

MATHEMATICAL MODEL FOR GLOBAL PERFORMANCE EVALUATION OF HISTORIC CENTRE INDUSTRIES

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Abstract: *The vitality and viability of the historic centres, respectively of the related industries, implies an integrated quality-risk management that handles the opportunities and risks in their complexity and dynamism. In this context, a mathematical model was developed which involves a multi-criteria approach based on a series of selected indicators, taking into account the major factors involved in the evaluation of historic centre performance, namely: historic centre industries, historic centre economic performance, historic centre risks.*

Key words: *historic centre industries, risks, performance evaluation.*

1. Introduction

The assessment of the performance of historic centre industries involves a multi-criteria approach based on a series of indicators [2]. The management of the industries related to the historic centres, refers to the complex relationships between different facilities and functions. This includes a number of industries, public institutions and private sector services such as housing, cultural education, religious, leisure etc.

Lack of concern regarding the integrated Quality-Risk Management of the industries affiliated to the historic centres can cause great distortions in their functioning and can affect the quality of life in cities. It is necessary to professionalize these efforts both in the academic space, at the level of the administration, respectively bringing the issue on the public agenda. The present paper aims to develop a mathematical model for evaluation of annual global performance of historic centre industries using quantitative and qualitative methods [1], [3-7].

2. Methods

For city centre located companies, the indicators were selected taking into account the major factors involved in the evaluation of total performance, namely: type of industries in evaluated historic centre, individual performance of each industry and risks performance.

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Thus, the total performance of a historic centre can be defined as:

$$P_T = P_I \cdot P_R, \quad (1)$$

where: P_T - total performance (global performance) of city centre industrial companies; P_I - individual performance; P_R - risk performance.

The individual performance (P_I) is defined as a function that takes into account the quality of the environment (Q), the turnover (C) and the preservation of the historic heritage (E), estimated by the criteria of determining the global (total) performance (Table 1) and is of the form of Equation (2):

$$P_I = f(Q, C, E). \quad (2)$$

The risk performance (P_R) is a function that takes into account the risk indicator on the lack of integrated management (IRM), the risk indicator on crime (IRC), the risk indicator on depopulation of spaces (IRD), the risk indicator on heritage degradation (IRP) and is of the form:

$$P_R = f(IRM, IRC, IRD, IRP). \quad (3)$$

The first step in determination of the performance of industries (P_I) is to have data organized according to the table below [1]:

Determination of individual performance

Table 1

Industries corresponding to historic centres	CRITERIA					
	C_1	C_2	.....	C_j	.....	C_m
e_1	x_{11}	x_{12}	.....	x_{1j}	.....	x_{1m}
.....
e_i	x_{i1}	x_{i2}	.....	x_{ij}	.....	x_{im}
.....
e_n	x_{n1}	x_{n2}	.....	x_{nj}	.....	x_{nm}

For each criterion " C_j " is determined the score of the criterion with Equation (4) where n is the number of industries located in city centre:

$$S_{C_j} = \sum_{i=1}^n X_{ij}. \quad (4)$$

The values of X_{ij} are considered as:

$X_{ij} = 1$ if criterion C_j influences its industry e_i ;

$X_{ij} = 0$ if criterion C_j does not influence its industry e_i .

For each industry located in historic centres it is determined its score with the Equation (5):

$$S_{ind_i} = \sum_{j=1}^m X_{ij} , \quad (5)$$

where m is the number of criterion and the values of X_{ij} are established as previously stated.

In case of comparison of two entities A and B, a weighting coefficient of each criterion C_j is determined by the relation (6):

$$C_{pcj} = K_j \cdot S_{C_j} \sum_{i=1}^n \frac{X_{ij}}{S_{ind_i}} \quad (j = 1...m), \quad (6)$$

where K_j is a correction coefficient that is determined based on the comparison between the quantitative or qualitative values of the criteria for the two entities evaluated A and B.

For quantitative values data is organized as in Table 2.

Determination of the correction coefficient K_j

Table 2

	CRITERION					
	C_1	C_2	...	C_j	...	C_m
Value of criterion C_j for entity A	V_{1A}	V_{2A}	...	V_{jA}	...	V_{mA}
Value of criterion C_j for entity B	V_{1B}	V_{2B}	...	V_{jB}	...	V_{mB}
The correction coefficient K_j for entity A	V_{1A} / V_{1B}	V_{2A} / V_{2B}	...	V_{jA} / V_{jB}	...	V_{mA} / V_{mB}

For qualitative values correction coefficients are set as:

$K_j = 0.5$ if the estimated value $V_{jA} < V_{jB}$;

$K_j = 1$ if the estimated value $V_{jA} \approx V_{jB}$;

$K_j = 2$ if the estimated value $V_{jA} > V_{jB}$.

Furthermore, according to C_j criteria, scores are established for the three performance indicators: environmental quality (Q), turnover (C), preservation of historic heritage (E).

The scores N_j are awarded based on the opinions of the specialists in the field and may have the values from 1 to 3:

$N_j = 1$ for low performance;

$N_j = 2$ for average performance;

$N_j = 3$ for high performance.

The next step is organizing data in a table as shown in Table 3:

Performance criteria and indicators Table 3

CRITERION	Scores of criteria		
	Performance indicators		
	<i>Q</i>	<i>C</i>	<i>E</i>
	N_{jQ}	N_{jC}	N_{jE}
C_1	N_{1Q}	N_{1C}	N_{1E}
.....	
C_j	N_{jQ}	N_{jC}	N_{jE}
.....	
C_m	N_{mQ}	N_{mC}	N_{mE}
Sum of scores	S_Q	S_C	S_E

For each performance indicator, the sum of the scores determined with Equations (7-9):

$$S_Q = \sum_{j=1}^m N_{jQ}, \quad (7)$$

$$S_C = \sum_{j=1}^m N_{jC}, \quad (8)$$

$$S_E = \sum_{j=1}^m N_{jE}. \quad (9)$$

The total score for the performance indicators, according to the scores given to the indicators and the coefficients of weight of the criteria (C_{pcj}) is calculated with Equations:

• **For entity A**

$$S_{TQ} = \sum_{j=1}^m N_{jQ} \cdot C_{pcj} \cdot K_j, \quad (10)$$

$$S_{TC} = \sum_{j=1}^m N_{jC} \cdot C_{pcj} \cdot K_j, \quad (11)$$

$$S_{TE} = \sum_{j=1}^m N_{jE} \cdot C_{pcj} \cdot K_j. \quad (12)$$

• **For entity B**

$$S_{TQ} = \sum_{j=1}^m N_{jQ} \cdot C_{pcj}, \quad (13)$$

$$S_{TC} = \sum_{j=1}^m N_{jC} \cdot C_{pcj}, \quad (14)$$

$$S_{TE} = \sum_{j=1}^m N_{jE} \cdot C_{pcj}. \quad (15)$$

Using Equations (10), (11), (12) and (13), (14), (15) is obtained:

$$S_T = S_{TQ} + S_{TC} + S_{TE}. \quad (16)$$

In this context, the weights [%] for each performance indicator (p_Q, p_C, p_E) are

$$p_Q = S_{TQ} / S_T, \quad (17)$$

$$p_C = S_{TC} / S_T, \quad (18)$$

$$p_E = S_{TE} / S_T. \quad (19)$$

Considering Equations (7), (8), (9) and (17), (18), (19) is calculated the individual performance of industries (P_I) as in Equation (20):

$$P_I = p_Q \cdot S_Q + p_C \cdot S_C + p_E \cdot S_E. \quad (20)$$

The determination of risk performance (P_R) starts from the definition and evaluation of the four risk indicators, respectively *IRM* (risk indicator for the lack of integrated management), *IRC* (crime risk indicator), *IRD* (risk indicator for depopulation of spaces) and *IRP* (risk indicator for patrimonial degradation).

The risk indicator for the lack of integrated management (*IRM*) is determined based on the type of management practiced for historic centres administration, having the following alternatives:

- a) Private management - maximum performance;
- b) Public-private management - average performance;
- c) Public management - reduced performance.

The crime risk indicator (*IRC*) is determined based on the number of crimes during a year in the CI area, resulting in the following alternatives:

- a) low risk - small number of offenses;
- b) average risk - average number of crimes;
- c) high risk - large number of crimes.

The risk indicator for depopulation of spaces (*IRD*) is determined based on the number of vacant commercial and real estate spaces resulting in the following alternatives:

- a) low risk - small number of vacant spaces;
- b) average risk - average number of vacant spaces;
- c) high risk - large number of vacant spaces.

The risk indicator for patrimonial degradation (*IRP*) is determined based on the number of buildings in the historic centres that show traces of degradation, resulting in the following alternatives:

- a) low risk - small number of degraded buildings;
- b) average - risk (average number of degraded buildings);
- c) high risk - large number of degraded buildings.

For the previously mentioned risk indicators the weighting coefficients (y_{ij}) are determined according to the data organized in the following table:

Weighting coefficients for risk indicators

Table 4

Risk indicator	I_{RM}	I_{RC}	I_{RD}	I_{RP}	SCORE	Weight
I_{RM}	y_{11}	y_{12}	y_{13}	y_{14}	S_{RM}	p_{RM}
I_{RC}	y_{21}	y_{22}	y_{23}	y_{24}	S_{RC}	p_{RC}
I_{RD}	y_{31}	y_{32}	y_{33}	y_{34}	S_{RD}	p_{RD}
I_{RP}	y_{41}	y_{42}	y_{43}	y_{44}	S_{RP}	p_{RP}

Values y_{ij} of Table 4 are set as following:

$y_{ij} = 1$ if indicator "*i*" it is more important than indicator "*j*";

$y_{ij} = 0.5$ if indicator "*i*" it is as important as indicator "*j*";

$y_{ij} = 0$ if indicator "*i*" it is less important than indicator "*j*".

The total score is then:

$$S_T = S_{RM} + S_{RC} + S_{RP} \quad (21)$$

The weighting coefficients are calculated with:

$$p_{RM} = S_{RM} / S_T, \quad (22)$$

$$p_{RC} = S_{RC} / S_T, \quad (23)$$

$$p_{RD} = S_{RD} / S_T, \quad (24)$$

$$p_{RP} = S_{RP} / S_T. \quad (25)$$

Hence, are established scores for all four risk indicators related to management performance, turnover, depopulation of spaces and patrimonial degradation as follows:

- a) $N_{RM} = 5$ for high management performance;
 $N_{RM} = 3$ for average management performance;
 $N_{RM} = 1$ for low management performance.
- b) $N_{RC} = 1$ for high risk;
 $N_{RC} = 3$ for average risk;
 $N_{RC} = 5$ for low risk.
- c) $N_{RD} = 1$ for high risk;
 $N_{RD} = 3$ for average risk;
 $N_{RD} = 5$ for low risk.
- d) $N_{RP} = 1$ for high risk;
 $N_{RP} = 3$ for average risk;
 $N_{RP} = 5$ for low risk.

Using previously set scores, the performance concerning risks is:

$$P_R = P_{RM} \cdot N_{RM} + P_{RC} \cdot N_{RC} + P_{RD} \cdot N_{RD} + P_{RP} \cdot N_{RP}. \quad (26)$$

In conclusion, global (total) performance of historic centres can be determined as follows:

$$P_T = (P_Q \cdot S_Q + P_C \cdot S_C + P_E \cdot S_E) \cdot (P_{RM} \cdot N_{RM} + P_{RC} \cdot N_{RC} + P_{RD} \cdot N_{RD} + P_{RP} \cdot N_{RP}). \quad (27)$$

The Equation (27) allows both the evaluation and comparison of the annual global performances of a historic centre industries and the evaluation and comparison of two or more historic centres.

3. Conclusion

The presented mathematical model can be a very useful tool for evaluating the performance of industries in the historic centres of cities and at the same time it can lead to the improvement of local policies regarding their harmonious and sustainable development.

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