

Recovery from the Pandemic: The Study of Fluctuations and Short-Term Forecasting in The Canadian Health System Workforce

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Abstract. The healthcare industry is an area that should be meticulously planned to meet the needs of the population under any circumstances. Studying changes in the healthcare and social assistance workforce can provide direction and data support for these plans. However, at times, the factors influencing workforce changes are diverse and unpredictable. The grey system is a simple method used for handling incomplete data and conducting short-term forecasts. Its main advantages lie in its adaptability to small sample sizes and incomplete data, as well as its interpretability. Nearly all businesses were significantly impacted by the COVID-19 epidemic in 2020, but the healthcare industry was particularly heavily afflicted. By establishing a grey forecasting model based on data of the healthcare and social assistance industry workforce in Canada, this study aimed to simulate trends and predict future values of the industry's labour force. The results indicate that the data has consistently grown at a relatively constant rate in the decade, with noticeable fluctuations in growth rate occurring during the COVID-19 pandemic. However, after 2021, the growth rate gradually returned to pre-pandemic levels.

Keywords: Grey System; grey model; GM (1,1) model; health system; workforce.

1. Introduction

Unprecedented problems were undoubtedly presented to health systems across the world by the COVID-19 epidemic, and Canada's health system faced labor shortages as one of its most critical challenges during this period. Studying the employment figures in the healthcare industry contributes to a better understanding of the healthcare system's functioning, the challenges it encountered, and future preparedness for similar situations.

Grey systems were first proposed by Professor Deng in 1982 [1]. Grey systems are suitable for situations where data may be insufficient or influenced by various factors due to their minimal data sample and integrity requirements [2]. Also, with the emphasis on trends and regularities, grey systems are frequently employed for short-term forecasting of indicators, such as the employment figures in the Canadian healthcare and social assistance industry studied in this paper. The GM (1,1) model is used in this study to suit the latest workforce statistics for the Canadian healthcare and social assistance systems, followed by providing future forecasts. Given the inherent limitations of achieving long-term and highly accurate forecasts, coupled with the fact that grey systems are more suited for short-term predictions, a two-year forecast period is chosen. The study observes the impact of the pandemic by analyzing trends in the pre-pandemic, during-pandemic, and post-pandemic periods, along with some discussions on the development of Canada's health system during and after the pandemic.

2. Method

The original data constitutes a non-negative sequence [3, 4]: $X^{(0)} = \{x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(n)\}$. To enhance the inherent coherence of the initial sequence, mitigate stochastic fluctuations, and achieve the Accumulating Generation Operator [5] of X^0 , let: $X^{(1)} = \{x^{(1)}(1), x^{(1)}(2), \dots, x^{(1)}(n)\}$, where:

$$x^{(1)}(k) = \left\{ \sum_{i=1}^k x^{(0)}(i) \right\}, k=1, 2, 3, \dots, n. \quad (1)$$

Subsequently, the sequence represents the generated mean values of consecutive neighbours in $X^{(1)}$ is [6]: $Z^{(1)} = \{z^{(1)}(2), z^{(1)}(3), \dots, z^{(1)}(n)\}$, where:

$$z^{(1)}(k) = \frac{1}{2}(x^{(1)}(k) + x^{(1)}(k-1)), k = 2, 3, \dots, n. \quad (2)$$

Establish GM (1,1) model:

$$x^{(0)}(k) + az^{(1)}(k) = u. \quad (3)$$

and the corresponding grey first-order differential equation:

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = u. \quad (4)$$

Here, the parameters a and u serve as identification parameters, and their values can be computed using the least squares method.

$$\begin{pmatrix} a \\ u \end{pmatrix} = (B^T B)^{-1} B^T Y \quad (5)$$

$$\text{Where: } B = \begin{pmatrix} -z^{(1)}(2)1 \\ -z^{(1)}(3)1 \\ \vdots \\ -z^{(1)}(n)1 \end{pmatrix}, \quad Y = \begin{pmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{pmatrix}.$$

The result of differential equation (4) is given by:

$$\hat{x}^{(1)}(k+1) = (x^{(0)}(1) - \frac{u}{a})e^{-ak} + \frac{u}{a}, k = 1, 2, 3, \dots, n. \quad (6)$$

Following a single instance of cumulative subtraction, the predictive value is obtained as:

$$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) = e^{-ak}(1 - e^a)(x^{(0)}(1) - \frac{u}{a}), k = 1, 2, \dots, n. \quad (7)$$

Let the $\varepsilon^{(0)}(k)$ denote as:

$$\varepsilon^{(0)}(k) = \frac{x^{(0)}(k) - \hat{x}^{(0)}(k)}{x^{(0)}(k)} 100\%. \quad (8)$$

Then, the accuracy of the model p° can be calculated as [3]:

$$p^\circ = (100 - (\frac{1}{n} \sum_{k=1}^n |\varepsilon^{(0)}(k)|))\%. \quad (9)$$

3. Analysis and Forecast to Canada's Health System Workforce

This article's main goal is to examine how recent worldwide events, notably the COVID-19 pandemic, have affected the workforce figures of the Canadian healthcare and social support industries. The article aims to provide forecasts for the upcoming years. Therefore, this study focused

on the period from 2012 to 2022, with particular emphasis on the years surrounding the outbreak of the pandemic, from 2018 to 2022.

3.1. Data

Below are the healthcare and social assistance workforce statistics within Canada from 2012 to 2022 (Table 1) and the number of cumulative workforces across all industries (Table 2), the data is sourced from Statistics Canada [7]. (Note: All industrial sectors are included in the industrial aggregate, although those primarily involved in agriculture, fishing, and trapping, private home services, religious groups, and military personnel employed by the defence forces are excluded.

Table 1. The number of workforces in Healthcare and Social Assistance industry.

Year	Healthcare & social assistance	Year	Healthcare & social assistance	Year	Healthcare & social assistance
2012	1720554	2016	1908828	2020	2023386
2013	1752567	2017	1957406	2021	2155721
2014	1790862	2018	2015661	2022	2223413
2015	1837557	2019	2078156		

Table 2. The number of workforces across all the industrial sectors in Canada.

Year	2012	2013	2014	2015	2016	2017
Workforce number	60449176	61269017	62048599	62699751	63366517	64601913
Year	2018	2019	2020	2021	2022	
Workforce number	66029886	67450001	61873210	65346648	69403585	

3.2. GM (1,1) Model of Healthcare & Social Assistance Workforce from 2018 to 2022

The data of the number of workforces in Healthcare and Social Assistance industry from 2018 to 2022 is utilized as raw input $X^{(0)}$ for generating the GM (1,1) model, then the calculation gives:

$$\hat{x}^{(1)}(k+1) = 74061484.98610996e^{0.02710146k} - 72045823.98610996, k = 1, 2, \dots, 6. \quad (10)$$

And the prediction values are:

$$\begin{aligned} \hat{X}^{(0)} &= \{\hat{x}^{(0)}(2), \hat{x}^{(0)}(3), \hat{x}^{(0)}(4), \hat{x}^{(0)}(5), \hat{x}^{(0)}(6), \hat{x}^{(0)}(7)\} \\ &= \left\{ \begin{array}{l} 2034620.27622619, 2090515.45128524, 2147946.18097889, \\ 2206954.65012966, 2267584.20246321, 2329879.37244593 \end{array} \right\}. \end{aligned} \quad (11)$$

Performing ratio test on the forecasted data:

$$\lambda(k) = \frac{x^{(0)}(k-1)}{x^{(0)}(k)}, k = 1, 2, \dots, 5 \text{ and determine if the test values fall within the interval}$$

$(e^{-\frac{2}{n+1}}, e^{\frac{2}{n+1}})$. In this case, $n=5$ and all forecasted values falls within the specified range; hence, the original data $X^{(0)}$ is suitable for constructing a non-aberrant GM (1,1) model [3] with a theoretical accuracy p° of 99.9869730225871%, Figure. 1 illustrates the employment numbers in the Healthcare and Social Assistance industry from 2018 to 2022, along with the fitted and forecasted values provided by the GM (1,1) model. Note that there is a significant decrease of employment in 2020.

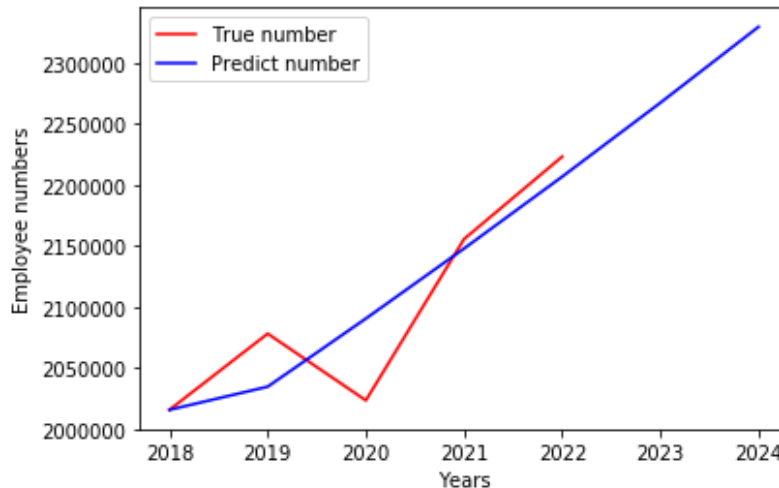


Fig.1 The employments in Healthcare & Social assistance prediction (4 years)

3.3. GM (1,1) Model of Healthcare & Social Assistance Workforce from 2012 to 2022.

In section 3-b, an exploration of the changing trend in healthcare industry employment over recent years was conducted. To form a comprehensive understanding of this trend and facilitate a comparison with the results from section 3-b, the same methodology was applied to the healthcare employment data from 2012 to 2022.

Applying the aforementioned process to the data of healthcare industry employment from 2012 to 2022 yields the following results:

$$a = -0.02542447, u = 1690161.44800056, \tag{12}$$

$$\hat{x}^{(1)'}(k+1) = 68198303.02348685e^{0.02542447k} - 66477749.02348685, k = 1, 2, \dots, 12.$$

The prediction values are:

$$\hat{X}^{(0)'} = \{\hat{x}^{(0)'}(2), \hat{x}^{(0)'}(3), \dots, \hat{x}^{(0)'}(13)\}$$

$$= \left\{ \begin{array}{l} 1756135.42770646, 1801356.66494726, 1847742.36835927, \\ 1895322.52344365, 1944127.88784109, 1994190.01121469, \\ 2045541.25564471, 2098214.81654894, 2152244.74414128, \\ 2207665.96544324, 2264514.30686195, 2322826.51734993 \end{array} \right\}. \tag{13}$$

Performing ratio test on the forecasted data:

$$\lambda(k) = \frac{x^{(0)}(k-1)}{x^{(0)}(k)}, k = 1, 2, \dots, 11 \text{ and determine if the test values fall within the range}$$

$(e^{-\frac{2}{n+1}}, e^{\frac{2}{n+1}})$. In this case, $n=11$ and all forecasted values falls within the specified range; hence, the original data $X^{(0)'}$ is suitable for constructing a non-aberrant GM (1,1) model [3] with a theoretical accuracy p° of 99.9909708182582%, Figure. 2 illustrates the employment numbers in the Healthcare and Social Assistance industry from 2012 to 2022, along with the fitted and forecasted values provided by the GM (1,1) model. The fitted values provided by the model align well with the actual data, with relatively larger fluctuations observed around the year 2020. The grey model is indeed primarily suitable for short-term forecasting. Therefore, both forecasting periods have been set to two years, extending up to 2024.

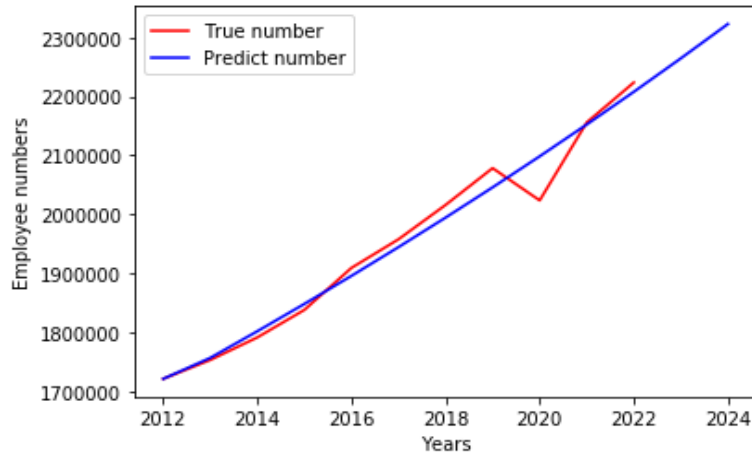


Fig.2 The employments in Healthcare & Social assistance prediction (10 years)

3.4. The Comprehensive Trend

In order to better explore the overall trend in healthcare industry employment, the graphs depicting the total workforce (Fig.3) and the percentage of healthcare industry workforce relative to the total workforce across all industries from 2012 to 2022 (Fig.4) is also presented.

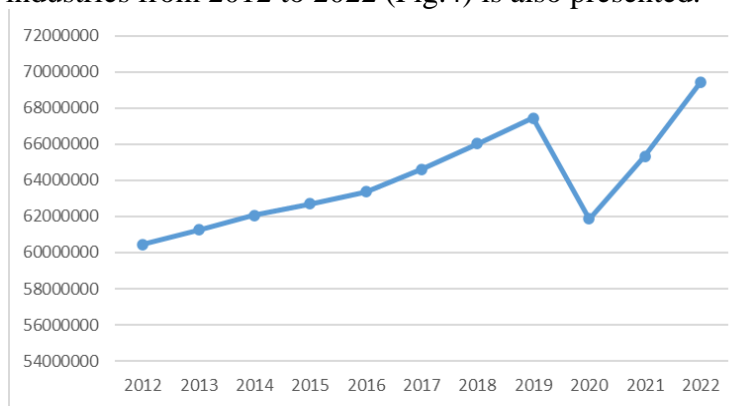


Fig. 3 The total workforce across all industries

Note that even though a significant decline in healthcare industry employment can be observed in both Figure 1 and 2 for the year 2020, there was a pronounced decrease in employment across all industries during the same period. Consequently, the proportion of healthcare industry employment relative to the total workforce in all industries actually experienced a notable increase. By 2022, the growth rates of both the healthcare industry employment and the total workforce for all industries have essentially returned to pre-pandemic levels, aligning with the outcomes presented by the GM (1,1) model discussed earlier.

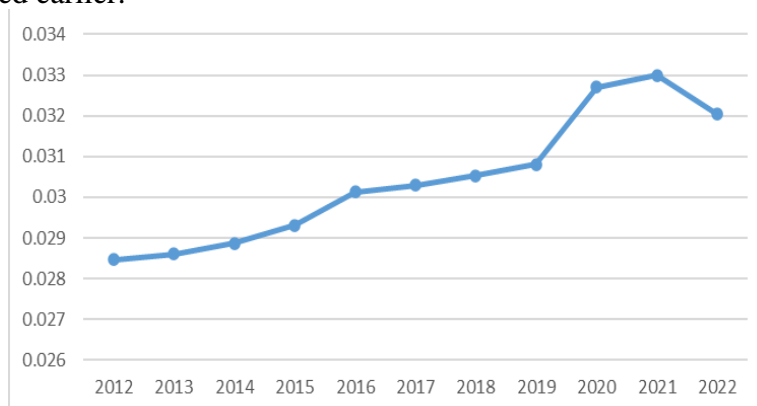


Fig. 4 The percentage of healthcare industry workforce

4. Discussion

The labor shortages caused by the COVID-19 pandemic had a significant impact on nearly all industries. During the period from February to April 2020, COVID-19 led to a 32% reduction in the overall weekly working hours in Canada, along with a 15% decrease in national employment figures [8].

Although monthly data specifically for health system workforce was not found, on an annual basis, it appears that the employment figures for 2020 only declined by approximately 2.6355% compared to 2019. In contrast, the national workforce data used in this study showed a decline of about 8.2680% during the same period. The primary reason for this disparity, which is less significant than the larger decline observed in April, could be attributed to the health system gradually adapting to the pandemic's impact by the end of 2020. Additionally, scientists had developed robust monitoring and epidemiological surveillance systems, rapid diagnostic kits, identified high-risk populations, and prepared several effective vaccines for global distribution by that time [9].

Considering the results in section 3-d, it appears that the decline in healthcare workforce during the pandemic was not as rapid as in some other industries. However, in comparison to the exponential increase in the number of infections at that time, the available healthcare and social assistance workforce was still stretched thin. COVID has proved that the existing workforce and response efficiency were not able to effectively contain the outbreak in its early stages., the public health sector faced significant shortages in human resources for monitoring activities, epidemiological investigations, as well as promotional and preventive efforts. The availability and distribution of healthcare providers also revealed substantial challenges. Additionally, the pandemic exacerbated the existing labor shortages in Long-Term Care Facilities, making an already difficult situation even more challenging [10]. Leaving these issues unresolved, even if the workforce has returned to pre-pandemic levels, the Canadian healthcare industry may not necessarily be better prepared to handle the next crisis that could potentially occur in the future.

However, the advantage of the grey system in requiring minimal data integrity also inevitably brings certain limitations. For instance, grey models may inevitably introduce some errors and are not suitable for long-term forecasts. The main factors influencing the grey model's accuracy are the mode of the initial data, the method of generating the cumulative data, and the choice of background value. Consequently, various techniques for increasing model precision are described, include but not limited to modify the initial value, use the buffer operator, and add damping trend factor [10].

5. Conclusion

Over the past decade, the workforce in the Canadian healthcare industry has steadily grown at a stable rate. However, in 2020, it experienced a decline of approximately 2.6355% due to the impact of the pandemic. While this decline might not appear significant when compared to the overall average decline of 8.2680% across all industries, it is evident that the healthcare system faced considerable pressure during this period, considering its frontline role in battling the disease. Following a two-year recovery period, the workforce growth rate in 2022 has essentially returned to pre-pandemic levels. When fitting the data for four years and ten years, both GM (1,1) models passed ratio-to-test examinations, with model accuracy rates of 99.9869730225871% and 99.9909708182582%, respectively. The forecast horizon is set at two years, and both forecasts for the two-time spans indicate that the healthcare industry's workforce will continue to maintain its current growth rate.

While the recovered workforce does not guarantee significant progress in the healthcare system's ability to handle potential future crises, it is clear that crises of a similar level will not impact long-term workforce growth. The immediate priority remains implementing solutions to address various issues within the healthcare system.

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