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Development of Circular Economy in the Visegrad Group of Countries

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ABSTRACT The circular economy is important in implementing EU Green Deal targets, climate change mitigation commitments, and pursuing sustainable development. A circular economy allows the reduction of waste and environmental damages linked to waste to save natural resources and mitigate climate change. The transition from linear to circular economy models provides many economic and environmental benefits and is a priority for most countries, especially developed ones. There is a need to measure and monitor the circular economy's progress. In this context, indicators can be useful tools to assess progress achieved by countries in pursuing circular economy development. The paper developed an indicators framework to measure circular economy development progress in the EU and applies the developed framework for Visegrad countries. The Visegrad Group (V4) includes four Central European countries, Poland, the Czech Republic, Slovakia, and Hungary, linked by similar geographical and geopolitical situations and common history and culture. MCDM tool ARAS was applied to ranking four Visegrad countries in 2010 and 2021 based on the progress achieved in circular economy development.

KEY WORDS: circular economy, indicators, ranking, Visegrad group, MCDM, assessment.

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1. Introduction

The circular economy is a concept which aims to encourage the responsible and cyclic use of natural and other resources and materials. The main policy is to minimize environmental burdens, reduce GHG emissions, and stimulate the economy.

The circular economy approach was formulated as a strategy for refining economic activities while minimizing the negative environmental impacts of economic activities by decreasing the entry of resources and wastes generated (Velasco-Muñoz et al., 2021). The circular economy can be treated as an alternative to the linear economy of "take-produce-consume-discard" which was prevailing for many years (Aznar-Sánchez et al., 2020; Bauwens et al., 2020; Centobelli et al., 2020; Ghisellini et al., 2016;), however, though the circular is a rapidly expanding topic, particularly in the European Union, there is no agreement among authors even on conception of circular economy. Though the circular economy idea incorporates many different meanings and is not well-defined (Kirchherr et al., 2017; Korhonen et al., 2018), the circular economy is turned into defined action plans and strategic directions reinforced by various specific indicators and their frameworks (Acerbi et al., 2021; Moraga et al., 2019; Calzolari et al., 2022).

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Though there are many studies analyzing circular economy approaches and models in various sectors or proposing indicators set to measure circularity in various sectors of the economy, industries, and companies, there is a lack of empirical studies dealing with the progress achieved by countries in implementing policies and measures to promote circular economy.

The paper aims to overcome this gap and develop an indicators framework to assess the progress in implementing a circular economy strategy for EU countries. It applies this framework to the Visegrad group countries to track and compare their progress during 2010-2021 in pursuing circular economy development.

The article is structured in the following way: in the next section, the literature review on the EU policies to promote circular economy and the main indicators, systems, and measures created to assess the progress in circular economy development is provided; in section 3, methods and data are introduced; in section 4 the case study of Visegrad countries is provided with application of MCDM tools for ranking four Visegrad countries in 2010 and 2021 based on the progress achieved in circular economy development and in section 5 conclusions and policy implications are provided.

2. Literature Review

Many different strategic documents have been established in order to encourage the sustainable growth of the EU economy. It can be stated, that the main strategic document is the European Green Deal (European Commission, 2019), which supports challenges towards a prosperous, fair, and sustainable EU economy. To achieve this the new Circular Economy Action Plan (CEAP) (European Commission, 2020) was launched in line with the new Industrial Strategy for Europe, which was updated in 2021 (European Commission, 2021). In this new CEAP, measures to create a strategic framework emphasizing the value chain, reduction of waste, and efficient operation of the EU internal market for secondary raw materials are introduced with the aim of generating significant economic, environmental, and social benefits.

The successful transition to a circular economy of the EU is dependent on many aspects, where the most influencing are various stakeholders (Chiappetta Jabbour et al., 2020; Ghinoi et al., 2020; Piao et al., 2023), investors (Silva et al., 2020), and different barriers challenging the transition (de Jesus & Mendonca, 2018; Grafstrom & Aasma, 2021). One of the most significant groups of stakeholders is policymakers, who have a direct impact on legislation and requirements for industry (Opferkuch et al., 2021). Also, the scientific literature (e.g., Koval et al., 2023; Lyu & Liu, 2023; Masi et al., 2017; Rizos & Bryhn, 2022; Singh & Giacosa, 2019; Tura et al., 2019) identifies some barriers affecting the implementation of circular economy, these can be singled out in some groups which are: technological, market, regulatory and social (perception, cultural, behavioural). This division is conditional, since there are many different classifications in the literature. For example, Pasqualotto et al. (2023) also singled out such categories as information, organizational, and environmental. AlJaber et al. (2023) stressed the importance of support and financial incentives. Additionally, Zhang et al. (2023) emphasized the two policy-related barriers, which are new in the literature and are the most influential in the case of China, these are: too rapid and unsuitable planning and insufficiency of policy support at the primary (basic) level. These outcomes are in line with the affirmations, that policymakers are those, who are the most affecting the successful circular economy implementation. All these aspects significantly affect the implementation of the circular economy not only in the EU but also in other countries or regions (e.g., Gedam et al., 2021; Mhatre et al., 2023).

De Pascale et al. (2023) analysed the implementation of circular economy at the EU level through a review of circular economy practices in various economic sectors and industries in the last eight years (2015-2023). The research framework was based on the analysis of circular strategies considered in the EU political framework. The findings of the study show, that recycling is the most popular strategy (24 %) to return back materials into the economy and decrease the usage of raw materials (19 %). According to the results of this study, the Food and Beverage industry shows the best performance results in terms of circular strategies. While the least number of circular strategies was observed in the sector of Capital Equipment. These results are in line with the previous study by Mhatre et al. (2021), where the authors analysed circular economy practices across the EU and stated, that recycling is the most widely used strategy for bringing back materials into the system. Also, the influence of government were stressed for the successful transition as well as the required infrastructure and technologies, awareness, collaboration of various stakeholders, and integration of supply-chain. The importance of policymakers to the EU transition is especially stressed in the study by Kirchherr et al. (2018), where the main barrier to the transition a lack of synergistic governmental interventions was identified. The governmental aspect was mentioned also in many other studies. For example, Friant et al. (2021) critically analysed the policy and actions of the EU towards circular economy implementation and found, that mainly, the policy focus on "end of pipe" solutions and do not correspond to many socio-ecological implications.

One of the most significant attempts to overview circular economy indicators can be outlined in the research performed by Saidani et al. (2019), where the authors performed a systematic literature review and identified 55 indicator sets for the measurement of circular economy performance in various economic sectors at different levels (micro, meso, and macro). Fundamentally, the indicators used for the assessment of the implementation of the circular economy were divided into three basic categories, which are: recycling, reuse, and maintenance (Saidani et al., 2019). In the other large-scale study performed by De Pascale et al. (2021), where the authors reviewed 61 indicator sets, all the indicators were categorized into recycle, reuse, and reduce groups. As found by Calzolari et al. (2022) social and circularity measurements receive relatively to little attention, because still focus on classical environmental impact and economic dimension persist. These findings are in line with the results of the study by de Oliveira et al. (2021), where the authors analysed 58 indicators sets and found, that the majority of indicators focused on resource recirculation and considered environmental and economic dimensions, while social repercussions are addressed very rarely. This shortage in approaches used leads to a narrower approach to sustainability and its implementation in practice (Kristensen and Mosgaard, 2020).

At the EU level, the indicators set to monitor the circular economy were established and are publicly available in the Eurostat database. These indicators can be grouped into four thematic areas, which are indicators for Production and consumption, Waste management indicators, Secondary raw materials, and indicators presenting Competitiveness and innovations (Vranjanac et al., 2023). However, according to Pacurariu et al. (2021), the EU framework has some limits, as it does not include indicators related to the extension of the life cycle of products and materials. The main indicators available in the EUROSTAT database were selected for evaluation of circular economy development for the selected case study in Visegrad countries.

3. Methods and Data

The study applied the Multi-criteria decision method (MCDM) method was applied for ranking of Visegrad countries based on the development of the circular economy. The Additive Ratio Assessment (ARAS) Method was applied to rank countries. The method is described in the following sub-section 3.1. The circular economy indicators used for assessing Visegrad countries according to circular economy development are provided in the next sub-section 3.2.

3.1. The Additive Ratio Assessment (ARAS) Method

One of the relatively recent multicriteria decision-making techniques created by Zavadskas and Turskis (2010) is the Additive Ratio Assessment (ARAS) method. When there are several factors to take into account, this approach is highly effective and simple to apply. Zavadskas and Turskis (2010) state that there are multiple steps that make up the ARAS approach:

Step 1. Create a matrix for decision-making (DMM)

M realistic options (rows) are evaluated according to n sign complete criteria (columns) in a decision-making matrix.

$$X = \begin{bmatrix} x_{01} & \cdots & x_{0j} & \cdots & x_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix}; i = \overline{0,m}, j = \overline{1,n}; \quad (1)$$

where xij is a value that represents the performance value of the i-th option in terms of the j-th criterion, x0j is the optimal value of the j-th criterion, m is the number of alternatives, and n is the number of criteria describing each alternative. In the event that the j-th criterion's ideal value is unknown, then:

$$x_{0j} = max_i x_{ij}, if\ max_i x_{ij}\ is\ pereferable;$$
$$x_{0j} = min_i x_{ij}^{*}, if\ min_i x_{ij}^{*}\ is\ pereferable; \quad (2)$$

A DMM's entries are often thought of as the criteria weights Wj and performance values xij. Experts establish the criterion system, values, and initial weights of the criteria. The interested parties may correct the information by considering their objectives and available resources. Step 2: Make the input data normal The first stage involves normalizing the starting values of each criterion, which defines the values $\overline{x_{ij}}$ of the normalized decision-making matrix $\bar{x}$.

$$\bar{X} = \begin{bmatrix} \bar{x}_{01} & \cdots & \bar{x}_{0j} & \cdots & \bar{x}_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \bar{x}_{i1} & \cdots & \bar{x}_{ij} & \cdots & \bar{x}_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \bar{x}_{m1} & \cdots & \bar{x}_{mj} & \cdots & \bar{x}_{mn} \end{bmatrix}; i = \overline{0,m}, j = \overline{1,n}; \quad (3)$$

The normalization process for the criteria with the maximum preferred values is carried out using the subsequent equation:

$$\overline{X_{ij}} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}} \quad (4)$$

The normalization process for the criteria with the least desirable values is carried out in two stages using the following equation:

$$x_{ij} = \frac{1}{x_{ij}^{*}}; \bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}}; \quad (5)$$

Define the Normalized-weighted Matrix -X^ in Step 3.

The criteria can be assessed using weights 0 < Wj < 1. Since weights are inherently subjective and affect the outcome, they should only be applied when they are well-founded. The expert evaluation method is typically used to determine the values of weight Wj. The following limits apply to the total weights Wj:

$$\sum_{j=1}^{n} w_j = 1; \quad (6)$$

$$\hat{X} = \begin{bmatrix} \hat{x}_{01} & \cdots & \hat{x}_{0j} & \cdots & \hat{x}_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \hat{x}_{i1} & \cdots & \hat{x}_{ij} & \cdots & \hat{x}_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \hat{x}_{m1} & \cdots & \hat{x}_{mj} & \cdots & \hat{x}_{mn} \end{bmatrix}; i = \overline{0,m}, j = \overline{1,n}; \quad (7)$$

The following formula is used to get the normalized-weighted values for each criterion:

$$\hat{x}_{ij} = \hat{x}_{ij}.W_j; i = \overline{0,m} \quad (8)$$

where $\bar{x}_{ij}$ the normalized rating of the j-th criterion and Wj is its weight (importance).

Step 4. Determine the Value of Optimality Function

$$S_i = \sum_{j=1}^{n} \hat{x}_{ij}; \ i = \overline{0,m} \quad (9)$$

Where the optimality function value of the i-th alternative is represented by Si. The best Si value is the largest; the worst Si value is the smallest. Consequently, the more effective the alternative, the larger the value of the optimality function Si. The value Si can be used to rank the choices in order of priority.

Step 5: Determine the Alternative Utility's Degree It is required to compare the variations with the optimal one, S0, in order to determine the degree of the alternative utility. Below is the computation of an alternate AI's utility degree (Ki).;

$$k_i = \frac{s_i}{s_0}; i = 0, m \quad (10)$$

where Si and S0, which come from Equation (10), are the optimality criteria values. The range of the computed values, Ki, is 0 to 1.

3.2. Circular Economy Indicators Framework

Based on the analysis of circular economy studies provided in the literature review section, the following indicators to measure the development of circular economy are selected based on an available dataset in EUROSTAT (see Table 1).

The selected indicators framework to monitor circular economy progress provided in Table 1 cover important issues of circular economy: resource productivity and raw material consumption per capita, waste generation per capita and GDP, recycling rate of wastes and circular material use rate, as well as investments, patents and persons working in circular economy sectors.

Table 1
Circular Economy Indicators

Indicator	Measure	Description
Productivity of resources	Euro per kilogram, chain-linked volumes (2015)	The indicator is calculated as GDP divided by domestic material consumption (DMC). DMC shows the total quantity of materials consumed in the economy on an annual basis.
Raw material consumption	tones per capita	This indicator shows the main raw material (biomass, metal ores, non-metallic minerals, and fossil energy) consumption on an annual basis divided by the population.
Generation of total waste except mineral waste per capita	Kg/capita	This indicator measures the total waste including minerals generated per year in a country divided by the number of inhabitants
Total waste excluding major mineral waste generation per GDP	Kilograms per thousand euro, chain-linked volumes (2010)	The indicator is calculated by dividing total waste excluding minerals created in a country per year by annual GDP.
The recycling rate of total waste excluding mineral waste	%	This indicator is computed by dividing the recycled waste by the total waste treated per year, excluding mineral waste, and multiplied by 100. Recycled waste includes hazardous and non-hazardous waste excluding mineral waste coming from all economic sectors.
Recycling rate of municipal waste	%	The indicator calculates the share of recycled solid waste in the total municipal waste generated in the country on an annual basis.
Circular material use rate	%	The circular material use or circularity rate is an indicator calculated as the ratio of the circular use of materials to the total material use in the country on an annual basis. A higher circularity rate shows that more secondary materials are replacing primary raw materials thus reducing the negative environmental effects.
Patents related to recycling and secondary raw materials	Per million inhabitants	This indicator shows the number of patents linked to recycling and secondary raw materials production and related activities.
Private investment and gross added value linked to sectors of circular economy	Percentage of GDP	This indicator covers investments in these sectors: recycling, repair and reuse, rental, and leasing. Investments are assessed during the reference year in all tangible goods.
Persons employed in circular economy sectors	Percentage of total employment in full-time equivalent (FTE)	This indicator shows the number of persons employed in recycling, repair and reuse, rental, and leasing sectors divided by number of persons employed totally in the country.

Source: created by authors based on (European Commission, 2024)

4. Case Study on Circular Economy Development Progression in the Visegrad Group

The data for 4 Visegrad countries (Czechia, Hungary, Poland, and Slovakia was collected to develop indicators of circular economy development in 2010 and 2021 based on the framework presented. Table 1.

In Table 2, the circular economy development indicators for Visegrad countries in 2010 and 2020 are given.

In Table 3 the normalized matrix was developed for countries ranking in 2010.

In Table 4 the normalized weighted matrix was developed for Visegrad group countries ranking according to ten criteria in 2010.

As one can see from Table 4, Hungary was ranked as the best-performing country, followed by Slovakia in the Visegrad group according to circular economy development in 2010. The worst-ranked country was Czechia.

In Table 5 the normalized matrix was developed for countries ranking in 2021.

In Table 6, the normalized weighted matrix was developed for Visegrad group countries ranking according to ten criteria in 2021.

In Table 7, the results of the final ranking of Visegrad countries according to circular economy development in 2021 are given.

As one can see from Table 8, Czechia was ranked as the best-performing country, followed by Slovakia, the Visegrad group, according to circular economy development in 2021. The worst-ranked country in 2021, according to circular economy development in 2021, was Poland, followed by Hungary. Therefore, the situation has drastically changed in the Visegrad region and the best-performing country in 2010 fell into the last position in ranking.

5. Conclusions

The circular economy is the main approach to sustainable consumption and production, allowing the saving of natural resources and reducing climate change and the negative environmental effects of consumption and production. It aims at extending the life cycle of products and includes sharing, leasing, reusing, repairing, refurbishing, and recycling products and materials.

However, in circular economy development initiated by EU policy documents, EU countries achieved different results because of different policies and approaches used to promote the circularity of economic processes.

The framework of indicators to measure progress towards circular economy development was created based on circular economy indicators established for the EU, covering the main areas linked to a circular economy: resource consumption, waste generation, and management, and indicators representing competitiveness and innovations. The ranking of the four selected countries in the Visegrad region based on ten criteria was performed using the advanced MCDM tool ARAS to track their progress in circular economy development from 2010 until 2021.

Results of the case study showed that Hungary was ranked as the best-performing country, followed by Slovakia in the Visegrad group according to circular economy development in 2010. The worst-ranked country was Czechia in 2010; however, in 2021, the situation changed drastically, and Czechia was ranked as the best-performing country, followed by Slovakia, the Visegrad group, according to circular economy development in 2021. The worst-ranked country in 2021, according to Circular Economy Development 2021, was Poland, followed by Hungary.

In 2010 Hungary was distinguished by the highest resource productivity, lowest material consumption and total waste generated per capita, and highest rate of municipal waste recycling. Also, Hungary had the highest rate of persons employed in the circular economy sector and private investments, and gross value added related to circular economy sectors among Visegrad countries.

In 2021, resource productivity reduced in Hungary compared to the year 2010, and the country fell to the worst position among Visegrad countries. At the same time, raw material consumption per capita and waste generation increased in 2021, and though the rate of municipal waste recycling has increased significantly over ten years, in 2021, Hungary was the worst-performing country ac-

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Table 2
Circular Economy Development Indicators for Visegrad Countries in 2010 and 2021

Indicator	Symbol	Czechia (A1)	Hungary (A2)	Poland (A3)	Slovakia (A4)	Desirable trend
		2010				
Productivity of resources	C1	0.93	1.03	0.59	0.99	Increase
Raw material consumption,	C2	16.6	9.5	15.6	18.9	Decrease
Generation of total waste except mineral waste per capita	C3	2.27	1.67	4.17	1.74	Decrease
Total waste excluding major mineral waste generation per GDP	C4	78	116	186	96	Decrease
The recycling rate of total waste excluding mineral waste	C5	50	36	58	38	Increase
Recycling rate of municipal waste	C6	15.8	19.6	16.3	9.1	Increase
Circular material use rate	C7	5.3	5.2	11.1	51	Increase
Patents related to recycling and secondary raw materials	C8	0.42	0.46	0.97	0	Increase
Private investment and gross added value linked to sectors of circular economy	C9	0.3	0.5	0.5	0.4	Increase
Persons employed in circular economy sectors	C19	2.4	2.8	2.5	2.0	Increase
2021						
Productivity of resources	C1	1.14	0.99	0.80	1.39	Increase
Raw material consumption,	C2	18.5	14.9	19.9	12.8	Decrease
Generation of total waste except mineral waste per capita	C3	3.60	1.76	4.49	2.34	Decrease
Total waste excluding major mineral waste generation per GDP	C4	83	91	150	92	Decrease
The recycling rate of total waste excluding mineral waste	C5	59	54	52	60	Increase
Recycling rate of municipal waste	C6	43.3	34.9	40.3	48.9	Increase
Circular material use rate	C7	11.9	7.9	8.4	9.1	Increase
Patents related to recycling and secondary raw materials	C8	0.67	0	0.46	0	Increase
Private investment and gross added value linked to sectors of circular economy	C9	0.4	0.7	0.7	0.5	Increase
Persons employed in circular economy sectors	C19	2.3	2.3	2.7	2.2	Increase

Source: created by authors based on (European Commission, 2024)

Table 3

A Normalized Matrix was Developed for Visegrad Group Countries Ranking According to Ten Criteria in 2010

Normalized matrix										
weights of criteria	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
kind of criteria	1	-1	-1	-1	1	1	1	1	1	1
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Czechia: A1	0.93	16.6	2.27	78	50	15.8	5.3	0.42	0.3	2.4
Hungary: A2	1.03	9.5	1.67	116	36	19.6	5.2	0.46	0.5	2.8
Poland: A3	0.59	15.6	4.17	186	58	16.3	11.1	0.97	0.5	2.5
Slovakia: A4	0.99	18.9	1.74	96	38	9.1	51	0	0.4	2

Table 4

Ranking of Visegrad Countries Based on Circular Economy in 2010

	S	K	Ranking
0-Optimal Value	0.2690	1.0000	
Czechia: A1	0.1720	0.6392	4
Hungary: A2	0.1963	0.7298	1
Poland: A3	0.1805	0.6709	3
Slovakia: A4	0.1821	0.6770	2

Table 5

A Normalized Matrix was Developed for Visegrad Group Countries Ranking According to Ten Criteria in 2021

Normalized matrix										
weights of criteria	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
kind of criteria	1	-1	-1	-1	1	1	1	1	1	1
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Czechia: A1	1.14	18.5	3.6	83	59	43.3	11.9	0.67	0.4	2.3
Hungary: A2	0.99	14.9	1.76	91	54	34.9	7.9	0	0.7	2.3
Poland: A3	0.8	19.9	4.49	150	52	40.3	8.4	0.46	0.7	2.7
Slovakia: A4	1.39	12.8	2.34	92	60	48.9	9.1	0	0.5	2.2

Table 6

A Normalized Weighted Matrix for Visegrad Group Countries Ranking According to Ten Criteria in 2021

Normalized Weighted Matrix										
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
0-Optimal Value	0.024	0.024	0.028	0.023	0.021	0.023	0.024	0.037	0.023	0.022
Czechia: A1	0.020	0.017	0.014	0.023	0.021	0.020	0.024	0.037	0.013	0.019
Hungary: A2	0.017	0.021	0.028	0.021	0.019	0.016	0.016	0.000	0.023	0.019
Poland: A3	0.014	0.015	0.011	0.013	0.018	0.019	0.017	0.026	0.023	0.022
Slovakia: A4	0.024	0.024	0.021	0.021	0.021	0.023	0.019	0.000	0.017	0.018

Table 7
Ranking of Visegrad Countries Based on Circular Economy in 2021

	S	K	Ranking
0-Optimal Value	0.2491	1.0000	
Czechia: A1	0.2071	0.8314	1
Hungary: A2	0.1796	0.7207	3
Poland: A3	0.1778	0.7136	4
Slovakia: A4	0.1864	0.7482	2

cording to this criterion in the Visegrad region. The innovation indicators, such as persons employed in circular economy sectors and patents related to recycling and the secondary sector, have also declined in Hungary compared to 2010.

Contrarily, in Czechia, the resource productivity and recycling rates of all waste and municipal waste, as well as persons employed in circular economy sectors, investments, and patents related to recycling and the secondary sector have increased in 2021 compared to 2010. The country showed the best progress among other Visegrad countries in pursuing circular economy development.

The paper has limitations as a deeper policy analysis of circular economy promotion in Visegrad countries is necessary to show what policies were driving significant progress achieved in Czechia compared to Hungary and other countries of the Visegrad group.

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