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TRIZ contradiction modelling in family business succession process management: quantitative approach with an application of Grey Incidence Analysis

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Abstract. The aim of the paper is to improve the quality management system, in the field of the family business succession process management, with the application of TRIZ contradiction modelling. In this work, the authors focus on cognitive activity in contradictions modelling, which is the basis for the first two stages of ARIZ85C, i.e., analysing the problem and analysing the problem model. The application of TRIZ contradiction modelling in the field of quality management is discussed. The selected methods of the acquisition of contradictions are analysed. To identify the contradictions in management systems the method which facilitate the implication of quantitative approach using Grey Incidence Analysis is developed. As a result, the information about the system components and their interactions, functions, contradictions and about the degree of grey incidence between the system components and the system as a whole is obtained. The proposed concept of contradiction modelling is applied and tested in selected family enterprise.

Keywords: TRIZ contradiction modelling, Grey Incidence Analysis, Quality Management, Family Business Succession Process.

1 Introduction

Family businesses are seen as important to national economies all over the world. Their development is parallel to the history of families, and their life cycles are intertwined. The main problem faced by companies of this type is succession, which is associated with difficult decisions and changes in enterprise management. The importance of this problem in Poland is additionally emphasized by the number of family enterprises. As estimated by institutions related to family entrepreneurship (the Family Business Institute, Family Business Foundation, Family Business Initiative) and researchers in this area, the first succession concerns nearly 800.000 enterprises, which exist now at the end of the second decade of the 21st century. The succession process does not always end with success understood as the company's survival on the market. According to the research reports, only 30% of family businesses pass into the hands of the second and only 10% of the third generation (Fleming, 2006; Babikan, 2007). Failures related to transferring enterprise management to successors may

lead to the collapse of enterprises, which in the current situation of the "first wave of succession" (Więcek-Janka, 2018) may significantly affect the condition of the economy and cause, for example, a sharp increase in retirement benefits, an increase in the unemployment rate, a collapse or breaking the cooperation network on regional markets. In conclusion, the succession process should be considered important not only in the micro scale, for the family business itself, but also in the macro scale, for the condition of the national economy. Therefore, it is reasonable to search for new methods and tools supporting succession processes not only in Poland but also all over the world.

This study indicates the possibility of improving the methods and tools for managing the quality of the family business succession process in reference to the basics of the Theory of Inventive Problem Solving (TRIZ). The use of selected TRIZ methods and tools manifests itself in order to improve such methods and quality management tools as, among others, Quality Function Deployment (QFD) (e.g., Wang et al., 2017; Weijie, 2020; Tursch et al., 2015; Su, Lin, 2008; Shahin et al., 2016; Chaoqun, 2010), the Failure Mode and Effects Analysis (FMEA) (e.g., Vysotskaya, 2020; Thurnes et al., 2015), Kansei Engineering and Kano method (e.g., Hartono et al., 2019; Chen et al., 2008; Hartono, 2016), Six Sigma approach (e.g. Wang et al., 2010; Wang et al., 2016), SERVQUAL methodology (Altuntaş, Yener, 2012), as well as the developed concept of applying 40 Inventive Principles in quality management (Retseptor, 2003). To refer to the applied selected TRIZ method of contradiction modelling at the stage of analysing the problem of family business succession the reference is made to the selected method of Grey Systems Theory (GST).

2 The acquisition of contradictions in management systems

The classic theory of TRIZ is based on three postulates, i.e., the postulate of objective laws of system evolution, the postulate of contradiction, and the postulate of specific situations (Khomenko and Ashtiani, 2007). The postulate of contradiction implies that in the course of a system evolution it has to overcome a certain set of contradictions. To progress a system to the next stage, the contradiction has to be resolved. Originally TRIZ instruments were intended for dealing with engineering problems. However, recently TRIZ set of principles of thinking management has been developed and applied for dealing with system which do not deal with technology (see Chechurin, 2016; Chechurin and Borgianni, 2016). The basis for TRIZ is not to compromise or optimize contradictions: "don't compromise - or choose between two conflicting solutions - have both" (Gadd, 2011, p. 103). Classical TRIZ supply problem solvers with instruments that are helpful in uncovering, analysing and then solving contradictions, i.e., organized in Algorithm of Inventive Problem Solving (ARIZ85C). New branches of Classical TRIZ, such as General Theory of Powerful Thinking (OTSM), propose approaches dedicated for complex, non-typical and interdisciplinary problem situation, e.g., Problem Flow Networks approach (PFN) (Khomenko and De Guio, 2007; Khomenko and Ashtiani, 2007).

In modelling management systems, adopting the foundations of qualitative system modelling (Mantura, 2020), two interconnected spheres of activity are distinguished, i.e., (1) cognitive, consisting in the systematic expansion and accumulation of knowledge about the quality of systems and their environment, resulting in shaping cognitive models of systems, (2) creative, consisting in the conscious creation and practical shaping of a new reality, which results in shaping the postulated qualitative models of systems. In this work, authors focus on cognitive activity for system of family business succession process management. The references to the first two stages of ARIZ85C (i.e., analysing the problem and analysing the problem model) to identify the main contradiction in system of family business succession. In TRIZ, these initial stages, use, among others, the following tools (Cavallucci et al., 2008; Mysior et al., 2019; Bielefeld et al., 2019): OSTM graphical representation of problem and partial solutions which help to identify the main engineering contradictions, Inventive Design Method (IDM), Function Analysis (FA), Cause Effect Chain Analysis (CECA), the Multi-Screen Analysis with the Laws of Engineering Systems Evolution. Concepts integrating TRIZ instruments with other methods are being developed as well. In this regard, attention is also drawn to the need to improve the targeting contradictions to be solved leading to more robustness in the process (Cavallucci et al., 2015). Improving the methods and techniques leading to the identification of significant contradictions, improvement methods are developed, among others, to represent the whole set of contradictions and to structure their interrelationships in relation to the basics of mathematical modelling (Cavallucci et al., 2008; Cavallucci et al., 2011; Baldussu et al., 2011; Becattini et al., 2015), graphical representation techniques of the decision's impact on the system from various perspectives, which can lead to more robust decisions (Cavallucci et al., 2015), improvement concepts of Function Analysis based on, for example, its combination with a simplified version of Inventive Standards (Lee, 2017), concepts referring to the basics of Systems Engineering and Model-Based System Engineering (Bielefeld et al., 2019), concepts using computer-aided analysis of patents and search for TRIZ contradictions (Cascini, Russo, 2007). In this work which analyses the problem in the field of quality management, in the area of contradiction modelling in family business succession process management, reference is made to the basics of Grey System Theory (GST). GST methods are used in conjunction with TRIZ instruments, among others as a form of improving the applied quality management tools (Gadakh, Kumar, 2018), as tools supporting the solutions evaluation (Wu et al., 2020) and the ones used for network of contradictions analysis (Majchrzak, Miądowicz, 2020). This paper presents the use of Grey Incidence Analysis to analyse the strength of relations between the system parameters. The recognized character system structure allows for identification of the relation matrix and presentation of the substantial contradictions.

3 Proposal: The acquisition of contradictions in family business succession process management

3.1 The family business succession process

Adjusting the path of the succession process to the family business seems to be the first challenge faced by the business family on the threshold of intergenerational transfer. The most natural of the observed succession processes is "education to succession". This process is based on the assumption that the owners' children will take over the family business in the future. Such solutions are popular in countries with a centuries-old history of family businesses. The process consists in a constant systemic approach of parents to raising children in accordance with the family values, transferring knowledge about the functioning and organization of the company, as well as the natural inclusion of children in work for the company, whether by working during the holiday period, or by making decisions about development directions or also, ultimately, by transferring some power in the company. The last step is the transfer of property under conditions previously agreed in the family. Due to its natural nature, this process does not have a time frame and follows the life cycle of the family and its members. Assuming the will to keep the company in the family, the process of transferring it into new hands should be well prepared. Not only because a successful transfer requires a number of tasks to be performed, which poses a serious challenge for both the owner and his future successor. It is therefore all the more important to set a strategy in the company to secure the future of the company and the family. The basic succession process consists of four phases: (1) Preparation and exploration phase, (2) Clarification phase, (3) Agreement (compromise) and new order establishment phase, (4) Intergenerational transfer phase. It is important to prepare the family and key employees in the business sphere for the planned change, both in the personal and professional area. The last phase - the intergenerational transfer phase, includes the process of implementing the successor in not only strategic but also operational activities. Experiences of one of the authors in research in projects: "Value codes" (2012-2014), Succession coaching (2018-2021) and the continuous work of a succession coach of Polish family businesses allowed for the identification of key succession factors (Więcek-Janka et al., 2020), which were included as the main components of the analysed family business succession process: company's legal status, company's financial situation; company's development vision; senior's readiness for succession, successor's readiness for succession, successor's competency preparation, family's readiness for succession and business readiness for succession.

3.2 TRIZ contradiction modelling with Grey Incidence Analysis

In management systems, two types of systems are distinguished (Hamrol, 2007), i.e., the management system (which is responsible for information processing and management decision-making) and the managed system (which is responsible for information processing and making executive decisions). Management systems, as distinct

from technical systems, are characterized by the occurrence of a social subsystem in both the management and managed system. A common phenomenon in social systems, such as considering in this research family business succession system, is incomplete information. The features of the elements belonging to the management systems have, in most cases, low level of measurability. This means that the values of these features come from the "weak" scales (i.e., the nominal and rank scale). As distinct from technical systems, in which the values of features belonging to the system elements can be mostly determined using "strong" scales (i.e., interval and ratio scale). In family business management systems other problems occur, such as, the reluctant to provide confidential information about the company and family (Winter et al., 1998; Schulze et al., 2001) and to accept collecting information from employees (Ward 1997). The business owners are responsive to share the information related to the values and traditions of family business to protect their reputation (Aronoff et al., 1998). Due to the specificity of, and difficulties in, research processes in the field of management systems, the use of method of Grey System Theory in the analysis of the problem model thought the acquisition of contradictions seems to be justified. Grey System Theory was initiated, in 1982, in China by prof. Deng Julong (Liu and Lin 2006). Research methods and models of Grey System Theory are applied to reasoning based on incomplete information that usually occurs when information about system elements, structure, boundary, or behaviour is incomplete (Liu et al. 2016). Currently, this theory is being dynamically developed, which is confirmed by an increase in publications related to its application in economic and social and technical sciences. The sequence of activities in the contradiction modelling in management systems of family companies, with an application of Grey Incidence Analysis, is presented and explained below.

Step 1. Analysis of management system components and their functions.

The work adopts a systemic approach to management in which the results of the organization's functioning are perceived as the sum of partial effects of processes taking place in the organization, in time and space. As a result of the literature analysis (see Subchapter 3.1.), five elements of the succession process (managed system) have been distinguished, i.e.: senior's readiness for succession, successor's readiness for succession, successor's competency preparation, readiness of the family for succession, business readiness for succession.

When determining the functions of management system elements, a set of the most frequently used functions of system elements is used (Ikovenko, 2018). From the set of these functions, a subset of functions suitable for functional modelling in the area of management is distinguished. As a result, obtaining a set of functions, i.e.: {move, delete, pass, throw, accelerate, inhibit, hold, consume, form, control, destroy, direct, separate, combine, contain, limit, divide, generate, create, modify, separate, inform, strengthen, load, save, record}. This set supports owners and experts of family businesses at the stage of identifying individual functions between components in the succession process. For each of the identified functions, their category is determined (i.e., useful function, harmful function), the function is assessed (i.e., primary function (3 points), additional function (2 points), auxiliary function (1 point)) and the degree

of execution of the function (i.e., normal level, insufficient level, redundant level) and the functional index of the individual system components is calculated.

Step 2. Analysis of relations between system components.

In management systems we often face situations involving incomplete information on relations between system components, i.e., on the system structure, and information on system boundary is incomplete. Having “incomplete information” is the fundamental premise of referring to the foundations of Grey System Theory. The GST is used to study problems of small samples and poor information. The grey systems described with a grey number is a such a number whose exact value is unknown but a range within which the value lies is known (Liu, Lin, 2006; Liu et al., 2016). In the study of relations between management system components the method of Grey Incidence Analysis (GIA) is applied. The level of dependence between the individual components of the managed system is the interval grey number, i.e.: a grey number with both a lower, \underline{a} , and an upper limit, \bar{a} , denoted as $\otimes \in [\underline{a}, \bar{a}]$. Here, the relations, such as the levels of dependence between the individual components of the succession process is assessed by family business owners using a scale from 1 (no dependence) to 10 (full dependence). The grey number is represented by a specific number in the range of its variability based on the experience and knowledge of the family business owners. Thus, being aware of human cognitive limitation, the interval grey number, in the assessment of the level of dependence between the system components are defined as: $\otimes \in [1, 10]$. Grey Incidence Operators are determined, i.e., behavioural horizontal sequences of the factors (system components) X_i, X_j :

$$X_i = (x_i(1), x_i(2), \dots, x_i(n)).$$

$$X_j = (x_j(1), x_j(2), \dots, x_j(n))$$

Here: X_i - sequence of dependency variables for the i -th element of the management system in the succession process, $x_i(k)$ - assessment of the level of dependence between the i -th and the j -th component of the management system in the succession process, $i = 1, 2, \dots, n; j = 1, 2, \dots, n$.

Using Grey Incidence Analysis, the strength of the dependence between the system elements is calculated:

Step 2.1. Compute the average image for each sequence of i -th element of the management system dependency variable:

$$X_i D_1 = (x_i(1)d_1, x_i(2)d_1, \dots, x_i(n)d_1), X_j D_1 = (x_j(1)d_1, x_j(2)d_1, \dots, x_j(n)d_1),$$

$$x_i(k)d_1 = \frac{x_i(k)}{\bar{X}_i}, x_j(k)d_1 = \frac{x_j(k)}{\bar{X}_j}.$$

Step 2.2. Compute difference sequence and find the maximum and minimum differences:

$$\Delta_i(k) = |x_i(k)d_1 - x_j(k)d_1|,$$

$$\Delta_i = (\Delta_i(1), \Delta_i(2), \dots, \Delta_i(n)),$$

$$M = \max_i \max_k \Delta_i(k), m = \min_i \min_k \Delta_i(k).$$

Step 2.3. Compute the incidence coefficients $\gamma_{ij}(k)$ and the degree of incidence, γ_{ij} , between the i -th element and j -th element of the management system dependency variable:

$$\gamma_{ij}(k) = \frac{m + \zeta M}{\Delta_i(k) + \zeta M},$$

for $\zeta \in (0,1)$, $k = 1, 2, \dots, n$,

$$\gamma_{ij} = \frac{1}{n} \sum_{k=1}^n \gamma_{ij}(k).$$

The calculated degree of incidence value for individual system components provides information about the level of impact of individual system components on changes in the behaviour of other components. This information is important during the subsequent stages of contradiction modelling, e.g., when analysing the network of contradiction and determining the hierarchy of importance of contradictions (i.e., identifying those contradictions in the system that should be resolved in the first place). But also, during trimming, before deciding about the eminence of a given group of elements from the system, one obtains information about the level of their impact on the variability of other parts of the system and the supersystem, which allows you to see the scale of system changes caused by their elimination.

4 Case study: TRIZ contradiction modelling with Grey Incidence Analysis for the acquisition of contradictions in family business succession process management

The developed concept of TRIZ contradiction modelling with the use of Grey Incidence Analysis was tested in a Polish family business. The company was established in 1991 and operates in the production and trade in the food industry. Currently, two generations work in the company and have been in the process of succession for three years. The whole process is expected to end in 2022-23. The company is classified as a medium-sized enterprise employing 180 people. 120 people work in the field of production, and 60 people in the area of trade (a network of own company stores). The company employs 8 people being family members, including the founders couple (Seniors), two children with their spouses, and two members of the extended family. The interview leading to the determination of the basic functions, relationships, and strength of the impact of individual succession process factors was carried out remotely using the Skype platform, the answers were provided by both company owners after mutual agreement.

Step 1. Analysis of management system components and their functions.

Here, five components of the managed system have been distinguished:

X_1 - Senior's readiness for succession, X_2 - Successor's readiness for succession, X_3 - Successor's competency preparation, X_4 - Family's readiness for succession, X_5 - Business readiness for succession.

The aim of the analysed management system is to prepare the successor to take over a family business, i.e., to transfer between generations. Table 1 presents a part of the results of analysis of the management system components with the assigned name and category of the function, as well as the function evaluation.

Table 1. A part of the results of functional modelling.

Function carrier	Name/ Function	Function object	Function category	Function evaluation (y_i)
X_1	generates	X_2	useful	1
	strengthens	X_3	useful	1
	connects	X_4	useful	1
	connects	X_5	useful	1
X_5	strengthens	X_1	useful	3
	directs	X_2	useful	2
	directs	X_3	harmful	-
	limits	X_4	harmful	-

Here, X_1, \dots, X_5 - five components of the managed system.

Step 2. Analysis of relations between system components.

Grey Incidence Operators are determined, i.e., behavioural horizontal sequence of the factor (system component). The assessment of the level of dependence of the system components expressed by the grey interval number, i.e., $\otimes \in [1,10]$, is presented below:

$$\begin{aligned}
 X_1 &= (10,10,5,9,9), \\
 X_2 &= (10,10,10,8,8), \\
 X_3 &= (5,10,10,9,9), \\
 X_4 &= (9,9,9,10,9), \\
 X_5 &= (9,7,7,9,10).
 \end{aligned}$$

Grey Incidence Analysis is applied (according to the steps 2.1 to 2.3) and the strength of the dependence of the system on its individual elements is calculated. Table 2 presented the computed value of the incidence coefficients, $\gamma_{ij}(k)$, between the management system components.

Table 2. Relation matrix.

$\gamma_{ij}(k)$	X_1	X_2	X_3	X_4	X_5
X_1	1.000	0.795	0.704	0.712	0.712
X_2	0.795	1.000	0.835	0.809	0.681
X_3	0.704	0.835	1.000	0.574	0.682
X_4	0.712	0.809	0.574	1.000	0.733
X_5	0.712	0.681	0.682	0.733	1.000

Here, X_1 - Senior's readiness for succession, X_2 - Successor's readiness for succession, X_3 - Successor's competency preparation, X_4 - Family's readiness for succession, X_5 - Business readiness for succession.

The values of the incidence coefficients, $\gamma_{ij}(k)$, are between 0 and 1, the more i -element and j -element of the management system are dependent the greater γ_{ij} , and vice versa. The results of the functional analysis (y_i) of the management system elements and compute average value of the degree of incidence (γ_{ij}) between the management system elements are summarized below, i.e., $X_i = [y_i, \gamma_{ij}]$:

$X_1 = [4, 0.784]$, $X_2 = [6, 0.824]$, $X_3 = [6, 0.759]$, $X_4 = [6, 0.765]$, $X_5 = [4, 0.762]$.

The obtained results make it possible to arrange the individual components of the system in terms of the intensity of their impact on changes in the system as a whole:

X_2 (Successor's readiness for succession) $> X_1$ (Senior's readiness for succession) $> X_4$ (Family's readiness for succession) $> X_5$ (Business readiness for succession) $> X_3$ (Successor's competency preparation).

As a result of the application of Grey Incidence Analysis, individual system components are mapped in dimensions, i.e., y_i - index of the functionality of the system components and γ_{ij} - degree of grey incidence, i.e., the information on the impact of individual system components on changes in other parts of the system. The contradictions are identified with the reference to function categories of system elements. Here, the contradictions related with the element X_5 (Business readiness for succession) are identified. Table 3 presents generic table of the listed contradictions (from the TRIZ point of view, Cavallucci et al., 2011) with the value of the incidence coefficients, $\gamma_{ij}(k)$, between the system elements.

Table 3. Generic table of a contradiction (from the TRIZ point of view).

TC_{ij}	$\gamma_{ij}(k)$	Active Parameter X_5	
		Va	$V\bar{a}$
Evaluation Parameter X_1	0.712	😊	😞
Evaluation Parameter X_2	0.681		
Evaluation Parameter X_3	0.682	😞	😊
Evaluation Parameter X_4	0.733		

The obtained results make it possible to distinguish the contradiction which should be resolved in the first place. Here, it is the contradiction related with Active Parameter X_5 (Business readiness for succession) impact on the Evaluation Parameter X_1 (Senior's readiness for succession) and Evaluation Parameter X_4 (Family's readiness for succession). The business readiness for succession strengthens the senior's readiness for succession and at the same time may limit family's readiness for succession. Thus, the main management problem which should be solve is to prepare the business readiness for succession including issues such as, a.o., organization structure and organization culture, human factor, and dynamics of the development of family enterprises, regarding its contradicting impact on the Senior's readiness and Family's readiness for the succession.

5 Conclusions

Theory of Inventive Problem Solving (TRIZ) was used to identify the problems of contradiction in family business succession process quality management. It was noted that in management systems we often face situations involving incomplete information on relations between system components, i.e., on the system structure, and that information on system boundary is incomplete. This was a premise for the application of the Grey System Theory at the stage of determining the relations between the elements of the management system in the process of family business succession. The interaction study using the grey interval number allowed not only to determine the relations matrix but also led to the calculation of the degree of grey incidence. The degree of grey incidence determines the level of influence of individual system components on the other parts of the system and on system as a whole. The proposed concept of TRIZ contradiction modelling with the application of Grey Incidence Analysis enables more complete mapping of the analysed system, which is a value during the subsequent stages of contradiction modelling, i.e., network of contradiction analysis or trimming. A developed approach facilitates: (1) the recognition of the management system components, (2) the specification of the components functions, (3) the evaluation of the values of the grey incidence coefficients, $\gamma_{ij}(k)$, between the system components, (4) the arrangement the individual components of the system in terms of the intensity of their impact on changes in the system as a whole, (5) the acquisition of the main contradictions in regard to the active parameters function index and to their impact on the evaluation parameters. The direction of further research is the application and testing of the developed method in a greater number of family enterprises and the development of an integrated model of contradictions occurring in quality management in the processes of family business succession. In the next stages of the research, it is planned to apply the next stages of contradiction modelling, i.e., network of contradiction analysis and trimming to improve the quality of the succession process in family businesses and its environment (supersystem).

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