Application of Lexicographic Goal Programming Method on Stock Portfolio Optimization With Expected Shortfall Approach

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Abstract **– The purpose of this study is to form several optimal portfolios based on the proportion of funds invested in stocks, then the most optimal portfolio will be selected among the optimal portfolios that have been formed. The method used in this study is the lexicographic goal programming method, which is to determine the optimal portfolio based on the proportion of invested funds, then the selection of the most optimal portfolio is determined using the expected shortfall method. This study used data from 5 companies contained in Indonesia Stock Exchange (IDX). The results showed that from the proportion of invested funds, 11 optimal portfolios were obtained. Using the expected shortfall method, the most optimal portfolio of 11 portfolios was obtained, namely type 5 portfolio.**

Keywords **– Lexicographic goal programming, stock, portfolio, expected shortfall.**

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1. Introduction

Lexicographic goal programming method is a method that is used when there are multiple and competing goals, allowing the prioritized goals to be determined [1], [2]. Each priority level has a number of undesirable deviations that should be minimized [3]. One of the multi-purpose problems that can be solved by this method is the problem of optimizing the stock portfolio. With a stock portfolio, it can make it easier for investors to make an investment. Investment is a commitment to a certain amount of funds or other resources that are carried out at the moment, with the aim of obtaining a certain amount of money in the future [4], [5]. One of the assets most often used to make investments is stocks. In Indonesia, the party that organizes and provides a system as well as a means to carry out stock investment activities is the Indonesia Stock Exchange (IDX) or the Indonesia Stock Exchange (IDX). One of the stock indices on the IDX is the Composite Stock Price Index (JCI).

In actuality, investment or portfolio decisions are frequently made with inadequate knowledge. Also, the asset share in the portfolio must be implicitly added. This "breakdown" technique may not provide the support needed to make a sound investment decision. As a result, sophisticated decision-making techniques are designed in order to achieve practicality [6], [7].

Modern portfolio theory is based on the assumption that all investors do not like risks. This theory teaches how to combine stocks into a portfolio to obtain maximum profit with minimal risk. Risk in stock portfolios can be calculated using one of the approach methods, namely the Expected Shortfall approach or also called Conditional Value at Risk (CvaR) [8].

Expected Shortfall is an expectation of a measure of risk whose value is superior to Value at Risk (VaR) and is an estimated risk that can work on data that is normally distributed or not usual. This study will discuss the application of the lexicographic goal programming method on stock portfolio optimization with an expected shortfall approach.

2. Method

The Lexicographic Goal Programming is a method used when there are different and conflicting goals; it can be possible to determine the prioritized goals. Each priority level contains a number of unintended deviations and should be minimized. The meaning of minimizing in lexicographic goal programming of its objective function is to minimize deviation variables that are placed at a higher priority level and are considered more important than deviation variables placed at a lower priority level [9]. The notation used to mark the priority of such a goal is P_i (i = 1.2,..., m). The priority factors of such goals have the following relationship:

$$P_1 \gg P_2 \gg \cdots \gg P_m$$

where ≫ means "much more important than". Model lexicographic goal programming can be written as follows:

Minimize:

$$Z = P_1(d_1^+, d_1^-) + P_2(d_2^+, d_2^-) + \cdots + P_m(d_m^+, d_m^-) \quad (1)$$

Constraints:

$$\sum_{j=1}^{n} c_{ij}x_j + d_i^- - d_i^+ = z_i \ , \ \ i = 1,2,\dots,m \quad (2)$$

$$\sum_{j=1}^{n} a_{ij}x_j \le b_i \quad (3)$$

$$d_i^- \ge 0, d_i^+ \ge 0, x_j \ge 0, j = 1,2,\dots,n$$

where:

P_i = i-th priority
d_i^- = i-th bottom deviation (underachievement)
d_i^+ = deviation over i-th (overachievement*)*
x_j = decision variables
c_{ij} = coefficient x_j
b_i = number of available resources
z_i = value of the i-th goal function to be achieved

Expected shortfall is a measure of risk of a lowered nature for the distribution of losses. In general, the risk size of expected shortfall is closely related to VaR, which is a measure of risk that takes into account losses exceeding the VaR level [10], [11]. Expected shortfall is used as an alternative in risk measurement that serves to reduce the problems associated with VaR. Expected shortfall has the advantage of being a coherent measure of risk and being convex and sub-additive [8], [12].

Here is the expected shortfall formula for a normal distribution with an average of μ and variance is: σ^2

$$ES = \mu + \sigma\left(\frac{1}{\alpha}\int_{V_{1-\alpha}}^{\infty} zf(z)dz\right)$$

Where $f(z)$ is the standard normal distribution with the following formula:

$$f(z) = \frac{1}{\sqrt{2\pi}}exp^{-\frac{1}{2}z^2}$$

ES for $X \sim N$ (0,1) where $\alpha \epsilon$ (0,1) is:

$$ES = \mu + \sigma\left(\frac{1}{\alpha}\int_{V_{1-\alpha}}^{\infty}\frac{1}{\sqrt{2\pi}}exp\left[-\frac{z^2}{2}\right]zdz\right)$$

$$ES = \mu + \sigma\left(\frac{1}{\alpha}\cdot\frac{1}{\sqrt{2\pi}}\int_{V_{1-\alpha}}^{\infty}exp\left[-\frac{z^2}{2}\right]zdz\right)$$

$$ES = \mu + \sigma\left(\frac{1}{\alpha}\cdot\left[-\frac{1}{\sqrt{2\pi}}exp\left[-\frac{z^2}{2}\right]\right]_{V_{1-\alpha}}^{\infty}\right)$$

So the predictions of the expected shortfall are as follows:

$$ES = \mu + \sigma\frac{\phi(\hat{V}_{1-\alpha})}{\alpha} \quad (4)$$

To calculate the average return value (μ), standard deviation value (σ), and standard normal distribution density value ($\phi(\hat{V}_{1-\alpha})$) used the formula as follows:

$$\mu = \frac{x_i.E(R_i)}{n} \quad (5)$$

$$\sigma = \sqrt{\frac{\sum_{t=1}^{n}\left(R_{it}-E(R_i)\right)^2}{n-1}} \quad (6)$$

$$\phi\left(\hat{V}_{1-\alpha}\right) = -\frac{1}{\sqrt{2\pi}} \times e^{(-0,5\times z^2)} \quad (7)$$

where:

ES = expected shortfall
VaR = Value at Risk value
$V_{1-\alpha}$ = Value at Risk value calculated based on the same time as the confidence interval $\alpha \in [0,1]$
t = time period
μ = calculated average return value
$\Phi^{-1}(1-\alpha)$= α the quantile value of the return distribution
σ = standard deviation value of calculated return
Φ^{-1} = inverse of the distribution function
ϕ = standard normal distribution density

3. Results

Sampling in this study was carried out based on the daily closing price of shares on the IDX during the January-December 2019 period. The selected company is the fifth highest ranked company that has the best stock sales value out of the 50 active shares on the IDX during the 2019 period, the five issuers are BBRI, BBCA, TLKM, BMRI, and ASII.

A. IDX Stock Portfolio Formation

In this study, the problems to be identified were as follows:

1. Maximize the total invested funds.
   It is assumed that the total funds invested by the investor are 100% ($M_0 = 1$).
2. Maximizing portfolio returns
   The investor's expected portfolio return is assumed to be more than the minimum return value. The minimum return is obtained from the mean expected return of all invested shares during the 2019 period.
3. Minimizing portfolio risk
   Investors always expect the risk from the portfolio to be as minimal as possible, then investors want the portfolio beta (β_p) to be less than a certain value of K ($\beta_p \leq K$). The chosen K value is 0,8, meaning that the portfolio risk borne by the investor has less risk than the market average.
4. Limits on the proportion of funds
   Investors want the value of the proportion of funds of each share to be no more than the value of V, the desired value of *V* is between 20% - 30% of the amount of funds. At least investors invest a fund amount of *D* which is 5% for each share. Then 11 portfolios will be formed.

B. Lexicographic Goal Programming Method in Stock Portfolios

The formation of a stock portfolio by the lexicographic goal programming method is as follows:

1. Maximize the total invested funds. It is assumed that the total funds invested by the investor are 100% ($M_0 = 1$), so the mathematical model can be written:

   $$\sum_{j=1}^{5} x_j = M_0 \quad (8)$$

   Where M_0 are the invested funds. The first constraint in the goal programming function will be minimized d_1^- and d_1^+ so that equation (8) is changed to:

   $$\sum_{j=1}^{5} x_j + d_1^- - d_1^+ = M_0 \quad (9)$$

2. The investor's expected portfolio return is assumed to be more than the minimum return value. The minimum return is obtained from the mean expected return of all invested stocks during the 2019 period. So the mathematical model for the second constraint is:

   $$\sum_{j=1}^{5} E(R_j)x_j \geq M_0 \times DR \quad (10)$$

   Where DR is the minimum return value in the capital market and is the x_j proportion of *issuer j* as the subject of research, namely as many as 5 issuers. Unexpected deviations that are below the minimum return value must be minimized. Thus, the second constraint in the objective function of goal programming is to minimize the deviation variable namely d_2^-, then the second goal function is written as:

   $$\sum_{j=1}^{5} E\left(R_j\right)x_j + d_2^- - d_2^+ = M_0 DR \quad (11)$$

3. Investors always expect the risk from the portfolio to be as minimal as possible, then investors want the portfolio beta (β_p) to be less than a certain value of K ($\beta_p \leq K$). The selected K value is as large as 0.8, meaning that the portfolio risk borne by the investor has less risk than the market average. Since the goal is to minimize risks from the portfolio, then deviations above the K value should be minimized. The third obstacle in the objective function of goal programming is minimizing the deviation variable, namely d_3^+, then the third goal function can be written as:

   $$\sum_{j=1}^{5} \beta_j x_j + d_3^- - d_3^+ = K \quad (12)$$

4. Investors want the proportional value of each share to be no more than the value of V, the desired value of *V* is between 20% - 30% of the amount of funds. Then 11 portfolios will be formed. So, the fourth constraint is d_4^-. Deviations below V are minimized, and d_4^+ deviations above D are minimized, so the fourth objective function can be written as:

$$\begin{aligned} x_1 + d_4^- - d_4^+ &= M_0 V \\ x_2 + d_5^- - d_5^+ &= M_0 V \\ &\vdots \\ x_n + d_{n+3}^- - d_{n+3}^+ &= M_0 V \end{aligned}$$

and (13)

$$\begin{aligned} x_1 + d_{n+4}^- - d_{n+4}^+ &= M_0 D \\ x_2 + d_{n+5}^- - d_{n+5}^+ &= M_0 D \\ &\vdots \\ x_n + d_{2n+3}^- - d_{2n+3}^+ &= M_0 D \end{aligned}$$

In accordance with the rules on the lexicographic goal programming method, which is to determine the top priorities first, then p there is this study the problems prioritized by investors are as follows:

1. Minimizing portfolio risk.
2. Maximizing portfolio returns.
3. Maximize the total invested funds.
4. The limit on the proportion of funds of each share is no more than the value of V, the desired value of *V* is between 20% - 30% of the amount of funds. At least investors invest a fund amount of *D* which is 5% for each share.

Based on the problems that have been identified and the priorities formed, a portfolio model is obtained with the lexicographic goal programming method as follows:

Minimize:

$$Z = P_1(d_3^+) + P_2(d_2^-) + P_3(d_1^- + d_1^+) + P_4(d_4^- + d_5^- + d_6^- + d_7^- + d_8^- + d_9^+ + d_{10}^+ + d_{11}^+ + d_{12}^+ + d_{13}^+)$$

with constraints:

$$x_1 + x_2 + x_3 + x_4 + x_5 + d_1^- - d_1^+ = M_0$$
$$E(R_1)x_1 + E(R_2)x_2 + \cdots + E(R_5)x_5 + d_2^- - d_2^+ = M_0 D$$
$$\beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots + \beta_5 x_5 + d_3^- - d_3^+ = M_0 K$$

$$\begin{aligned} x_1 + d_4^- - d_4^+ &= M_0 V \qquad & x_1 + d_9^- - d_9^+ &= M_0 D \\ x_2 + d_5^- - d_5^+ &= M_0 V & x_2 + d_{10}^- - d_{10}^+ &= M_0 D \\ x_3 + d_6^- - d_6^+ &= M_0 V & x_3 + d_{11}^- - d_{11}^+ &= M_0 D \\ x_4 + d_7^- - d_7^+ &= M_0 V & x_4 + d_{12}^- - d_{12}^+ &= M_0 D \\ x_5 + d_8^- - d_8^+ &= M_0 V & x_5 + d_{13}^- - d_{13}^+ &= M_0 D \end{aligned} \tag{14}$$

C. Application of Lexicographic Goal Programming Model in Forming a Stock Portfolio

This study contains 5 stocks, namely BBRI, BBCA, TLKM, BMRI, and ASII. Before forming a stock portfolio with the Lexicographic Goal Programming method, first look for expected return, minimal return, beta stocks, and limits on the proportion of funds.

Expected return and minimal return can be calculated using the following formula:

$$R_i = \frac{P_t - P_{t-1}}{P_{t-1}}$$
$$E(R_M) = \frac{\sum_{i=1}^{n} R_M}{n} \tag{15}$$

where:

R_i = Stock returns
P_t = Share price in period t
P_{t-1} = Share price in the t-1 period
$E(R_M)$ = Expected stock return
R_M = Market returns
n = Number of possible periods

Here is a table *of* expected returns of the five selected stocks.

Table 1. Stock Returns

Stock Code	*Return*
BBRI	0,00081
BBCA	0,00102
TLKM	0,00033
BMRI	0,00028
ASII	-0,0005

*The minimum return (*DR) that investors want is the mean value of the expected return of all stocks included in the portfolio in Table 1 following the calculation of the minimum return value (DR).

$$DR = \frac{0{,}00081 + 0{,}00102 + 0{,}00033 + 0{,}00028 + (-0{,}0005)}{5} = 0{,}00038$$

The beta value of the stock can be calculated using the following formula:

$$\beta_i = \frac{\sum_{t=1}^{n}(R_{it} - E(R_i))(R_{mt} - E(R_m))}{\sum_{t=1}^{n}\left((R_{mt} - E(R_m))\right)^2} \tag{16}$$

where:

β_i = i-th stock beta
R_{mt} = t-th period market return
R_m = market return
$E(R_i)$ = expected stock return
$E(R_m)$ = Expected Market Return

Here is a beta table of the five selected stocks.

Table 2. Stock Beta

Stock Code	Beta Shares
BBRI	0,00655
BBCA	0,00297
TLKM	0,00572
BMRI	0,01104
ASII	-0,00048

Investors want the value of the proportion of funds of each share to be no more than the value of V, the desired value of *V* is between 20% - 30% of the amount of funds. At least investors invest a fund amount of *D* which is 5% for each share. This is so that the amount of funds invested is 100% or the capital owned is used entirely in investment. Here is a table of assumptions of combinations of proportions of funds.

Table 3. Limits on the Proportion of Funds

Portfolio	Proportion of Funds
1	$0{,}05 \leq x_1, x_2, x_3, x_4, x_5 \leq 0{,}20$
2	$0{,}05 \leq x_1, x_2, x_3, x_4, x_5 \leq 0{,}21$
3	$0{,}05 \leq x_1, x_2, x_3, x_4, x_5 \leq 0{,}22$
4	$0{,}05 \leq x_1, x_2, x_3, x_4, x_5 \leq 0{,}23$
5	$0{,}05 \leq x_1, x_2, x_3, x_4, x_5 \leq 0{,}24$
6	$0{,}05 \leq x_1, x_2, x_3, x_4, x_5 \leq 0{,}25$
7	$0{,}05 \leq x_1, x_2, x_3, x_4, x_5 \leq 0{,}26$
8	$0{,}05 \leq x_1, x_2, x_3, x_4, x_5 \leq 0{,}27$
9	$0{,}05 \leq x_1, x_2, x_3, x_4, x_5 \leq 0{,}28$
10	$0{,}05 \leq x_1, x_2, x_3, x_4, x_5 \leq 0{,}29$
11	$0{,}05 \leq x_1, x_2, x_3, x_4, x_5 \leq 0{,}30$

D. Lexicographic Goal Programming Portfolio Analysis

Here is a common model of lexicographic goal programming on portfolio type 1:

Minimize:

$$Z = P_1(d_2^+) + P_2(d_1^-) + P_3(d_3^- + d_3^+) + P_4(d_4^- + d_5^- + d_6^- + d_7^- + d_8^- + d_9^+ + d_{10}^+ + d_{11}^+ + d_{12}^+ + d_{13}^+)$$

With constraints:

$$x_1 + x_2 + x_3 + x_4 + x_5 + d_1^- - d_1^+ = M_0$$

$$0{,}00081x_1 + 0{,}00102x_2 + 0{,}00033x_3 + 0{,}00028x_4 + (-0{,}0005)x_5 + d_2^- - d_2^+ = 0{,}00038$$

$$0{,}00655x_1 + 0{,}00297x_2 + 0{,}00572x_3 + 0{,}01104x_4 + (-0{,}00048)x_5 + d_3^- - d_3^+ = 0{,}8$$

$$\begin{array}{ll} x_1 + d_4^- - d_4^+ = 0{,}05 & x_1 + d_9^- - d_9^+ = 0{,}20 \\ x_2 + d_5^- - d_5^+ = 0{,}05 & x_2 + d_{10}^- - d_{10}^+ = 0{,}20 \\ x_3 + d_6^- - d_6^+ = 0{,}05 & x_3 + d_{11}^- - d_{11}^+ = 0{,}20 \\ x_4 + d_7^- - d_7^+ = 0{,}05 & x_4 + d_{12}^- - d_{12}^+ = 0{,}20 \\ x_5 + d_8^- - d_8^+ = 0{,}05 & x_5 + d_{13}^- - d_{13}^+ = 0{,}20 \end{array} \quad (17)$$

In accordance with the provisions of the lexicographic goal programming method, the top priority must be done first. Here are the steps to complete the lexicographic goal programming model:

1. P_1: Minimize d_3^+ with constraints in Equation (17)

The optimum value for this problem is$d_3^+ = 0$. Furthermore, $d_3^+ = 0$ it is included as an obstacle in the next calculation, namely on the minimization of the second priority.

2. P_2: Minimize d_2^- with constrains in Equation (17)

The optimum value for this problem is$d_2^- = 0$. Next $d_2^- = 0$ and $d_3^+ = 0$ will be included be the constraints on the next calculation.

3. P_3: Minimize $(d_1^- + d_1^+)$ with constrains in Equation (17)

The optimum value for this problem is$d_1^- + d_1^+ = 0$. Furthermore $d_2^- = 0$, $d_3^+ = 0$, and $d_1^- + d_1^+ = 0$ will be included as an obstacle to subsequent calculations.

4. P_4: minimize $(d_4^+ + d_5^+ + d_6^+ + d_7^+ + d_8^+ + d_9^+ + d_{10}^+ + d_{11}^+ + d_{12}^+ + d_{13}^+)$ with constrains in Equation (17)

The optimum solution to this last problem is the optimal value of lexicographic goal programming in the formation of a type 1 portfolio. The result of completing steps 1-4 gives the result of an objective value of zero, which means that all deviational variables minimized in the goal function are zero-valued in other words that each goal is achieved.

The completion of the model to obtain the proportion of investment of each share is obtained with the help of the software *LINGO*. Using the same steps can be obtained the value of each proportion of each share on the other 10 portfolio, the lingo output is attached to Appendix 4. Here is a table of the value of the proportion of investments of each portfolio:

Table 4. Proportion of Shares of Lexicographic Goal Programming Method

Portfolio	x_1	x_2	x_3	x_4	x_5
1	0,20	0,20	0,20	0,20	0,20
2	0,21	0,21	0,21	0,21	0,16
3	0,22	0,22	0,22	0,22	0,12
4	0,23	0,23	0,23	0,23	0,08
5	0,24	0,24	0,23	0,24	0,05
6	0,25	0,25	0,20	0,25	0,05
7	0,26	0,26	0,17	0,26	0,05
8	0,27	0,27	0,14	0,27	0,05
9	0,28	0,28	0,11	0,28	0,05
10	0,29	0,29	0,08	0,29	0,05
11	0,30	0,30	0,05	0,30	0,05

After calculating the value of the proportion of investment of each stock in each portfolio, the next step is to calculate the value of the expected return of the portfolio and expected shortfall using equations (4) and (15). Here is a table of portfolio expected returns and expected shortfalls on each portfolio.

Table 5 is the result of calculating the expected return of the portfolio and the expected shortfall, it can be seen that the smallest expected shortfall value is in the portfolio type 5, which is 0.0115% with a return portfolio of 0.0556%. So, type 5 portfolios are optimal portfolios that can be used in investing.

Table 5. Portfolio Expected Return and *Expected Shortfall*

Portfolio	*Expected Return* (%)	*Expected Shortfall* (%)
1	0,0380%	0,0175%
2	0,0426%	0.0157%
3	0,0472%	0.0140%
4	0,0518%	0.0124%
5	0,0556%	0.0115%
6	0,0567%	0.0124%
7	0,0579%	0.0134%
8	0,0590%	0.0144%
9	0,0602%	0.0154%
10	0,0613%	0.0165%
11	0,0624%	0.0176%

After obtaining the expected return value of the portfolio and the expected shortfall of the portfolio, the Sharpe index value of each portfolio will then be calculated to measure the performance of the portfolio. The calculation of the Sharpe index is to calculate the ratio of return to risk of the portfolio. The largest ratio value is the optimal portfolio that will be used for investment. The following is the formula for calculating the Sharpe index of a portfolio:

$$S = \frac{E(R_p)}{ES} \quad (18)$$

The following table presents the Sharpe index values of each portfolio.

Table 6. Sharpe Portfolio Index Values

Portfolio	*Sharpe Index*
1	2.171428571
2	2.713375796
3	3.371428571
4	4.177419355
5	4.834782609
6	4.572580645
7	4.320895522
8	4.097222222
9	3.909090909
10	3.715151515
11	3.545454545

From the Table 6 it can be seen that the highest Sharpe index value is a portfolio of type 5. So type 5 portfolios are the optimal portfolio of 11 portfolios formed using the lexicographic goal programming method. Therefore, investors are advised to use type 5 portfolios as a reference in investing.

5. Conclusion

Based on the results of this study, it can be concluded that type 5 portfolios are the optimal portfolio of 11 portfolios formed using the lexicographic goal programming method. The investment proportion in the type 5 portfolio obtained was 24% of BBRI, BBCA, and BMRI shares, as large as TLKM shares, and as 23% large as ASII shares. Based on the portfolio of type 5, 5% of investors will get an expected profit rate of 0.0556% and an accepted risk level of 0.0115%. The lexicographic goal programming method can be used on other research objects such as optimization of production. The limitations that are the criteria of the investor can be added to more than four other limiting functions in decision making.

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References:

[1]. González, J., Ortega, J., Escobar, J. J., & Damas, M. (2021). A lexicographic cooperative co-evolutionary approach for feature selection. *Neurocomputing, 463*, 59–76. Doi: 10.1016/j.neucom.2021.08.003

[2]. Spracklen, P., Dang, N., Akgün, Ö., & Miguel, I. (2023). Automated Streamliner Portfolios for Constraint Satisfaction Problems. *Artificial Intelligence, 319* , 103915. Doi: 10.1016/j.artint.2023.103915

[3]. Parks, H. R. (2006). Symmetrized-lexicographic order and the method of points. *Journal of Mathematical Analysis and Applications*, *324*(2), 934–940. Doi: 10.1016/j.jmaa.2005.12.075

[4]. Xu, S., Shavarani, S. M., Ghadiri Nejad, M., Vizvari, B., & Toghraie, D. (2023). A novel competitive exact approach to solve assembly line balancing problems based on lexicographic order of vectors. *Heliyon, 9*(3), e13925. Doi: 10.1016/j.heliyon.2023.e13925

[5]. Lozano, S., & Contreras, I. (2022). Centralised resource allocation using Lexicographic Goal Programming. Application to the Spanish public university system. *Socio-Economic Planning Sciences*, *84*. Doi: 10.1016/j.seps.2022.101419

[6]. Borovička, A. (2020). New complex fuzzy multiple objective programming procedure for a portfolio making under uncertainty. *Applied Soft Computing Journal*, *96*, 106607. Doi: 10.1016/j.asoc.2020.106607

[7]. Mariani, M., Platanakis, E., Stafylas, D., & Sutcliffe, C. (2023). Identifying a destination's optimal tourist market mix: Does a superior portfolio model exist? *Tourism Management*, *96*, 104722. Doi: 10.1016/j.tourman.2023.104722

[8]. Qin, X., & Zhou, C. (2021). Systemic risk allocation using the asymptotic marginal expected shortfall. *Journal of Banking and Finance*, *126*, 106099. Doi: 10.1016/j.jbankfin.2021.106099

[9]. Jones, D., & Tamiz, M. (2010). *Practical Goal Programming*. Springer US.

[10]. Cradock-Henry, N. A., & Fountain, J. (2019). Characterising resilience in the wine industry: Insights and evidence from Marlborough, New Zealand. *Environmental Science & Policy*, *94*, 182–190. Doi: 10.1016/j.envsci.2019.01.015

[11]. Forouli, A., Nikas, A., Van de Ven, D. J., Sampedro, J., & Doukas, H. (2020). A multiple-uncertainty analysis framework for integrated assessment modelling of several sustainable development goals. *Environmental Modelling and Software*, *131*, 104795. Doi: 10.1016/j.envsoft.2020.104795

[12]. Ortobelli L, S., & Rachev, S. T. (2001). Safety-first analysis and stable Paretian approach to portfolio choice theory. *Mathematical and Computer Modelling*, *34*, 1037–1072. Doi: 10.1016/S0895-7177(01)00116-9