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Investigating the Barriers to Electric Vehicle Adoption among Older Adults using Grey Relational Analysis: A Cross-country Survey

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Abstract: The adoption of electric vehicles (EVs) is a critical step towards the achievement of sustainable transportation, mitigated environmental challenges, and reduction in dependence on fossil fuels. In recent years, the popularity of EVs has grown, yet their adoption among seniors (older adults aged 50 and above) remains a challenge. This paper presents a comparative analysis of the barriers to EV adoption among seniors in two major economies, China and Russia. These two major economies have vast territories and significant transportation demands and as such they play crucial roles in the global shift towards EV adoption. We collected data from Russian and Chinese senior citizens using a comprehensive drafted questionnaire (252 respondents). Also, the Dynamic Grey Relational Analysis (DGRA) is used to analyze the quantitative data and rank the barriers to EV adoption. Our results suggest the inability of seniors to smartly locate available charging stations as the barrier to adopting EVs in China, while the lack of charging infrastructure at home is identified as the main barrier for seniors in Russia. Our findings provide valuable insights for manufacturers, technology firms, and policymakers, in the ongoing promotion of electric mobility.

Keywords: Electric vehicle; barriers; elderly; dynamic grey relational analysis; China; Russia

1. Introduction

The growing trend towards sustainable transportation is evident through the rising prevalence of EVs. These vehicles offer a promising solution to environmental issues and the reduction of carbon emissions within the transport industry (Luna *et al.*, 2020; Ma *et al.*, 2019; 2017). A growing number of countries around the world have announced plans to end the sale of fuel cars in the next few years, accompanied by a clear timetable for phasing out such vehicles (Du *et al.*, 2023; Jessop *et al.*, 2021). Regardless of the different economic statuses and policy supports in China and Russia, both countries share a mutual objective of mitigating emissions and improving urban surroundings.

China's rapid urbanization and growing environmental concerns have driven the government to make sustainable mobility a priority. To encourage the adoption of EVs, the Chinese government has enacted a series of policies such as substantial subsidies, exemption from license plate restrictions, and investments in charging infrastructure (Li *et al.*, 2019; 2018b; Zhang *et al.*, 2013). These measures have led to China emerging as the world's largest EV market and a key hub for EV manufacturing (Bryła *et al.*, 2022; Li *et al.*, 2020a; 2020b). Various researchers have studied EVs and its adoption in China and other parts of the world (Chhikara *et al.*, 2021; Irfan & Ahmad, 2021; Wang *et al.*, 2017), however, seniors are often overlooked when it comes to discussions surrounding the adoption of EVs and new technologies. Research suggests that seniors exhibit specific preferences and barriers with respect to new technology adoption, making their attitudes toward EVs an interesting area of study (Czaja & Lee, 2007; Olphert & Damodaran, 2013).

Russia, characterized by its expansive geography and diverse climates, presents distinct challenges and opportunities for seniors to adopt EVs. Despite its substantial reserves of fossil fuels, Russia recognizes the significance of transitioning to greener transportation methods. However, inadequate regulatory support, limited charging infrastructure, and economic constraints have impeded the widespread acceptance of EVs in Russia (Shahboz *et al.*, 2023). Among the sizable senior population in Russia, factors such as EV affordability and suitability for local conditions exert notable influence on their decisions. Proposals to counter the challenges in Russia's EV industry often fall short of addressing the specific needs of seniors. It is crucial to understand the perceptions, preferences, and challenges that seniors encounter as they consider adopting EVs.

As the global shift towards sustainable transportation gains momentum, the adoption of EVs plays a pivotal role in reducing carbon emissions and promoting eco-friendly modes of travel. Nevertheless, despite the increasing acceptance of EVs, there is a notable knowledge gap regarding the specific obstacles that deter seniors from embracing this technology, both in China and Russia. The aim of this study is to identify this gap by conducting a comparative analysis of the primary challenges faced by seniors in these two distinct countries when considering the adoption of electric vehicles. China, renowned as one of the largest and fastest-growing EV markets globally, presents a unique context for comprehending the difficulties and possibilities associated with this transition. Conversely, Russia is in the early stages of EV adoption, offering valuable insights into the initial hurdles that could shape future adoption rates among seniors.

This research will delve into economic, technological, and social factors contributing to these challenges. By identifying and contrasting these obstacles, this study seeks to provide practical recommendations for policymakers, industry stakeholders, and advocates to facilitate the inclusion of seniors in the expanding community of electric vehicle users. Ultimately, this will contribute to a more sustainable and inclusive future of transportation. Through the examination of the barriers, this study will shed light on effective strategies to promote EV adoption in both countries. Furthermore, the outcome of this research is expected to not only enhance our comprehension of EV adoption by seniors but also provide valuable guidance for policymakers, manufacturers, and stakeholders who are dedicated to expediting the shift toward sustainable transportation. The main contributions of this research are: (*a*) Identification of the barriers that often hinder seniors from adopting EVs as the majority of existing studies mostly overlooked senior citizens, (*b*) Studying China and Russia as cross-national surveys on barriers to EV adoption are extremely limited, and (*c*) Applying the Dynamic Grey Relational Analysis, a nonparametric mathemathical model, to evaluate and rank the barriers to EV adoption among seniors as it has never been used before on this kind of problem.

The structure of the rest of the paper is outlined as follows: Section 2 provides background and a comprehensive review of existing research. Section 3 explains our methodology and data collection strategy. The presentation and discussion of our findings are detailed in Section 4. Lastly, the conclusion is presented in Section 5.

2. Literature review

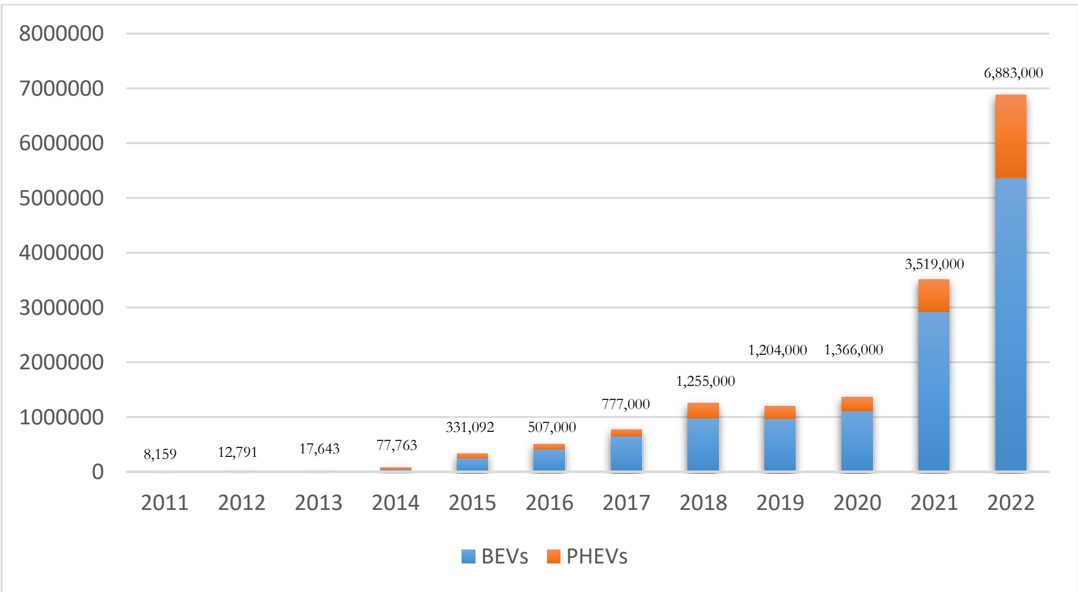
2.1 EV Industry in China

The EV market in China has undergone a remarkable transformation, evolving into a global leader in the adoption and production of electric mobility solutions. Fueled by a combination of policy support, technological innovation, and growing consumer demand, China's EV market has emerged as a critical driver of the transition toward sustainable transportation. Recognizing the environmental challenges posed by traditional combustion-engine vehicles, the Chinese government has implemented a series of policies aimed at promoting EV adoption (Ouyang *et al.*, 2020). These policies have not only accelerated consumer interest but also spurred investments in research, development, and manufacturing of EV technology.

Domestic automakers, backed by government support and strategic partnerships, have gained significant market share both domestically and internationally. The emergence of new players and start-ups further underscores China's commitment to leading the EV revolution. The country's transition from being an EV importer to an EV exporter is a testament to its industry's prowess. Moreover, investments in charging infrastructure have addressed range anxiety and further bolstered EV adoption rates. As China continues to prioritize clean energy and environmental sustainability, its EV market growth remains pivotal in shaping the global trajectory toward cleaner transportation alternatives. Figure 1 shows the sales of new electric vehicles (NEVs) in China for both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) from 2011 to 2022.

2.2 EV Industry in Russia

The EV market in Russia has shown gradual but promising signs of growth, albeit in the context of unique challenges. Unlike China, Russia's EV market growth has been influenced by factors such as the nation's rich fossil fuel reserves, distinct policy landscape, and geographic considerations. While EV adoption in Russia has been comparatively slower, recent initiatives hint at a shift towards embracing sustainable transportation (Smirnov *et al.*, 2022). Russia's vast energy resources, particularly oil and natural gas, have historically contributed to a preference for conventional vehicles (Potashnikov *et al.*, 2022). However, changing global trends towards sustainability and environmental awareness have nudged the nation to explore electric mobility.



Source: Statista (2023a)

Fig 1. Annual sales of new energy vehicles in China from 2011 to 2022

The government's measures to encourage domestic EV manufacturing and research signal a nascent commitment to cleaner transportation solutions. Despite the absence of comprehensive incentives, Russia's automotive industry, with its manufacturing capabilities, has started to explore EV technologies.

The road to substantial EV market growth in Russia involves overcoming challenges such as developing widespread charging infrastructure and addressing consumer concerns. While the journey may be distinctive due to Russia's energy landscape, the nation's potential as a key player in the global electric mobility movement remains significant, with opportunities to balance its energy heritage with a cleaner and sustainable transportation future. Figure 2 shows the sales of NEVs in Russia from 2015 to 2022. Unlike the Chinese EV industry which started recording sales in millions of units in 2018, sales in Russia are still in the thousands as of 2022.

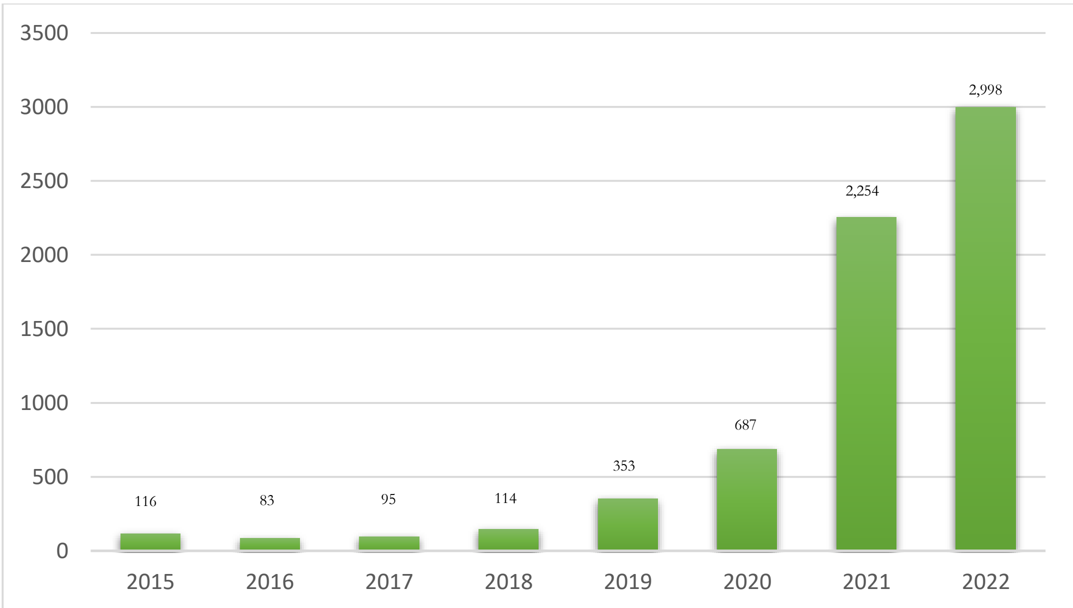
2.3 Relevant literature

Recent studies on EV adoption continue to examine the impact of consumer attitudes, financial incentives, charging infrastructure, and environmental consciousness. Insights from these analyses illuminate the challenges hindering EV adoption, while also revealing strategies to accelerate adoption rates. In this study, we carefully review recent research works, particularly focusing on their identified barriers, data samples, and methodology. Table 1 summarizes the relevant literature on the topic. Guided by the literature, we categorize the barriers into six categories namely; range (R), cost (C), lack of infrastructure (I), consumer or dealer knowledge/perception (K), lack of incentives/subsidies (N) and safety concerns (S). In Table 2, we categorize the 19 barriers to EV adoption into 4 main types namely: financial, infrastructure, vehicle performance, and health barriers.

3. Research methodology

3.1 Data collection and pre-processing

There is a lack of consensus on the definition of "seniors," "senior citizens," "older adults," "older people," or "elderly" in literature and practice. In various countries the retirement age is different. The current study would follow the definition of the American Association of Retired Persons (AARP), which offers senior membership at age 50 (Britannica, 2023).



Source: Statista (2023b)

Fig 2. NEVs sales in Russia from 2015 to 2022

Table 1. Summary of the existing related works on barriers to EV adoption

Authors	Identified barriers						Study area	Data samples	Methodology
	R	C	I	K	N	S			
She *et al.* (2017)	✓			✓		✓	Tianjin, China	476	SEM
Wang *et al.* (2017)			✓	✓			Shenzhen, China	406	Chi-square and Fisher's tests
Habich-Sobiegalla *et al.* (2018)		✓	✓	✓			China, Russia and Brazil	2806 (China = 1078, Russia = 799 and Brazil = 929)	MLR
Rubens *et al.* (2018)				✓			Denmark, Finland, Iceland, Sweden and Norway	126	MSA
Sovacool *et al.* (2019)	✓		✓			✓	China	805	PCA
Wei *et al.* (2020)		✓	✓	✓	✓		China	172	PCA and MVM
Yang *et al.* (2020)				✓			China	417	SEM
Jaiswal *et al.* (2021)				✓	✓	✓	India	418	SEM
Kongklaew *et al.* (2021)	✓		✓				Thailand	454	Chi-square test
Ling *et al.* (2021)		✓	✓				Beijing, China	1216	Logistic regression, Car Type Choice Model
Candra (2022)	✓	✓	✓	✓	✓	✓	Indonesia	11	OPA-G
Shakeel (2022)		✓	✓	✓	✓		Pakistan	511	SEM

NOTE: SEM = Structural Equation Modeling, MLR = Multiple Linear Regression, PCA = Principal Component Analysis, MSA = Mystery Shopper Approach, OPA-G = Grey Ordinal Priority Approach, MVM = Maximum variance methods

A stratified random sampling approach is used to select representative samples of senior citizens aged 50 and above in both China and Russia, with the sample size determined to achieve statistical significance for comparative analysis. The online-based survey questionnaire employed in this study is divided into three parts. The first part elicits personal details of the respondents such as gender, age, level of education, etc., while the second part gathers information about the knowledge, perceptions, and attitudes of respondents on EVs. The third part of the questionnaire is based on pre-validated measures from earlier studies of barriers to the adoption of EVs (Junquera *et al.*, 2016; Rezvani *et al.*, 2015). As seen in Table 2, these pre-validated measures (financial barriers, infrastructural barriers, vehicle performance barriers, and health barriers) are briefly explained.

A total of 301 responses were collected, nonetheless, after cleaning and preparing the data for analysis, 252 responses were left. The data pre-processing included dropping respondents aged below 50 years and respondents who had no valid driving license and, inaccurate/incomplete responses were deleted.

3.2 Designing research instrument

To capture both quantitative and qualitative data, the questionnaire incorporates a mix of closed-ended and open-ended questions. Also, a 7-point Likert scale (ranging from 'strongly disagree' (1) to 'strongly agree' (7)) was adopted to classify respondents' perceptions towards EV adoption. Again, to ensure linguistic and cultural relevance, the questionnaire was translated into Chinese (Mandarin) and Russian languages. The translated versions are thoroughly localized to reflect each country's cultural peculiarities and vocabulary. This stage ensures that the questions are simply understood and related to by the respondents.

3.3 Dynamic grey relational analysis model

In the current study, the Dynamic Grey Relational Analysis (DGRA) model was used for data analysis. The DGRA method is used to analyse quantitative data collected from the respondents.

Table 2. Categorized barriers to EV adoption

Barrier type	Code	Possible barrier	Description	Source
Financial barriers	B1	Price	Initial cost of EVs prior to factoring in any purchase subsidies.	Krishna (2021)
	B2	Cost of Battery	The expense associated with replacing the battery of a vehicle when it has reached the end of its functional life.	Tarei *et al.* (2021)
	B3	Charging cost	Charging cost pertains to the electricity expenditure or money paid while charging EVs.	The current study
	B4	Maintenance cost	Maintenance cost encompasses the routine expenses associated with upkeeping EVs, excluding any costs related to repairing damages resulting from accidents.	Sierzchula (2014)
Infrastructure barrier	B5	Availability of public infrastructure	The quantity and coverage area of public charging spots or charging stations available for electric vehicles.	Tanaka *et al.* (2014)
	B6	Availability of infrastructure at work	The availability and functionality of charging facilities for electric vehicles within workplace environments, including office buildings.	Jensen *et al.* (2013)
	B7	Availability of infrastructure at home	The accessibility and functionality of charging facilities for electric vehicles within residential communities.	Caperello and Kurani (2011)
	B8	Availability of infrastructure on highway	The availability and functionality of charging facilities for electric vehicles at highway service stations.	Lane and Potter (2007)
	B9	Inability to smartly locate the nearest charging stations	Integration of charging station locations in maps and electric vehicle navigation systems.	The current study
Vehicle performance barriers	B10	Safety	The sense of safety experienced while driving an EV.	She *et al.* (2017)
	B11	Range	The maximum distance that can be travelled on a single full charge of an EV.	Schneidereit *et al.* (2015)
	B12	Reliability	The overall quality and stability of the entire vehicle.	She *et al.* (2017)
	B13	Battery life	The duration of time during which a battery remains functional, accounting for the gradual degradation it experiences over its operational life.	Haddadian *et al.* (2015)
	B14	Battery-swapping	A fast way to replace a drained EV battery with a fully charged one at specific stations, eliminating charging time for EVs.	Adu-Gyamfi *et al.* (2022)
	B15	Charging time	Comprehensive evaluation of the time required to fully charge an EV using both quick and slow charging methods.	Li *et al.* (2018a)
	B16	Power	The highest achievable speed and the vehicle's capability to accelerate swiftly in the case of EVs.	Habich-Sobiegalla *et al.* (2018)
Health barriers	B17	Limited Mobility	Age-related conditions such as arthritis or reduced muscle strength	Pellichero *et al.* (2021)
	B18	Vision or hearing impairment	Age-related conditions such as vision or hearing impairment	NIA (2023)
	B19	Fatigue or slow reaction time	Age-related conditions such as fatigue or slow reaction time	Pellichero *et al.* (2021)

Grey relational analysis was developed by Ju-Long (1982) and it uses a specific concept of information, defining situations with no information as black, and those with perfect information as white. Also, situations between these extremes (black and white) are described as being grey. Deng's GRA model had an issue surrounding its one parameter and, thus, the output was not precise (Angela & Angelina, 2021). In 2022, Javed *et al.* (2022) proposed an improved version of Deng's GRA model called the DGRA that overwhelmed the issue in the original model. Later studies have confirmed the validity of the improved model (Ouali, 2022; Ervural, 2023; Matambo, 2023). The steps involved in the execution of the DGRA model are given below:

STEP 1. We collect quantitative data on the impediments that prohibit seniors in China and Russia from purchasing EVs.

STEP 2. If $X_0 = X_{max} = (x_{max}(1), x_{max}(2), \ldots, x_{max}(n))$ is considered an ideal data set and $X_k=(x_k(1), x_k(2), \ldots, x_k(n))$, k=1,2,3, … , m, is considered another data set of same length needed to be compared with X_{max}, we calculate the absolute difference matrix $\Delta_{0k}(j)$ using the expression below:

$$|\Delta_{0k}(j)| = |x_{\max}(j) - x_k(j)| \tag{1}$$

where x_{max} is the maximum numerical value assigned to the barriers {1, 2, 3,…19} by each respondent and x_k represents the actual value assigned to a barrier.

STEP 3. We then calculate the vectors $\Delta_{avg}(j)$ and $\psi(j)$ using the methods defined below:

$$\Delta_{avg}(j) = \frac{\sum_{i=1}^{m} \Delta_{0k}(j)}{m} \tag{2}$$

$$\psi(j) = \frac{\Delta_{avg}(j)}{\vartheta} \tag{3}$$

where m represents the number of barriers (m = 19) and ϑ represents the maximum value of $\Delta_{0k}(j)$.

STEP 4. Next, we estimate h-multiplier, and then the dynamic distinguishing coefficients using the linear programming method below:

$$\begin{aligned} &Maximize\, \xi(j) = h(\psi(1) + \psi(2) \cdots + \psi(n)) \\ &s.t \\ &h \in [1,2] \\ &h\psi(j) \leq 1 \end{aligned} \tag{4}$$

STEP 5. The Grey Relational Coefficient (GRC) ($\gamma_{0k}(j)$) is then calculated using

$$\gamma_{0k}(j) = \frac{\rho + \xi(j) * \vartheta}{|\Delta_{0k}(j)| + \xi(j) * \vartheta} \tag{5}$$

where ρ represents the minimum value of $\Delta_{0k}(j)$.

STEP 6. Following GRC, Grey Relational Grade (GRG) (Γ_{0k}) is obtained. For every barrier j, the GRG is the average GRC of that barrier for all respondents n.

$$\Gamma_{0k}(j) = \frac{\sum_{j=1}^{n} \gamma_{0k}(j)}{n} \tag{6}$$

STEP 7. We then rank the barriers based on their corresponding GRG value. A higher GRG value means a higher ranking, while a lower GRG value means a lower ranking.

STEP 8. Finally, to find the Grey Relational Standard Deviation (GRSD) (σ) we used the expression:

$$\sigma = \sqrt{\frac{\sum_{j=1}^{n}(\Gamma_{0k}(j) - \gamma_{0k}(j))^2}{n-1}} \tag{7}$$

For complete details on the DGRA model, the GRSD and their properties the readers are directed to Javed *et al.* (2022).

4. Results and discussion

4.1 The demographics of the sample

The demographic information of the respondents involved in the study is given in Table 3. The overall number of respondents were 301, nonetheless, the demographic details provided represents the selected 252. Most of the respondents were Chinese and males whose age were between 50 to 59. Most of them had attended university. Also, to keep the table simple and easy to understand, details on respondents' knowledge, usage and possession of EVs were not included. Raw data is shown in *Appendix*.

4.2 The quantitative analysis

To allow for a detailed analysis, the quantitative data were divided into 4 categories (Chinese females, Chinese males, Russian females, and Russian males). As shown in Table 3, 45.86% of the data from China were female, while 54.14% were male. Whereas for Russia, 36.97% represented females with males represented by 63.03%. The DGRA analysis is then performed on these 4 categories, making it possible for us to understand the decision-making process for both males and females respectively.

4.2.1 Grey Relational Analysis of the Chinese market. The dynamic grey relational grade (GRG) values and ranks against the Chinese females and males are given in Table 4. One can see that that both Chinese females and males believe B9 (inability to smartly locate the nearest charging stations) to be the most significant barrier to the EV adoption. The results have also been illustrated in Figure 3. When data contains uncertainty, it is better to have an interval GRG with known upper and lower bounds. For this purpose, the dynamic grey relational standard deviation (GRSD) is useful. Figure 4 shows the interval GRG with lower (GRG - σ) and upper (GRG + σ) bounds for both Chinese females and males.

4.2.2 Grey Relational Analysis of the Russian market. The GRG values and ranks against the Russian females and males are given in Table 5. One can see that that both Russian females and males believe B7 (availability of infrastructure at home) to be the most significant barrier to the EV adoption. The results have also been illustrated in Figure 5. Figure 6 shows the interval GRG with upper (GRG + σ) and lower (GRG - σ) bounds.

4.3 Discussion

Among the 19 barriers, B9 (which we defined as the ability to smartly locate nearest charging stations) is identified as the key barrier to EV adoption in China for both male and female seniors,

Table 3. The demographic information of the respondents

Country	Respondent percentage	Gender		Age			Education			
		Male	Female	50-59	60-69	70+	High School	College	University	Other
China (n=133)	52.78%	72	61	109	19	5	8	24	98	3
Russia (n=119)	47.22%	75	44	87	26	6	15	20	78	6

NOTE: n = total number of respondents

Table 4. The grey relational grades and ranks of the barriers against both Chinese groups

	Chinese female		Chinese male	
Barrier	**GRG**	**Rank**	**GRG**	**Rank**
B1	0.653	2	0.736	3
B2	0.637	5	0.736	2
B3	0.644	4	0.662	4
B4	0.652	3	0.657	5
B5	0.59	10	0.617	10
B6	0.601	7	0.646	6
B7	0.574	15	0.623	9
B8	0.582	12	0.609	12
B9	0.856	1	0.914	1
B10	0.487	19	0.516	17
B11	0.52	17	0.54	13
B12	0.541	16	0.536	14
B13	0.595	9	0.628	8
B14	0.636	6	0.629	7
B15	0.581	13	0.61	11
B16	0.498	18	0.487	19
B17	0.589	11	0.532	15
B18	0.581	14	0.502	18
B19	0.599	8	0.528	16

while in Russia, B7 (which we defined as the availability of infrastructure at home) is identified as the key barrier. The top five barriers in each group are shown in Figure 7.

With respect to our findings, it is not surprising to see infrastructure as the key barrier for seniors in Russia. Unlike other developed countries, Russia grapples with a scarcity of charging stations at homes, urban centers, and along highways, impeding the convenience of EV use. This deficiency in infrastructure not only hampers the accessibility of charging points but also contributes to range

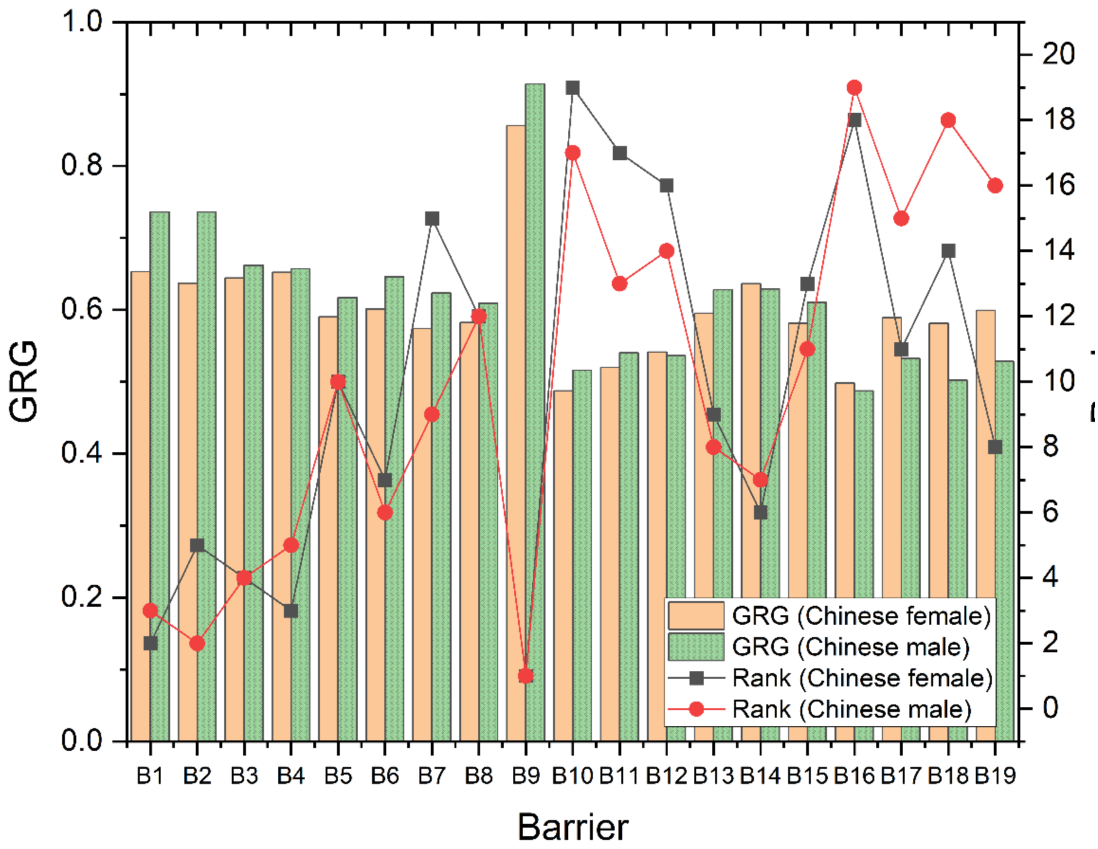


Fig 3. The grey relational grades and ranks against both Chinese groups

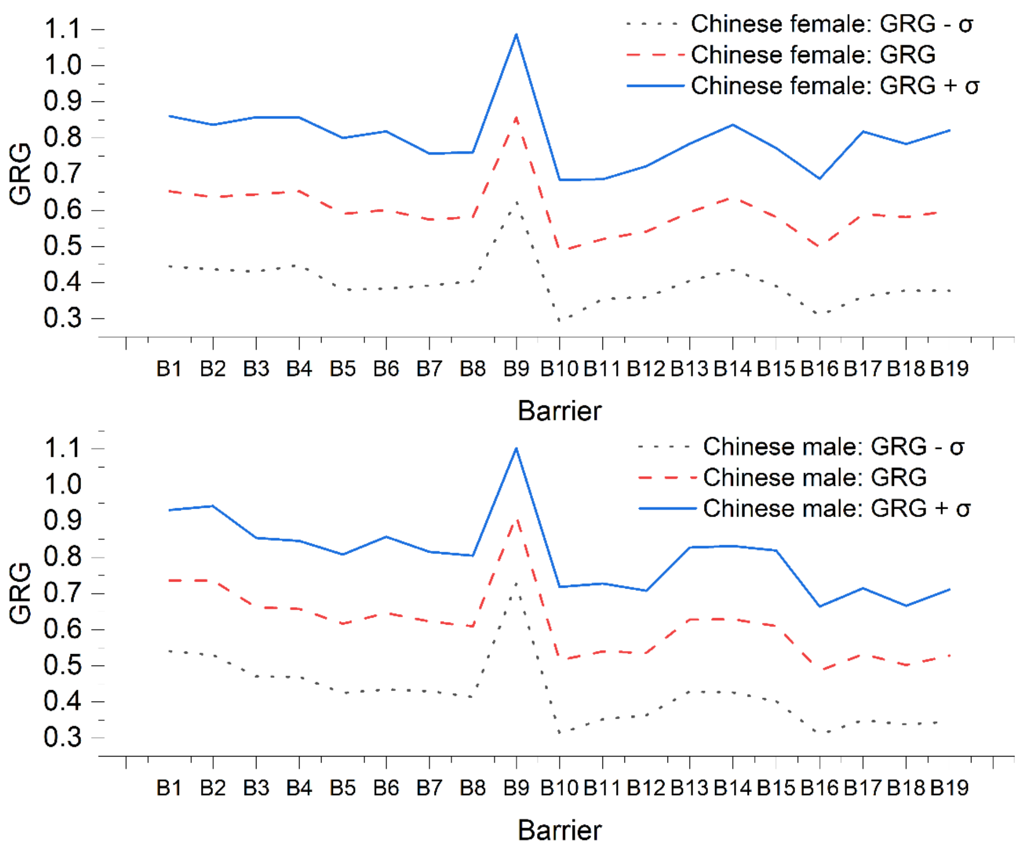


Fig 4. The interval grey relational grades against both Chinese groups

Table 5. The grey relational grades and ranks of the barriers against both Russian groups

	Russian female		Russian male	
Barrier	**GRG**	**Rank**	**GRG**	**Rank**
B1	0.77	6	0.708	16
B2	0.74	9	0.726	13
B3	0.717	12	0.748	8
B4	0.766	7	0.75	7
B5	0.846	5	0.795	2
B6	0.9	3	0.773	4
B7	0.915	1	0.801	1
B8	0.902	2	0.794	3
B9	0.862	4	0.766	5
B10	0.599	16	0.65	19
B11	0.621	14	0.729	10
B12	0.632	13	0.685	18
B13	0.749	8	0.717	15
B14	0.739	10	0.722	14
B15	0.719	11	0.728	11
B16	0.518	19	0.707	17
B17	0.56	18	0.727	12
B18	0.602	15	0.751	6
B19	0.584	17	0.742	9

anxiety among prospective buyers, who fear being stranded without a charging option. Shahboz *et al.* (2023) also points to limited charging infrastructure as a significant hindrance to EV adoption in Russia.

On the other hand, in China, despite the country's ambitious push towards electrification and the substantial growth of the EV market, the inability to smartly and easily locate available charging

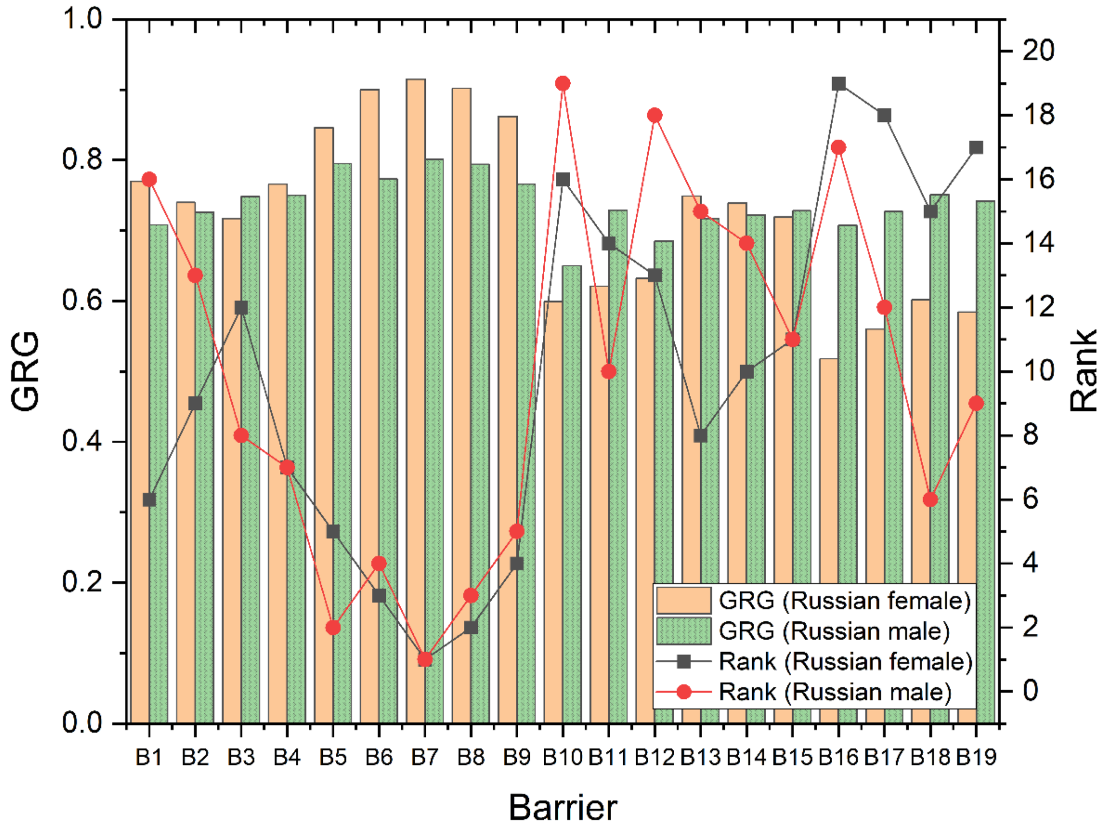


Fig 5. The grey relational grades and ranks against both Russian groups

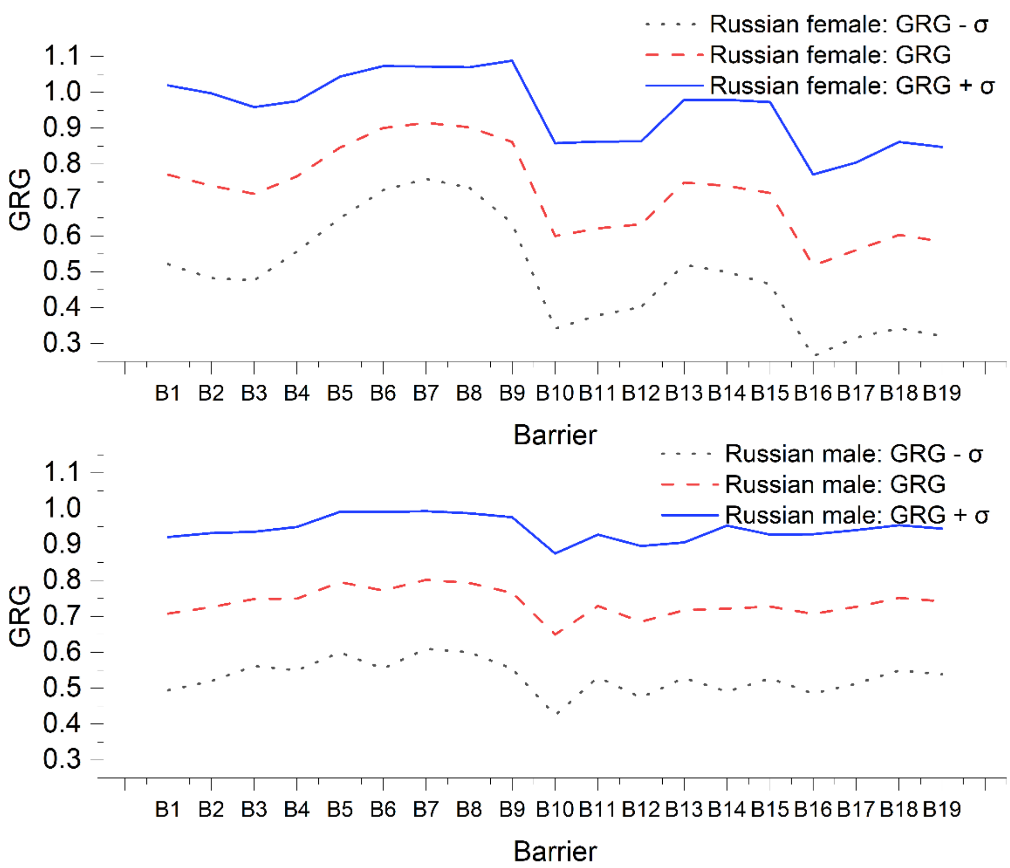


Fig 6. The interval grey relational grades against both Russian groups

Rank	Chinese females	Chinese males	Russian females	Russian males
1	Inability to locate nearest charging station	Inability to locate nearest charging station	Lack of infrastructure at home	Lack of infrastructure at home
2	Price	Battery cost	Lack of infrastructure on highways	Lack of public infrastructure
3	Maintenance cost	Price	Lack of infrastructure at work	Lack of infrastructure on highways
4	Charging cost	Charging cost	Inability to locate nearest charging station	Lack of infrastructure at work
5	Battery cost	Maintenance cost	Lack of public infrastructure	Inability to locate nearest charging station

Fig 7. Top five barriers against each group

stations pose a significant barrier for both male and female senior citizens. Addressing this issue requires a coordinated effort involving urban planning and government initiatives to strategically deploy charging stations that can be electronically located. A more intelligent and systematic approach to charging station deployment is essential to mitigate this barrier.

If one looks at Figure 7, one can argue that these barriers are manifestations of different levels of development in these countries. For instance, China is the world's largest EV market and the EV infrastructure is more developed than any other market in the world thus one could not find the "lack of infrastructure" among top barriers. On the other hand, the Russian EV market is still in its infancy and thus "lack of infrastructure" was the primary concern for both male and female seniors in Russia. Unlike the competitive market of China where the "price" of the vehicle is among the top barriers, in the Russian market, "price" failed to garner significant attention. It's possible that the seniors in Russia are less aware of the difference between the process of EVs and the fuel vehicles. Loosely speaking, in China since the primary needs have been met ("infrastructure"), the potential customers are concerned about secondary needs ("price", "battery cost", "charging cost," etc.) whereas the potential consumers in Russia are still affixed on primary needs thus the secondary needs have received relatively lesser attention. Meanwhile, even though the "inability to locate the nearest charging station" turned out to be an important barrier for both Russian and Chinese seniors, it is very likely that their definition of "nearest" is not the same because of the difference in infrastructure in the two countries.

5. Conclusion

The study undertook a survey involving two hundred fifty-two senior respondents to investigate the perceived barriers to EV adoption in China and Russia. Despite a majority of respondents perceiving a promising future for EVs, respondents from Russia displayed reluctance to adopt EVs due to insufficient charging infrastructure, while those from China suggested their inability to smartly locate available charging stations as a significant impediment.

In China, where rapid urbanization and technological integration define the landscape, infrastructure, in general, is not an issue however it is recommended that the government and manufacturers consider moving towards smart charging stations to make it easier for EV users to be able to easily locate the nearest available stations with ease. Conversely, in Russia, with its expansive geography and diverse climates, policymakers and manufacturers are recommended to expand and build more charging infrastructures to tackle the limited infrastructure barrier that continues to hinder senior citizens from adopting EVs. In the future, efforts can be made to link the barriers to EV adoption to the primary and secondary needs of the senior drivers. However, what are the primary and secondary needs of senior customers of EVs is a question that was out of the scope of the current study and, will be studied in the future.

Our results also demonstrate the efficiency of DGRA in analyzing and providing insights from our complex datasets. The DGRA methodology not only quantifies the significance of identified barriers but also provides a framework for continuous assessment, aligning with the evolving landscape of EV adoption. In our future work, we will expand our survey and consider investigating other developing countries.

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Appendix

Supplementary data used in this study can be found in this section. The rows {B1, B2, … , B_m} represent the barriers as defined in Table 2, while the columns {C1, C2, ... , C_n} represent the respondents.

Table A. Data collected from the Chinese females

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	…	C61
B1	6	5	5	7	7	3	3	2	6	2	6	4	5	5	…	4
B2	6	5	4	7	7	5	3	7	6	2	5	5	6	4	…	5
B3	7	7	3	4	7	4	3	3	7	3	4	5	6	5	…	5
B4	7	7	3	4	7	3	1	2	7	3	5	5	5	5	…	5
B5	7	5	2	3	3	3	1	6	7	2	4	5	6	6	…	4
B6	7	5	2	3	3	2	1	3	7	2	6	5	4	6	…	3
B7	7	5	2	3	3	2	3	6	6	2	5	5	4	4	…	4
B8	7	5	2	2	3	3	3	4	3	2	6	6	4	5	…	4
B9	7	7	7	7	7	7	7	5	7	6	5	7	6	3	…	5
B10	5	4	1	1	1	1	1	3	1	2	6	1	3	5	…	3
B11	6	4	3	2	5	1	1	3	4	5	5	2	7	5	…	3
B12	7	3	1	1	4	1	1	5	4	5	5	3	5	5	…	3
B13	7	5	3	5	4	3	1	2	2	6	5	5	7	5	…	3
B14	7	7	3	5	4	3	1	5	7	4	6	5	5	4	…	3
B15	4	7	2	5	5	2	1	6	6	5	6	4	6	5	…	3
B16	5	4	1	2	3	1	1	3	1	2	5	1	4	4	…	2
B17	7	7	1	2	5	2	1	6	2	7	6	3	4	5	…	4
B18	7	7	1	2	5	2	1	3	2	7	5	3	5	5	…	4
B19	7	7	1	2	5	2	1	5	2	7	5	3	5	6	…	5

Table B. Data collected from the Chinese males

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	…	C72
B1	4	7	3	3	5	4	5	4	7	3	6	6	6	3	…	4
B2	4	7	3	3	6	4	6	5	6	3	6	6	6	3	…	4
B3	5	7	7	2	5	4	5	4	7	3	6	6	6	3	…	4
B4	5	7	7	2	6	3	6	6	6	3	6	6	4	3	…	5
B5	3	7	7	2	5	2	5	4	7	2	6	6	5	3	…	3
B6	3	7	7	2	6	2	6	7	6	2	7	6	5	3	…	3
B7	3	7	7	2	5	2	5	4	7	2	5	5	5	3	…	3
B8	3	6	7	3	6	2	6	7	6	2	7	6	6	3	…	3
B9	7	7	3	7	5	7	5	4	7	7	6	7	7	7	…	7
B10	2	7	3	1	2	1	2	6	3	2	2	3	2	1	…	1
B11	3	7	3	2	3	1	3	4	2	3	3	3	4	1	…	3
B12	3	5	7	1	2	1	2	5	3	2	2	3	4	1	…	3
B13	4	5	3	3	3	3	3	4	2	3	3	3	5	4	…	2
B14	4	5	3	3	2	3	2	5	3	3	2	3	5	4	…	2
B15	2	4	3	1	3	1	3	4	2	1	3	3	7	1	…	2
B16	1	4	3	1	2	1	2	6	3	1	2	2	3	1	…	1
B17	2	5	3	1	1	2	1	4	2	2	1	1	1	2	…	2
B18	3	3	3	1	1	2	1	5	1	2	2	1	1	2	…	1
B19	4	5	3	1	1	2	1	5	1	2	1	1	1	2	…	2

Table C. Data collected from the Russian females

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	…	C44
B1	7	7	7	7	7	6	3	7	7	4	7	3	3	3	…	7
B2	7	7	7	7	7	5	6	7	7	4	7	3	3	3	…	6
B3	7	7	7	7	7	5	2	4	5	4	7	6	6	3	…	5
B4	7	7	7	7	7	4	5	4	5	4	7	6	7	5	…	5
B5	7	7	7	7	7	6	4	5	4	7	7	7	7	5	…	6
B6	7	7	7	7	7	7	3	5	5	7	7	7	7	6	…	6
B7	7	7	7	7	7	7	3	7	6	7	7	7	7	6	…	6
B8	7	7	7	7	7	7	6	5	4	7	7	7	7	6	…	6
B9	7	7	7	3	1	7	3	6	6	7	7	7	7	6	…	6
B10	7	1	7	7	7	4	6	4	1	3	7	4	3	4	…	2
B11	7	4	7	7	7	3	2	6	7	3	7	4	3	4	…	3
B12	7	7	7	7	7	4	2	4	2	3	7	4	3	3	…	2
B13	7	5	7	7	7	7	7	6	5	3	7	4	3	3	…	5
B14	7	5	7	7	7	7	5	4	3	3	7	3	3	3	…	7
B15	7	7	7	7	7	7	3	6	5	3	7	3	3	3	…	4
B16	6	1	6	7	7	5	5	4	5	3	3	3	3	3	…	3
B17	5	6	7	1	1	4	4	3	2	3	4	3	3	3	…	3
B18	5	5	7	1	1	3	5	4	1	3	3	3	4	4	…	3
B19	5	5	7	1	1	2	2	2	3	3	4	3	3	3	…	3

Table D. Data collected from the Russian males

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	…	C75
B1	6	4	2	4	6	6	5	6	6	6	6	4	6	6	…	6
B2	5	3	3	5	7	6	7	6	6	6	7	4	6	6	…	6
B3	4	7	6	4	6	6	6	6	6	6	6	7	7	6	…	6
B4	4	7	7	7	7	5	6	5	7	6	6	7	6	6	…	6
B5	5	7	7	6	7	7	5	7	6	6	6	7	6	6	…	6
B6	6	7	7	6	6	5	7	6	6	6	6	7	6	6	…	6
B7	5	7	7	5	6	6	6	7	6	6	5	7	6	6	…	6
B8	3	7	7	6	7	7	6	6	6	5	5	7	6	6	…	6
B9	6	7	4	5	6	7	6	6	6	5	6	4	6	7	…	6
B10	6	3	3	4	7	6	6	5	6	5	5	3	6	6	…	6
B11	6	3	3	6	5	7	7	7	6	6	6	3	6	6	…	6
B12	3	3	3	6	6	7	6	6	6	7	6	4	6	6	…	6
B13	6	3	4	6	5	6	7	6	6	6	6	3	6	6	…	6
B14	6	3	4	4	7	7	6	6	6	7	6	3	6	6	…	6
B15	3	3	3	7	5	6	6	6	6	6	5	3	6	6	…	6
B16	4	3	3	7	6	6	7	7	6	6	6	3	6	7	…	7
B17	4	3	3	5	5	6	6	7	6	5	6	3	6	6	…	6
B18	5	3	3	7	6	7	7	6	6	6	6	3	6	6	…	6
B19	5	3	3	5	6	7	5	6	6	6	6	3	6	6	…	6

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