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Proposal of a diversified investment portfolio in stocks: An approach to AHP-Gaussian method

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Abstract

The purpose of this article is to assist decision-making in the selection of diversified investment portfolios in Brazilian stocks, proposing alternatives in a hierarchical manner within each sector of the Stock Exchange. Among various multicriteria decision methods, the AHP-Gaussian method, a new approach to the traditional AHP that does not require prior evaluation by a decision-maker, was chosen. Using criteria from fundamental analysis of companies, the methodology hierarchizes alternatives within each sector of the Stock Exchange. As a result, the proposal suggests the best companies for investment in each sector, which can be viewed through a web application that allows filters according to the investor's needs. Thus, the methodology presented in this study can provide valuable support for decision-making in the financial market.

Keywords: Analytical Hierarchy Process; Financial Market; AHP-Gaussian.

1. Introduction

The stock market is the place where institutions and individuals negotiate equity interests in publicly traded companies, to which they make part of their equity available for shareholders to become partners of the company. The stocks represent a shareholding in the company and the investors who acquire them become partners of the company, with the right to share in profits (dividends) and strategic decisions. This market offers a wide range of investment

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opportunities for investors, who can choose between companies in different sectors and sizes. However, investing in stocks also presents risks, such as market volatility and the possibility of capital loss. Therefore, investors need to understand the risks and adopt appropriate investment strategies to achieve their financial goals.

In Brazil, the number of individual investors present in the Brazilian Stock Exchange (B3) is still very small compared to the number of people in the country, but in recent years there has been a significant increase in the search for investment in the capital market. According to B3 [1], in January 2022 a number of 5 million accounts opened by individuals in Brazilian brokerages was reached, an increase of 56% compared to December 2020. This increase is largely due to the greater accessibility of information about the stock market through the internet and the reduction of brokerage fees. In addition, with falling interest rates in the years 2021-2022, many investors have been looking to diversify their portfolios in search of higher financial returns. This increase in the number of investors has generated positive impacts on the market, making it more liquid and increasing the demand for shares, in addition to strengthening the Brazilian economy.

However, most individuals on the stock exchange do not know how to assess whether a company is good, whether it has good fundamentals, and whether the price is consistent with the value of the company. The success of investments invariably passes through the choice of assets that can ensure greater profitability, or lower loss in periods of crisis [2]. In addition, they make the mistake of buying several companies in the same sector, not diversifying their equity, and this causes that in times of crisis, where some sectors are more affected than others, there may be a significant loss of capital [3–5].

Considering the context in which more and more people will migrate to the variable income market, it was intended, through this work, to create a proposal for a diversified investment portfolio in stocks, using as a basis the fundamental analysis of the companies. For this, attributes such as Price, Equity Value, Revenue, Dividends, Net Margin and Return on Equity of the companies were considered.

2. Literature Background

Operations research (OR) is a comprehensive and highly multidisciplinary field that makes use of mathematical and analytical models to solve complex and real problems of everyday life [6–12]. When it is necessary to prioritize something, it provides a model for constructing clear, objective, and mathematical criteria [13].

In the daily life of organizations, decision-making is a fundamental part of business management, making the decision-making process increasingly important to seek better alternatives, and it is hampered by inaccuracy in data, multiple criteria, and multiple decision-makers [14–16]. In this context, the MCDA methods are very useful to supporting decision-making processes, since it considers both value judgments and technical issues, to evaluate alternatives to solve problems [17–25].

Among the MCDA methods, the Analytical Hierarchy Process (AHP) developed by Prof. Thomas Saaty in the 1970s is recognized as one of the most well-known and widely used decision-making tools [26]. The AHP is a hierarchical and compensatory method used primarily for problems with a moderate number of alternatives and criteria [27], and allows the evaluation of alternatives about multiple criteria, being applied in decision-making scenarios [28].

The use of the AHP begins with the hierarchical analysis of the variables and the weighting of the weights of the criteria by a decision-maker. The decision-maker must complete a matrix comparing the criteria with each other according to their importance, using a metric known as the Saaty Fundamental Scale [29]. The scale is in table 1.

Table 1. Saaty Fundamental Scale

Importance	Definition	Explanation
1	Equal importance	The two activities contribute equally to the goal
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very Strong importance	One activity is strongly favored over another; element is very dominant as shown in practice
9	Extremely importance	The evidence is in favor of one activity over another, to the greatest extent possible
2, 4, 6, 8	Intermediate values	They are used to express preferences that are between the values of the above scale

According to [30] the step-by-step implementation of the AHP method follow below:

1. Definition of the goal, the decision criteria, and the alternatives.
2. Development of a pairwise comparison matrix.
3. Perform a standardization/normalization of the matrix.
4. Development of a priority vector.
5. Calculate the Consistency Index, which must be less than 0.1 to be considered consistent.
6. Development of the priority matrix.
7. After steps 2 through 5 have been performed for each criterion, the results of step 4 are summarized in a matrix that lists the decision alternatives vertically and the criteria horizontally. The column entries are the priority vectors for each criterion.
8. Elaboration of a matrix of development of criteria in pairs. Development of a general priority vector by multiplying the criteria priority vector (step 7) by the priority matrix (step 6).
9. Choose the top-rated alternative.

The method chosen for this research was the AHP-Gaussian, a new approach to the traditional AHP method. According [15], this method is based on a sensitivity analysis from the Gaussian factor. With this approach, it is no longer necessary to evaluate pairwise or use the Saaty scale by a decision-maker to define the weights for each criterion, since it is possible to obtain the weights of the criteria through the quantitative inputs of the alternatives in each criterion under analysis from the decision matrix itself. According to [31], to apply the AHP-Gaussian method, it is necessary to follow the step-by-step defined in the following steps:

1. Elaborate the decision matrix.
2. Normalize the matrix by dividing the value of each criterion by the sum of the column values.
3. Calculate the average of the alternatives in each of the criteria.
4. Calculate the standard deviation of the criteria based on the alternatives.
5. Calculate the Gaussian factor for each criterion.
6. Normalization of the Gaussian factor, dividing each factor by the sum of all Gaussian factors.
7. Decision matrix weighting
8. Obtaining the ranking: Sum of the weightings of each alternative.

The use of the multicriteria decision, through the AHP-Gaussian method, is appropriate to this research of proposal of a diversified investment portfolio in shares. This is because the data of the financial indicators of the companies will be used as the basis of the criteria for the decision-making process, and the method will be applied within each sector of B3 to choose the best company. At the end, the best companies by sector will make up the diversified stock portfolio. With the use of this method, it is possible to assign different weights to each criterion, considering its relative importance in the decision. To implement this methodology, computational support was used through a decision support system (DSS) that provides an interactive interface to investors. The use of an DSS is very important for the correct application of the method and eliminate errors of analysts [32–34], and possible personal biases in the selection of shares, making decisions more objective and consistent. Thus, the use of the AHP-Gaussian method with an SSD can contribute to a more judicious and efficient selection of the assets of the investment portfolio.

3. Methodology

In conjunction with the AHP-Gaussian method, the fundamental analysis of the companies of the Brazilian Stock Exchange will be used. Fundamental analysis is one of the main techniques used for investors in the stock market.

Unlike technical analysis, which is based on charts and price indicators, fundamental analysis focuses on the analysis of a company's financial and economic conditions, as well as macroeconomic factors that can affect its performance. This approach is not appropriate for short-term speculative investments, as it takes at least three months to know the balance sheets and results of the companies. Therefore, fundamental analysis is a great tool in an uncertain economic environment, so the momentary value of a stock is not necessarily related to the company value [24,35,36].

For the development of this project, six fundamental indicators were considered: Price over Profit (P/E), Price over Equity Value (P/EV), Dividends (DY), Annual Revenue Growth, Net Margin and Return on Equity (ROE).

3.1. Data collect

For the development of the project, were used the Python Programming Language and the data used for the research were collected through the "Fundamentus" Application Programming Interface (API), which provides updated information about the companies listed on B3. Through this API, the fundamentals indicators of the companies were obtained, which will be used as criteria for the construction of the model. A "data_collect" function was created and returns all companies information. The data set generated through the "data_collect" function contains 987 observations and 20 attributes, of which the observations are about the companies and the attributes are the information about the companies. The Figure 1 contains a sample with the five first observations of the dataset.

papel	cotação	p/l	p/vp	psr	div.yield	p/ativo	p/cap.giro	p/ebit	p/ativ circ.liq	ev/ebit	ev/ebitda	mrg ebit	marg_liquida	liq. corr.	roic	roe	liq.2meses	patrim. líq	div.brut/ patrim.	cresc. rec.5a
AALR3	20.57	-17.96	2.27	2.228	0.0000	0.925	-29.66	80.97	-2.39	103.01	21.15	0.0275	-0.1180	0.86	0.0132	-0.1263	7898420.0	1.072550e+09	0.85	0.0116
ABCB3	0.00	0.00	0.00	0.000	0.0000	0.000	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.00	0.0000	0.1505	0.0	5.070730e+09	0.00	0.3047
ABCB4	18.40	5.45	0.82	0.000	0.0695	0.000	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.00	0.0000	0.1505	18089700.0	5.070730e+09	0.00	0.3047
ABEV3	15.24	18.33	2.66	3.037	0.0396	1.690	36.49	15.60	-26.80	14.56	10.80	0.1947	0.1715	1.19	0.1498	0.1452	447864000.0	9.017800e+10	0.03	0.1298
ABYA3	4.91	-214.80	1.76	2.055	0.0000	0.527	1.98	19.96	-2.75	33.67	33.67	0.1029	-0.0096	2.09	0.0278	-0.0082	0.0	2.920600e+08	1.31	0.1641

Figure 1. Sample with five first observations of the dataset

3.2. Data cleaning and sectors definition

A "data_cleaning" function was created to perform the general cleaning of the data, which receives the previously collected data. Also, the data collected do not have sector attributes, which is indispensable for this project, since the diversification of investments is carried out by sectors. A "sectors_definition" function was created, which receives a dictionary with all companies and their respective sectors and maps these sectors, creating a new attribute in the dataset.

3.3. Data filtering

To filter only the data of interest in the project, the "data_filtering" function was created, which receives the data with defined sectors of the previous function and filters only the columns and rows that will be used in the construction of the solution. The columns chosen will be the criteria used for the implementation of the AHP-Gaussian method. Six criteria were selected, which are detailed below.

Price over Earnings (P/E): is one of the most used indicators to compare them with other companies in the same sector. It measures the relationship between the price of a stock and the net profit generated by the company. Another interpretation is that this indicator measures the number of years for a shareholder to recover their investment [20].

Price over Equity Value (P/EV): is an indicator used to assess whether a stock's price is above or below its equity value. It helps determine whether the stock is trading at a premium (P/EV > 1) or a discount (P/EV >1).

Dividend Yield (DY): is an indicator to evaluate the return the investor can obtain through dividends distributed by the company. Good dividend-paying companies tend to have lower volatility in stock prices, because these companies have a consolidated business and can distribute a higher percentage of profits to shareholders.

Annual Revenue Growth: is a revenue indicator used to measure the average annual revenue growth of a company over period and is useful for assessing a company's ability to generate revenue growth. In the dataset used in this project, the average annual revenue growth over the last five years was used as a calculation.

Net Margin: is an indicator used to evaluate the effectiveness of the company in transforming its activities into profit, as well as the efficiency in management of costs and expenses.

Return on Equity (ROE): is an indicator to evaluate the company's ability to generate profit from the resources invested by shareholders. It is a crucial indicator for analyzing companies within the same sector and evaluating management efficiency.

Unknown sector filter: All observations in which the sector classified as "unknown_sector" was disregarded.

P/E Filter > 0: A positive P/E means that the company is generating a profit and that investors can expect to receive a return on the investment made in the company. On the other hand, a negative P/E indicates that the company is having losses and for this reason, these companies wore discarded from the base.

Filter P/EV > 0: An ideal P/EV would be the closest to 1, and above this value, the company is overvalued and below that is undervalued, that is, being traded at a discount. However, a negative P/EV indicates that this company also has a negative P/E, and due to this, these companies are also discarded from the base.

DY < 100 filter: A company's dividends should not exceed 100% of profits. If a company distributes more than its profits, it will be paying dividends with the capital invested by shareholders or taking on debt to fund the payment of dividends. This can be unsustainable in the long run and lead to financial problems for the company.

3.4. Separate sectors

To compare the shares and build a diversified portfolio, the AHP-Gaussian method will be applied separately in each sector of the Exchange. To this separation, a "separate_sectors" function was created, which receives the filtered data from the previous function and separates the companies according to their respective sector.

With previous data, the decision matrix was created for each sector composed of the six criteria in the columns and all the companies in the rows. Figure 2 shows the decision matrix for the agricultural sector as an example.

papel	setor	p/l	p/vp	div.yield	cresc. rec.5a	marg_liquida	roe
AGRO3	agropecuaria	6.13	1.18	0.2010	0.3976	0.2568	0.1920
SLCE3	agropecuaria	6.93	1.93	0.0557	0.3620	0.1520	0.2788
SOJA3	agropecuaria	9.46	1.52	0.0115	0.7023	0.0793	0.1608
TTEN3	agropecuaria	8.40	1.67	0.0018	0.0000	0.0808	0.1984

Figure 2. Decision matrix for the agricultural sector

3.5. Implementation of the AHP-Gaussian method by sector

After the decision matrices were defined, the function called "ahp_gaussiano" was created, which receives the data separated by sectors and applies the AHP-Gaussian method within a single sector at a time, returning a table with the stocks of that sector, ranked from best to worst according to the method and its criteria. All the steps of the method are contained in the "ahp_gaussiano" function (Figure 3), starting with the application of the inverse of the values in the P/E and P/VP criteria, followed by the normalization of the decision matrix. Next, the Gaussian factor was created, and the normalization of this factor and the weighting of the decision matrix using the normalized Gaussian factor. Finally, the sector was ranked according to the sum of the weightings of the matrix.

```
def ahp_gaussiano( df, top_stocks ):
    df['p/l'] = df['p/l'].apply( lambda x: 1/x )
    df['p/vp'] = df['p/vp'].apply( lambda x: 1/x )

    setor_normalizado = ( df[['p/l', 'p/vp', 'div.yield', 'cresc. rec.5a', 'marg_liquida', 'roe']].apply( lambda x: x/sum(x)) )

    fator_gaussiano = setor_normalizado.std() / setor_normalizado.mean()
    fator_normalizado = fator_gaussiano / fator_gaussiano.sum()

    setor_normalizado['p/l']           = setor_normalizado['p/l'] * fator_normalizado['p/l']
    setor_normalizado['p/vp']          = setor_normalizado['p/vp'] * fator_normalizado['p/vp']
    setor_normalizado['div.yield']    = setor_normalizado['div.yield'] * fator_normalizado['div.yield']
    setor_normalizado['cresc. rec.5a'] = setor_normalizado['cresc. rec.5a'] * fator_normalizado['cresc. rec.5a']
    setor_normalizado['marg_liquida'] = setor_normalizado['marg_liquida'] * fator_normalizado['marg_liquida']
    setor_normalizado['roe']          = setor_normalizado['roe'] * fator_normalizado['roe']

    setor_normalizado['ranking_(%)'] = setor_normalizado.sum( axis=1 )*100
    setor_normalizado = setor_normalizado.sort_values('ranking_(%)', ascending= False).head( top_stocks )
    return setor_normalizado
```

Figure 3. Function for application of the AHP-Gaussian method

3.6. Overall ranking

The final table with all the top-ranked stocks in their respective sectors was created with the "final_table" function. This function receives the list of sectors of the resulting function "separete_sectors" along with the parameter "top_stocks" that allows the user to choose the amount of the best stocks by sector, which can vary from 1 to 3 companies. Then, the function applies the AHP-Gaussian method in all sectors of the Exchange present in the list of sectors and returns to the user a final table with the proposal of a stock portfolio with the best companies in each sector, according to the applied method. The function code is in Figure 4.

```
def final_table( setor_lista, top_stocks, table_type = 'original' ):
    df_result = pd.DataFrame()
    for setor in setor_lista:
        df_aux = ahp_gaussiano( setor, top_stocks )
        df_result = pd.concat( [df_result, df_aux] )

    if table_type == 'normalizada':
        df_final = pd.merge( df_result, df_filtered['setor'], how='left',
        right_index= True, left_index=True).sort_values( 'setor' )

    else:
        df_final = ( pd.merge( df_result['ranking_(%)'], df_filtered, how='left', left_index=True, right_index= True ).sort_values( 'setor' ))

        df_final = df_final[['p/l', 'p/vp', 'div.yield', 'cresc. rec.5a', 'marg_liquida', 'roe', 'ranking_(%)', 'setor']]
    return df_final
```

Figure 4. Function for general raking of stocks by sector

4. Results

After applying all the previous functions, the result was a proposal for a stock investment portfolio with all the best companies in each sector according to the AHP-Gaussian method and the selected criteria. The fifteen first result obtained according to market data as of March 31, 2023, is shown in Figure 5.

papel	p/l	p/vp	div.yield	cresc. rec.5a	marg_liquida	roe	ranking_(%)	setor
AGRO3	6.13	1.18	0.2010	0.3976	0.2568	0.1920	48.219786	agropecuaria
AMBP3	24.63	2.20	0.0151	1.2466	0.0422	0.0892	44.850707	agua_e_saneamento
BEEF3	8.67	11.58	0.0473	0.1994	0.0263	1.3361	19.485180	alimentos_processados
LEVE3	6.31	2.19	0.1492	0.1337	0.1409	0.3478	75.702239	automoveis_e_motocicletas
LJQQ3	285.01	1.54	0.0288	0.1463	0.0012	0.0054	13.912063	comercio
ASAI3	19.07	7.11	0.0066	0.9731	0.0268	0.3730	18.132559	comercio_e_distribuicao
INTB3	21.68	4.26	0.0131	0.3752	0.1066	0.1966	55.474677	computadores_e_equipamentos
CURY3	8.96	4.15	0.0491	0.3615	0.1609	0.4630	14.042847	construcao_civil
SOND5	4.68	1.32	0.2126	0.2259	0.1358	0.2831	21.522664	construcao_e_engenharia
ARML3	31.95	3.47	0.0252	2.6972	0.1473	0.1085	31.657976	diversos
GPAR3	4.13	3.00	0.3479	-0.0329	4.4828	0.7259	7.298482	energia_eletrica
BALM3	4.22	0.80	0.0227	0.0532	0.1732	0.1890	51.074058	equipamentos
SYNE3	0.53	0.42	2.0358	0.3715	0.5652	0.7934	41.054080	exploracao_de_imoveis
SIMH3	10.02	1.91	0.0979	0.6992	0.0483	0.1903	306.698528	holdings_diversificadas
ITSA3	5.79	1.18	0.0671	0.1537	1.7330	0.2043	23.054924	intermediarios_financeiros
SUZB3	4.10	2.67	0.0243	0.3551	0.3889	0.6524	15.759472	madeira_e_papel

Figure 5. Function for general raking of stocks by sector

For simplicity, we will analyze the performance of the agricultural sector as an example and why the code company AGRO3 did better than its competitors. Figure 6 shows all the companies in this sector and their respective values in the ranking performed by the method.

papel	p/l	p/vp	div.yield	cresc. rec.5a	marg_liquida	roe	ranking_(%)	setor
AGRO3	6.13	1.18	0.2010	0.3976	0.2568	0.1920	49.560247	agropecuaria
SLCE3	6.93	1.93	0.0557	0.3620	0.1520	0.2788	23.887725	agropecuaria
SOJA3	9.46	1.52	0.0115	0.7023	0.0793	0.1608	19.393833	agropecuaria
TTEN3	8.40	1.67	0.0018	0.0000	0.0808	0.1984	7.158195	agropecuaria

Figure 6. Result of the ranking of agricultural sector

It should be noted that the company AGRO3 stands out from other companies in the agricultural sector. It presented the best indicators in almost all the criteria evaluated. First, AGRO3 has the lowest Price/Earnings (P/E), which means that investors can recoup the amount invested in a shorter period than other companies. In addition, it has the lowest Price/Equity Value (P/VP), indicating that its shares are not overvalued and that the market is valuing the company fairly. Another highlight is this is the company that distributed the most Dividends (DY) to shareholders in the last year, which may be an indication that the company is in a good financial moment. Regarding average revenue growth, AGRO3 was in second place, second only to the company SOJA3. This indicates that the company has been able to expand its revenues consistently. The company also has the highest net margin among competitors, which means that the company manages to obtain good profitability concerning the sales made. Finally, although it does not have the

highest Return on Equity (ROE), AGRO3 still has a very significant and competitive ROE concerning other companies in the sector. Therefore, based on the indicators evaluated by the AHP-Gaussian method, AGRO3 is recognized as the most interesting company in the agricultural sector, as it has good fundamentals and presents results superior to those of its competitors.

However, the results presented are based on the six criteria previously chosen. A new approach for this project that has not yet been applied would be the application of the AHP-Gaussian method in all columns of the dataset to compare the results presented here.

4.1. Visualization of the investment portfolio

The visualization of the investment portfolio was done through a "dashboard" in Streamlit, which is a Python framework for web applications used to create interactive layouts of web pages and can be used in a web browser. It is also important to note that the dashboard automatically requests the data of the stocks every time it is started, updating the data daily, which avoids the need for manual updating by the user.

To better user experience, interactive filters have been added, in which is possible to filter both the number of the best stocks by sector (from 1 to 3 companies) or choose only the desired sectors.

4.2. Publication of the algorithm

The developed code was put into production on Streamlit Cloud, a cloud platform that allows users to deploy interactive web applications developed with Streamlit. To this, users can easily access them from a device if they have access to the internet. The result of the project can be accessed through the link: https://samuel-tcc-dsa.streamlit.app.

5. Conclusion

The application of the AHP-Gaussian method, combined with the fundamental analysis of stocks, as proposed in this article, fulfills the task of offering better alternatives for a diversified investment portfolio in stocks. In addition, the elimination of empiricism in decision-making provided by this mathematical method, as well as the non-need to insert weight for the criteria using the Saaty scale, represent important advances in the process of selecting the best alternatives for the investor since the Gaussian AHP determines the weights through the mean and standard deviation between each criterion.

In addition, a new application of the method using all the columns of the dataset as criteria, highlighted in the Results section of this article also relevant, allowing to obtain better results in the build of an investment portfolio.

Thus, the proposal presented in this article can contribute significantly to investors achieving better results strategically and efficiently. However, it is worth mentioning that this is a tool to support decision-making and not an investment recommendation, so it is responsibility of each investor to evaluate the alternatives presented by the method and perform a thorough analysis before making their contributions.

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