegradable and mixed fractions. The analysis identified five priority streams—biodegradable waste, paper/cardboard, plastics, metals, and textiles/wood—that have the greatest potential to yield secondary raw materials and support the transition. However, the availability of recycled secondary raw materials remains limited, with metals dominating recovery and plastics declining in 2023 due to market conditions. A Delphi study involving 7 experts projected that the circular economy would be adopted more widely in 3.6 years, with the highest probability in 2030 (P = 0.998). Results indicate that Serbia remains in an early CE phase, and that transition priorities should include strengthening separate collection, improving the quality of secondary raw materials, and focusing on the five priority waste streams.

Keywords: secondary raw materials, sustainable development, obstacles, sustainable transition, resource efficiency

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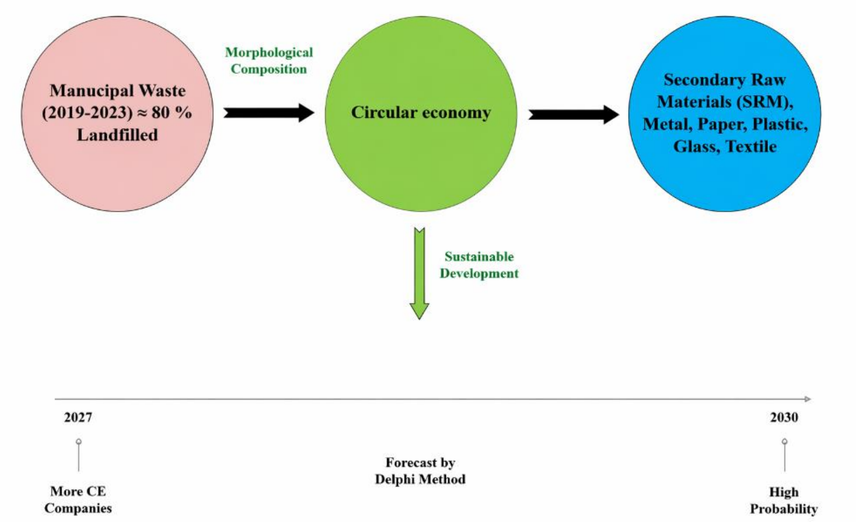
Graphical abstract



1. Introduction

The globalisation of markets necessitates a revised approach to studying business management processes. The circular economy (CE) has emerged as a systemic paradigm of production, consumption and resource-flow optimisation, not just in Europe but globally. Empirical studies now apply quantitative modelling to trace their dynamics of their transitions across regions (Zhao *et al.*, 2025). Organisations cannot achieve sustainable success by relying on outdated management practices and principles. Effective organisational management must be aligned with consumer demands and environmental considerations.

The development of modern business, which prioritises environmental quality and the conservation of natural resources, has introduced new concepts in the production and design of products, namely the circular economy. In addition, a rapidly advancing technological development, known as Industry 4.0, has enabled an easier and faster exchange of information and technology transfer, which can have a huge impact on and contribute to the circular economy, modern business, and solving environmental problems on a global level (Hu *et al.*, 2025; Qiao, Xu and Lei, 2025).

The Circular Economy (CE) is regarded as a strategic and significant factor for organisations focused on profitability and value creation. The degree of CE implementation is positively influenced by Environmental Management System (EMS) certification and a commitment to enhancing environmental performance and adopting a sustainable business model (Fonseca *et al.*, 2018). CE boosts sustainabile developement and reduces risks without harming the environment or depleting resources (Ghisellini, Cialani and Ulgiati, 2016). Nevertheless, the successful adoption of CE faces several challenges, including insufficient technical and technological expertise (Rizos *et al.*, 2016). Resistance to change can stem from risk aversion, a lack of information and knowledge, or misperceptions (Van Buren *et al.*, 2016). Additionally, various stakeholders may require substantial short-term investments, such as acquiring new skills, securing contracts, redesigning products and processes, and purchasing new equipment, with returns expected over a longer period (Kavalić *et al.*, 2021).

Sustainability is not yet the first choice for management. In this context, the circular economy can offer business models that integrate growth with sustainability, and companies across different industries that demonstrate improved environmental performance and numerous benefits, including the rational use of resources, lower costs and economies, and flexible production (Nußholz, 2018; Rattalino, 2018). Also, some studies reveal that sustainability enables companies to achieve strategic goals and survive in a market that expects socially responsible, sustainable business (Hart and Milstein, 2003; Kiron *et al.*, 2013). Companies that prioritisee environmental responsibility stay ahead of future regulations, gaing an advantage over traditional competitors andbuildg a positive image with consumers (Rattalino, 2018). Moreover, advances in corporate governance and financial structures show how CE and green innovation are interwoven in markets and firms (Ma, Benkraiem, *et al.*, 2025).

The global population continues to grow, leading to rising human needs and the emergence of social challenges that are often addressed through economic growth. Economic growth is generally expected to follow an upward trajectory, supporting the stable development of individual nations and the global community. However, achieving a complete and lasting decoupling of economic growth from environmental pressures and impacts appears unlikely globally (European Environment Agency, 2021). Linking CE to climate and biodiversity agendas has become increasingly important, as corporate and financial systems respond to resource- and ecosystem-related risks (Hu *et al.*, 2025; Zeng *et al.*, 2025). Current greenhouse gas emissions and waste generation far exceed the Earth's natural capacity for self-purification. For instance, modern economic activities produce approximately 300 million tons of plastic industrial waste annually. Critical environmental issues include rising lower-atmosphere temperatures, biodiversity loss, land degradation, and water pollution. Currently, it is estimated that each individual generates 0.74 kg of waste per day, contributing to the overall waste burden of the global population of 8 billion (Singh *et al.*, 2023; Skripnuk *et al.*, 2023). Even sectors such as agriculture and mechanisation show CE-relevant pathways towards low-carbon production in the Global South (Ma, Yan, *et al.*, 2025).

Although policy and infrastructure support the CE transition in emerging economies such as Serbia, effective resource recovery increasingly depends on advanced digital technologies (Selvanarayanan et al. 2025). IoT-based real-time monitoring, integrated with Hybrid-RNN and Fuzzy logic models, enhances data accuracy, supports predictive decision-making, and improves resource management, thereby addressing persistent challenges related to secondary raw material quality and enabling optimized wastewater recycling and environmental remediation (Lekhya et al. 2024; Selvanarayanan et al. 2025). In addition, recent studies show that municipal solid waste incineration fly ash can be valorised into geopolymer backfill with stable mechanical performance, supporting the role of secondary raw materials in circular construction (Su et al. 2024)

The European Union (EU) introduced the circular economy concept in 2014 with a long-term strategy focused on minimising, recycling, or repurposing waste and recognising waste as a secondary raw material (European Commission, 2018). In 2015, the EU Action Plan for the Circular Economy was introduced, as well as the Circular Economy Package in 2018, which established ambitious targets for member states on recycling municipal and packaging waste, reducing landfill use, implementing source separation systems, expanding producer responsibility, and improving food waste management (European Commission, 2014b, 2014a). In 2020, the EU adopted the new circular economy action plan 2020, with one of the aims to reduce waste and focus on the sectors that use the most resources and where the potential for circularity is high, for example, packaging waste plastics, setting 70% 55% targets by 2030.

The Waste Framework Directive (WFD) was subsequently amended in 2018 by Directives (2018)/850/EU, 2018/851/EU, and 2018/852/EU, collectively known as the Circular Economy Package (European Parliament and Council, 2018). This updated framework aimed to enhance resource efficiency, promote waste as a valuable resource, reduce dependence on raw material imports, and facilitate the transition to more sustainable material management and a circular economy (European Parliament and Council, 2018). Member states are required to meet specific targets, such as preparing municipal waste for reuse and recycling, with goals set at 55% by 2025, 60% by 2030, and 65% by 2035. Additionally, the landfill directive was amended by Directive (2018)/850/EU to further decrease the proportion of waste sent to landfills, with a target of no more than 10% by (Eurostat, 2024). At the EU level in 2021, the average EU recycling rate was 64%, while the highest recycling rate among EU members has Belgium at 80%, the Netherlands at 78%, Slovakia at 74 %, and Luxemburg and Italy at 73% for monitoring compliance with policy targets, by type of packaging. In contrast, Europe's circular material use rate slightly increases to 11,5% (Eurostat, 2024). Less than 12% of all materials used in the EU are recycled.

In Serbia, a hierarchy of waste management has been established. However, the dominant waste treatment in Serbia is waste disposal (Mihajlović *et al.*, 2016). As a result of the long-term linear economy, 80% of Serbia's waste is landfilled, in 12 sanitary landfills and more than 2,000 illegal dumpsites (SEPA, 2023a).

Following EU waste management practices, in 2020, Serbia adopted a Circular Economy Roadmap aimed at transitioning from a linear to circular economy within the country. The roadmap, through the adoption of circular business models, promotes the creation of new job opportunities in the industry and supports business innovation by identifying sustainable solutions in the market (SMoEP, 2020).

Applying the circular economy concept before the waste management process - during the design, production, and use phases - can substantially decrease the volume of waste that requires recycling. In addition, the circular economy framework promotes the efficient reintegration of waste into the production system, facilitating a connection between waste generators and those who can repurpose it as a resource. This approach, as opposed to traditional waste recycling models, enhances resources management efficiency, reduces associated costs, and lowers the expenses related to recycling and waste processing (Kalkan *et al.*, 2018).

In many transition and developing economies, circular economy implementation commonly begins at the waste-management stage—often described as the "end-of-pipe" approach—because product eco-design, green public procurement, and industrial symbiosis practices are still in early stages of development. Under such conditions, improvements in collection, sorting, recycling, and landfill diversion become the most immediate and practical entry points to circularity. This "waste-first" pathway enables governments and municipalities to achieve visible environmental results while gradually building institutional, technical, and market capacity for more advanced circular-economy strategies.

This paper aims to analyse the current status of the circular economy concept in Serbia and identify municipal waste flows and quantities which can be used as secondary raw materials to foster sustainable development and support transition to circular economy in Serbia. Additionally, the objective is to assess the current state of CE adoption among companies in Serbia, identify the key factors influencing its implementation, anticipate the implementation of CE, and increase the number of companies in Serbia operating according to circular economy principles. The paper uses collection, analysis, and synthesis methods to draw on data from various national statistics to inform strategies for waste reduction. Also, an exploratory approach - an intuitive method of technological forecasting - a standardised Delphi technique, was used to analyse the situation in the area of municipal waste management as well as the development of a circular economy in companies.

The paper's novelty lies in its fusion of quantitative national MSW evidence (2019–2023) with a rigorous, multi-round expert Delphi forecasting method to analyse and predict the necessary steps and estimated timelines for successful Circular Economy uptake, specifically addressing the unique waste management challenges and implementation gaps prevalent in a transition economy like Serbia. Therefore, the research combines qualitative data, national MSW data (2019–2023), with an expert-based Delphi forecast to predict and quantify the timeline for CE adoption under Serbia's transition-economy conditions.

2. Methodology

Serbia is a country in Southeast Europe and a candidate for European Union membership. In recent years, the country has experienced challenging development, which can be considered a transition period in terms of changes in sector polices by following EU criteria. Meeting and aligned with criteria is particularly challenging for developing and transition countries like Serbia. These nations face numerous social, political, institutional, and technical obstacles from the past that need to be resolved.

2.1. Research Framework

The increasing amounts of municipal waste ending up in landfills in Serbia, driven by accelerated technological development and production alongside growing resource consumption, are not aligned with suthe Sustainable Development Goals Companies often prioritise profit, neglecting socially responsible business practices and sociological and ecological concerns.

This research is twofold. The first part aims to analyse the current situation in the Republic of Serbia regarding the circular economy and solid waste management. It seeks to identify potential material flows from municipal solid waste quantities that can be utilised as secondary raw materials (SRM) and other waste streams supporting the "green transition" in Serbia, facilitating a shift from a linear to a circular economy. The newly adopted long-term Programme for waste management in Serbia, effective from 2022-2023, focuses on aligning with the new EU goals in the waste management sector as part of the "green transition." To transition to a circular economy in the EU, it is necessary to establish new objectives for waste management in the Republic of Serbia (Official Gazzette, 2023). Given that the long-term Programme for the "green transition" has set a timeframe for the transition to a circular economy, the second part of the research employs the Delphi method to identify when improvements can be anticipated in the circular economy, including a greater number of companies in Serbia operating on the principles of a circular economy.

The research problem addresses the increasing amounts of municipal waste in landfills, driven by accelerated technological development and production. It also addresses growing resource consumption that is not aligned with the Sustainable Development Goals. Companies aim for profit, often neglecting socially responsible business practices and sociological and ecological aspects.

Companies have access to a number of techniques, tools, analyses and concepts that can help them achieve their goals while operating in a sustainable manner. The circular economy is one concept that makes this possible. Landfill and exported waste can be used as SRM in companies, reducing their dependence on raw materials, cutting costs and creating numerous advantages (Đorđević *et al.*, 2023).

2.2. Data collection

Data used to identify material flows that can be used as SRM are from the national GIS (Geographic Information System) database for Waste Management and official national reports from 2019-2024 (SEPA, 2020, pp. 2011–2019, 2021, pp. 2011–2019, 2022, pp. 2011–2019, 2023b, pp. 2011–2019, 2024, pp. 2011–2019, 2025). GIS database includes data on Serbia and its regions, on generated waste, treated waste, temporary stored waste, collected waste, waste treatment, exported and imported waste. Waste flows are listed according to the national waste catalogue. The national waste catalogue has twenty main groups, including hazardous and non-hazardous waste flows. Data on imported and exported waste, which can be used as SRM, has also been used.

National reports include data on generated waste, generated MSW treatment, used waste, hazardous and industrial waste, landfilled waste, transboundary waste flows, and exported and imported waste.

All quantitative waste data come from national SEPA reports and GIS waste portal for 2019–2023 and hazardous/industrial waste was excluded because of data gaps and different treatment chains. The material flows of interest for this research are the ones which can be used as SRM and flows for which recycling and reuse technologies are well established.

Data from official reports, national strategies on environmental protection and waste management, and national databases on waste flows have been used to identify waste flows and quantities that can be used as secondary raw materials (SRM). The material flow of interest for this research is the one that can be used as SRM and flows for which recycling and reuse technologies are well established. Based on the results, recommendations are made for improving and developing waste management to achieve sustainable development and transit to circular economy.

2.3. Data analysis

Data from national reports and the GIS database were summarized based on the morphological properties of the waste flow. Regarding the morphological composition of MSW in Serbia, 45% is biodegradable waste, paper and cardboard 6%, PET packaging 5%, and other plastic waste 5%. Other potential secondary raw materials, including glass, metal, metal Al cans, composite materials, other plastic waste, plastic bags, and textiles, account for 23% of waste landfilled (SEPA, 2021). In addition, the municipal solid waste flows that are landfilled can be used as SRM. In this analysis, textile and wood waste flows have been assessed as SRM, and batteries and accumulators have been analyzed since recycling capacities are available in the country.

For this study, a group of decision-makers and experts involved in waste management and the circular economy in Serbia has been identified.

The questions were selected and formulated using the Delphi method, which was achieved by selecting a previously formed set of questions after analysing the available relevant, verified data and the current status of CE implementation in Serbia.

Although history and events from the past play a role and are fully appreciated in forecasting methods, technological forecasts require more than that: the application of imagination and creativity, which is connected with the talent, knowledge and intuition of individuals, to be able to perceive changes in the long term successfully (Levi-Jakšić, Marinković and Obradović, 2011). Thus, for our research, the experts were chosen based on their expertise, knowledge, business functions, narrow speciality closely related to forecasting and prior consent, and according to the standardised Delphi method. Participants are anonymous and do not know each other to avoid influence and achieve objectivity. The selected group of participants that provides the answers are called a panel.

During the questionnaire implementation, the participants were asked several questions needed to answer the research question.

Intuition, judgment, and expertise are essential to applying the technical forecasting method and are more important than the forecasting technique in making a successful forecast. However, one should not ignore the role and connection of the forecasting techniques themselves, the goal of which is to organise the knowledge, intuition and abilities of people rationally and systematically in the direction of performing the most successful qualitative, technological forecasting for the sake of formalising thought processes and predicting the future.

In the Delphi method, the model used as a basis for prediction is always knowledge expertise, and individual knowledge is also used.

The Delphi method includes repeated voting, with the same experts giving answers, considering previous results. This approach is used to avoid the influence of “lawyers”.

The Delphi method (Linstone, 2002) is one of the fundamental forecasting methods and represents the most well-known and widely used expert evaluation method. Expert evaluation methods significantly improve the traditional ways of obtaining forecasts through the joint consultation of experts on the studied phenomenon. In other words, it is a methodologically organised use of expert knowledge to predict future states.

The Delphi technique is a flexible and rapid research method that can be used to analyse educational needs. This technique becomes more valid and effective if a group of experts monitors and analyses information until a consensus is reached. Its significance is reflected in the characteristics of the Delphi method, which include:

- Anonymity
- Interactive Process, conducted in “rounds” with controlled feedback
- Statistical Calculation
- Defined Questionnaires

The starting point of the method is the definition of the problem for which a forecast is sought. After defining the problem, a group of experts is formed to participate in the forecasting process. It is recommended that the group contains 7-15 experts, with a maximum of 35. Experts are asked to provide forecasts and other information via questionnaires, ensuring the anonymity of both the experts and the forecasts obtained. The Delphi method is a quantitative research method with qualitative elements, relying on the opinions of a panel of experts and conducted through several rounds of inquiry.

In our study, experts were selected for their competence, years of experience, and specialist knowledge, with a mandatory inclusion criterion requiring direct involvement in MSW or CE policymaking or operational activities (Levi-Jakšić, Marinković and Obradović, 2011). This approach ensures methodological relevance and strengthens the panel's representativeness.

The expertise of the panel members covered several key sectors relevant to CE implementation:

- national ministries and state environmental agencies,
- local government authorities,
- operators of waste-treatment and recycling facilities,
- representatives of the business/industry sector,
- academia and research institutions, and
- chambers of commerce and sectoral organisations.

All participants provided informed consent, and the Delphi process was conducted anonymously to prevent mutual influence and ensure impartiality of responses.

The Delphi method is carried out through several rounds of inquiry. In the first round, experts complete a questionnaire. After processing the statistical data, the questionnaire results are returned to participants, and the same questionnaires are completed again. However, they may change their opinions based on the results of the first round. The number of rounds is not defined; typically, four rounds are conducted, whereas in this study, five rounds were performed. From this, we can conclude that the Delphi method is:

- An exploratory and intuitive method;
- A method that leverages the advantages of group thinking
- A method that overcomes obstacles that arise in group work
- A technique that relies on expert opinions;
- Conducted through several rounds of inquiry.

There are two distinct forms of the Delphi method:

2.3.1. Conventional Delphi Technique

Often referred to in literature as the Delphi exercise, this approach is conducted manually using paper and pencil. A team is formed to oversee and implement the method questionnaires are developed, and responses are collected, in accordance with the standard procedure described.

2.3.2. Online Delphi (Delphi Conference)

This is a more recent form of the Delphi method, in which the implementation and coordination team is largely replaced by a computer that performs statistical data processing. This approach has advantages in terms of faster result processing, allowing immediate forecasting, as all members simultaneously respond to questionnaire items and can revise their answers more efficiently in the next round. Results can be presented as graphs, comparative tables, etc. (Sharma *et al.*, 2021).

For this study, the Online Delphi method was used. Standardised formulas will be employed to calculate each expert's individual prediction time, the overall expected value, the dispersion for each expert t_i, the total dispersion, the standard deviation, and the probability values using the Laplace table.

A variation based on response was used - the Delphi method allows for three possible answers. These three responses can relate to 1. the earliest, optimistic *(o)*, 2. the expected *(m)*, and 3. the latest realisation of the event, pessimistic *(p)*.

An online Delphi method was used to determine the timeframe within which progress in the implementation of the circular economy can realistically be expected in Serbia. This method is particularly suitable for transition economies, where official statistics are fragmented, and policy development is still evolving (Linstone, 2002). The Delphi technique enables structured collection of expert opinions across several rounds, ensuring anonymity, controlled feedback, and gradual convergence toward more reliable estimates.

In this study, the Delphi method is used not to provide a general overview of trends, but to establish an expert-based timeline for when circular-economy practices may become operational in Serbia. Conditions typical of transition economies-fragmented and incomplete data, unstable regulatory frameworks, and strong dependence on external funding-make expert judgement especially appropriate, offering a robust form of prediction where quantitative indicators are insufficient.

2.4. Validity, Security, and Reliability

The Delphi method ensures a high level of validity and reliability through several core procedural elements. Expert anonymity prevents dominance effects and conformity bias, thereby securing independent judgment. Controlled feedback enables reflection, argumentation, and potential adjustment of views across rounds. The multi-round structure contributes to the gradual stabilization of opinions and the reduction of extreme values, while the combination of expert intuition, experience, and analytical reasoning is particularly relevant in contexts where reliable quantitative data are lacking (Levi-Jakšić, Marinković and Obradović, 2011).

Validation of results is achieved by assessing response stability across rounds and measuring convergence toward consensus. A reduction in variance between rounds represents a key indicator of validated and stable outcomes.

Security of the process is ensured by participants' complete anonymity, controlled access to the online platform, and the absence of direct communication among experts. These measures eliminate mutual influence and minimize the risk of bias. The online environment further enhances procedural safety by reducing operational errors and facilitating efficient processing of responses.

Reliability of results is strengthened by the use of standardized statistical procedures applied during data analysis, which enable accurate calculation of central tendency measures, dispersion values, and probabilities of realization. Although the Delphi method provides a high degree of reliability, its inherent limitation remains the subjective nature of expert assessments. Consequently, careful interpretation of the results is required, particularly in highly uncertain policy environments.

2.5. Measurements and Data Processing

During data processing, standardized statistical procedures commonly used in Delphi studies were employed. The following formulas and accompanying calculations were employed:

1. The formula for deriving the individual expected prediction time based on the combination of optimistic (o), most likely/median (m), and pessimistic (p) estimates;
2. The formula for calculating the expected time of event realization (E);
3. The formula for computing the individual expert's variance.
4. The formula for calculating the overall variance (dispersion) of the expert panel;
5. The formula for obtaining the standard deviation and the standardized value γ;
6. The probability estimation based on the Laplace cumulative distribution table.

For additional clarity, this section now includes a brief mathematical overview explaining the logic behind the performance evaluation of the Delphi panel. Individual expert assessments are first transformed into expected values through weighted combinations of o/m/p estimates. Subsequently, variances and standard deviations are calculated to quantify the degree of agreement within the panel. The total dispersion and γ-values provide insight into the stability and convergence of expert responses across rounds, while the calculated probabilities indicate the reliability of the predicted timeframes.

All formulas (1)–(6), numerical examples, probability tables, and graphical illustrations are presented in **Appendix A** for transparency and reproducibility.

3. Results and Discussion

3.1. Analysis of the Circular Economy and Waste Management in Serbia

Serbia's progress in the circular economy and sustainable development, which are important for economic development and future growth, remains limited. A key indicator of this issue is the substantial amount of waste that ends up in landfills and is poorly managed, despite the potential to repurpose it as SRM. This mismanagement affects all dimensions of sustainable development, including the economic, social, and ecological. Additionally, excessive resource consumption generates large volumes of waste from manufacturing processes, which are not used as secondary raw materials. Therefore, it is essential to analyse the current situation thoroughly and develop guidelines for improvement.

Table 1. Municipal solid waste indicators in Serbia from 2018-2022 [33].

Indicator	2019	2020	2021	2022	2023
MSW generated (t)	2 827 910	2 947 497	3 021 741	3 178 770	3 095 422
Total MSW landfilled (t)	2 243 661	2 341 732	2 356 432	2 457 216	2 460 777
Generated MSW landfilled (%)	79.34	79.45	77.98	77.30	79.5

Table 2. Comparison of EU and Serbia Waste Indicators

Indicator	European Union (average 2023)	Serbia (2023)
Circular Material Use Rate	11.7 %	1.4 %
Municipal Waste Landfilled	< 20 %	≈ 80 %
Packaging Waste Recycling	64 %	30–35 %
Illegal Dumpsites	-	> 2 000

The total amount of municipal waste deposited in Serbia for 2019-2023 is shown in **Table 1**. Despite the legal framework in the area of waste management, which is adopted, a significant amount of municipal solid waste is landfilled, around 80% of total generated waste, where the amount of waste that is landfilled has risen in the past five years (Mihajlović *et al.*, 2016; SEPA, 2023a).

Regarding the morphological composition of landfilled waste, 45% is biodegradable waste, 6% paper and cardboard, 5% PET packaging, and 5% other plastic waste. In contrast, other potential secondary raw materials include glass, metal, metal-aluminum cans, composite materials, other plastic waste, plastic bags, and textiles, accounting for 23% of landfilled waste (Mihajlović *et al.*, 2016). Fine elements and other materials account for 16% of landfilled waste. Therefore, excluding fine elements and other potential secondary raw materials, which are landfilled, is 84%, 2.034.575 tons of MSW in 2023, Figure 1. The largest share of landfilled waste in 2023 was biodegradable waste (1 120 490 tons), of which only 1.32% was recycled (SEPA, 2023a). The rise of landfilled waste shows that CE is not at a satisfactory level in Serbia, and landfilled waste is a lost SRM, which can be used instead of virgin materials, which cost more and increase the cost in the production chain.

However, Serbia continues to export waste to neighbouring countries despite its available processing capacity. Most of the waste was exported to the Republic of Croatia, the Republic of Bulgaria, the Republic of North Macedonia, the Republic of Slovenia, and Hungary. Also, Serbia imports a significant amount of waste, mostly hazardous waste, and the same material waste flows that are exported (Levi-Jakšić, Marinković and Obradović, 2011; SEPA, 2021, pp. 2011–2020, 2022, pp. 2011–2020, 2023b, pp. 2011–2020, 2024, pp. 2011–2020). Exporting SRM to neighbouring countries despite available processing capacity indicates that strategic planning is important for implementing the CE concept and that CE is not at a satisfactory level. SRM exports persist due to unstable feedstock from poor source separation, variable quality, and lower prices of virgin materials.

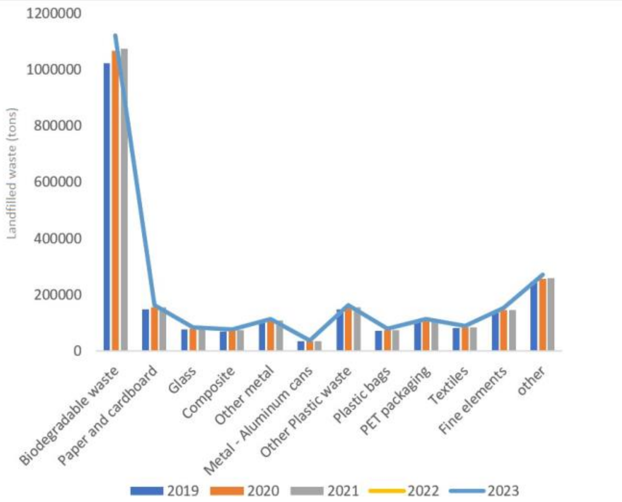


Figure 1. Morphological composition of waste landfilled in Serbia from 2019 to 2023

Material flows of recycled waste used as secondary raw materials 2020-2023 are shown in Figure 2 (SEPA, 2020, pp. 2011–2020, 2021, pp. 2011–2020, 2022, pp. 2011–

2020, 2023b, pp. 2011–2020, 2024, pp. 2011–2020). The highest share is metals; the price is per kg, so the profit is higher. The share of plastic waste decreased in 2023, and the share of paper and cardboard decreased significantly due to fluctuations in the prices of secondary raw materials. The share of other material flows is much lower, even insignificant, in the case of textiles and accumulators.

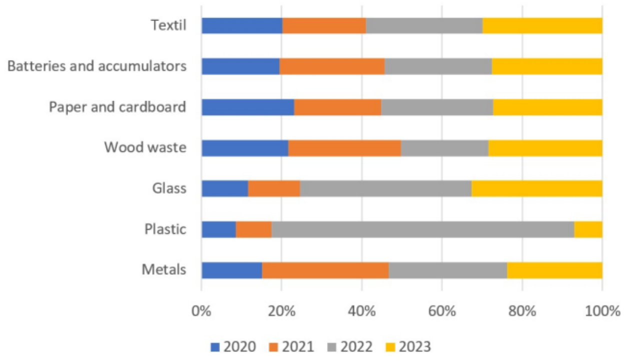


Figure 2. Material flows of recycled waste used as secondary raw materials from 2020 to 2023

The import and export of secondary raw materials for 2019-2023 are shown in Figures 3 and 4 (SEPA, 2020, pp. 2011–2020, 2021, pp. 2011–2020, 2022, pp. 2011–2020, 2023b, pp. 2011–2020, 2024, pp. 2011–2020).

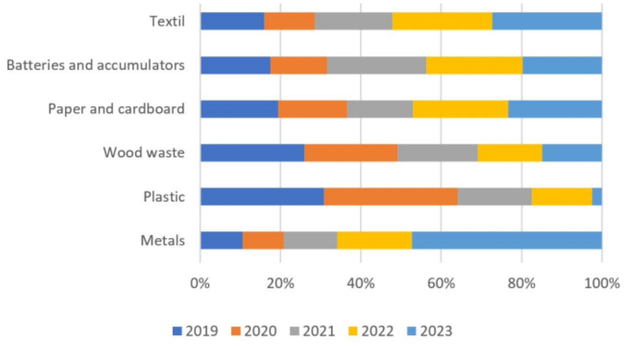


Figure 3. Import of waste as secondary raw materials in Serbia from 2019 to 2023

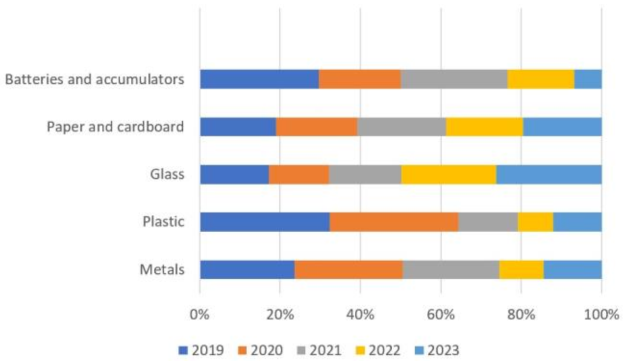


Figure 4. Export of waste as secondary raw materials in Serbia from 2019 to 2023

In addition to importing and exporting waste for use as an SRM, Serbia lacks primary materials that could be recycled. Additionally, waste prices fluctuate throughout the year, and in Serbia, virgin materials remain more attractive and cheaper than recycled materials, which are more expensive. Therefore, unprocessed materials are often more affordable than recycled materials, while large amounts of plastic waste are still disposed of in landfills.

Market drivers further shape SRM recovery patterns, as evidenced by the dominance of metals in recycled material flows (Figure 2). Metals remain economically attractive due to higher and more stable market prices, whereas plastics and paper exhibit strong volatility, resulting in declining recovery rates in 2023. This market sensitivity explains the continued export of SRM despite the availability of domestic processing capacity (Figures 3 and 4), as inconsistent quality and price competitiveness undermines local recycling value chains and limit the integration of secondary materials into domestic circular-economy production systems.

The comparison with EU averages—where SRM utilisation exceeds **11% of material consumption**—highlights Serbia's gap and also its growth potential. Integrating SRM recovery into industrial value chains, particularly in the metal, paper, and plastic sectors, could create **1,500–2,000 new jobs** in collection and reprocessing by 2030. These empirical results confirm that SRM development is both an environmental and an economic opportunity, positioning waste management as a central lever in Serbia's circular-economy transition. In neighbouring countries Croatia, Romania, and Bulgaria, one of the main obstacles to transition to a circular economy is that key drivers of the circular economy, technology and innovation, and human resources are very low (World Bank, 2022). This implies that green production has not yet developed, as sectoral policies remain focused on waste management activities at the end of a product's lifecycle.

In contrast, the potential for circular products is typically established at the outset, during the design phase. A regional and material-specific focus can enhance the viability of developing a circular business. Developers emphasised the importance of public financing availability while underscoring the need to integrate circular requirements into public procurement processes. Studies have shown that product branding is crucial in utilising waste as a raw material. Additionally, key market drivers, including price volatility, resource scarcity, increased resource consumption, material cost savings, and the creation of new markets, significantly influence the adoption of circular practices (Rizos *et al.*, 2016; Feng and Goli, 2023; Reis, Barreto and Capelari, 2023).

The European Union set a target for the circular material use rate of 23.2%, but only 11.7% of these materials came from recycled waste. Data on the circular material use rate in Serbia for 2019 indicate 1.4%, which is far lower than the EU average and, compared with EU members, is comparable to Romania (Statistical Office of the Republic of Serbia, 2021). In addition to the circular material use rate, Serbia also lags in other waste management indicators **Table 2**.

These quantitative comparisons clearly demonstrate that Serbia's waste-management system remains in the early phase of a CE transition, dominated by disposal rather than recovery. However, the growing trend in waste generation, coupled with the existing domestic recycling capacity, highlights a significant untapped opportunity: redirecting even a fraction of landfilled materials into recycling streams could substantially increase Serbia's CMU rate within the following policy cycle. The findings confirm that improving source separation, expanding composting for biodegradable fractions, and strengthening extended producer responsibility mechanisms are the most empirically justified measures for accelerating progress toward the circular economy. The differences in material use and disposal pathways highlight that the primary obstacle to CE uptake in Serbia is rooted in fundamental inefficiencies in the end-of-pipe waste management system (collection, sorting, and landfill diversion).

The observed trends in recycling, landfilling, and SRM flows are closely linked to both policy implementation gaps and market dynamics. Despite the formal alignment of Serbia's waste-management framework with EU directives, the persistently high landfilling rate (≈80%) reflects delayed enforcement of source separation obligations, the absence of landfill taxation, and weak economic incentives for recycling. Figures 1 and 2 clearly show that biodegradable waste and plastics dominate landfilled fractions, indicating that policy measures have not yet translated into effective upstream separation or stable recycling feedstock, thereby slowing the transition from a linear to a circular resource model.

Table 2 highlights the structural gap between Serbia and EU averages, confirming that limited SRM utilization is not primarily a capacity issue but a systemic outcome of insufficient policy enforcement, fragmented collection systems, and market uncertainty. These results indicate that accelerating the development of the circular-economy in Serbia requires not only infrastructure investment but also coordinated policy instruments—such as landfill taxes, extended producer responsibility enforcement, and price-stabilization mechanisms—to improve SRM quality, reduce landfilling, and strengthen domestic recycling markets. By developing production models that reduce reliance on raw materials and consistently recycle materials back into production, companies can gain a competitive advantage and mitigate market volatility (SEPA, 2023b). However, planning a waste management system in line with EU legislation is costly for less-developed countries, and economic stability is a prerequisite for long-term, sustainable waste management (Ly, 2021).

The Ministry of Environmental Protection has recognized and awarded innovative initiatives that advance circular economy principles. Additionally, local communities have implemented waste-separation programs and incentivized citizen participation. Despite these advances, however, a substantial share of waste still ends up in landfills. This includes materials that could otherwise be used as secondary raw materials, underscoring a significant gap in the effective implementation of circular economy practices. Moreover, Serbia's recycling sector is characterized by excess capacity, exacerbated by the absence of an efficient primary waste-separation system. As a result, a considerable amount of recyclable material is lost in landfills because the available raw materials for recycling are of insufficient quality, preventing the industry from reaching its potential. The underperformance of Serbia's waste management sector - characterized by the absence of a landfill tax, a weak market for raw materials, insufficient financing for the circular economy industry, and limited capacity for waste management, particularly in separate collection - represents a significant barrier to initiating the transition to a circular economy.

The national strategic documents aim to enhance the industrial sector's sustainable development by addressing issues of excessive waste generation and inefficient use of raw materials. At the same time, transitioning to a circular economy cannot be achieved without integrating knowledge, innovation, sustainable innovative technologies, and advanced assessments. Furthermore, adopting sustainable high-tech production methods and modern bussines concepts, such as CE, is essential for driving this transformation (Official Gazette of RS", number 21/20, 2020; "Official Gazette of the RS", no. 35/20, 2021).

Table 3. Global Green Economy Index for EU countries adjusted from (Dual Citizen, 2023)

Country	Global Green Economy Index
Sweden	0.799
France	0.744
Denmark	0.742
Austria	0.711
Ireland	0.703
Portugal	0.701
Latvia	0.697
Luxembourg	0.696
Belgium	0.693
Spain	0.689
Finland	0.688
The Netherlands	0.685
Germany	0.674
Malta	0.672
Italy	0.699
Lithuania	0.668
Croatia	0.667
Estonia	0.666
Slovenia	0.639
Romania	0.623
Greece	0.617
Cyprus	0.613
Slovakia	0.606
Bulgaria	0.604
Czech Republic	0.585
Poland	0.559
Hungary	0557
Serbia	0,495

According to the Waste Management Programme of the Republic of Serbia 2022–2030, transitioning the industrial sector from a linear to a circular economy model requires the continuous development of a legal framework aligned with European Union (EU) standards. Promoting recycling and waste reuse is expected to reduce demand for primary raw materials. In cases where these materials were previously imported, this shift will enhance local sustainable development by stimulating domestic production and reducing reliance on foreign resources (Tomić and Schneider, 2020).

The economic dimensions of sustainable development and strategic planning are crucial to the successful transition from a linear to a circular economy (Lei, 2025; Ma and Appolloni, 2025). Alongside the ecological and social aspects, the economic aspect of the business/production organisation (OP) is essential.

This triumvirate and its synergy constitute the Circular Economy (CE) concept. The successful implementation of the CE requires significant investments, which is a key obstacle to the transition to a circular economy. On the other hand, the transition to the CE opens new opportunities, such as creating new jobs, reducing the unemployment rate, decreasing the consumption of natural resources, strengthening sustainable development, and fostering creativity and innovation.

In addition, data show very poor performance in terms of circular economy in waste management in Serbia, and the global green economy index is low compared to European countries as well **Table 3**. The transition from a "brown" to a "green" economy is a focus of economic policymakers, who seek a global index to measure the performance of the green economy. In this sense, the Global Green Economy Index (GGEI) initiative, launched by the private consulting firm Dual Citizen based in the United States of America, is particularly noteworthy (Dual Citizen, 2023).

3.1.1. Priority streams

The composition of municipal solid waste (MSW) in Serbia indicates several key fractions suitable for circular-economy (CE) initiatives. Based on the morphological composition of municipal solid waste (MSW), five priority streams can be identified for circular-economy action:

1. Biodegradable waste (food and green waste) - suitable for composting and anaerobic digestion to produce biogas and compost;
2. Paper and cardboard - can be efficiently recycled within existing industrial capacities;
3. Metals - offering high recycling value and direct substitution for virgin materials;
4. Plastics - particularly packaging fractions, which are price-sensitive but essential for reducing landfill volumes; and
5. Textiles and wood - currently low in generated quantities and recovery but showing rising potential through reuse and upcycling.

Prioritizing these five material streams would yield the fastest progress toward higher recycling rates and reduced landfilling, thereby providing a practical foundation for Serbia's circular-economy transition.

Also, it will provide clear guidance for policymakers and municipalities to achieve measurable progress toward circular-economy targets.

Table 4. Expert Responses

Experts	In how many years?	0	1	2	3	4	5	6	7
	Year	2024	2025	2026	2027	2028	2029	2030	2031
Expert 1				O		m	p		
Expert 2						m			
Expert 3					M				
Expert 4				O		m		p	
Expert 5			O		M			p	
Expert 6				O	M	p			
Expert 7						m			

3.2. Forecasts and Projections - Delphi Method

The preparation and implementation of the Delphi method adhered to the previously defined rules. Questionnaires were completed with response options: o (optimistic), m (expected), and p (pessimistic), and statistical formulas were used for calculations. The predictions were made in 2024; therefore, the first answer is also possible, i.e., the current year, which would mean that the observed event will take place in 0 years. Furthermore, the answers can be 2025, 2026, 2027,..., which would mean in 1, 2, 3,... years, respectively. A group of experts relevant to planning and forecasting were selected, questionnaires were formulated, and questions were posed in line with the established goals. **Table 4** shows the experts' responses after the third round of inquiry.

The standardized formulas which are used for the calculations, as well as the complete calculation, are given in the Appendix.

Due to the length of the calculations, the application of the Delphi method formulas is provided in the Appendix. Based on the experts' responses, statistical indicators are calculated. Probability Values are given in **Table 5**.

Table 5. Probability Values

Year	Time t_1 (year)	Value ϒ	Probability P
2024	0	-5.88	0.0001
2025	1	-4.24	0.001
2026	2	-2.61	0.0045
2027	3	-0.98	0.1635
2028	4	0.65	0.742
2029	5	2.28	0.988
2030	6	3.9	0.9986
2031	7	5.5	0.9999

Using the Laplace table, probabilities can be graphically represented, as shown in Figure 5 (Rizos *et al.*, 2016).

Based on the experts' responses, a larger number of companies in Serbia operating on the principles of a circular economy can be expected in 3.6 years, i.e., by mid-2027, with the highest probability of realisation in 2030.

Positive examples in practice exist and should serve as a model for transitioning from a linear to a circular economy. Germany was the first country to formally adopt this concept and incorporate its principles into legislation, enacting the Closed Substance Cycle Waste Management Act in 1996. Japan followed suit in 2000 by adopting the Basic Act for Establishing a Sound Material-Cycle Society. China and the European Union have made the most significant progress in transitioning to a circular economy. China passed the Circular Economy Promotion Law in 2009, laying the legal and political foundations and initiating activities to promote the concept of a circular economy.

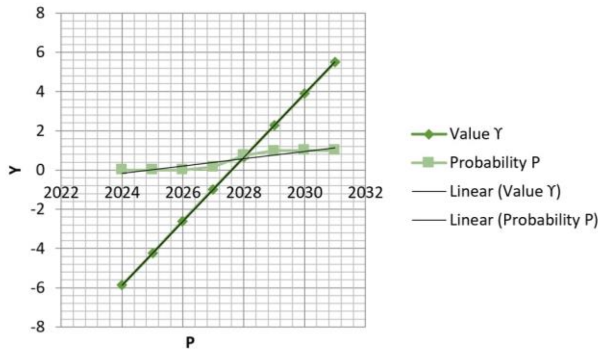


Figure 5. Probability Values

Energy recovery, specifically anaerobic digestion with energy recovery, of the separated biological waste fraction from mixed waste, which in other cases would be landfilled, in Serbia could support economic and social sustainability in implementing changes to the waste management of biodegradable waste. Integrating material and energy recovery technologies transforms the existing economy into a low-carbon, sustainable, and resource-efficient economy as a part of the circular economy and the "closing the loop" concept (Dual Citizen, 2023).

Despite the development of a waste management system, some studies have identified obstacles and barriers to CE implementation. In Finland, sustainable development professionals do not share a common view of the key barriers and means of overcoming them, which can lead to a lack of commitment or even to conflicting measures to facilitate the CE transition (Salmenperä *et al.*, 2021). According to research on performance in the transition to a circular economy, countries in the SEE region have not achieved significant transition outcomes relative to EU investments in the transition process, due to difficulties in implementation and in the transition strategy (Marino and Pariso, 2020). Croatia, Bulgaria, and Romania primarily focus on waste management, without tax incentives to introduce circular-economy measures that support CE investments, and actions to transition from a linear to a circular economy are partial and uncoordinated. Evidence from developing economies indicates that inefficient construction-waste management increases life-cycle human-health impacts, highlighting the broader consequences of low circular-economy uptake (Wang et al. 2025). However, Slovenia has undertaken numerous successful initiatives but still lacks improvements in waste management and a production system that remains firmly anchored in the linear economy. Evidence from recent regional studies confirms that transition economies, including those in Southeast Europe, face systemic barriers to CE implementation but also emerging opportunities for policy-driven industrial innovation (Zhang et al., 2025).

The roadmap for the circular economy adopted in Serbia aligns with the EU legal framework, supporting the transition to a Green Economy, smart, inclusive, and sustainable development, increasing waste-management targets for recycling, and reducing the amount of waste landfilled. Circular economy models may be considered key drivers towards the transition to a Green Economy, whereas waste management plays an important role. Adapting and strengthening the implementation of legal regulations and strategic frameworks at the local and national level in sustainable development and circular economy is one of the prerequisites for the transition to a circular economy.

4. Conclusion

Results indicate that the number of companies in Serbia operating on the principles of a circular economy is expected to increase in 3.6 years (i.e. by mid 2027), with the highest probability of realisation in 2030. Material consumption and waste generation remain high, and the implementation of a circular economy in Serbia is unsatisfactory; examples of circular-economy models are scarce.

To begin the transformation to a circular economy, some of the guidelines for achieving sustainable development in waste management may include adapting and strengthening legal regulations, focusing on strategic planning, changing the habits of individuals and producers, educating the community on circular economy benefits, applying green technologies, and producing green products that are easier to reuse in production after use.

The economic aspect and modern business practices must consider both profit and socially responsible behaviour from consumers and producers, sustainable production and consumption, and GDP growth. Strategic planning is crucial and requires thorough analysis, assessment of the situation, and the definition of goals, priorities, action strategies, vision, and mission.

Shifting to the circular economy business model will enable the development of a resilient economic system by reducing waste and maximising resource efficiency. In addition, companies can optimise resource use, reducing the need to extract raw materials and minimising production costs, thereby improving profitability. As a transition country, Serbia will change and develop its economic system and open the market to the EU as a member state. Companies that adopt circular business models early will achieve sustainable long-term growth.

Investments are inevitable for transitioning from the traditional to the circular economy, which alone can provide sustainable development. However, the initial transition to a circular economy may be characterized by lower investment costs and greater reliance on markets, making it less sensitive to changes in waste quantity and quality and more sustainable over the long term. It is necessary to raise awareness about the importance of a circular economy. In the long term, CE provides numerous advantages, including creating new jobs, reducing the unemployment rate, promoting sustainable resource consumption, reducing waste, advancing clean, green technologies, encouraging innovation, and fostering a sustainable society and economy overall. Additionally, the utilisation of waste energy can help reduce dependence on fossil fuels.

The study is limited to MSW and the reliance on aggregated national data prevents a detailed assessment of regional and local disparities in CE readiness. While the Delphi methodology yields a strong consensus forecast, the reliance on a small, targeted panel of national experts means that the projected timelines and policy conclusions should be interpreted as expert consensus rather than as a definitive prediction derived from comprehensive economic or infrastructure modeling.

Future research should focus on expanding the database to include industrial, construction, and hazardous waste streams and to integrate regional-level indicators of CE performance. Broader Delphi panels, including private-sector investors, non-governmental organizations, and regional development agencies, could enhance representativeness and robustness of consensus. Moreover, applying econometric modelling and life-cycle assessment (LCA) techniques could quantify the potential environmental and economic benefits of CE adoption. In addition, future work should explore mechanisms to increase circular-material-use rates by strengthening extended producer responsibility (EPR), introducing landfill taxes, and promoting green public procurement. In parallel, investments in recycling infrastructure, composting facilities, and digital monitoring systems (IoT and smart waste platforms) will be crucial.

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Conflicts of Interest

The authors declare no conflicts of interest.

Appendix A

The preparation and implementation of the Delphi method adhered to the previously defined rules. Questionnaires were completed with response options: o (optimistic), m (expected), and p (pessimistic), and statistical formulas were used for calculations.

The individual prediction time for each expert is computed as follows:

$$t1 = \frac{r_1 \cdot o_1 + r_2 \cdot m_1 + r_3 \cdot p_1}{r_1 + r_2 + r_3} \quad (1)$$

r 1-3 are constant $r_1 = 1 \quad r_2 = 4 \quad r_3 = 1$

$$t1 = \frac{r_1 \cdot o_1 + r_2 \cdot m_1 + r_3 \cdot p_1}{r_1 + r_2 + r_3} = \frac{1*2+4*4+1*5}{1+4+1} = \frac{2+16+5}{6} = \frac{23}{6} = 3.83 \quad (2)$$

$$t2 = 4 \quad (3)$$

$$t3 = 3 \quad (4)$$

$$t4 = \frac{r1o4 + r2m4 + r3p4}{r1 + r2 + r3} = \frac{1*2+4*4+1*6}{1+4+1} = \frac{2+16+6}{6} = \frac{24}{6} = 4 \quad (5)$$

$$t_5 = \frac{r^1 o5 + r^2 m5 + r^3 p5}{r1 + r2 + r3} = \frac{1*1+4*3+1*6}{1+4+1} = \frac{1+12+6}{6} = \frac{19}{6} = 3{,}16 \quad (6)$$

$$t_6 = \frac{r^1 o^6 + r^2 m^6 + r^3 p^6}{r^1 + r^2 + r^3} = \frac{1*2+4*4+1*4}{1+4+1} = \frac{2+16+4}{6} = \frac{22}{6} = 3.66 \quad (7)$$

* Note If only “m” is marked in the table, the formula is not used, but only the value for “m” is considered.

Overall Expected Value:

$$\text{tn} = \frac{1}{n}\sum_{i=1}^{n}\text{t1} \tag{8}$$

n is total number of experts

$$tn = \frac{1}{7}*\left(3{,}83+4+3+4+3{,}16+3{,}66+4\right) = 3.6\,years \tag{9}$$

Dispersion for Each Expert (Mean Square Deviation from the Arithmetic Mean):

$$\delta_i^2 = \frac{\left(p_i - o_i\right)^2}{r_4} \tag{10}$$

$$r_4\,is\,constant, r_4 = 36 \tag{11}$$

$$\delta_1^2 = \frac{\left(p_1 - o_1\right)^2}{r_4} = \frac{(5-2)^2}{36} = \frac{9}{36} = 0.25 \tag{12}$$

$$\delta_2^2 = \frac{\left(p_2 - o_2\right)^2}{r_4} = \frac{(0-0)^2}{36} = 0 \tag{13}$$

$$\delta_3^2 = \frac{\left(p_3 - o_3\right)^2}{r_4} = \frac{(0-0)^2}{36} = 0 \tag{14}$$

$$\delta_4^2 = \frac{\left(p_4 - o_4\right)^2}{r_4} = \frac{(6-2)^2}{36} = \frac{16}{36} = 0.444 \tag{15}$$

$$\delta_5^2 = \frac{\left(p_5 - o_5\right)^2}{r_4} = \frac{(6-1)^2}{36} = \frac{25}{36} = 0.694 \tag{16}$$

$$\delta_6^2 = \frac{\left(p_6 - o_6\right)^2}{r_4} = \frac{(4-2)^2}{36} = \frac{4}{36} = 0.111 \tag{17}$$

$$\delta_7^2 = \frac{\left(p_7 - o_7\right)^2}{r_4} = \frac{(0-0)^2}{36} = 0 \tag{18}$$

Total Dispersion:

$$\delta_\text{n}^2 = \frac{1}{n}*[\sum_{\text{i}=1}^{\text{n}}\delta\text{i}^2 + \sum_{i=1}^{n}\left(\text{ti} - \text{tn}\right)^2] \tag{19}$$

$$\delta_\text{n}^2 = \frac{1}{n}*\begin{bmatrix}\left(\delta_1^2 + \delta_2^2 + \delta_3^2 + \delta_4^2 + \delta_5^2 + \delta_6^2 + \delta_7^2\right) + \left(t_1 - t_n\right)^2 + \left(t_2 - t_n\right)^2 + \\ \left(t_3 - t_n\right)^2 + \left(t_4 - t_n\right)^2 + \left(t_5 - t_n\right)^2 + \left(t_6 - t_n\right)^2 + \left(t_7 - t_n\right)^2\end{bmatrix}] \tag{20}$$

$$\delta_\text{n}^2 = \frac{1}{7}*\begin{bmatrix}\left(0{,}25+0+0+0{,}444+0{,}694+0{,}111+0\right) + \left(3{,}83-3{,}6\right)^2 + \left(4-3{,}6\right)^2 + \left(3-3{,}6\right)^2 \\ +\left(4-3{,}6\right)^2 + \left(3{,}16-3{,}6\right)^2 + \left(3{,}66-3{,}6\right)^2 + \left(4-3{,}6\right)^2\end{bmatrix} \tag{21}$$

$$\delta_\text{n}^2 = \frac{1}{7}*\left[1.499+0.053+0.16+0.36+0.16+0.193+0.036+0.16\right] = \frac{1}{7}*2.621 = 0.375 \tag{22}$$

$$\delta_n^2 = \sqrt{0.375} = 0.612 \tag{23}$$

Probability Values:

$$\Upsilon = \frac{ti - tn}{\delta n} \tag{24}$$

t is referenced year 2024 having value 0, 2025 value is 1, 2026 value is 2

$$y2024: \frac{0-3.6}{0.612} = \frac{-3.6}{0.612} = -5.88 \tag{25}$$

$$y2025: \frac{1-3.6}{0.612} = \frac{-2.6}{0.612} = -4.24 \tag{26}$$

$$y2026: \frac{2-3,6}{0,612} = \frac{-1,6}{0,612} = -2,61 \tag{27}$$

$$y2027: \frac{3-3.6}{0.612} = \frac{-0.6}{0.612} = -0.980 \tag{28}$$

$$y2028: \frac{4-3.6}{0.612} = \frac{0.4}{0.612} = 0.653 \tag{29}$$

$$y2029: \frac{5-3.6}{0.612} = \frac{1.4}{0.612} = 2.28 \tag{30}$$

$$y2030: \frac{6-3.6}{0.612} = \frac{2.4}{0.612} = 3.9 \tag{31}$$

$$y2031: \frac{7-3.6}{0.612} = \frac{3.4}{0.612} = 5.5 \tag{32}$$

$$2024: P = 1-(0.5+0.499) = 1-0.9999 = 0.0001 \tag{33}$$

$$2025: P = 1-(0.5+0.499) = 1-0.999 = 0.001 \tag{34}$$

$$2026: P = 1-(0.5+0.4955) = 1-0.9955 = 0.0045 \tag{35}$$

$$2027: P = 1-(0.5+0.3365) = 1-0.8365 = 0.1635 \tag{36}$$

$$2028: P = 0.5+0.2420 = 0.742 \tag{37}$$

$$2029: P = 0.5+0,4885 = 0,998 \tag{38}$$

$$2030: P = 0,5+0.4986 = 0.9986 \tag{39}$$

$$2031: P = 0.5+0.4999 = 0.9999 \tag{40}$$

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