Future of Quality Management System (ISO 9001) Certification: Novel Grey Forecasting Approach

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Abstract

Regarded as one of the most effective tools to guide quality systems management, ISO 9001 is a valuable certification. Yet, the growth observed throughout the world by this standard provides a strong polarization of interest in this practice by the companies. Our research goals are to analyze and forecast trends involving ISO 9001 certification of six countries, China, Italy, Germany, Japan, the United Kingdom, and India. We gathered ISO 9001 countrywide certification data over nine years from 2018 to 2026. The methods used in this study include Even GM (1, 1), Discrete GM (1, 1) and Non-homogeneous discrete grey model (NDGM) with an accompanying synthetic growth rate and synthetic doubling time grey models to investigate the comparison among these countries. The result reveals that Germany will likely continue to lead ISO 9001 certifications at a country level through 2026. We also find that Japan and UK required more time for ISO 9001 certification to double than other countries. Our forecasting of the uptake of the ISO 9001 standard is significant for the certification bodies to understand market diffusion and trends. Implications include this study providing valuable policy guidelines for decision-makers, and new opportunities for further research for scholars.

Keywords: Quality management; grey System Theory; ISO 9001; forecasting: Non-homogeneous discrete grey model.

Highlights

- Analysis and forecast trends of ISO 9001 certification of six selected countries, China, Italy, Germany, Japan, the United Kingdom, and India for the period 2018 to 2026.
- Germany is predicted to continue to lead ISO 9001 certifications at a country level through 2026.
- Japan and UK will require more time for ISO 9001 certification to double than other countries.
- New insights from ISO 9001 certifications novel Synthetic Doubling Time and Synthetic Relative Growth Rate models.

1. Introduction

The continuously increasing popularity of ISO 9001 quality management system certifications motivates organizations to take into consideration the quality practitioner's points of view in business decision making. The integration of the ISO 9001 standard can ensure a quality benchmark within organizations. Quality management in business organizations effectively makes sure the business benefits of products and services avoid the drawbacks while directly helping to identify responsibilities and implementation opportunities for this standard (To et al., 2012). Globally the increasing diversity of firms utilizing and market size of the adoption of ISO 9001 enables businesses to reshape the world economy through the quality concerns in business organizations, their products, and trade. According to the World Bank, trade represented 24% of the world's total GDP in 1962, and this more than doubled to 57% by 2017 (Villarreal, 2019).

Organizations have been adopting many international management standards providing guidance and requirements for sound quality management practices (Sampaio et al., 2012: Ikram et al., 2019). The management standards integration into a single system is being carried out by an increasing amount of companies, with different strategies and levels of integration (Cabecinhas et al., 2018; Ikram et al., 2020b). The expansion of management standards highlights the idea that organizations want to improve management systems. There are many published standards, but limited research that looks at how these standards are integrated within economies as they gain global prominence and ISO 9001 has been instrumental in its influence on management systems (Sampaio et al., 2014; Gingele et al., 2002). The trends of ISO 9001 certification demand have been increasing in both public and private sector organizations. According to latest ISO report (ISO, 2018), by the end of 2016, approximately 1,106,356 companies were certified worldwide i.e., approximately 7%, and China has the highest number of ISO 9001 certification followed by Italy, Germany, and Japan (ISO, 2016a) making the ISO 9001standard global and significant.

However, our own research finds few studies regarding the diffusion of ISO 9001 worldwide (Llach et al., 2011; del Mar Alonso-Almeida et al., 2013; Marimon Viadiu et al., 2006). These studies have highlighted impressive outcomes but provide only a limited view of the scientific evidence in this line of research based on a limited set of variables. There are numerous studies on the implementation of ISO 9001 (Franceschini et al., 2004). And plenty of discussion regarding the importance and benefits of ISO 9001 (Sampaio et al., 2009; Corbett et al., 2002). To date, they mostly characterized the advantages of ISO 9001 standard as external and internal advantages for firms. The internal advantage includes cultural differences of personnel, systematic functioning, establishing awareness of quality in the organization, the proficiency of the board, better documentation, the progress level changes, and efficiency and reductions in costs. The external advantages of management standards include but are not limited to consumer devotion and satisfaction levels, expansion of market share, preparation for reviews, increasing the quality for the organization's profile and raising its competitive capabilities. Yet while reviewing the literature, we find a gap in research regarding forecasting ISO 9001certification and the insights this can provide. Our timing for this study is also important as in recent years there have been studies regarding de-certification, see for example, (Kafel and Simon, 2017, and Simon and Kafel, 2018).

Our objective is to describe the future trends of ISO 9001 certification. In this study, we forecast ISO 9001 certification from 2018-2026 based on data from 2005-2017 available from the International Organization for Standardization (ISO). To enable this, we can utilize advanced mathematical modeling techniques including grey forecasting models Even GM, Discrete GM, and Non-homogenous discrete grey model (NDGM). These models can be applied to the World Trade Organization member countries of China, Italy, Germany, Japan, United Kingdon, and

India. Through the application of a relative growth rate (RGR) and doubling time (Dt), there is an opportunity to provide new insights. These synthetic grey tests will allow analysis and competition among multiple countries while making future predictions as to where and by how much certifications will change.

Based on the results, managers and researchers will be interested in the investigation of certification diffusion, evolution, and application of forecasting techniques as contributions of this study. Our primary focus is to assess the diffusion rate/future trend of ISO 9001 among leading countries. This study should be interesting to the certification bodies as they identify the future of ISO 9001 standard across countries. Mansfield (1961), cited in (Sampaio et al., 2011) conducted a study and used s-shaped growth curve and a well-known logistic function to investigate the diffusion of process technology. This literature is related to the diffusion of management systems and paradoxically, when we searched for studies over the last five years on ISO 9001 or ISO 14001 found only a few focused on international diffusion (Raweni and MajstovoiÄ, 2016). Despite the spread of management standards, their implementation, and known effects of ISO 9001, a more contemporary look at international diffusion is a gap to fill in the literature, (Albuquerque et al., 2007; Ikram et al., 2020).

The objective of the international management standard is the implementation of business management systems and systematic alignment with organization operations. Franceschini et al. (Franceschini et al., 2006) reported that the diffusion curve indicates some management standards over time in each country can lead to a saturation effect. This saturation implies that due to the rapid growth of the management standard, a psychological break takes place at a specified period.

Adding to this, del Mar Alonso-Almeida et al., (2013) conducted a study on diffusion and evolution of ISO 9001standard of different countries. They reported that different countries are at different stages of diffusion. They also investigated that some European countries are more experienced in the regulatory system have reached a saturation level at a short period compared to other countries where the quality standard has a shorter history of diffusion.

Numerous studies Saraiva and Duarte, (2003) and, Franceschini et al., (2006) focus on the growth of the ISO 9001 quality standard in European countries and showed a relationship between diffusion of quality standard and population growth using a logistic curve modeling approach. Moreover, Cabecinhas et al., (2019) conducted a study to analyze the diffusion and forecasting trends of ISO 9001, ISO 14001 am OHSAS 18001 by using the logistic curve model of in Portuguese. They observed a difference in the saturation level of these management standards. These differences could result from the revision of the standards since ISO 9001 standard and ISO 14001 were revised in 2015. This research suggests that the diffusion of ISO 9001 certifications will reach a certain saturation level in each country. Thus, the uptake of ISO 9001 accreditation becomes less attractive and reduces competitive advantage gaps among certified and non-certified companies (Franceschini et al., 2004). Our focus in this study is to forecast the performance of ISO 9001.

In doing this, we also need to unpack the forecasting models namely grey forecasting models available to decision-makers when assessing decisions about ISO 9001 certification. For this, we can use three novel forecasting models, Even Grey Model (EGM), Discrete Grey Model (DGM) and Non-homogeneous Discrete Grey Model (NDGM) methods to calculate the simulated and forecasting values based on actual data of top six ISO 9001 certified countries. The advantages of grey forecasting models include accuracy in assessment when using small samples. Further, with the help of Relative Growth Rate (RGR) and Doubling time (Dt) models, we can take this a step further to obtain the relative growth rate and total time required to make ISO 9001 certification double in number. Some of the advantages of using techniques for grey forecasting models methods include high accuracy, rational, comprehensibility, and good computational efficiency with the ability to measure the relative performance for top ISO 9001 certified countries in a simple mathematical form.

The purpose of this study is to empirically forecast ISO 9001 certifications for the years 2018-2026 of six leading countries: China, Italy, Germany, Japan, the United Kingdom, and India. This will be based on available data from ISO (2018) spanning 2005-2017. In doing so, we utilize novel grey forecasting models EGM, DGM and NDGM. We also utilize Synthetic Relative and doubling time models the first time to measure the relative growth rate of ISO 9001 standard among the selected countries. The proposed grey mathematical models, particularly the GM models, are considered as a robust approach as compared to other forecasting models in the context of small samples and possibilities of incomplete information and uncertainty (Ikram et al., 2019a). The insights from this study will contribute to the understanding of expectations regarding ISO 9001 performance in China, Italy, Germany, Japan, the United Kingdom, and India and the regions these countries are within. Outcomes of this study include new insights regarding the spread of ISO 9001 by relative growth rate and doubling time as this can help scholars, policymakers, and practitioners in understanding the momentum of standards and when making decisions. The proposed methodology is a novel and innovative application in ISO 9001 forecasting.

The structure of this article has five sections. Section 2 represents the background of Quality Management Systems and ISO 9001. Section 3 describes methodologies for the three novel grey forecasting models. Section 4 reports the results. Finally, the conclusion and implications for contributions to the field and insights for policymakers is covered in the last section.

2. Overview of Quality Management Systems and ISO 9001

In 1947, the International Organization for Standardization (ISO) center was formed in Geneva, Switzerland. ISO has various kinds of memberships i.e., 119 are establishment members, 39 are correspondence members, and 3 subscriber members (ISO, 2016b). The primary objective of ISO is to assess company applications for International management standard certification and inspect the organization's operations and processes to ensure standard requirements are met for trade improvement (ISO, 2016c).

The Quality Management System ISO 9001 standard is a generic system that can be applied to any organization. The details regarding the development of ISO 9001 is in table 1. The last major review to ISO 9001 standard was in 2015. ISO 9001 version 2015 was revised to consider various performance characteristics including increment documentation adaptability, integration of benchmarks, initiative, look after pertinence, give a reliable establishment to the future, give expanded recognition of service enterprises and office workplace including non-office and virtual workplaces and hazard/risk-based reasoning (Anttila, and Jussila, 2017; da Fonseca and Domingues, 2016). The standard has experienced a progression of improvement stages before becoming 'resolutions/statutes', e.g., a working draft; board of trustee's draft, draft worldwide standard, last draft universal standard and, finally, the global standard. The objective of the ISO 9001standard is to improve the company operations and processes while removings obstacles and issues with quality. ISO describes the structure of document controlling, organization hierarchy chart, authorize assigned responsibilities, adequate resource allocation, managing customer complaints and customer satisfaction, planning of product realization, conformity of purchase product and purchase requirement, measurement, and analysis of data, performance evaluation through internal and external audits. Different quality management systems can become the standard operating procedure for an organization (Chiarini, 2015; Başaran, 2016).

ISO 9001 standard methodology includes processes for creation, structure and implementation, plus verification by a third party. By far the most successful, in terms of diffusion, are two groups of standards, the ISO 9000 series of standards, related to the implementation of quality assurance systems, and the second is the ISO 14000 series, related to the implementation of environmental management systems (Viadiu et. al., 2006). In its early stages, ISO 9000 spread around the world from European Union countries, specifically from where these standards originated, the United Kingdom. In 1996, more than 62% of certificates in the world were found in the EU. More than 50% had been issued in the United Kingdom. This may have been due to various administrations and European institutions actively supporting the use of ISO 9000 in working towards harmonization in the European Union (Peach, 2002). Since these earlier times, the successful diffusion of these standards has been linked to the globalization of western economies, extending global supply chains, and the growth of transnational corporations (Braun, 2005).

The review of ISO 9001 literature finds insights on diffusion and researchers concentrating on the effects of ISO9001 certification as opposed to ISO 9001 adoption (LMCM Fonseca et. al, (2019). They utilize a binary variable to investigate whether an organization is guaranteed or not. Apparently, they expect homogeneous adoption. However, having a certification isn't equivalent to adoption of the ISO9001 standard. An organization may acquire ISO9001 certification without embracing the standard legitimately or utilizing it routinely in its everyday processes (M. Ikram et al., 2019b).

ISO 9001 has a lot of internal and external benefits for organizations such as (Internal) documentation, quality awareness, cost reduction, inline company processes, easy traceability, improve the efficiency of the company operations, organized culture (External) customer satisfaction, improve company image, build competitive strength over competitor, rise up in market share (Martínez-Costa et al., 2008). After reviewing the standard, its evolution and benefits, we now turn to our methods for this study.

Table 1: ISO 9001 Historical Perspective

Year	Authorize Body	Standard Type	Discipline
1963	USA	MIL/Q/9858	Defense technology
1968	NATO	AQAP	Defense Product
1979	BSI	BS 5750	Generic/all
1987	ISO	9000 series	Generic/all
1988	CEN	EN 29000	Generic/all
1994	ISO	9001.1994/9002:1994/9003:1994	Generic/all
1996	ISO	EN 9000	Generic / all
2000	ISO	9001:2000	Generic / all
2008	ISO	9001:2008	Generic / all
2015	ISO	9001:2015	Generic / all

2.1 ISO 9001:2015

ISO 9001:2015 (ISO, 2015) was published in September 2015 comprising a twofold goal: reliability- by ensuring that organizations who meet its requirements on a consistent basis provide products and services that satisfy their customers' needs and expectations addressing the relevant statutory and regulatory requirements; flexibility- by developing the 2015 edition appropriate and suitable for the present complex, demanding and dynamic business environments (Domingues, et al., 2019).

ISO 9001:2015 promotes the adoption of a process approach when developing, implementing, and improving the effectiveness of a QMS to enhance customer satisfaction by meeting customer requirements (Fonseca et al., 2019). The standard also gives general textbook-like bullet points as specific requirements to be considered essential for the adoption of the process approach. Here, the standard goes too much into general details that are not necessarily suitable for all different modern organizational situations. These kinds of requirements may lead to superficial solutions. The practical approach in an organization is a much more complicated issue (Glick et. al, 2015).

Fonseca and Domingues, (2018) studied and compared the Draft DISO 9001:2015 version with Total Quality Management approaches concluding it is a step towards that direction and can represent significant benefits for the organizations, such as less emphasis on documentation and new/reinforced approaches. Georgiev and Georgiev (2015), presented a stepwise ISO-TQM implementation approach based on ISO 9001:2015 and Hussain et al., (2018) proposed a model for integrating Lean and or Six Sigma projects by systematically linking with the applicable clauses and sub-clauses of ISO 9001:2015. Rybski et al., (2017) analyzed the ISO 9001:2015 International Standard and gathered feedback during the first six months of its application. They concluded that there are improvements in the ISO 9001 edition of 2015, such as the new harmonized structure, the adoption of risk-based thinking (Chiarini, 2017) and the reinforced business-centered focus on business processes; however, they claim it is ambiguous, and it has incomplete and imperfect text and requirements.

The ISO Survey 2017 (ISO, 2018) indicated that as of December 31, 2017, only 42% of the ISO 9001-certified organizations had successfully transitioned to ISO 9001:2015, with countries such as Japan boasting a transition rate of more than 65%, while other countries like Italy reported a transition rate of only 24%. With the validity of ISO 9001:2008 certifications ending soon, there is a strong need to investigate the ISO 9001:2015 transition process, namely the methodologies, the difficulties, the benefits, leading practices, and the overall lessons learned with these processes.

Numerous authors contributed to the debate of previous ISO 9000 standards revisions (Vouzas & Gotzamani,2005; van der Wiele, van Iwaarden, Brown, Steimle & Zink, 2009) and ISO 9001:2015 caught researchers' attention. However, due to its novelty, few investigations have addressed its implementation. This is unfortunate, as the ISO 9001:2015 aims at embedding quality management on several organizational levels and linking QMS more with the overall strategy and the prevailing mindset of an organization. An implementation, therefore, affects an organization systemically and should subsequently be treated with appropriate management care and attention.

3. Research Methodology

Data used in this article was gathered from the ISO website spanning the periods of 2005 to 2017 of selected six World Trade Organization and ISO 9001 certified countries China, Italy Germany, Japan, UK, and India. Nanjing University of Aeronautics and Astronautics designed grey system and modeling software 8.0 used to predict ISO 9001 certifications from 2018 to 2026 by actual data. Moreover, NDGM has been solved by using MATLAB. Meanwhile, Even grey model GM (1,1) and discrete grey model GM (1,1) is explained below and based on the work of (Liu et al., 2016).

3.1 Even Grey Model GM (1, 1)

The first or second data value after the last origin in EGM (1,1) is so essential for forecasting reliability in data sequence (Liu et al., 2016). If $x^{(0)}$ is the actual data sequences then the time response formula of $x^{(0)}$ follow as

$$\hat{x}^{(0)}(k)=\left(1-e^{a}\right)\left(x^{(0)}(1)-\frac{b}{a}\right)e^{-a(k-1)}, \quad k=1,2,\ldots n \tag{1}$$

Furthermore, a and b are two parameters grey development index and grey actuating quantity, whereas 'a' describe the trend of $\hat{x}^{(0)}$ and $\hat{x}^{(1)}$.

$$\hat{x}^{(1)}(k)=\left(x^{(0)}(1)-\frac{b}{a}\right)e^{-a(k-1)}+\frac{b}{a},\quad k=1,2,\ldots n \tag{2}$$

3.2 Discrete Grey Model GM (1,1)

Although the results obtained by the even gey model are satisfactory, there is a still need to get more accurate results. Despite that DGM is a forecasting model in GM (1,1) group, the accuracy level of DGM is better than EGM. Various researchers pay attention to this in order to remove the errors. Xie and Liu, (2009), conducted a study in which they analyzed that the accuracy level of DGM (1,1) is better than EGM (1,1) by using McLaurin formula. If $x^{(1)}$ indicates the generally increased sequences and $x^{(0)}$ indicates the original data sequence, then the equation of discrete grey model is given by

$$\hat{x}^{(0)}(k) = [x^{(0)}(1) - \frac{\beta_2}{1-\beta_1}]\beta_1^k + \frac{\beta_2}{1-\beta_1} \tag{3}$$

3.3 Non-homogeneous Discrete Grey Model NDGM

The mechanism of both EGM and DGM based on hypotheses that the original data sequence aligned to the homogenous trend. Non-homogenous discrete grey model (NDGM) designed based on a nonhomogeneous trend sequence, and there is no error between the original value and forecasting value (Xie et al., 2013; Ikram et al., 2019). They also proved that NDGM accuracy level is better than EGM and DGM.

If $x^{(1)}$, $x^{(0)}$ indicates the accumulated and actual data sequence then the nonhomogeneous discrete grey model represented by (Liu and Forrest, 2010).

$$\hat{x}^{(1)}(k+1)=\beta_1\hat{x}^{(1)}(k)+\beta_2.k+\beta_3 \tag{4}$$

$$\hat{x}^{(1)}(1)=x^{(1)}(1)+\beta_4 \tag{5}$$

$\hat{x}^{(1)}$(k) is the simulated value of $x^{(1)}$ with four parameters $\beta_1, \beta_2, \beta_3$ and β_4 we can rearrange the equation in matrix form If k=1,2,3….n-1

$$\begin{bmatrix} x^{(1)}(2) \\ x^{(1)}(3) \\ \vdots \\ x^{(1)}(n) \end{bmatrix} = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \end{bmatrix} \begin{bmatrix} x^{(1)}(1) & 1 & 1 \\ x^{(1)}(2) & 2 & 1 \\ \vdots & \vdots & \vdots \\ x^{(1)}(n-1) & n-1 & 1 \end{bmatrix}$$

Through applying the following relation of matrix equation satisfied parameters $\beta_1, \beta_2, \beta_3$ and β_4 by input data.

$$\hat{\beta} = (B^{\mathrm{T}}B)^{-1}B^{\mathrm{T}}Y = [\beta_1, \beta_2, \beta_3]^{\mathrm{T}} \quad \textbf{(6)}$$

Where,

$$B = \begin{bmatrix} x^{(1)}(1) & 1 & 1 \\ x^{(1)}(2) & 2 & 1 \\ \mathrm{M} & \mathrm{M} & \mathrm{M} \\ x^{(1)}(n-1) & n-1 & 1 \end{bmatrix} Y = \begin{bmatrix} x^{(1)}(2) \\ x^{(1)}(3) \\ \mathrm{M} \\ x^{(1)}(n) \end{bmatrix},$$

For minimizing the sum of square error,the formula β_4 is given by

$$\beta_4 = \frac{\sum_{k=1}^{n-1}\left[x^{(1)}(k+1) - \beta_1^k x^{(1)}(1) - \beta_2 \sum_{j=1}^{k} j\beta_1^{k-j} - \frac{1-\beta_1^k}{1-\beta_1} . \beta_3\right] . \beta_1^k}{1 - \sum_{k=1}^{n-1}\left(\beta_1^k\right)^2} \quad \textbf{(7)}$$

$$\hat{x}^{(1)}(k+1) = \beta_1^k \hat{x}^{(1)}(1) + \beta_2 \sum_{j=1}^{k} j\beta_1^{k-j} + \frac{1-\beta_1^k}{1-\beta_1} \cdot \beta_3; \quad k = 1, 2, \ldots, n-1 \quad \textbf{(8)}$$

Note: $\hat{x}^{(1)}$(k) in the equation (8) is the simulative value of $x^{(1)}$

More information about NDGM modsel, properties, parameters, and characteristics can be found in (Liu and Forrest, 2010).

3.4 Mean Absolute Percentage Error (MAPE %)

By using Mean absolute percentage error, the performance was measured with the help of three novel forecasting grey models even EGM (1,1), DGM (1,1) and NDGM, given by the following formula

$$\text{MAPE}(\%) = \frac{1}{n}\sum_{k=1}^{n}\left|\frac{x^{(0)}(k) - \hat{x}^{(0)}(k)}{x^{(0)}(k)}\right| \times 100\% \qquad \textbf{(9)}$$

Here $x^{(0)}(k)$ and $\hat{x}^{(0)}(k)$ in equation (9) are indicating model-based original sequence and forecasting sequence data values. However, the accuracy of the model represents less MAPE value (Johannesen et al., 2019). Moreover, we can interpret the MAPE % accuracy level clearly in table 2 for better understanding and comparison of our results for interpretation.

Table 2: MAPE for model evaluation based on accuracy level.

MAPE %	Forecasting accuracy
Greater than 50 %	Weak and inaccurate
20–50 %	Reasonable
10–20 %	Good
Less than 10%	Highly Accurate

Source: (Lewis, 1982)

3.5 ISO 9001 certification growth analysis

There is no model of ISO 9001 certifications output available to monitor the rate of growth. RGR model used in this way to analyze the country-wise relative growth of ISO 9001 certification; whereas D_t model is employed to investigate how much time is required to make the ISO 9001 certifications double in numbers. In order to reach this objective, the literature proposes the use of relative growth rate and doubling time models that have been used to analyze the ISO 14001 certification and research output growth over time (Ikram et al., 2019; Javed and Liu, 2018). Relative growth rate (RGR) and doubling time (D_t) measured of top ISO 9001 certified selected countries by following formula.

$$\mathrm{RGR} = (\ln N_2 - \ln N_1)/(t_2 - t_1) \qquad \textbf{(10)}$$

Javed and Liu, (2018) used to measure publication growth by using the relative growth rate and doubling time parameters. In the given years $(t_2 - t_1)$ where N_2 and N_1 in equation (10) shows the cumulative number of ISO 9001 certifications. In our case $(t_2 - t_1)$ is one year so above equation can be written as

$$\mathrm{RGR} = (\ln N_2 - \ln N_1) \qquad \textbf{(11)}$$

Whereas in specific RGR doubling time (D_t) represents the time required to convert ISO 9001 certification double in numbers by the following equation.

$$D_{\mathrm{t}} = (t_2 - t_1)\ln[2/(\ln N_2 - \ln N_1)] \qquad \textbf{(12)}$$

Similarly $(t_2 - t_1)$ is one year in our case, the above equation reduces to

$$D_{\mathrm{t}} = \ln[2/(\ln N_2 - \ln N_1)] \qquad \textbf{(13)}$$

4. Results and Discussions

The results build on the early insights regarding the diffusion of ISO standards and their genesis in the UK. What started as the spread of ISO 9000 around the world from European countries still finds the UK as an important enabler of this standard, but not the leader in the future. Building on prior insights regarding the diffusion of the standards continued globalization, and global supply chains connecting transnational corporations, we next review the results by country and discuss insights. To do this, we utilized data from 2005 to 2017 in order to measure the simulated values with the help of even grey model GM (1,1), discrete grey model GM (1,1) and NDGM in tables 3,2,3,4,5 and 7. The graphical representation of selected countries' predictions can be seen Figures 1 to 6.

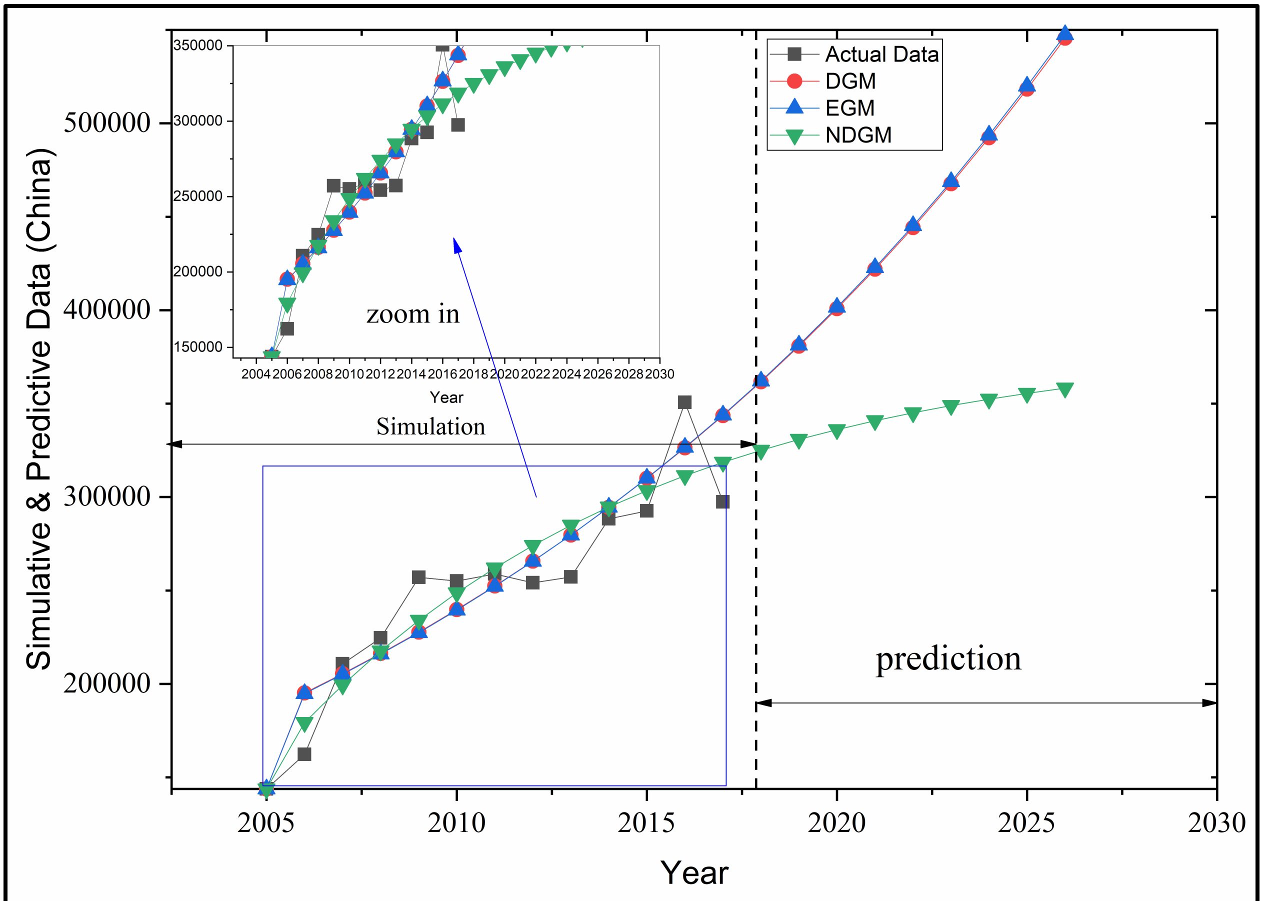

***Figure1**: Forecasting of China's ISO 9001*

Table 3: ISO 9001 growth for China

Years	Actual Data	EGM	DGM	NDGM	Cumulative	RGR	Mean RGR	Dt	Mean Dt
2005	143823	143823	143823	143823	143823				
2006	162259	194823	195201	179312	306082	0.755	0.275	0.974	2.182
2007	210773	205151	205495	199457	516855	0.524		1.340	
2008	224616	216028	216333	217620	741471	0.361		1.712	
2009	257076	227481	227741	233998	998547	0.298		1.905	
2010	255052	239541	239752	248766	1253599	0.227		2.174	
2011	258830	252241	252395	262082	1512429	0.188		2.366	
2012	254162	265614	265706	274089	1766591	0.155		2.555	
2013	257256	279695	279718	284915	2023847	0.136		2.689	
2014	288389	294524	294470	294676	2312236	0.133		2.709	
2015	292559	310138	309999	303478	2604795	0.119		2.821	
2016	350631	326581	326348	311415	2955426	0.126		2.762	
2017	297437	340895	356521	300571	318571				
2018		362127	361676	325024	643595	0.703	0.263	1.045	2.210
2019		381326	380750	330842	974438	0.415		1.573	
2020		401542	400829	336089	1310526	0.296		1.909	
2021		422831	421968	340819	1651345	0.231		2.158	
2022		445248	444221	345084	1996430	0.190		2.355	
2023		468853	467648	348930	2345360	0.161		2.519	

2024	493710	492310	352398	2697758	0.140	2.659
2025	519885	518273	355525	3053283	0.124	2.782
2026	547447	545605	358345	3411628	0.111	2.892
MAPE (%)	6.81	6.61	6.12			

Table 3 shows the ISO 9001 certification growth/output for China. The proposed models have been evaluated and the outcomes show that NDGM model contains accurateness (MAPE %) about 94.78% which shows a better picture as compared to DGM and EGM 94.10 %, 93.92% respectively. However, China's results revealed that the level of accuracy turns out to 93.19, 93.39 and 93.88 correspondingly. The model of NDGM showed a robust and an effective forecasting of ISO 9001 certifications among three grey models. According to parameters a=-0.05165881 and b=182404.0714 proposed by EGM the following equation for China is followed by

$$x^{0}(k) = 3674761.312(1 - e^{-0.05165881})e^{0.05165881\,(k-1)}$$

By using the DGM forecasting based parameters β_1= 1.053 and β_2= 187616.452 for China, the equation is given by

$$\hat{x}^{(1)}(k) = [x^{(0)}(1) - \frac{187616.452}{1-1.053}](1.053)^{k} + \frac{187616.452}{1-1.053}$$

The NDGM model forecasting equation parameters for china are β_1= 0.901682, β_2= 37773.994, β_3= 155699.619 and β_4= 213.257 respectively. By using NDGM, the simulated values (from 2005 to 2017) has been calculated and the forecasting values were attained for the next nine years.

Table 4 illustrate the outcomes for Italy, EGM, DGM, and NDGM represent accuracy level 95.12, 95.11 and 96.52% respectively. Similarly, in the case of Italy NDGM slightly indicates more effective forecasting results than EGM and DGM. The given equation with the help of EGM parameters a= -0.02400807 and b= 112892.5594 follow by

$$x^{0}(k) = 4800303.502(1 - \mathrm{e}^{-0.02400807})\mathrm{e}^{0.02400807(k-1)}$$

For Italy, the results revealed according to DGM parameters β_1= 1.024 and β_2= 114393.563 the following forecasting equation is

$$\hat{x}^{(1)}(k) = [x^{(0)}(1) - \frac{114393.563}{1-1.024}](1.024)^{k} + \frac{114393.563}{1-1.024}$$

Likewise, by using the following NDGM parameters β_1= 0.634736, β_2= 51628.533, β_3= 86794.485 and β_4= 496.497 the NDGM equation can be generated for Italy.

Table 4: ISO 9001 growth for Italy

Years	Actual Data	EGM	DGM	NDGM	Cumulative	RGR	Mean RGR	Dt	Mean Dt
2005	98028	98028	98028	98028	98028				
2006	105799	116641	116758	102436	203827	0.732	0.251	1.005	2.284
2007	115359	119475	119574	116648	319186	0.449		1.495	
2008	118309	122378	122459	125669	437495	0.315		1.847	
2009	130066	125351	125413	131395	567561	0.260		2.039	
2010	143305	128397	128438	135030	710866	0.225		2.184	
2011	142853	131517	131536	137337	853719	0.183		2.391	
2012	136547	134713	134709	138801	990266	0.148		2.601	
2013	135939	137986	137958	139731	1126205	0.129		2.744	
2014	139416	141339	141286	140321	1265621	0.117		2.841	
2015	132870	144773	144694	140695	1398491	0.100		2.997	
2016	150143	148291	148184	140933	1548634	0.102		2.976	
2017	125994	151894	151758	134084	141084				
2018		155585	155419	141179	282263	0.693	0.256	1.059	2.247
2019		159366	159168	141240	423503	0.406		1.595	
2020		163238	163007	141279	564782	0.288		1.938	
2021		167205	166939	141303	706085	0.223		2.192	
2022		171267	170966	141319	847404	0.182		2.394	
2023		175429	175090	141329	988733	0.154		2.562	
2024		179692	179313	141335	1130067	0.134		2.706	
2025		184058	183638	141339	1271406	0.118		2.832	
2026		188530	188068	141341	1412748	0.105		2.943	
MAPE (%)		4.88	4.89	3.48					

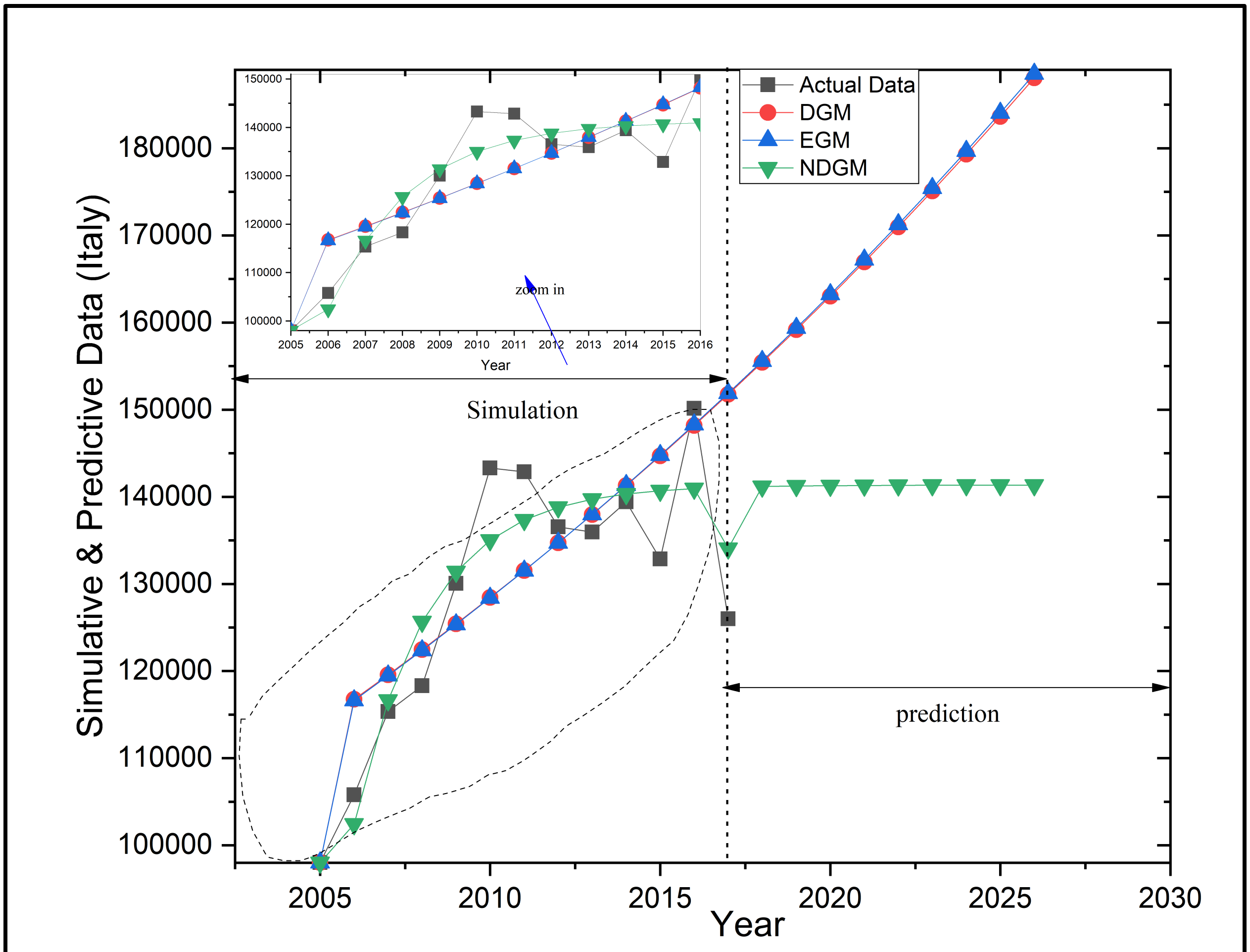

***Figure2**: Forecasting of Italy's ISO 9001*

Table 5 present the result for Germany, the level of accuracy for MAPE % attained through NDGM, DGM, and EGM. NDGM shows a somewhat more suitable forecasting model as compared to DGM and EGM forecasting models for ISO 9001 prediction turn out to 96.07, 96.06 and 96.62 % respectively in table 7. The outcomes revealed the EGM based forecasting equation with the help of parameters a= -0.0306286, b= 42331.697 for Germany.

$$x^0(k) = 14219013.037(1 - \mathrm{e}^{-0.03062860807})\mathrm{e}^{0.03062860807(k-1)}$$

For Italy, the results revealed according to DGM parameters β_1 = 1.031 and β_2 = 43033.465 the following forecasting equation for Germany is following as

$$\hat{x}^{(1)}(k) = [x^{(0)}(1) - \frac{43033.465}{1-1.031}](1.031)^{k} + \frac{43033.465}{1-1.031}$$

Using the parameters β_1= 1.184677, β_2= -7756.445, β_3= 46017.624 and β_4= 142.733, NDGM forecasting based equation can be generated for Germany.

Table 5: ISO 9001 growth for Germany

Years	Actual Data	EGM	DGM	NDGM	Cumulative	RGR	Mean RGR	Dt	Mean Dt
2005	39816	39816	39816	39816	39816				
2006	46458	44225	44266	45641	86274	0.773	0.248	0.950	2.294
2007	45195	45601	45636	46313	131469	0.421		1.558	
2008	48324	47019	47048	47110	179793	0.313		1.855	
2009	47156	48481	48505	48053	226949	0.233		2.150	
2010	50583	49989	50006	49171	277532	0.201		2.297	
2011	49540	51544	51554	50495	327072	0.164		2.500	
2012	51701	53147	53149	52064	378773	0.147		2.612	
2013	56303	54800	54795	53923	435076	0.139		2.669	
2014	55344	56504	56491	56125	490420	0.120		2.816	
2015	52995	58262	58239	58733	543415	0.103		2.970	
2016	66233	60074	60042	61824	609648	0.115		2.856	
2017	73559	61942	61900	72485	65485				
2018		63869	63816	69822	135306	0.726	0.301	1.014	2.016
2019		65855	65791	74960	210266	0.441		1.512	
2020		67904	67827	81047	291313	0.326		1.814	
2021		70016	69927	88258	379570	0.265		2.023	
2022		72193	72091	96800	476371	0.227		2.175	
2023		74439	74323	106921	583292	0.202		2.290	
2024		76754	76623	118910	702202	0.186		2.378	
2025		79141	78995	133114	835316	0.174		2.444	
2026		81603	81440	149941	985256	0.165		2.494	
MAPE (%)		3.93	3.94	3.38					

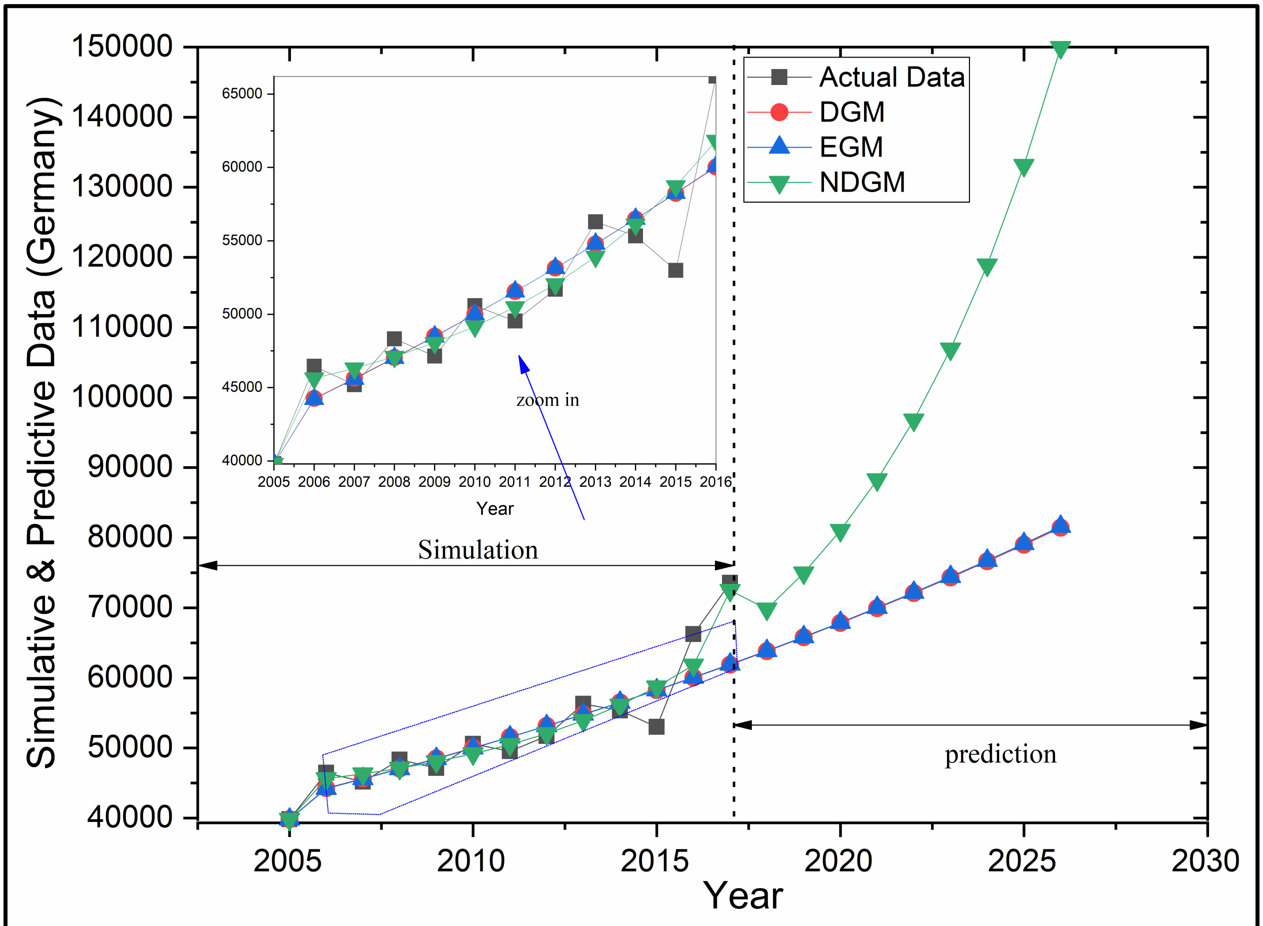

Figure3: *Forecasting of Germany's ISO 9001*

Table 6 represents the results for Japan, the level of accuracy level for EGM, DGM and NDGM obtained 94.16, 94.08 and 95.59 % respectively. These results reveal that NDGM shows suitable forecasted results as compared to EGM and DGM. Meanwhile, the EGM based forecasted equation through the parameters a=0.05969393, b= 82350.2471 for Japan is following as

$$x^0(k) = -1325770.389(1 - \mathrm{e}^{0.05969393})\mathrm{e}^{-0.05969393(k-1)}$$

By using parameters $\beta_1 = 0.942$ and $\beta_2 = 80040.633$ for Japan,the DGM forecasting based equation is

$$\hat{x}^{(1)}(k) = [x^{(0)}(1) - \frac{80040.633}{1-0.942}](0.942)^k + \frac{80040.633}{1-0.942}$$

The NDGM forecasting based equation can be generated by using parameters β_1= 0.808538, β_2= 7837.529, β_3= 83321.266 and β_4= -155.628 respectively.

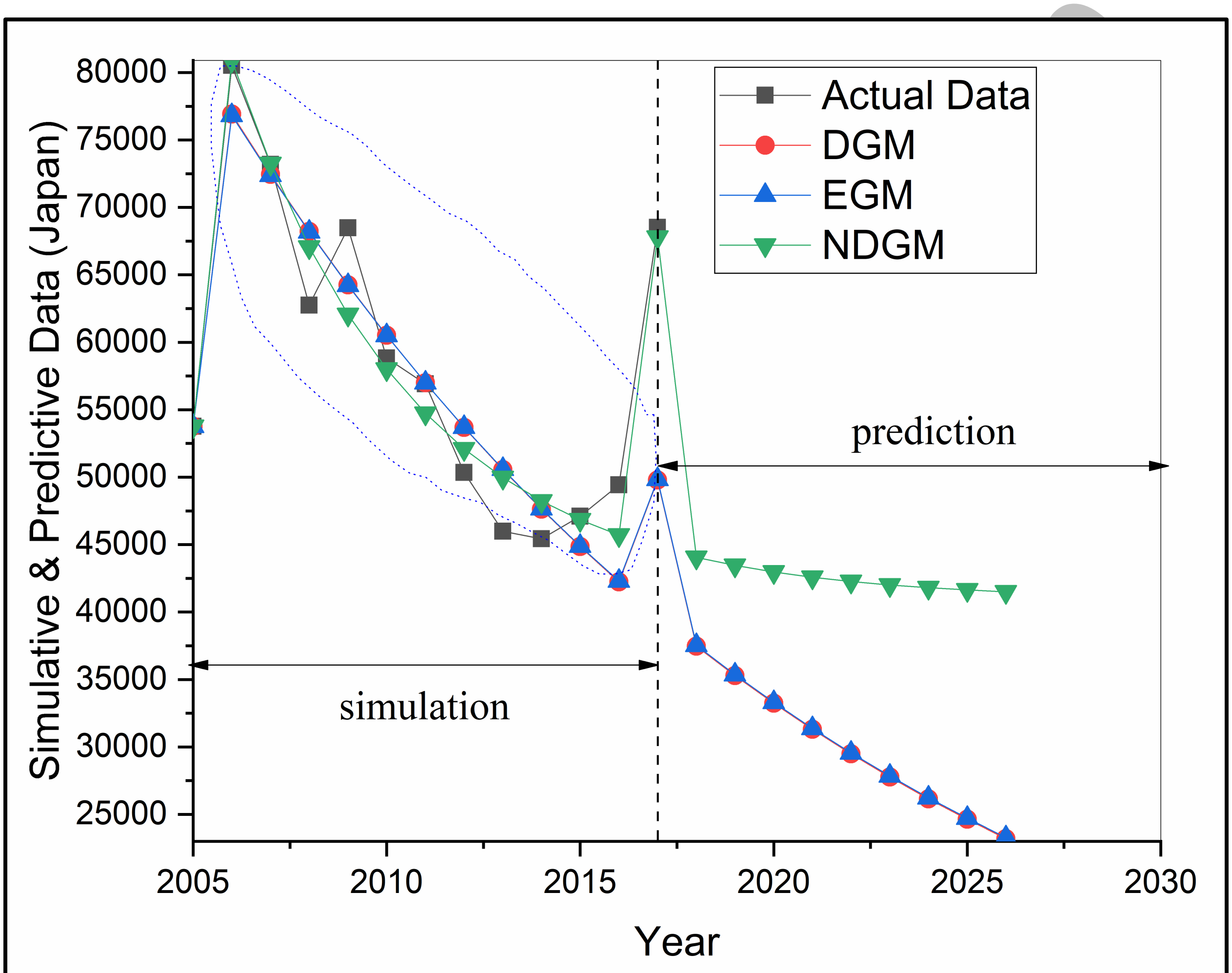

***Figure 4**: Forecasting of Japan's ISO 9001*

Table 6: ISO 9001 growth for Japan

Years	Actual Data	EGM	DGM	NDGM	Cumulative	RGR	Mean RGR	Dt	Mean Dt
2005	53771	53771	53771	53771	53771				
2006	80518	76825	76913	80894	134289	0.915	0.232	0.782	2.510
2007	73176	72373	72439	73243	207465	0.435		1.526	
2008	62746	68179	68225	67057	270211	0.264		2.024	
2009	68484	64228	64257	62056	338695	0.226		2.181	

2010	58836	60506	60519	58012	397531	0.160		2.525	
2011	56912	57000	56999	54743	454443	0.134		2.705	
2012	50339	53697	53683	52099	504782	0.105		2.946	
2013	45990	50586	50561	49962	550772	0.087		3.133	
2014	45433	47654	47620	48233	596205	0.079		3.228	
2015	47101	44893	44850	46836	643306	0.076		3.270	
2016	49429	42292	42241	45706	692735	0.074		3.296	
2017	68508	49841	49784	67793	44793				
2018		37532	37470	44054	88847	0.685	0.251	1.072	2.273
2019		35357	35290	43457	132304	0.398		1.614	
2020		33308	33237	42974	175278	0.281		1.962	
2021		31378	31304	42584	217862	0.217		2.219	
2022		29560	29483	42268	260131	0.177		2.423	
2023		27847	27768	42013	302144	0.150		2.592	
2024		26233	26153	41807	343950	0.130		2.736	
2025		24713	24632	41640	385590	0.114		2.862	
2026		23281	23199	41505	427095	0.102		2.974	
MAPE (%)		5.84	5.92	4.41					

Results in table 7 indicate that the accuracy level of the United Kingdom through EGM, DGM and NDGM obtained is 95.75, 95.71 and 95.90 % respectively. NDGM revealed to some extent, better forecasted values than DGM and EGM. Meanwhile, the following EGM based forecasting equation for the United Kingdom through the parameters a=-0.00050792, b= 40517.553 is given by

$$x^0(k) = 79817136.260(1 - \mathrm{e}^{0.05969393})\mathrm{e}^{-0.05969393(k-1)}$$

Using the parameters β_1= 1.01 and β_2= 40561.917 for the United Kingdom, the DGM forecasting based equation is

$$\hat{x}^{(1)}(k) = [x^{(0)}(1) - \frac{40561.917}{1-1.012}](1.012)^k + \frac{40561.917}{1-1.012}$$

Thus, the NDGM forecasting based equation can be generated by using parameters β_1= 0.487435, β_2= 21177.4537, β_3= 41049.0120 and β_4= 68.622 respectively.

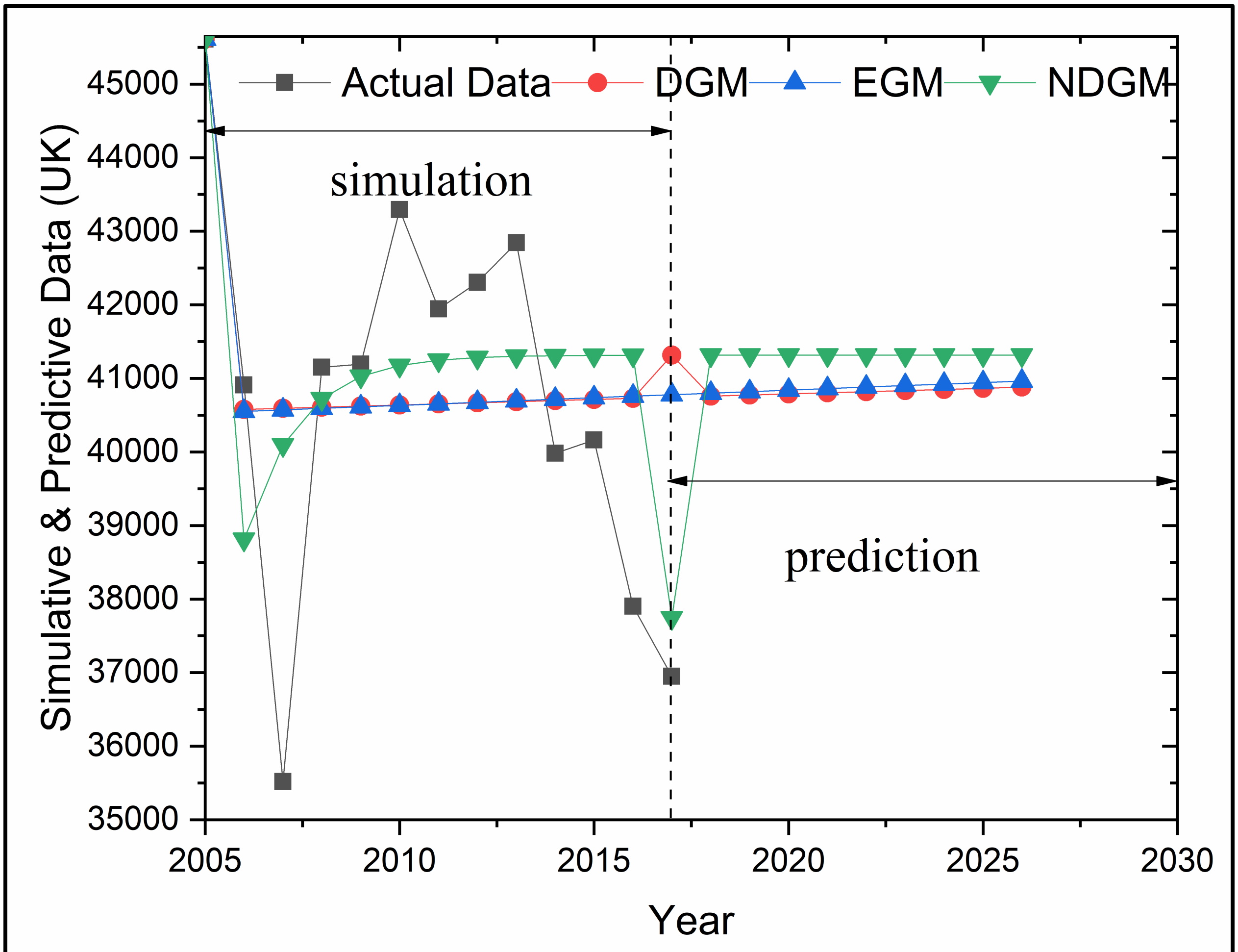

Figure 5: *Forecasting of UK's ISO 9001*

Table 7: ISO 9001 growth for the United Kingdom

Years	Actual Data	EGM	NDGM	DGM	Cumulative	RGR	Mean RGR	Dt	Mean Dt
2005	45612	45612	45612	45612	45612				
2006	40909	40551	38812	40579	86521	0.640	0.216	1.139	2.424
2007	35517	40572	40096	40594	122038	0.344		1.760	
2008	41150	40592	40722	40609	163188	0.291		1.929	
2009	41193	40613	41027	40624	204381	0.225		2.184	
2010	43293	40633	41175	40639	247674	0.192		2.343	
2011	41943	40654	41248	40654	289617	0.156		2.548	
2012	42304	40675	41283	40669	331921	0.136		2.686	
2013	42843	40695	41300	40684	374764	0.121		2.802	
2014	39982	40716	41309	40699	414746	0.101		2.982	
2015	40161	40737	41313	40715	454907	0.092		3.074	
2016	37901	40758	41315	40730	492808	0.080		3.219	
2017	36950	40778	41316	37745	40745				
2018		40799	41316	40760	81505	0.693	0.256	1.059	2.247
2019		40820	41316	40775	122280	0.406		1.595	

2020	40840	41316	40790	163070	0.288	1.938
2021	40861	41317	40805	203875	0.223	2.192
2022	40882	41317	40820	244695	0.183	2.394
2023	40903	41317	40836	285531	0.154	2.562
2024	40923	41317	40851	326382	0.134	2.705
2025	40944	41317	40866	367248	0.118	2.830
2026	40965	41317	40881	408129	0.106	2.942
MAPE (%)	4.25	4.29	4.10			

The level of accuracy (Table 8) for India, through EGM, DGM and NDGM appeared to 89.23%, 89.73% and 90.19 % respectively. In the same way, NDGM presented a better picture of forecasted outcomes as compared to DGM and EGM. For the meantime, EGM oriented forecasting model for India through the parameters a= 0.01294037, b= 40235.097 is given by

$$x^{0}(k) = -3084609.441(1 - \mathrm{e}^{0.01294037})\mathrm{e}^{-0.01294037(k-1)}$$

Similarly using the parameters β_1=0.986 and β_2=40151.628 for India, the DGM forecasting based equation is

$$\hat{x}^{(1)}(k) = [x^{(0)}(1) - \frac{40151.628}{1-0.986}](0.986)^{k} + \frac{40151.628}{1-0.986}$$

The NDGM forecasting based equation can be generated by using parameters β_1= 0.522714, β_2= 16855.9571, β_3= 38799.9581 and β_4= 119.786 respectively.

Table 8: ISO 9001 growth for India

Years	Actual Data	EGM	DGM	NDGM	Cumulative	RGR	Mean RGR	Dt	Mean Dt
2005	24660	24660	24660	24660	24660				
2006	40967	39659	39814	43829	65627	0.979	0.261	0.715	2.362
2007	46091	39149	39270	39766	111718	0.532		1.324	
2008	37958	38646	38733	37642	149676	0.292		1.922	
2009	37493	38149	38204	36532	187169	0.224		2.191	
2010	33932	37658	37682	35952	221101	0.167		2.485	
2011	29574	37174	37166	35648	250675	0.126		2.768	
2012	28600	36696	36658	35490	279275	0.108		2.918	
2013	40848	36224	36157	35407	320123	0.137		2.685	
2014	40481	35759	35663	35364	360604	0.119		2.821	
2015	36305	35299	35175	35341	396909	0.096		3.037	
2016	37052	34845	34694	35329	433961	0.089		3.109	
2017	33947	34397	34220	33323	35323				

2018	33955	33752	35320	70643	0.693	0.256	1.060	2.248
2019	33518	33291	35318	105961	0.405		1.596	
2020	33087	32836	35317	141278	0.288		1.939	
2021	32662	32387	35317	176595	0.223		2.193	
2022	32242	31944	35317	211912	0.182		2.395	
2023	31827	31507	35316	247228	0.154		2.563	
2024	31418	31077	35316	282544	0.134		2.707	
2025	31014	30652	35316	317861	0.118		2.832	
2026	30615	30233	35316	353177	0.105		2.944	
MAPE (%)	10.77	10.27	9.81					

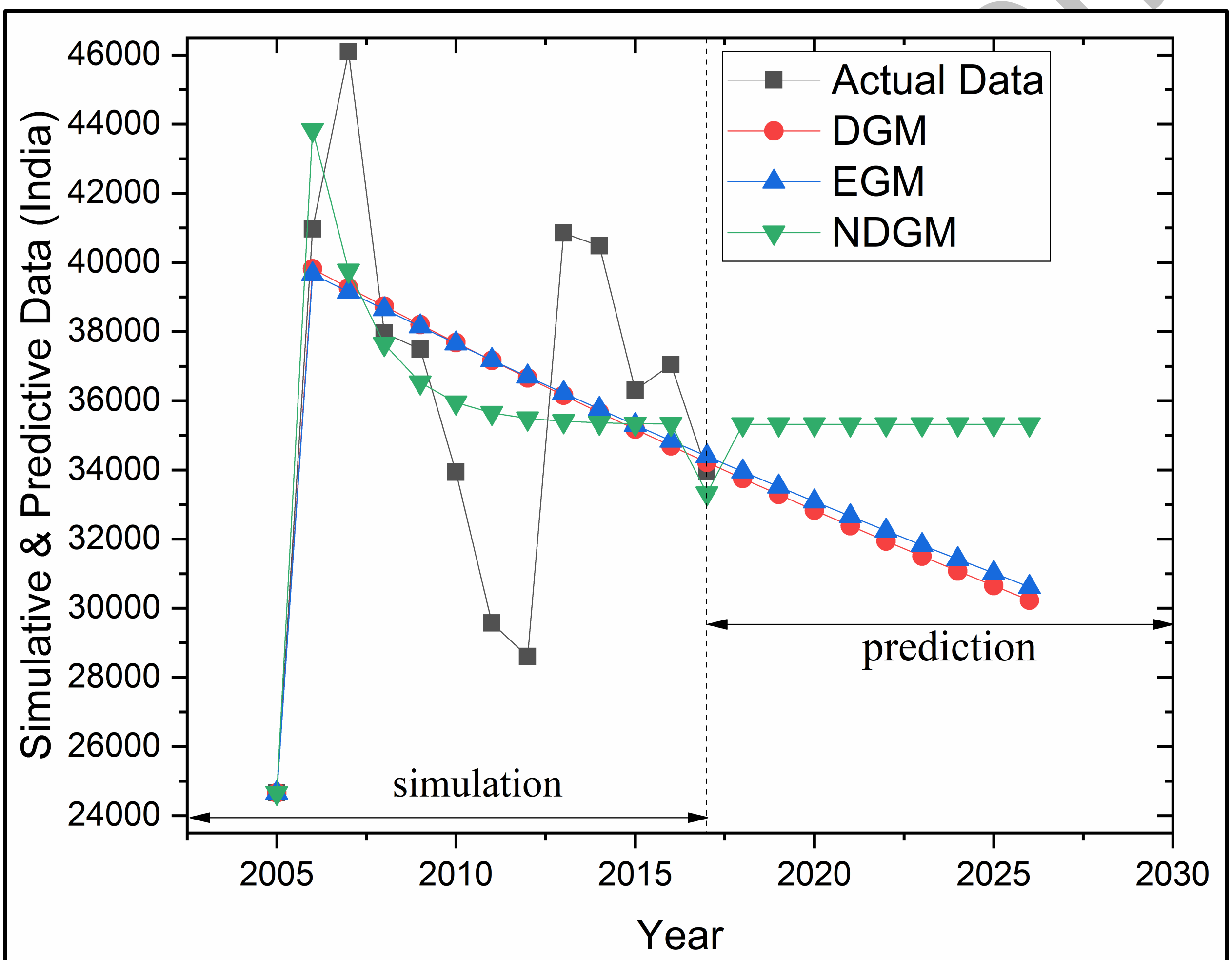

Figure 6: *Forecasting of India's ISO 9001*

The accuracy in forecasting ISO 9001 certification was a major focus of our attention. The results reveal the NDGM accuracy level was most effective as compared to EGM and DGM as shown in table 9. For a more clear understanding, Figures 1, through 6 present comparisons between actual and simulated based data from 2005 to 2017 among six countries against a total number of ISO 9001 certifications for each of three grey models. Our forecasting of the uptake of the ISO 9001 standard is significant for the certification bodies to understand market diffusion and trends. Presenting the country-level results in this way enables researchers, management decision-makers and policymakers insights they can apply to an individual company context, industry, or country-level considerations involving the viability and future of quality management.

A linear growth rate found China has an essential growth line among all six countries followed by Italy. Meanwhile, the other countries are nearest to each other, in the long run, one would observe that on forecasting base data China is likely to a leader in ISO 9001 certifications. According to the mean relative growth rate (RGR) based on actual data following the pattern of results was obtained

$$China_{(0.275)} > India_{(0.261)} > Italy_{(0.251)} > Germany_{(0.248)>}Japan_{(0.232)>}UK_{(0.216)}$$

According to doubling time mean value based on actual data, the following sequence of the result was obtained

$$Japan_{(2.510)} > UK_{(2.424)} > India_{(2.362)} > Germany_{(2.294)>}Italy_{(2.284)>}China_{(2.182)}$$

The results reveal that the relative growth rate of China is 0.275 which appeared higher among all six countries followed by India, Italy, Germany, Japan, and the UK. The implications of these results are that the world's largest economy while having unprecedented economic growth in recent years, is on track to have parallel growth in ISO certifications into the future. With industry and services making up over 90% of gross domestic product, quality management certifications will remain important to these business sectors in China. Meanwhile, Japan required almost (2.510) years to increase ISO 9001 certification double in number followed by UK, India, Germany, Italy, and China. The time it takes for ISO certification growth within a county can be a lagging indicator of industry growth, can influence labor productivity (Albulescu et. al, 2016), and can indicate the viability of country-level outputs. The International Organization of Standards itself, collects annual data on the number of certifications, the number of sectors per country covered, and the number of sites per country covered. This data collection and reporting provides a more comprehensive picture of country-level situations and comparable data from year to year that helps to inform research, decision making within industries, and inform policymakers.

The outcomes of the study also indicated that the growth rate of ISO 9001 certification in developing countries like China and India is increasing while the countries that are developed is decreasing. However rising relative growth of ISO 9001 is a source of competitive advantage for companies over competitors which improves company quality performance, reduces managerial cost, enhances customer satisfaction and improves processes (Molina-Azorín et al., 2015).

Using the NDGM forecasted/simulated oriented data to forecast the future tendency of ISO 9001 certification among six countries, according to relative growth rate represent the following sequence was obtained.

$$Germany_{(0.301)} > China_{(0.263)} > India_{(0.257)} > Italy_{(0.256)>}UK_{(0.255)>}Japan_{(0.251)}$$

Likewise, according to doubling time, and based on NDGM simulated data, the following sequences was obtained

$$Japan_{(2.510)} > India_{(2.424)} > Uk_{(2.362)} > Italy_{(2.294)>}China_{(2.284)>}Germany_{(2.182)}$$

These interesting results reveal that Germany expected higher growth rate which is (30.1%) in the next nine years followed by China, India, Italy, UK, and Japan. Correspondingly, the relative growth rate Japan needed nearly (2.510) years to make double values of ISO 9001 certification in numbers followed by India, UK, Italy, China, and Germany.

A critical question is, what countries will have more certifications in the long run? Our study proposes a novel grey synthetic model in order to measure both doubling time and relative growth rate through actual and forecasted data. Javed et al. (Javed and Liu, 2018) proposed two synthetic grey indices such as synthetic doubling time and Synthetic relative growth. The synthetic relative growth rate has been obtained through actual and forecasted/simulated data.

$$\mathrm{RGR}_{\mathrm{synthetic}} = \alpha(\mathrm{RGR}_{\mathrm{actual}}) + (1-\alpha)(\mathrm{RGR}_{\mathrm{simulated}})$$

Here, α represents the relative weight's coefficients and it can be considered as 0.5.

If decision-makers consider the relative growth rate of actual data more important in decision making, then it becomes $1-\alpha<\alpha$. With a doubling orientation, the synthetic doubling time pattern is as follows,

$$\mathrm{D}_{\mathrm{synthetic}} = \alpha(\mathrm{D}_{\mathrm{actual}}) + (1-\alpha)(D_{\mathrm{forecasted}})$$

Here, $\mathrm{D}_{\mathrm{synthetic}}$ shows the doubling time and it has been obtained through actual data and $\mathrm{D}_{\mathrm{forecasted}}$ represent the doubling time obtained through simulated/forecasting data. The value of α characterizes the relative weights coefficient. With the help of synthetic grey model accompanying with the value of relative growth rate α =0.5 the subsequent order of the outcomes was attained which is given as,

$$Germany_{(0.275)} > China_{(0.269)} > India_{(0.259} > Italy_{(0.254)>}Japan_{(0.242)>}UK_{(0.236)}$$

Similarly, through the synthetic grey model and by using doubling time at α =0.5 the succeeding order of outcomes were attained, and the pattern is given as,

$$Japan_{(2.392)} > UK_{(2.337)} > India_{(2.305)} > Italy_{(2.266)>}China_{(2.196)>}Germany_{(2.155)}$$

After employing the two synthetic grey indices such as the synthetic doubling time and synthetic RGR we obtain a parallel sequence obtained from the forecasted data whereas the outcomes are consistent with simulated data. The finding suggest that Germany and China required less time to double ISO 9001 certifications in number for a given relative growth rate followed by Italy, India, Uk, and Japan.

The results obtained through the proposed grey prediction models Even GM (1,1), Discrete GM (1,1) and NDGM showed robust results given in table 9.

Table 9: MAPE % by EGM, DGM, and NDGM

	MAPE %		
	EGM	**DGM**	**NDGM**
China	6.81	6.61	6.12
Italy	4.88	4.89	3.48
Germany	3.93	3.94	3.38
Japan	5.84	5.92	4.41
UK	4.25	4.29	4.10
India	10.77	10.27	9.81
Average MAPE %	6.08	5.99	5.22
Over all accuracy Level %	93.92	94.01	94.78

The growth of ISO quality management certifications has plateaued when compared to the boom of this standard over two decades ago. Changes in diffusion can reflect global economic uncertainty and changing political systems. In countries with longer-established traditions of certification, many of the large transnational companies are already certified and are branching out to other standards. The situation is expected to improve as markets improve and because of the introduction of the newest version of the standard since 2015 (ISO, 2014).

ISO standards enable trade by reducing transaction costs and technical barriers to trade (TBT) by improving the information on product requirements. The World Trade Organization's 2018 TBT agreement establishes rules for the preparation, adoption and application of international standards. It leaves room for WTO members, i.e., those countries in this study and others beyond this study, to achieve legitimate policy objectives beyond only quality such as the protection of the environment and consumer safety. This kind of trade agreement requires that the technical regulations and standards of WTO members be based on relevant international standards. Here we see ISO standards such as 9001 not going away over time, and affecting trade and GDP, globalization and global supply chains as they determine which products can be traded, along with the variety, quality and safety of products and services (Villarreal, 2019). Standards such as ISO 9001 enable economic development by promoting trade, specifically exports from developing countries, and they can be a tool for achieving sustainable development as they support countries in achieving national policies involving healthcare and protection of the environment that transform economic growth into sustainable development and transforming our world, making the 2030 Global Agenda from the United Nations a reality (UN, 2020).

5. Conclusion

We can predict the future of quality management system certifications utilizing novel grey forecasting methods. Understanding and predicting ISO standards diffusion can consider uncertainty while providing new insights with the help of novel modeling techniques. To accomplish the goals of this study, we conducted a forecasting analysis of ISO 9001 certification for nine years on historical data from 2005 to 2017 of nominated countries such as China, Italy, Germany, Japan, UK, and India. The results obtained through the grey prediction models Even GM (1,1), Discrete GM (1,1) and NDGM showed robust results. The outcomes of our modeling and insights show that the relative growth rate of China and India is higher followed by Itlay, Germany, Japan, and then the UK. Doubling time analysis showed Japan required (2.510) years to double ISO 9001 certification in numbers. We also concluded that the NDGM model presented more accurate results over EGM and DGM. It indicates that the growth rate of Germany and China reported higher by simulated data followed by India, Italy, Uk, and Japan. Further, the results of this study provide two novel grey models synthetic relative growth rate and synthetic doubling time in order to draw a certification growth and doubling time comparison of six WTO countries when simulated data and actual data show a different sequence of results in given period. The contributions of this study reveal that according to NDGM forecasting data, Germany is likely to continue in leading ISO 9001 certification till 2026. However, the ISO 9001 growth rate difference between China and Japan is likely to increase with time and other factors such as globalization, political uncertainty, and the expansion of global supply chains were not taken into account in this study but will be important to consider in future research.

Limitations of this study include the evaluation of a relatively small set of top-performing countries, forecasting from historical data and modeling methods enabling our focus on doubling times and growth rates. The advanced modeling methods employed in this study are not easy to operationalize, yet they are robust and help overcome issues surrounding sample size, incomplete information, and uncertainty. There is more work for scholars to do in predicting the future of standards certification across other countries, extending the findings from this study to examine economic impacts, supply chain implications, and to explain why and how some countries and industry sectors create more value from standards than do other countries of sectors.

Based on our findings, this study has implications for both practitioners and scholars. From an academic point of view, it provides a new contribution to studying ISO 9001 future scenarios by utilizing grey forecasting models. For practitioners, this study can help certification bodies learn about ISO 9001 diffusion trends. Our findings shed new light on forecasting the ISO 9001 certification market and its growth in the future. Several modeling and insights for future research come out of the evolution/diffusion of ISO 9001certification. The use of NDGM grey models presents more accurate results as other grey models could also be applied to other international management standards to analyze future trends in different countries and different industry sectors. Future research can investigate relationships between certification bodies and the growth of certification? Additionally, the approach used in this study can be used to compare and contrast grey forecasting models to other forecasting models while exploring significant relationships with new performance variables as we continuously look for new relationships to test, predict, and explain.

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