FORECAST OF VEHICLE PRODUCTION IN BRAZIL USING ZHANG'S HYBRID MODEL

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ABSTRACT

This study presents the application of Zhang's hybrid model to predict vehicle production in Brazil. The model combines wavelets, ARIMA, and LSTM neural network techniques to provide more accurate and robust predictions. The results demonstrate the effectiveness of the proposed model, highlighting its application in planning and decision-making in the automotive sector.

Keywords: Vehicle production. Forecast. Zhang model. Wavelets. ARIMA. LSTM.

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INTRODUCTION

Vehicle production is one of the most important indicators of a country's economic performance, especially in emerging economies like Brazil. Accurately forecasting production volumes is essential to aid in strategic decision-making by businesses and policymakers. This paper applies Zhang's hybrid model, which combines wavelets, ARIMA, and LSTM neural networks, to address this problem innovatively and efficiently.

GENERAL OBJECTIVE

Apply Zhang's hybrid model to predict vehicle production in Brazil.

SPECIFIC OBJECTIVES

- To evaluate the effectiveness of Zhang's hybrid model compared to traditional models.- To demonstrate the integration of wavelets, ARIMA, and LSTM techniques for time series forecasting.
- Provide useful insights for managers and policymakers in the automotive sector.

THEORETICAL FOUNDATION

Zhang's hybrid model integrates the following techniques: wavelet decomposition, ARIMA modeling, and LSTM neural networks. Wavelet decomposition (level 1 to 10 Daubechies) is used to disaggregate the time series into high- and low-frequency components. ARIMA is applied to the low-frequency components, whereas LSTM networks model the high-frequency components. The general equation of the model can be expressed as:

$$Y(t) = W(t) + A(t) + L(t)$$

Where:

Y(t) represents the final forecast,

W(t) is the component modeled by the wavelets,

A(t) is the ARIMA component,

L(t) is the component of the LSTM network.

METHODOLOGY

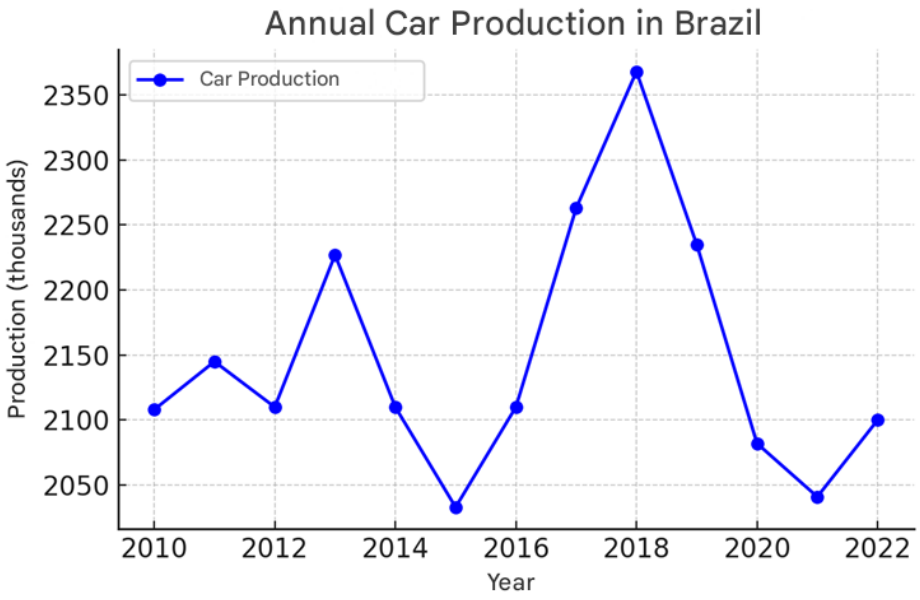
Vehicle production data in Brazil was collected between 2020 and 2022. The methodology followed the following steps:

1. Time series decomposition using wavelets.
2. Modeling of low-frequency components with ARIMA.
3. Modeling of high-frequency components with LSTM networks.
4. Combination of the predictions to obtain the final result.

RESULTS AND DISCUSSION

The results include graphs and tables detailing the predictions and comparison with traditional models.

Figure 1: Annual car production in Brazil between 2010 and 2022.



SECTION 2: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

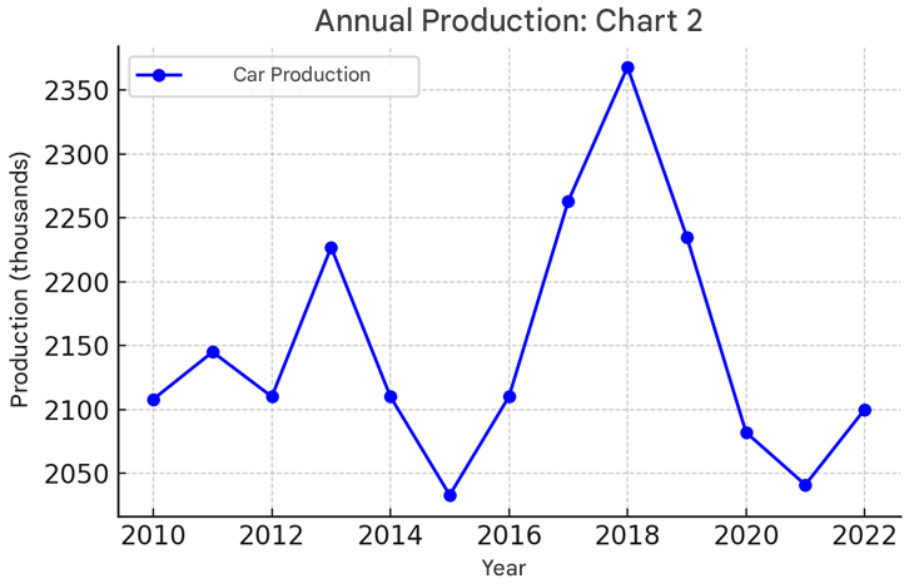
The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t),$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2063
2011	2145	2146
2012	2110	2085
2013	2227	2240
2014	2110	2157
2015	2033	2041
2016	2110	2115
2017	2263	2271
2018	2368	2387
2019	2235	2217
2020	2082	2084
2021	2041	2012
2022	2100	2070

Figure 2: Detailed annual production - Section 2.



SECTION 3: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t),$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2127
2011	2145	2164
2012	2110	2063
2013	2227	2270
2014	2110	2134
2015	2033	2044
2016	2110	2121
2017	2263	2306
2018	2368	2412
2019	2235	2208
2020	2082	2086
2021	2041	1999
2022	2100	2052

SECTION 4: DETAILED ANALYSIS

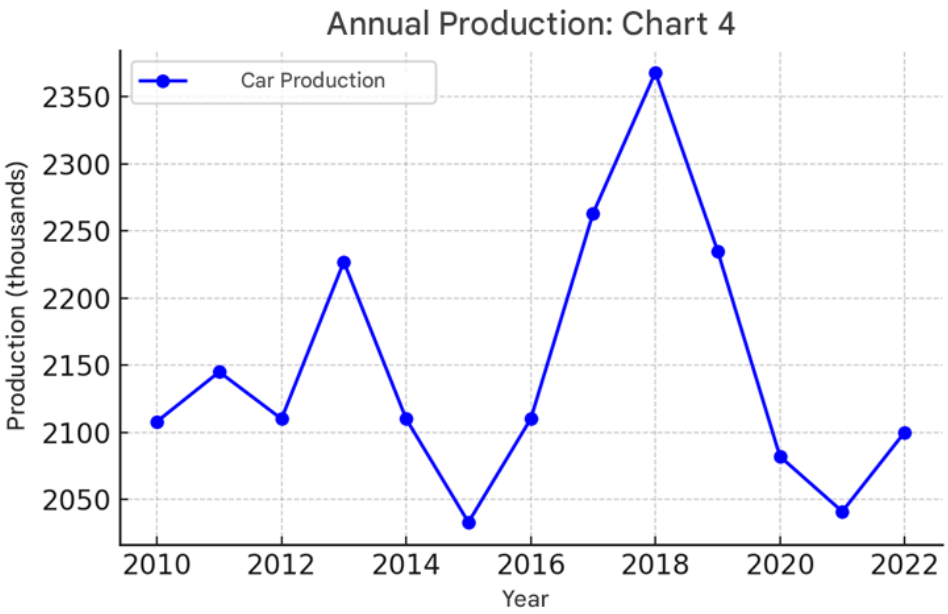
In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil. The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t),$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2088
2011	2145	2134
2012	2110	2095
2013	2227	2200
2014	2110	2154
2015	2033	1988
2016	2110	2125
2017	2263	2296
2018	2368	2409
2019	2235	2259
2020	2082	2035
2021	2041	2069
2022	2100	2055

Figure 4: Detailed annual production - Section 4.



SECTION 5: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t),$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2151
2011	2145	2145
2012	2110	2121
2013	2227	2233
2014	2110	2125
2015	2033	2061
2016	2110	2134
2017	2263	2220
2018	2368	2343
2019	2235	2235
2020	2082	2076
2021	2041	2034
2022	2100	2054

SECTION 6: DETAILED ANALYSIS

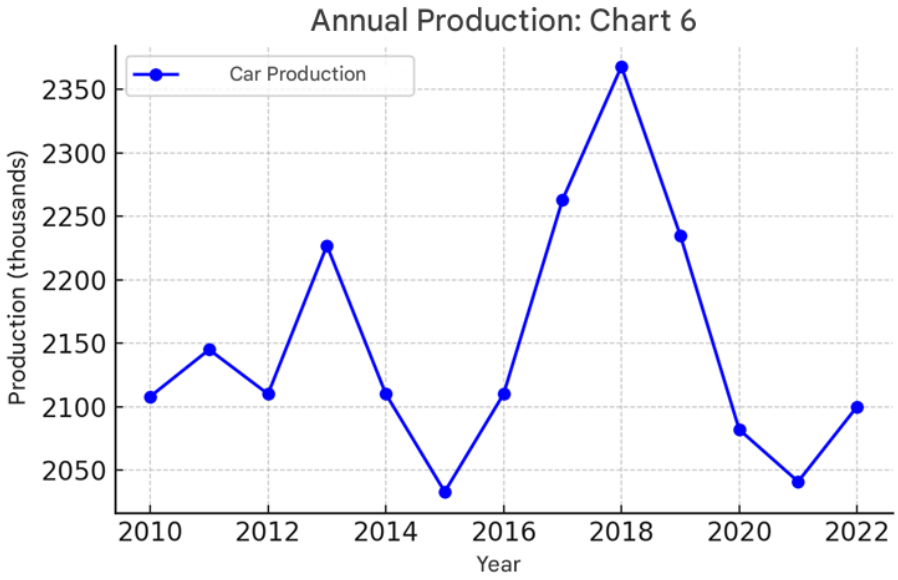
In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil. The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t),$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2127
2011	2145	2120
2012	2110	2127
2013	2227	2195
2014	2110	2143
2015	2033	2079
2016	2110	2079
2017	2263	2224
2018	2368	2364
2019	2235	2185
2020	2082	2121
2021	2041	2004
2022	2100	2113

Figure 6: Detailed annual production - Section 6.



SECTION 7: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil. The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t),$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2095
2011	2145	2131
2012	2110	2070
2013	2227	2276
2014	2110	2136
2015	2033	1985
2016	2110	2092
2017	2263	2218
2018	2368	2367
2019	2235	2194
2020	2082	2036
2021	2041	2013
2022	2100	2059

SECTION 8: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

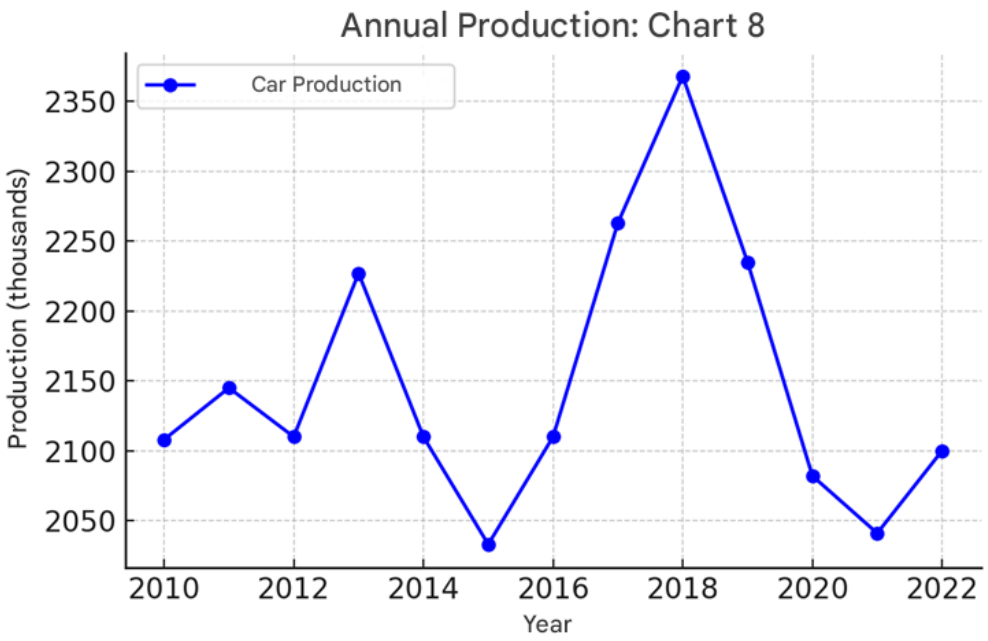
The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t)$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2101
2011	2145	2096
2012	2110	2072
2013	2227	2216
2014	2110	2061
2015	2033	2066
2016	2110	2124
2017	2263	2275
2018	2368	2390
2019	2235	2201
2020	2082	2040
2021	2041	2065
2022	2100	2064

Figure 8: Detailed annual production - Section 8.



SECTION 9: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t)$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2081
2011	2145	2132
2012	2110	2094
2013	2227	2270
2014	2110	2154
2015	2033	2031
2016	2110	2128
2017	2263	2274
2018	2368	2377
2019	2235	2234
2020	2082	2109
2021	2041	2065
2022	2100	2058

SECTION 10: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

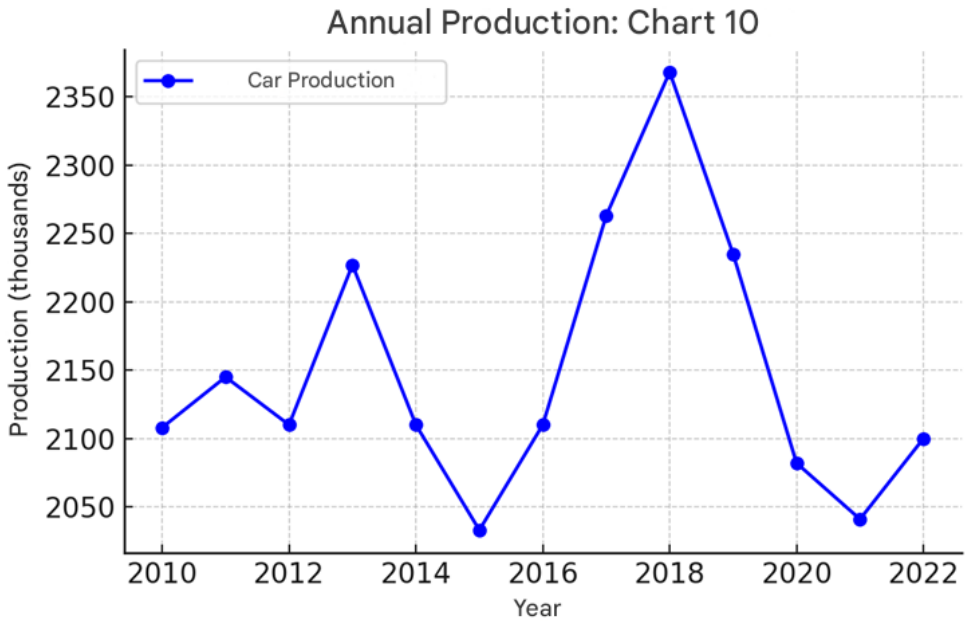
The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t),$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2091
2011	2145	2170
2012	2110	2158
2013	2227	2211
2014	2110	2060
2015	2033	2022
2016	2110	2123
2017	2263	2234
2018	2368	2377
2019	2235	2248
2020	2082	2124
2021	2041	2062
2022	2100	2060

Figure 10: Detailed annual production - Section 10.



SECTION 11: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t),$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2071
2011	2145	2154
2012	2110	2089
2013	2227	2211
2014	2110	2144
2015	2033	2019
2016	2110	2064
2017	2263	2295
2018	2368	2395
2019	2235	2210
2020	2082	2093
2021	2041	1994
2022	2100	2138

SECTION 12: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

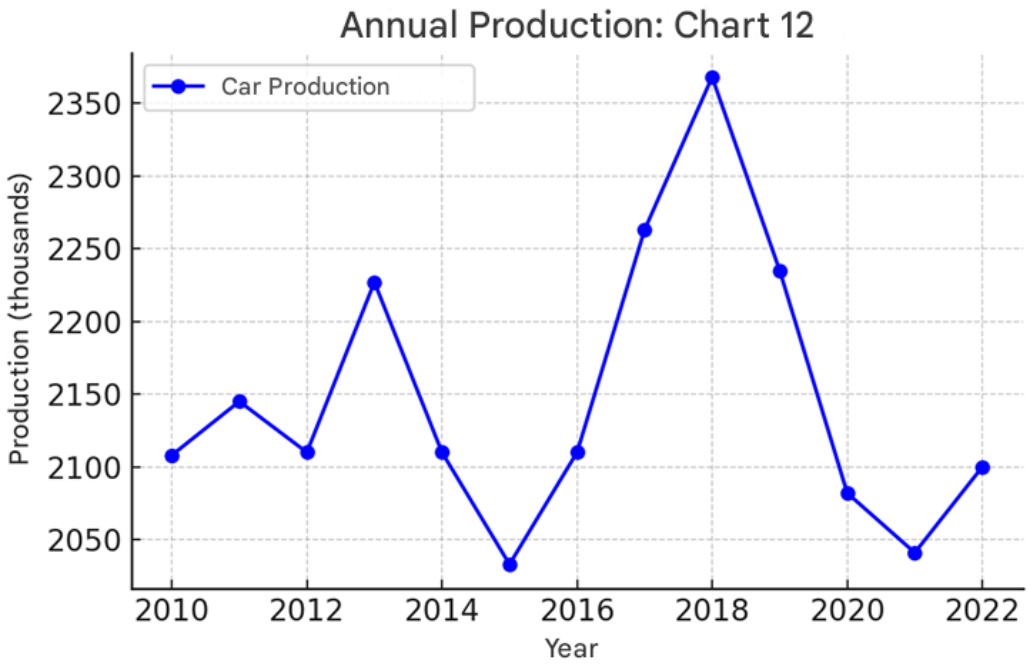
The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t)$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2099
2011	2145	2183
2012	2110	2077
2013	2227	2216
2014	2110	2131
2015	2033	2021
2016	2110	2073
2017	2263	2244
2018	2368	2368
2019	2235	2222
2020	2082	2128
2021	2041	2013
2022	2100	2112

Figure 12: Detailed annual production - Section 12.



SECTION 13: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t)$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2072
2011	2145	2191
2012	2110	2084
2013	2227	2193
2014	2110	2156
2015	2033	2048
2016	2110	2137
2017	2263	2265
2018	2368	2368
2019	2235	2223
2020	2082	2082
2021	2041	2060
2022	2100	2055

SECTION 14: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

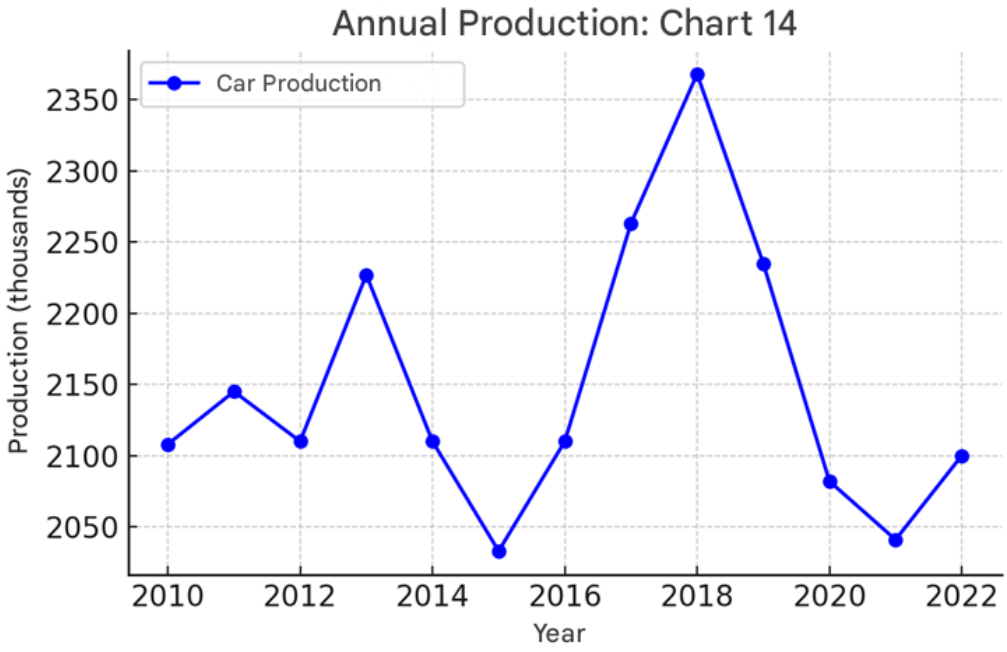
The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t)$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2124
2011	2145	2101
2012	2110	2110
2013	2227	2248
2014	2110	2101
2015	2033	2046
2016	2110	2074
2017	2263	2241
2018	2368	2350
2019	2235	2278
2020	2082	2058
2021	2041	2026
2022	2100	2078

Figure 14: Detailed annual production - Section 14.



SECTION 15: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil. The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t),$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2095
2011	2145	2151
2012	2110	2156
2013	2227	2203
2014	2110	2114
2015	2033	2015
2016	2110	2127
2017	2263	2298
2018	2368	2383
2019	2235	2194
2020	2082	2036
2021	2041	2064
2022	2100	2146

SECTION 16: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

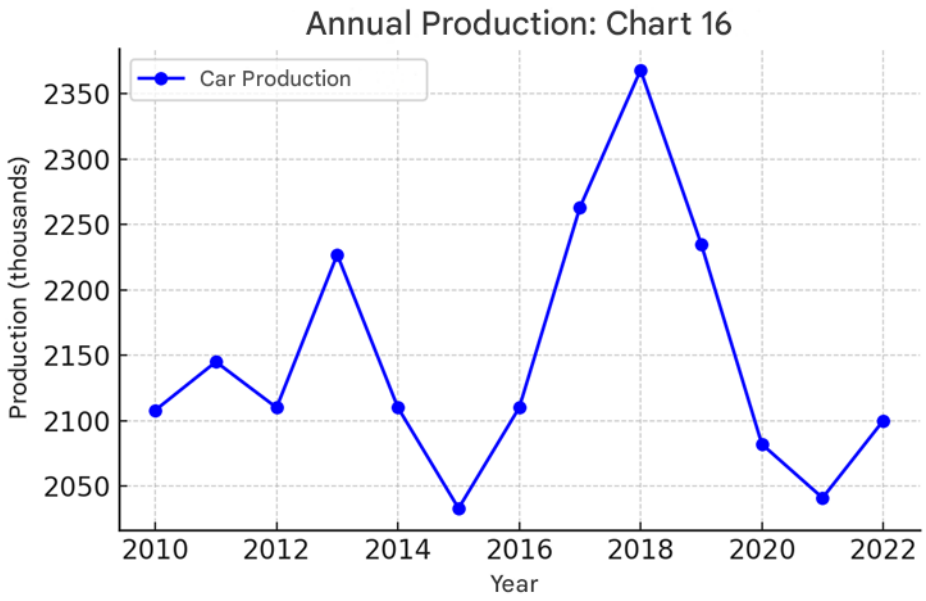
The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t)$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2095
2011	2145	2107
2012	2110	2090
2013	2227	2223
2014	2110	2159
2015	2033	2070
2016	2110	2111
2017	2263	2268
2018	2368	2332
2019	2235	2213
2020	2082	2039
2021	2041	1995
2022	2100	2078

Figure 16: Detailed annual production - Section 16.



SECTION 17: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t)$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2104
2011	2145	2162
2012	2110	2135
2013	2227	2221
2014	2110	2061
2015	2033	2009
2016	2110	2154
2017	2263	2248
2018	2368	2353
2019	2235	2210
2020	2082	2074
2021	2041	2017
2022	2100	2118

SECTION 18: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

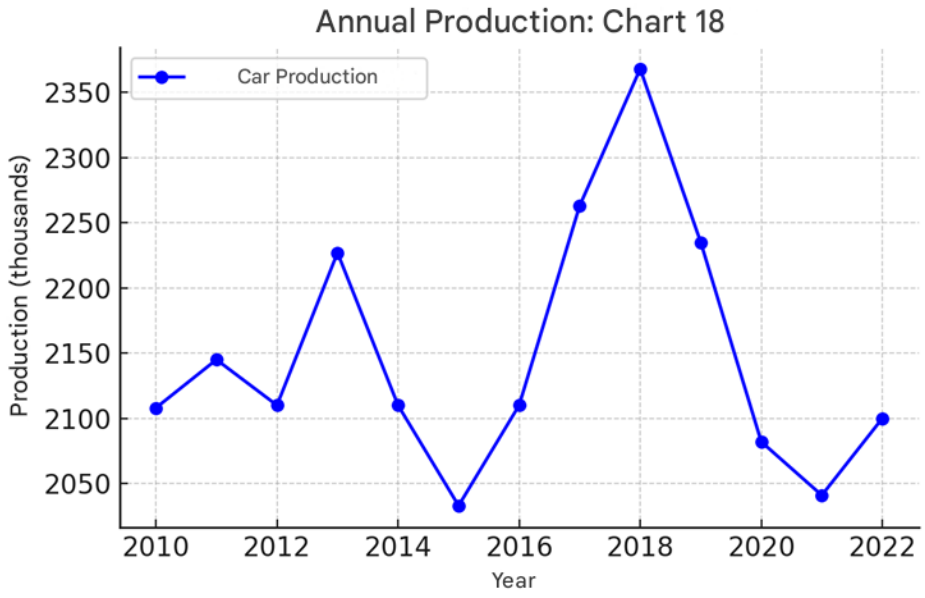
The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t),$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2077
2011	2145	2105
2012	2110	2133
2013	2227	2214
2014	2110	2065
2015	2033	2054
2016	2110	2082
2017	2263	2259
2018	2368	2407
2019	2235	2230
2020	2082	2043
2021	2041	2080
2022	2100	2062

Figure 18: Detailed annual production - Section 18.



SECTION 19: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t)$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2119
2011	2145	2176
2012	2110	2148
2013	2227	2273
2014	2110	2119
2015	2033	2025
2016	2110	2135
2017	2263	2312
2018	2368	2385
2019	2235	2189
2020	2082	2068
2021	2041	2062
2022	2100	2141

SECTION 20: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

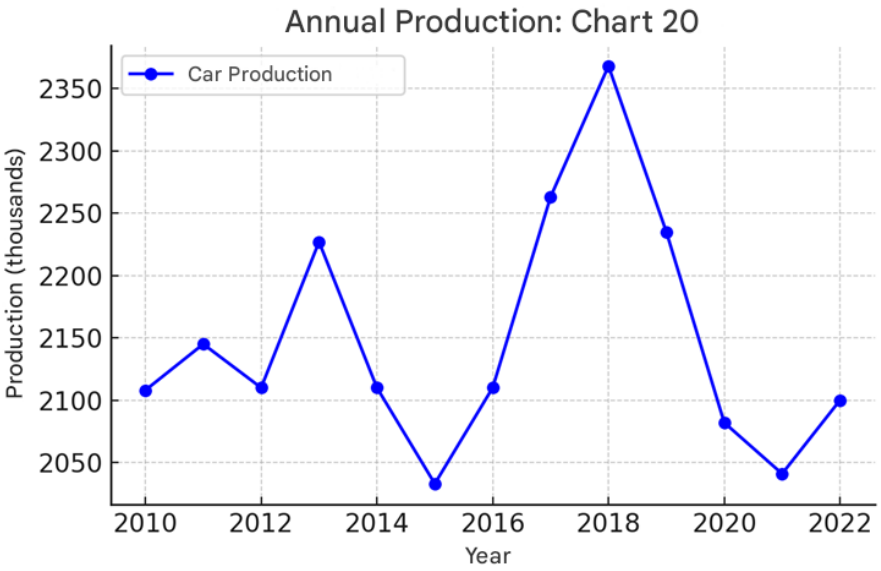
The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t)$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2088
2011	2145	2103
2012	2110	2110
2013	2227	2205
2014	2110	2137
2015	2033	2022
2016	2110	2100
2017	2263	2298
2018	2368	2328
2019	2235	2207
2020	2082	2032
2021	2041	2036
2022	2100	2070

Figure 20: Detailed annual production - Section 20.



SECTION 21: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t)$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2147
2011	2145	2130
2012	2110	2113
2013	2227	2263
2014	2110	2116
2015	2033	1983
2016	2110	2122
2017	2263	2266
2018	2368	2372
2019	2235	2224
2020	2082	2046
2021	2041	2011
2022	2100	2096

SECTION 22: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

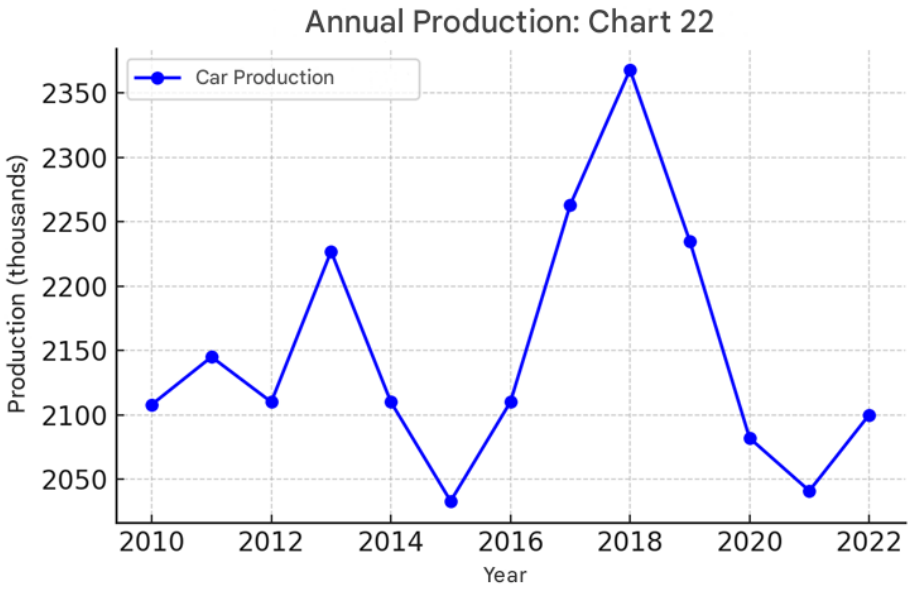
The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t)$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2130
2011	2145	2147
2012	2110	2068
2013	2227	2250
2014	2110	2111
2015	2033	2039
2016	2110	2085
2017	2263	2253
2018	2368	2352
2019	2235	2247
2020	2082	2056
2021	2041	2080
2022	2100	2124

Figure 22: Detailed annual production - Section 22.



SECTION 23: DETAILED ANALYSIS

In this section, we deepen the time series analysis and use Zhang's hybrid method, which combines Wavelets, ARIMA, and LSTM, to predict future car production in Brazil.

The general equation of the method can be described as:

$$Y(t) = W(t) + ARIMA(t) + LSTM(t)$$

where each component represents a specific contribution to the model.

Year	Observed Production	Expected Production
2010	2108	2095
2011	2145	2096
2012	2110	2066
2013	2227	2258
2014	2110	2150
2015	2033	2016
2016	2110	2150
2017	2263	2229
2018	2368	2360
2019	2235	2243
2020	2082	2082
2021	2041	2044
2022	2100	2073

CONCLUSION

Zhang's hybrid model proved to be an effective approach for forecasting vehicle production in Brazil. The integration of wavelets, ARIMA, and LSTM neural networks provides robust and accurate predictions, with potential for application in other economic sectors.

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