
Relationship between Various Components of Management in Pomeranian Communes Based on FUZZY-DEMATEL Approach

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Abstract:

Purpose: The study aims to determine and evaluate the mutual causal relationship between various management areas for Pomeranian communes. The research was conducted in four Pomeranian communes, and 15 experts took part in this study.

Methodology: A few research methods were applied: literature review, questionnaire method, comparative analysis, and FUZZY-DEMATEL method.

Findings: Conducted research implies that knowledge and human resources management is an essential component of management in Pomeranian communes. This area has the greatest impact on other fields of management identified in the communes.

Practical implications: The results of the study could be considered an interesting source of information for municipalities and communes. Understanding the role of knowledge and human resources management can be beneficial in the context of improving the efficiency of commune management, which can be perceived as an important factor in the quality of living within such a community.

Originality: This research is the first that attempted to find the causal relationship between various management areas in the communes.

Keywords: FUZZY-DEMATEL, municipality, commune, commune management, heat map.

JEL classification: D37, O31, M10.

Paper type: Research paper.

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1. Introduction

The basic unit of local government, which is the commune, is obliged to satisfy the needs of residents as well as improve the image of the municipality in the eyes of potential residents or investors. To achieve the aforementioned goals, commune governments undertake many activities, while striving to develop municipalities sustainably and effectively.

Successful development of communes in social, economic, and environmental terms requires efficient allocation of available resources among various areas of management, which arise from public tasks assigned and specified within the framework of applicable laws. The mentioned areas of municipal management include education management, risk management, infrastructure management, knowledge and human resources management, public investment management, environmental management, safety management, change management, and public health management.

The insufficient level of financial resources usually available to a municipality, forces the need to maximize the scope of their use. Public investment management requires extensive rules to make proper use of the financial resources at one's disposal in a transparent manner and accordance with the applicable legal norms (Skiba *et al.*, 2022). This is related not only to legal regulations on the management of public funds but also stems from the fact that the residents of a municipality are most interested in how the municipality manages and conducts public investments (Skiba, 2019).

Environmental management in municipalities mainly revolves around waste management issues. However, due to increased urbanization and climate change, there have been calls for more sustainable municipal management taking into account the requirements of protecting the surrounding environment (Wihlborg *et al.*, 2019).

Implementing environmentally friendly solutions is not just the domain of innovative business entities, similar solutions are increasingly being implemented in local government units. Environmental management in municipalities is not only a statutory requirement but also a necessity in light of the increasing awareness of citizens (Cristea *et al.*, 2022; Pham *et al.*, 2022).

Safety management from an economic perspective is one of the many tasks facing municipalities. The optimal level of security of the local community and the ability to respond quickly and effectively to threats is a challenge involving costs that often cannot be planned for. The starting point for the creation of an appropriate structure of the security system at the local level is social needs, the specifics of which can

vary greatly and depend on individual preferences, experiences, or other psychosociological factors, as well as legal, economic, or political conditions. All these elements affect the shape of the security system, without which it is impossible to talk about protecting values that are important for the life of the local community (Poreba, 2019).

The concept of change management is proving to be particularly relevant in the current highly turbulent reality also in the context of municipal management (Cameron *et al.*, 2019). At present, change management in municipalities is one of the factors that continuously and inextricably accompany their activities. This is a result of the intensely changing socio-economic situation, which leads to the need for municipalities to adapt individually to the dynamically changing situation.

Change management in a municipality is an extremely important process, involving the application of knowledge, skills, methods, and techniques to the activities specified in the process of change, the purpose of which is to meet the needs and expectations of the local community.

Public health protection is one of the own tasks carried out by the municipality. In addition to its tasks in the field of public health protection, the municipality also carries out commissioned tasks. The municipality's tasks in the field of public health protection, primarily include securing the availability of primary health care services. The municipality carries out all public tasks of local importance that are not assigned by law to other public administration bodies (Zhang *et al.*, 2023). Among the listed public health management tasks, the promotion of healthy lifestyles has become increasingly important in recent years. This task, even though it is not mandatory, is increasingly part of the public health management of municipal residents.

Providing access to public education expressed in preschool education and elementary school is an important task of communes. One of the factors influencing the pressure on the quality and budget of public education is the increasing population (Bovaird *et al.*, 2005).

Nowadays, schools need to be modern, hence more attention is paid to the implementation of up-to-date tools dedicated to the planning and delivery of educational services (Enteria and Role, 2018). Although, the recruitment of teachers and the provision of a suitable infrastructure is still a crucial aspect of managing the educational system on the commune level (Marmoah *et al.*, 2019).

Risk is an immanent feature of any activity, both professional and personal, and it can be perceived as a possibility of danger, damage, loss, injury, or other undesired consequences (Harland *et al.*, 2003).

Therefore, risks are connected with the likelihood of the occurrence of an uncertain event or set of circumstances that would have a negative impact on performance or the possibility of achieving targets. In municipality management it refers to various activities associated with public health, safety, and performance targets (Agarwal *et al.*, 2021; do Nascimento Beckert and Barros, 2022; Huimin *et al.*, 2020; Istrate *et al.*, 2014; Tokakis *et al.*, 2019). Thus, within a commune, risk management can be perceived as a crucial component of efficient management (Ullah, Qayyum *et al.*, 2021).

To operate properly and provide sufficient services, it is essential to have a suitable infrastructure, which can be divided into two main categories: real estate and land (Guarini *et al.*, 2018). The local municipality plays the role of a host for the land, overseeing land use and local development policies, where real estate management is one component of a comprehensive and coherent development strategy (Trojanek, 2015). Polish local governments employ a limited number of tools specifically designed for managing real estate resources (Gross and Wolny-Kucińska, 2021).

Knowledge and human resources management play a vital role in the management of any type of entity. Knowledge management can be viewed as a domain focused on enhancing actions that leverage knowledge to improve the enterprise's efficiency and performance (Durst *et al.*, 2019). Knowledge management in the municipality is determined by implemented information technology, organizational culture and structure, and human resources management (Gharehbiglo *et al.*, 2012).

Based on the above-mentioned research it can be assumed that risk management is the broadest concept of commune management. Therefore, it should have the causal character and the highest impact on other areas and it has causal character thus, the following hypotheses have been adopted.

Hypothesis 1: *Risk management has a causal character within commune management.*

Hypothesis 2: *Risk management has the highest impact on other fields of management in Pomeranian communes.*

2. Methodology and Data Gathering

There are few methods dedicated to the identification and evaluation of mutual causal relationships between various elements of a particular system. One of the most commonly used is the FUZZY-DEMATEL method, which through the implementation of elements of fuzzy set theory (Ertugrul Karsak and Tolga, 2001) is capable of illustrating the overall influence of various factors (Charlampowicz, 2022; Charlampowicz, 2023; Wang and Tzeng, 2012), visualizing causal relations

(Liaw *et al.*, 2011), and analyzing dependent factors (Liou *et al.*, 2008). Contrary to SEM (structural equation modeling), FUZZY-DEMATEL does not require a large research sample to provide reliable information concerning causal relationships among variables, since expert opinions based on the DEMATEL method yield good research results even with a small sample (Hwang *et al.*, 2016; Lee *et al.*, 2013). Nevertheless, it is agreed that the three experts included in the study are enough to obtain reliable results (Ullah, Sepasgozar *et al.*, 2021).

Based on the triangular membership function, it is possible to convert the assigned grades from 0 (no influence) to 4 (very high influence) into triangular fuzzy numbers. The set of triangular fuzzy numbers can be defined as set A (a, b, c), where a, b , and c denote the lower, medium, and upper number of fuzzy sets, respectively. The membership function can be defined as follows:

$$u_A(x) = \begin{cases} 0; & x < a \\ \frac{(x - a)}{(b - a)}; & a \leq x \leq b \\ \frac{(x - c)}{(b - c)}; & b \leq x \leq c \\ 0; & x > c \end{cases} \quad (1)$$

The next step is dedicated to defuzzify the fuzzy numbers into crisp values is Best Non-fuzzy Performance (BNP), which can be expressed as follows:

$$f = \frac{(c - a) + (b - a)}{3} + a \quad (2)$$

The triangular fuzzy numbers and their relation with the DEMATEL influence score are presented in table 1.

Table 1. Fuzzy linguistic scale

Linguistic term	Influence score	Triangular fuzzy number
Very high influence	4	(0.75, 1, 1)
High influence	3	(0.50, 0.75, 1)
Low influence	2	(0.25, 0.50, 0.75)
Very low influence	1	(0, 0.25, 0.5)
No influence	0	(0, 0, 0.25)

Source: Muhammad and Cavus, 2017.

Based on the pairwise comparison it is possible to set up a direct-relation $n \times n$ matrix, figures inside matrix Z show the influential extent between the elements.

The normalized fuzzy direct-relations matrix and standardized fuzzy direct-relation matrix \mathbf{X} can be computed using the following formula:

$$\mathbf{X} = \mathbf{S} \times \mathbf{Z}, \quad (3)$$

where:

\mathbf{X} – standardized fuzzy matrix of direct relationships,

$$\mathbf{S} = \frac{1}{\text{Max}_{1 \leq i \leq n} \sum_{j=1}^n Z_{ij}}, \quad (4)$$

\mathbf{Z} – matrix of direct relationships.

Another step is to calculate the total fuzzy impact matrix (direct and indirect) – the following formula is used to determine the matrix:

$$\mathbf{T} = \mathbf{X}(\mathbf{I} - \mathbf{X})^{-1}, \quad (5)$$

where:

\mathbf{T} – total fuzzy impact matrix (direct and indirect),

\mathbf{X} – standardized fuzzy matrix of direct relationship,

\mathbf{I} – unit matrix

Based on the significance indicator and the relation indicator it is possible to identify the causal character of factors. The average significance indicator can be perceived as a neutral point. If a particular indicator is greater, then this factor has a higher overall influence. If the particular relation indicator is a positive number then it has a causal character.

$$S_{ij} = D_{ij} + C_{ij} = \sum_{j=1}^n t_{ij} + \sum_{j=1}^n t_{ij} \quad (6)$$

$$R_{ij} = D_{ij} - C_{ij} = \sum_{j=1}^n t_{ij} - \sum_{j=1}^n t_{ij} \quad (7)$$

where:

S_{ij} – the significance indicator,

R_{ij} – the relation indicator,

D_{ij} – the total amount of each row,

C_{ij} – the total amount of each column,

t_{ij} – total (direct and indirect) influence from indicator i to indicator j ,

n – number of indicators.

The heat map, based on direct and indirect influence from matrix T , is a suitable and convenient tool for the presentation of all mutual relationships between factors included in the study.

Participants in this study were experienced employees belonging to management staff from various departments of communes. The study was conducted with 15 representatives of four communes in the Pomeranian voivodeship in Poland. Therefore, the condition of a minimum research sample has been fulfilled.

3. Results

The causal relation between various components of commune management has been made based on nine factors representing each management area (Table 2). The total fuzzy impact matrix is presented in Table 3.

Table 2. Commune management areas

Factor	Management area
f1	Education management
f2	Risk management
f3	Infrastructure management
f4	Knowledge and human resources management
f5	Public investment management
f6	Environmental management
f7	Safety management
f8	Change management
f9	Public health management

Source: Own elaboration based on research examined in 2022.

Table 3. Total fuzzy impact matrix T , D_i , and C_i .

	f1	f2	f3	f4	f5	f6	f7	f8	f9	D_i	C_i
f1	0.6444	0.7281	0.7771	0.7258	0.7032	0.7255	0.8370	0.7077	0.7097	6.5586	6.8404
f2	0.8039	0.7507	0.8660	0.7745	0.7620	0.8053	0.9631	0.8347	0.8123	7.3727	7.1011
f3	0.8188	0.8601	0.7861	0.7579	0.8245	0.8775	0.9567	0.8391	0.7993	7.5199	7.2972
f4	0.8955	0.8952	0.8945	0.7273	0.8434	0.8735	0.9939	0.8764	0.8603	7.8599	6.4561
f5	0.8128	0.8186	0.8679	0.7599	0.6945	0.8458	0.9195	0.8274	0.8025	7.3488	6.6004
f6	0.6791	0.7241	0.7659	0.6350	0.6750	0.6313	0.7936	0.7085	0.6960	6.3085	6.9720
f7	0.7722	0.8401	0.8536	0.7319	0.7310	0.7886	0.7984	0.7820	0.7834	7.0812	7.8808
f8	0.7921	0.8131	0.8265	0.7456	0.7725	0.7894	0.8967	0.6993	0.7570	7.0923	6.8845
f9	0.6217	0.6710	0.6598	0.5981	0.5942	0.6352	0.7218	0.6094	0.5516	5.6626	6.7721

Source: Own elaboration based on research examined in 2023.

Values listed in column D_i imply the sum of impact generated by a particular factor, the bolded value (f4) presents the highest influence, which means that knowledge and human resources management has the greatest impact on other aspects of commune management. On the other hand, the smallest value (f9) implies that public health management has the lowest impact on other factors.

The values in the Ci column are connected with the susceptibility to the influence of other factors. Factor f7 (safety management) is the most vulnerable on other components, while f4 (knowledge and human resources management) is the least susceptible. The analysis of the influence of each management area within the commune is presented in Table 4.

Table 4. *The analysis of the influence of each management area within the commune*

Factor	Management area	Significance indicator	Relation indicator	Causal character
f1	Education management	13.3990	-0.2818	effect
f2	Risk management	14.4738	0.2716	cause
f3	Infrastructure management	14.8171	0.2227	cause
f4	Knowledge and human resources management	14.3159	1.4038	cause
f5	Public investment management	13.9492	0.7484	cause
f6	Environmental management	13.2805	-0.6634	effect
f7	Safety management	14.9620	-0.7996	effect
f8	Change management	13.9768	0.2078	cause
f9	Public health management	12.4348	-1.1095	effect

Source: Own elaboration based on research examined in 2023.

Based on the results it can be stated that five out of nine identified management areas have causal character, which means that these should be improved first. Factor f4 (knowledge and human resources management) has the highest impact on other areas (relation indicator 1.4038), while the highest significance within the management system has factor f7 (safety management) with a value of 14.9620.

The heat map (Figure 1) presents all relations between management areas of the commune. Thus, even very weak relations can be identified.

Factor f7 (safety management) is the most susceptible to the influence of other areas, mostly influenced by knowledge and human resource management (f4 – impact value 0.9939), risk management (f2 – impact value 0.9631), and infrastructure management (f3 – impact value 0.9567).

4. Discussion and Conclusions

The research results obtained during the study indicate that knowledge and human resources management is the most important factor in managing commune. The significance of this factor is demonstrated through its impact on other factors. Moreover, this management component is the least susceptible to the influence of other factors.

Figure 1. Heat map of mutual relations between all identified areas of management in a commune



Source: Own elaboration using the Python programming language.

Based on the achieved outcomes hypothesis 1 is accepted. Risk management has a causal character within commune management (value 0.2716), although there are two areas, namely: knowledge and human resources management (value 1.4038), and public investment management (0.7484), having greater impact on other management components. Therefore, hypothesis 2 cannot be accepted.

The aforementioned results indicate that knowledge and human resources management can be perceived as the most important aspect of management in a commune. Properly motivated and managed employees are more efficient and effective in performing their responsibilities. This can be beneficial for management staff in the context of resource allocation.

The authors are aware of the limitations appearing in the course of the conducted research. First of all, even though all participants of this study were experts, the answers given to the questionnaire are subject to the risk of respondents' subjective approach to the analyzed areas. In addition, respondents representing selected municipalities were selected randomly from management staff, without in-depth

analysis regarding their knowledge in the area. Secondly, the research sample, although it complies with methodological requirements, could have been larger. Despite the limitations presented, they did not fundamentally affect the quality, and integrity of the research conducted. The results can be considered satisfactory.

The further research directions are connected with performing this study on a larger sample, including communes from other Polish voivodeships to empirically verify, if knowledge and human resources management is the most important aspect of management in other municipalities.

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