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Leadership Competencies in the Financial Industry during Digital Transformation: An Evaluation Framework Using the Z-DEMATEL Technique

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Abstract: In today's digital age, the financial industry, a cornerstone of the global economy, is undergoing monumental shifts. While business performance hinges on proficient leadership, the seismic wave of digital transformation poses new challenges and magnifies the need for specific leadership competencies. The urgency is clear: adapt or become obsolete. However, there is a lack of clarity regarding which competencies are essential during such transformations. To address this gap, the purpose of this study is to identify the leadership competencies that leaders in the financial industry should possess during the digital transformation process and to determine the influential relationships among these competencies and which ones are highly influential. This paper extensively investigates the criteria for evaluating leadership competencies and integrates expert judgments to construct an evaluation framework for leadership competencies during digital transformation. The Z-based decision-making trial and evaluation laboratory (Z-DEMATEL) technique was applied to identify the influential relationships among the criteria and generate influence weights for each criterion. In addition, based on the results of Z-DEMATEL, an Influence Classification Map (ICM) was plotted that categorized the criteria into four groups: core, driving, independent, and impact. Management implications and improvement suggestions are provided accordingly. Z-DEMATEL enhances the general form of fuzzy DEMATEL. By integrating the Z-fuzzy theory, Z-DEMATEL not only accounts for the uncertainty of the evaluation environment but also measures the confidence level of experts. Taking Taiwan's financial industry as a case study, this study revealed that "vision and imagination," "critical analysis," and "strategic perspective" were the top three criteria with higher weights, while "critical analysis" and "interpersonal sensitivity" were the core criteria. Business managers can use the results to design leadership training programs that meet the requirements of digital transformation and ultimately improve the performance of organizations during the transformation. Moreover, the concepts and methods presented in this study can be applied to other industries that are embarking on their digital transformation journeys.

Keywords: COVID-19; digital transformation; financial industry; leadership competencies; MCDM

MSC: 44A05; 03B52; 03E72

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1. Introduction

In the era of digital transformation, businesses and organizations are faced with the need to adapt to a rapidly changing, uncertain, and highly complex environment. With the globalized economy having a significant impact on various industries, traditional leadership competencies may no longer be sufficient [1]. Today, businesses rely heavily

on their leaders and operational teams to steer them toward collaborative efforts and achieve organizational goals with greater ease [2]. Effective leadership styles can enhance organizational sustainability, productivity, and competitiveness, which underscores the critical role of leadership competencies in achieving business success. Numerous studies have emphasized the importance of leadership competencies in influencing the success or failure of organizational teamwork. Essential leadership competencies now include forward thinking, motivation, effective communication skills, and appropriate empowerment [3]. In the era of digital transformation, it has become even more critical for businesses to embrace these dynamic leadership competencies as they seek to navigate the challenges and opportunities brought about by technological advancements and digital integration.

Since its outbreak, COVID-19 has acted as a catalyst for significant changes in social norms and economic activities, leading to a turning point in global economic development. As countries struggle to control the spread of the epidemic and grapple with inflationary factors and rising interest rates [4], the crisis has left nations, governments, communities, and organizations in urgent need of leadership guidance to navigate through difficult times [5]. In response to the challenges and opportunities presented by the current environment, the financial industry has been rapidly transforming and adapting, offering innovative services such as digital banking, cross-institution collaboration, blockchain technology, and automated processes [6]. In Taiwan, the financial industry plays an important role in the economy and people's lives, with government support and policies aimed at fostering innovation and transformation in the industry. Given the evolving landscape of the epidemic and post-epidemic era, traditional organizational leadership competencies are no longer sufficient in the financial industry. Today's leaders must possess a new set of competencies to drive successful transformations that improve operational performance [7]. It is time for true leaders to emerge to guide systems and individuals to overcome limitations, fears, and uncertainties while driving performance improvement and adapting to the digital transformation of the financial sector.

The interdependence and interconnectedness of leadership competencies are crucial in the ever-changing business landscape of the financial industry [8]. In light of the environmental context and the impact of the COVID-19 epidemic, identifying substantive leadership competencies and their influential relationships becomes essential to help managers, organizations, and employees in the financial sector to systematically develop their competencies and minimize the risk of task implementation failure. This paper presents an evaluation framework specifically tailored to evaluate leadership competencies in response to the demands of digital transformation.

The realm of leadership has been widely studied, with a multitude of models and approaches used to decipher and understand the competencies required for effective leadership. Traditional leadership research often adopts a piecewise approach, scrutinizing each factor that might affect a person's leadership competencies independently. However, leadership is multifaceted, and viewing each competency in isolation may not provide a comprehensive understanding of how they interrelate and collectively contribute to a leader's effectiveness. The research objectives of this study were to holistically examine what leadership competencies should be possessed by leaders in the financial industry to improve the performance of organizational operations and to understand the intricate relationships among these competencies. By focusing on the financial industry in Taiwan, we engaged senior executives from various financial institutions to form an expert panel. Drawing from existing literature, initial leadership competency criteria were identified and were further refined through the Delphi method.

Our adoption of the multiple-criteria decision-making (MCDM) methodology was pivotal in this context. Unlike traditional statistical theories that necessitate numerous hypotheses and predefined systems, MCDM uses expert samples for analysis, effectively summarizing the weights of criteria and their interrelationships. Moreover, the MCDM approach allows for a more integrated assessment of leadership competencies, highlighting how they are interconnected rather than viewing them as isolated traits. While a few

studies have touched upon leadership competencies from an MCDM perspective, this domain remains underexplored [9].

To fill the research gap and respond to the research objectives, the Z-based decision-making trial and evaluation laboratory (Z-DEMATEL) technique proposed by Hsu et al. [10] was applied in the study to identify the influential relationships among these leadership competency criteria and generate influence weights for the criteria. Furthermore, according to the results of Z-DEMATEL, an Influence Classification Map (ICM) could be plotted, and the criteria could be classified into four categories: core, driving, independent, and impact, providing management implications and recommendations for improvement, respectively. Z-DEMATEL, which integrates Z-fuzzy theory into DEMATEL, is feasible because it can cover a wider range of information to optimize the adaptability of conventional DEMATEL in practical applications. Z-fuzzy theory (the generated membership function is called Z-numbers) was proposed by Zadeh [11] as an augmented application of triangular fuzzy numbers. Z-numbers are mainly composed of two elements, namely taking into account the uncertainty of the evaluation environment and measuring the confidence level of the experts. Many studies have pointed out that DEMATEL is one of the most popular methods for MCDM, and it considers both direct and indirect effects among factors [12,13]. This technique is effective in the analysis of structured systems, especially when it is used to identify the critical factors of the system. In general, previous quantitative studies on leadership competencies have used more statistics-based methodologies [3,7,8]. The Z-DEMATEL method used in this study does not require the sample data to adhere to normality or independence constraints and allows for the use of expert data from small samples. On the other hand, this technique measures not only the direct influence among criteria but also takes into account indirect influences.

In this study, the concept of digital transformation was incorporated into the evaluation of leadership competencies. The expertise and experience of experts was first extracted through a qualitative survey, and the data were then quantified using soft computing techniques. Collaborative research was conducted with senior executives from various financial firms to develop a comprehensive theoretical framework for evaluating leadership competencies in the context of COVID-19 and digital transformation. By incorporating aspects of digital transformation, this study provides insights into the characteristics of leaders in the dynamic and rapidly evolving business environment. The research contributions of this paper are summarized below:

(i) The study identifies the essential leadership competencies expected of leaders in the context of COVID-19 and digital transformation and constructs an evaluation system based on these competencies.
(ii) The study took into account the uncertainty of the evaluation environment and considered the confidence levels of experts, acknowledging the ever-changing digital landscape.
(iii) An Influence Classification Map (ICM) was utilized to plot and illustrate the mutual influence relationships, weights, and influence categories of all the criteria, providing a comprehensive understanding of the interdependencies of leadership competencies.
(iv) The findings of this study provide valuable insights for Taiwan's financial industry regarding the crucial leadership competencies required by organizational leaders during digital transformation. These insights can assist decision makers in formulating effective talent-selection strategies and improvement plans.
(v) The study's methodology is replicable and can be applied to leadership analyses in other industries undergoing digital transformation. By incorporating digital transformation concepts, this research offers practical implications for enhancing leadership competencies in the ever-evolving business landscape, facilitating organizations' successful navigation through the challenges and opportunities presented by digital transformation.

This paper is organized as follows. Section 2 reviews relevant research on leadership competencies and describes the current state of research. Section 3 presents the proposed evaluation framework. Section 4 introduces the concepts and calculation steps

of Z-DEMATEL. Section 5 showcases data analysis using Taiwan's financial industry as an example. Section 6 provides extensive discussions, conclusions, and directions for future research.

2. Review of Literature on Leadership Competencies

Research on leadership competencies has been an active topic in the field of human resource management for several decades. Most of the research in this field has focused on specific leadership competencies, including leadership styles, authenticity, ambidexterity, and boundary spanning [14]. Leadership competencies have been studied more than other human behavior studies and are considered to be a critical skill for all industries, influencing the success of organizational tasks. Specifically, leadership competencies, organizational innovation, and task success are directly correlated and thus contribute to a better organizational return on investment [9].

Each of the leadership theories, models, and methods proposed in existing research has its own competencies, styles, and characteristics. For example, Shao et al. [15] used leadership theory and organizational learning theory to explore the influence of senior managers' styles and organizational learning on the successful implementation of enterprise resource planning (ERP) systems. The study categorized leadership competencies into seven dimensions, including management by exception, contingent rewards, interpersonal consideration, intellectual stimulation, inspirational motivation, idealized behaviors, and idealized attributes (the first two are transactional leadership and the last three are transformational leadership). The authors used statistical methods such as a paired-sample *t*-test, factor analysis, and correlation analysis to show that leaders should have both transactional leadership and transformational leadership attributes to help the organization adapt more quickly to ERP operations. Pham and Kim [2] used partial least squares structural equation modeling (PLS-SEM) to examine whether economic, environmental, and social practices have a significant influence on sustainability performance, with leadership competencies as the moderator. The results showed that leadership competencies moderate the relationship between environmental practices and sustainable development. Shum et al. [16] created a new model called the hospitality leadership competencies model based on the conventional competency model and then pooled the opinions of 30 senior hospitality leaders. In the study, they implemented a variety of statistical methods to show that the leadership competencies of frontline managers are the most important. When recruiting for this position, attention should be paid to intelligence, responsibility, extroversion, and agreeableness. Lambrechts et al. [17] took a qualitative case study approach to discuss 39 incidents related to individual sustainability competencies (ISCs) in four Dutch construction companies. The results of the interviews indicated that leadership competencies were measured by the dimensions of strategic management and execution, embracing diversity, cross-disciplinary competencies, and interpersonal competencies.

Wallace et al. [18] noted that current leadership and leadership development evaluation criteria lack some of the multidimensional and temporal nature of learning. In addition, much of the literature on leadership competency programs tends to focus on individual leadership development outcomes rather than on collective organizational outcomes. Muff et al. [19] evaluated the leaders of global companies on their responsible leadership competencies, with stakeholder engagement, ethics, values, systems thinking, and innovation as the main perspectives. The results of the analysis showed that executives did not improve their performance in responsible leadership competencies after attending the leadership competency development course, while undergraduate students significantly improved their responsible performance. In [20], da Silva et al. applied fuzzy-set qualitative comparative analysis (fsQCA) to measure the correlations of emotional, intellectual, and managerial activities with the demand phase of information systems (IS) projects. In addition, they specifically tested gender and holding project management certification to determine whether these two factors significantly influenced the success of the demand phase of the project. The study concluded that different activities required

different leadership competencies and that males were important for success regardless of the demand activities.

These studies have all contributed to the evaluation of the leadership competencies of leaders in organizations, and many of them discuss issues related to leadership competencies in various industries. The relevant papers from the last five years are compiled in Table 1, which includes the author(s), year, research aim, approach, application, and publication of each paper.

Table 1. Review of the literature on leadership.

Author(s) (Year)	Research Aim	Approach	Application	Publication
Shao et al. [15]	The study explored the influence of leadership style on the success of ERP system implementation.	Paired-sample T-test, factor analysis, correlation analysis	Manufacturing, retail, public administration, construction, information technology, service industries, etc.	*Information & Management*
Wallace et al. [18]	The study presented an integrated model of learning outcomes in leadership and leadership competency development from multiple perspectives.	Literature review	Various industries	*The Leadership Quarterly*
Pham and Kim [2]	The study discussed the influence of environmental, economic, and social practices on the performance of sustainable development, with leadership competencies as the moderator.	PLS-SEM	Construction industry	*Sustainable Production and Consumption*
Shum et al. [16]	The study developed a novel model of hospitality leadership competencies to improve the hospitality industry's ability to recruit, select, train, and evaluate future leaders.	Paired-sample *t*-tests, Wilcoxon signed-priority test, and Mann-Whitney U test	Restaurants/hotels	*International Journal of Hospitality Management*
Lambrechts et al. [17]	The study used several classic case studies to understand the role of individual sustainability competencies (ISCs) in eco-designed architectural projects.	Case study method	Construction industry	*Journal of Cleaner Production*
Muff et al. [19]	The study evaluated the responsible leadership competencies of leaders of global corporations.	Multiple one-way analyses of variance (MANOVA) and Wilcoxon test	Global companies	*Corporate Social Responsibility and Environmental Management*
da Silva et al. [20]	The study explored whether a combination of emotional, intellectual, and managerial competencies contributes to the success of the demand phase of projects in information systems.	Semi-structured expert interviews and FsQCA	Projects in information systems	*Journal of Business Research*
Shao [21]	The study investigated the role of project context in moderating the relationship between project managers' leadership competencies (intellectual, managerial, and emotional) and project success.	Moderated hierarchical regression analyses (MHRAs)	Project management	*International Journal of Project Management*
Wiewiora and Kowalkiewicz [22]	The study evaluated key factors that may contribute to leadership development. Special attention was given to developing students' leadership competencies.	Abductive approach	Higher education school students	*Assessment & Evaluation in Higher Education*
Swanson et al. [23]	The study constructed a conceptual model to explore leadership competencies based on social capital theory. The study focused on the relationships among leadership, knowledge sharing, employee performance, and employee loyalty.	Confirmatory factor analysis (CFA)	Hotel industry	Journal of Hospitality and Tourism Management

Table 1. *Cont.*

Author(s) (Year)	Research Aim	Approach	Application	Publication
Zhang et al. [24]	The study measured the causal relationship between leadership safety behaviors and safety performance. Data for the analysis were collected through a questionnaire survey of 305 miners in China.	Regression analysis and structural equation model analysis	China mining	*International Journal of Environmental Research and Public Health*
Alidrisi and Mohamed [25]	The study identified three leadership competencies of safety managers, including emotional, social, and cognitive. The influence of these three competencies on the influence skills of leaders was investigated.	Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA)	Construction site	*International Journal of Environmental Research and Public Health*
Korzynski et al. [14]	The study used bounded leadership theory to analyze "leadership constraints" as a mediator of the relationship between leadership competencies and organizational performance.	PLS-SEM and regression-based methods	Middle management leaders of various manufacturing industries in Poland	*European Management Journal*
Dirani et al. [5]	The study examined the influence of COVID-19 and the general epidemic on human resource development among U.S. and global leaders.	Literature review	Various industries	*Human Resource Development International*
Amoako et al. [26]	The study investigated the influence of organizational leadership, organizational structure, and employee technical skills on the success of electronic human resource management system implementation.	Exploratory factor analysis, regression analysis	Human resources industry	*SAGE Open*

The gaps between previous studies and this paper are apparent based on the information shown in Table 1. While many of these studies made significant contributions to the understanding of leadership competencies through expert interviews and statistical analyses, only a limited number of studies explored this topic using the concept of MCDM. Furthermore, the analysis of leadership competencies for the leaders in the financial industry in the context of COVID-19 remains unexplored. To address these gaps and introduce a novel research concept, this paper applied the relatively new analysis technique of mutual influence among criteria (Z-DEMATEL). By incorporating the concept of digital transformation and utilizing the MCDM approach, this study aimed to bridge the gap in previous research and offer fresh insights to both practitioners and academic researchers in the field of leadership competencies. This research approach sheds light on the interrelationships among various leadership criteria, which is particularly valuable in the rapidly changing landscape of digital transformation.

3. The Proposed Evaluation Framework

In developing a comprehensive leadership competency framework tailored for leaders in the financial industry, this study utilized a rigorous process of a literature review and expert interviews, grounding itself firmly within seminal leadership theories. The resulting three-dimensional evaluation model, consisting of business strategy (Q), organizational management (M), and personality traits (E), was not arbitrary. These dimensions were derived from extensive leadership literature. First of all, business strategy is a profit-making strategy for business development that focuses on improving business and organizational performance. Organizational management, which was defined as the process of establishing a clear organizational structure, assigning responsibilities, and clearly allocating authority, is a process for achieving organizational goals. Personality traits were defined as the unique personality traits that leaders bring to their organizations.

Although personality traits are considered inherent, their manifestations can profoundly influence organizational outcomes, providing a holistic blend of both inherent and

acquired leadership attributes. In addressing the concern regarding the interrelationships among dimensions, we recognized the intricate interplay between them. For instance, specific personality traits might bolster the efficacy of business strategies or enhance organizational managerial practices. While the current model assumed equivalence based on preliminary insights, we acknowledge the potential non-equivalence of interrelationships. Future iterations of this model will delve deeper into these nuanced interdependencies, aligning our approach more closely with contemporary leadership discussions and laying a robust foundation for further research in this domain. A total of 17 criteria are presented in Table 2.

Table 2. Proposed evaluation framework for leadership competencies.

Dimension	Criterion	References
Business strategy (Q)	Critical analysis and judgment (Q1)	[17,27,28]
	Vision and imagination (Q2)	[29]
	Strategic perspective (Q3)	[27,28]
	Teamwork (Q4)	[30]
Organizational management (M)	Empowering (M1)	[31]
	Resource management (M2)	[27,28,32]
	Internal exchanges (M3)	[33,34]
	Organizational development (M4)	[27,35]
	Achieving (M5)	[27,35]
	Fair and objective (M6)	[36,37]
Personality traits (E)	Self-awareness (E1)	[22,25]
	Emotional resilience (E2)	[5,14,24]
	Decisive (E3)	[38–40]
	Motivation (E4)	[38–40]
	Interpersonal sensitivity (E5)	[41]
	Influence (E6)	[42]
	Conscientiousness (E7)	[43]

Business strategy (Q):

The four corresponding criteria were critical analysis and judgment (Q1), vision and imagination (Q2), strategic perspective (Q3), and teamwork (Q4). Critical analysis and judgment (Q1) referred to a leader's ability to identify critical factors and make recommendations for improvement [17,27,28]. Vision and imagination (Q2) referred to a leader's ability to think big, be creative, and come up with new concepts and technologies [29]. Strategic perspective (Q3) referred to a leader's ability to develop strategies and goals that are conducive to organizational development [27,28]. Teamwork (Q4) referred to the leader's ability to lead a team of people to collaborate and work together to achieve organizational goals [30].

Organizational management (M):

There were six corresponding criteria, namely empowering (M1), resource management (M2), internal exchanges (M3), organizational development (M4), achieving (M5), and fair and objective (M6). Empowering (M1) was the ability of leaders to empower their subordinates or colleagues to make specific decisions to enhance organizational excellence [31]. Resource management (M2) referred to the ability of leaders to effectively coordinate and allocate resources [27,28,32]. Internal exchanges (M3) referred to the ability of leaders to coordinate the transfer of information among organizations and to improve the communication and coordination of organizational departments [33,34]. Organizational development (M4) referred to the ability of leaders to solve problems and provide innovative processes within the organization [27,35]. Achieving (M5) referred to the ability of leaders to systematically achieve the expected goals set by the organization [27,35]. Fair and objective (M6) referred to the ability of leaders to be consistent in their words and deeds, to be fair and upright in leading their teams, and analyze priorities from a rational perspective [36,37].

Personality traits (E):

There were seven corresponding criteria, namely self-awareness (E1), emotional resilience (E2), decisive (E3), motivation (E4), interpersonal sensitivity (E5), self-awareness (E6), and conscientiousness (E7). Self-awareness (E1) referred to the leader's ability to clearly measure the gap between their own abilities and their perceptions of what is expected of them [22,25]. Emotional resilience (E2) referred to the leader's ability to manage their own emotional ups and downs when performing leadership tasks to reduce the influence of negative emotions and make less irrational decisions [5,14,24]. Decisive (E3) referred to the leader's ability to not hesitate to lead the team but to make decisive judgments about everything [38–40]. Motivation (E4) referred to the leader's ability to think analytically and establish clear motivation before leading the team to perform tasks [38–40]. Interpersonal sensitivity (E5) referred to the leader's ability to lead the team in a way that is sensitive to the atmosphere in which the members of the organization get along with each other and reconcile disagreements and confrontations among them [41]. Influence (E6) referred to the leader's ability to become a role model for the team through their leadership and influence [42]. Conscientiousness (E7) referred to a leader's ability to lead any task with total commitment, courage to face mistakes and faults, and sense of responsibility [43].

4. Methodology

This section describes the applied Z-DEMATEL theory and analysis procedure. First, the basic concept of Z-numbers is introduced, and the linguistic comparison table of Z-DEMATEL evaluation is presented. Then, the calculational steps of the Z-DEMATEL technique are presented. The technique can map the ICM and provide decision makers with a quick understanding of the causal relationships of the criteria.

Z-numbers contain two types of fuzzy information; namely, the degree of certainty of an evaluation and the confidence level of its evaluation. The degree of certainty of a fuzzy event can be measured by its probability and reliability, and Z-numbers can convert both pieces of information into a set of fuzzy numbers [11]. For further illustration, the conversion of conventional fuzzy numbers to Z-numbers is described. Suppose a Z-number is denoted as $Z = \left(\widetilde{F},\ \widetilde{R}\right)$, where $\widetilde{F}$ is the triangular fuzzy numbers of the evaluation value, and $\widetilde{R}$ is the confidence level in $\widetilde{F}$. Both $\widetilde{F} = \left(f,\ \mu_{\widetilde{F}}\right)|x \in [0,\ 1]$ and $\widetilde{R} = \left(x,\ \mu_{\widetilde{R}}\right)|x \in [0,\ 1]$ are triangular membership functions. $\widetilde{R}$ can be converted into a crisp value as shown in Equation (1).

$$\alpha = \frac{\int^{x} \mu_{\widetilde{R}}\, dx}{\int^{\mu_{\widetilde{R}}} dx} \tag{1}$$

Next, the weight of confidence α is added to the evaluated value $\widetilde{F}$. The weighted Z-numbers are as shown in Equation (2).

$$Z^{\alpha} = \left\{ \left(x,\ \mu_{\widetilde{F}^{\alpha}}\right) \middle| \mu_{\widetilde{F}^{\alpha}}(x) = \alpha \mu_{\widetilde{F}}(x),\ x \in \sqrt{\alpha} X \right\} \tag{2}$$

where the notation "$x \in \sqrt{\alpha}X$" can be interpreted as "x belongs to the set $\sqrt{\alpha}X$." So, this expression states that the element x is a member of the set $\sqrt{\alpha}X$ [11].

A set of linguistic variables of Z-numbers can be integrated based on the linguistic variables of the evaluation values and the linguistic variables of the confidence levels. If an evaluation system has n criteria, then $c_i = \{c_1, c_2, \ldots, c_n\}$. These criteria must be compared with each other in pairwise comparisons to investigate the mutual influence; that is, to evaluate the degree of influence of c_i on c_j. Next, the experts were asked to formulate the level of confidence in the content of their answers, i.e., the confidence level of the evaluation. For example, if there is a set of evaluation terms that reads "the evaluation level is medium influence (M), and the reliability is medium (M)", then the corresponding Z-number is $Z = \left(\widetilde{F} = M,\ \widetilde{R} = M\right)$, which is calculated as follows.

$$Z = [(1,\ 2,\ 3),\ (0.3,\ 0.5,\ 0.7)]$$

According to Equation (1), the membership function of reliability is converted to an explicit value.

$$\alpha = \frac{\int^{x} \mu_{\widetilde{R}} dx}{\int^{\mu_{\widetilde{R}}} dx} = \frac{\int_{0.3}^{0.5} x\left(\frac{x-0.3}{0.5-0.3}\right)dx + \int_{0.5}^{0.7} x\left(\frac{0.7-x}{0.7-0.5}\right)dx}{\int_{0.3}^{0.5} \left(\frac{x-0.3}{0.5-0.3}\right)dx + \int_{0.5}^{0.7} \left(\frac{0.7-x}{0.7-0.5}\right)dx} = 0.4998$$

Next, the value α is added to the evaluation value $\widetilde{F} = M$.

$$Z^{\alpha} = \{(1,\ 2,\ 3)|\alpha = 0.4998\}$$

Then, the weighted Z-number can be converted into a conventional fuzzy number.

$$Z' = \left(\sqrt{0.4998} \cdot 1,\ \sqrt{0.4998} \cdot 2,\ \sqrt{0.4998} \cdot 1\right) = (0.707,\ 1.414,\ 2.121)$$

For other Z-number calculation examples, please refer to Zadeh [11].

According to the study by Hsu et al. [10], the rules of the Z-DEMATEL linguistic variable conversion and the Z-numbers are shown in Table 3. The evaluation scale for influence (in ascending order) was (0, 0, 1), (0, 1, 2), (1, 2, 3), (2, 3, 4), and (3, 4, 4). The evaluation scale for reliability (in ascending order) was (0, 0, 0.3), (0.1, 0.3, 0.5), (0.3, 0.5, 0.7), (0.5, 0.7, 0.9), and (0.7, 1, 1). Therefore, through the Z-number conversion, the member functions can be obtained. For instance, the function for "medium influence" and "low confidence" is denoted as (0.548, 1.096, 1.644).

Table 3. Linguistic variables of Z-numbers and their member functions.

Confidence Level	Influence Evaluation				
	No Influence	**Low Influence**	**Medium Influence**	**High Influence**	**Very High Influence**
Very low	(0, 0, 0.316)	(0, 0.316, 0.632)	(0.316, 0.632, 0.949)	(0.632, 0.949, 1.265)	(0.949, 1.265, 1.265)
Low	(0, 0, 0.548)	(0, 0.548, 1.096)	(0.548, 1.096, 1.644)	(1.096, 1.644, 2.192)	(1.644, 2.192, 2.192)
Medium	(0, 0, 0.707)	(0, 0.707, 1.414)	(0.707, 1.414, 2.121)	(1.414, 2.121, 2.828)	(2.121, 2.828, 2.828)
High	(0, 0, 0.837)	(0, 0.837, 1.673)	(0.837, 1.673, 2.510)	(1.673, 2.510, 3.347)	(2.510, 3.347, 3.347)
Very high	(0, 0, 0.949)	(0, 0.949, 1.897)	(0.949, 1.897, 2.846)	(1.897, 2.846, 3.795)	(2.846, 3.795, 3.795)

In an evaluation environment that is both complex and full of uncertainty, it is difficult for experts to use crisp values to reflect their true feelings. There have been many fuzzy theoretical approaches combined with DEMATEL to account for uncertainty. Unfortunately, these methods neglect the confidence levels that experts have in the evaluation. The Z-DEMATEL technique was used in this study to not only know the confidence level of each expert in the evaluation but also to retain the form of the triangular fuzzy number for the calculation to avoid information loss. Simply put, compared to traditional DEMATEL, Z-DEMATEL includes more extensive fuzzy information and can adjust standard fuzzy numbers based on the experts' confidence when answering.

The detailed steps of the Z-DEMATEL technique are as follows [10].

Step 1. Develop a set of evaluation criteria/objects

A group of experts form a decision-making team to develop a set of appropriate evaluation criteria/objects (c_i). In this study, the objects of the development trend were considered as the criteria $c_i = \{c_1,\ c_2, \ldots,\ c_n\}$.

Step 2. Build the direct relation matrix $\otimes \boldsymbol{A}$

Assume there are n criteria and that the influences among these criteria need to be evaluated. Each expert evaluates the degree of direct influence of criterion i on criterion j

and assigns a confidence level to each rating. The opinions of all experts are integrated into a group direct relation matrix $\otimes \boldsymbol{A}$ via the "arithmetic mean," as shown in Equation (3).

$$\otimes \boldsymbol{A} = \left[\otimes a_{ij}\right]_{n\times n} = \begin{bmatrix} \otimes a_{11} & \otimes a_{12} & \cdots & \otimes a_{1j} & \cdots & \otimes a_{1n} \\ \otimes a_{21} & \otimes a_{22} & \cdots & \otimes a_{2j} & \cdots & \otimes a_{2n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \otimes a_{i1} & \otimes a_{i2} & \cdots & \otimes a_{ij} & \cdots & \otimes a_{in} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \otimes a_{n1} & \otimes a_{n2} & \cdots & \otimes a_{nj} & \cdots & \otimes a_{nn} \end{bmatrix}_{n\times n}, i = j = 1,\ 2, \ldots,\ n \quad (3)$$

where $\otimes a_{ij} = \left(a_{ij}^{L},\ a_{ij}^{M},\ a_{ij}^{U}\right)$.

Here, DEMATEL requires the diagonal elements of the matrix to be 0, i.e., $\otimes a_{ij} = 0$ when $i = j$.

Step 3. Obtain the normalized direct relation matrix $\otimes \boldsymbol{X}$

Since the values of $\otimes a_{ij}$ range from (0, 0, 0.316) to (2.846, 3.795, 3.795), these evaluation values (including the minimum, median, and maximum values) can be converted to 0 to 1 using normalization (Equations (4) and (5)).

$$\otimes \boldsymbol{X} = \left[\otimes x_{ij}\right]_{n\times n} = \begin{bmatrix} \varepsilon \cdot \otimes a_{11} & \varepsilon \cdot \otimes a_{12} & \cdots & \varepsilon \cdot \otimes a_{1j} & \cdots & \varepsilon \cdot \otimes a_{1n} \\ \varepsilon \cdot \otimes a_{21} & \varepsilon \cdot \otimes a_{22} & \cdots & \varepsilon \cdot \otimes a_{2j} & \cdots & \varepsilon \cdot \otimes a_{2n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \varepsilon \cdot \otimes a_{i1} & \varepsilon \cdot \otimes a_{i2} & \cdots & \varepsilon \cdot \otimes a_{ij} & \cdots & \varepsilon \cdot \otimes a_{in} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \varepsilon \cdot \otimes a_{n1} & \varepsilon \cdot \otimes a_{n2} & \cdots & \varepsilon \cdot \otimes a_{nj} & \cdots & \varepsilon \cdot \otimes a_{nn} \end{bmatrix}_{n\times n}, i = j = 1,\ 2, \ldots,\ n \quad (4)$$

where $\otimes x_{ij} = \left(x_{ij}^{L},\ x_{ij}^{M},\ x_{ij}^{U}\right)$.

$$\varepsilon = \min\left\{\frac{1}{\max_i \sum_{j=1}^{n} a_{ij}^{U}}, \frac{1}{\max_j \sum_{i=1}^{n} a_{ij}^{U}}\right\} \quad (5)$$

Step 4. Generate the total influence matrix $\otimes \boldsymbol{T}$

The total influence matrix $\otimes \boldsymbol{T}$ (Equation (6)) can be calculated using Equation (7) to integrate the normalized direct relation matrix $\otimes \boldsymbol{X}$. This step sums up all the direct and indirect influential relations from the first power to the infinite power of $\otimes \boldsymbol{X}$. Since the procedure of Equation (7) is tedious, a faster formula can be derived from Equation (8).

$$\otimes \boldsymbol{T} = \left[\otimes t_{ij}\right]_{n\times n} = \begin{bmatrix} \otimes t_{11} & \otimes t_{12} & \cdots & \otimes t_{1j} & \cdots & \otimes t_{1n} \\ \otimes t_{21} & \otimes t_{22} & \cdots & \otimes t_{2j} & \cdots & \otimes t_{2n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \otimes t_{i1} & \otimes t_{i2} & \cdots & \otimes t_{ij} & \cdots & \otimes t_{in} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \otimes t_{n1} & \otimes t_{n2} & \cdots & \otimes t_{nj} & \cdots & \otimes t_{nn} \end{bmatrix}_{n\times n}, i = j = 1,\ 2, \ldots,\ n \quad (6)$$

where $\otimes t_{ij} = \left(t_{ij}^{L},\ t_{ij}^{M},\ t_{ij}^{U}\right)$.

$$\otimes \boldsymbol{T} = \otimes \boldsymbol{X} + \otimes \boldsymbol{X}^2 + \cdots + \lim_{\theta\to\infty} (\otimes \boldsymbol{X})^{\theta} \quad (7)$$

$$\begin{aligned} \otimes \boldsymbol{T} &= \otimes \boldsymbol{X} + \otimes \boldsymbol{X}^2 + \cdots + \lim_{\theta \to \infty} (\otimes \boldsymbol{X})^{\theta} = \otimes \boldsymbol{X}\left(\boldsymbol{I} + \otimes \boldsymbol{X} + \otimes \boldsymbol{X}^2 + \cdots + \lim_{\theta \to \infty} (\otimes \boldsymbol{X})^{\theta-1}\right) \\ &= \otimes \boldsymbol{X}\left(\boldsymbol{I} - \lim_{\theta \to \infty} (\otimes \boldsymbol{X})^{\theta}\right)(\boldsymbol{I} - \otimes \boldsymbol{X})^{-1} = \otimes \boldsymbol{X}(\boldsymbol{I} - \otimes \boldsymbol{X})^{-1} \end{aligned} \tag{8}$$

where $\lim_{\theta \to \infty} (\otimes \boldsymbol{X})^{\theta} = [0]_{n \times n}$ and $\boldsymbol{I}$ is the identity matrix.

Step 5. Establish ICM to identify the mutual influence of development objects

Using Equations (9) and (10), $\otimes \boldsymbol{r}$ is obtained by summing up each column of the total influence matrix $\otimes \boldsymbol{T}$. Similarly, using Equations (11) and (12), $\otimes \boldsymbol{s}$ is obtained by summing up each row.

$$\otimes \boldsymbol{r} = [\otimes r_i]_{n \times 1} = (\otimes r_1,\ \otimes r_2, \ldots,\ \otimes r_i, \ldots,\ \otimes r_n) \tag{9}$$

$$[\otimes r_i]_{n \times 1} = \left[\sum_{j=1}^{n} \otimes t_{ij}\right]_{n \times 1} \tag{10}$$

$$\otimes \boldsymbol{s} = \left[\otimes s_j\right]_{1 \times n} = \left(\otimes s_1,\ \otimes s_2, \ldots,\ \otimes s_j, \ldots,\ \otimes s_n\right)^T \tag{11}$$

$$\left[\otimes s_j\right]_{1 \times n} = \left[\sum_{i=1}^{n} \otimes t_{ij}\right]_{1 \times n} = [\otimes s_i]_{n \times 1}^T \tag{12}$$

where the symbol "superscript T" represents the matrix transposition; in addition, $\otimes r_i = \left(r_i^L,\ r_i^M,\ r_i^U\right)$ and $\otimes s_i = \left(s_i^L,\ s_i^M,\ s_i^U\right)$. $\otimes r_i + \otimes s_i$ is the index of the strength of influences given and received. On the other hand, $\otimes r_i - \otimes s_i$ represents the net influence. If $\otimes r_i - \otimes s_i$ is larger, it means that object i has a greater degree of influence on the evaluation system. If $\otimes r_i - \otimes s_i > 0$, it means that object i has a significant effect on other objects and is called a causal factor; conversely, if $\otimes r_i - \otimes s_i < 0$, it means that object i is more influenced by other objects and is called an affected factor.

Here, the centroid method is used to defuzzify the value (e.g., $\otimes \lambda = \left(\lambda^L,\ \lambda^M,\ \lambda^U\right)$) to obtain the crisp value (λ) as shown in Equation (13).

$$\lambda = \frac{\lambda^L + \lambda^M + \lambda^U}{3} \tag{13}$$

Next, $\otimes r_i$ and $\otimes s_i$ are obtained as r_i and s_i, respectively, by using the defuzzification procedure of Equation (13). By using $r_i + s_i$ as the horizontal axis and $r_i - s_i$ as the vertical axis, the relative coordinates of each item can be clearly plotted. The total influence matrix $\otimes \boldsymbol{T}$ is used to identify the influence among the objects, and the arrows (indicating the direction of influence) are plotted to generate a systematic ICM.

Step 6. Obtain the influence weights of the development objects

Here, $r_i + s_i$ reflects the total influence of the objects on the evaluation system, so the influence weights of the objects can be constructed by using Equation (14), $w_i = \{w_1,\ w_2, \ldots,\ w_n\}$. Here, the sum of the weights is required to be 1.

$$w_i = \frac{(r_i + s_i)}{\sum_{i=1}^{n} (r_i + s_i)} \tag{14}$$

To ensure the consensus of the experts' responses, the Average Sample Gap (ASG) was adopted in this study as shown in Equation (15).

$$ASG = (n(n-1))^{-1} \times \sum_{i=1}^{n} \sum_{j=1}^{n} \left(\left| t_{ij}^{p} - t_{ij}^{p-1} \right| / t_{ij}^{p}\right) \times 100\% \tag{15}$$

where t_{ij}^{p} are the crisp values obtained after defuzzifying the elements of the total influence matrix, and p represents the pth expert.

5. Case Study: Financial Industry of Taiwan

According to the report on the 2022 Global Banking 500 survey by Brand Finance, a UK-based research institute, the COVID-19 pandemic has had a profound impact on people's consumption habits, creating transformational pressure on the financial industry and posing significant challenges to its overall development. Despite the global financial industry facing a slowdown, Taiwan's financial sector has shown resilience and growth during the pandemic thanks to the visionary leadership and sound decision making of leaders within Taiwan's financial industry, leading to an improvement in its overall ranking. This emphasizes the crucial role of leadership in the financial industry.

However, achieving comprehensive innovation and transformation across the entire financial industry in Taiwan is a complex and challenging endeavor, given the dynamic nature of the business and the ever-changing factors influencing leadership competencies. Currently, there is a lack of a specific leadership evaluation system tailored for the financial industry that identifies the most critical leadership competencies. Moreover, most existing studies did not explore the mutual influence relationships among leadership competency criteria. To address these gaps, this study convened a group of 24 senior executives from financial institutions during the COVID-19 epidemic in Taiwan's financial industry. These experts, each with at least 10 years of experience in the financial sector, played pivotal roles in driving the industry's development. The proposed leadership evaluation framework presented in Section 3 identified three dimensions with 17 criteria classified under them. This framework aims to shed light on the vital leadership competencies required for successful digital transformation and innovation in Taiwan's financial industry, providing valuable insights for both practitioners and academic researchers in navigating the complexities of the rapidly changing digital landscape.

The calculation process of Z-DEMATEL was described in Section 4. First, the study used structured interviews to interview 24 experts in the financial industry; their backgrounds are shown in Table 4. The interviews were conducted in the experts' respective meeting rooms. After confirming that the experts understood the interview and signed the consent form, the study followed the Z-DEMATEL evaluation proposed by Hsu et al. [21] to administer the leadership competency criteria questionnaire. Experts were asked to conduct paired comparisons for all criteria to obtain a 17×17 matrix. In order to avoid distortion of the survey data due to the fatigue of the experts during the filling process, five breaks were scheduled during the interviews, and the total survey time was 5 h. The survey was collected and reviewed by all experts to confirm that the survey was correct before starting the calculation.

Table 4. Backgrounds of the 24 experts who evaluated the competencies of key leaders in the financial industry.

Expert No.	Job Title	Education	Years of Experience	Expert No.	Job Title	Education	Years of Experience
Expert 1	Manager	Master's	30 years	*Expert 13*	Manager	Bachelor's	20 years
Expert 2	Bank president	Bachelor's	20 years	*Expert 14*	Director	Master's	25 years
Expert 3	Manager	Master's	35 years	*Expert 15*	Assistant manager	Bachelor's	10 years
Expert 4	Bank president	Master's	15 years	*Expert 16*	Supervisor	Master's	20 years
Expert 5	Bank president	Master's	20 years	*Expert 17*	Deputy manager	High school	20 years
Expert 6	Assistant manager	Master's	15 years	*Expert 18*	Assistant manager	Bachelor's	20 years
Expert 7	Managing director	Master's	15 years	*Expert 19*	Assistant manager	Bachelor's	15 years

Table 4. *Cont.*

Expert No.	Job Title	Education	Years of Experience	Expert No.	Job Title	Education	Years of Experience
Expert 8	Vice president	Master's	20 years	*Expert 20*	Assistant manager	Bachelor's	20 years
Expert 9	Manager	Master's	20 years	*Expert 21*	Assistant manager	Bachelor's	15 years
Expert 10	General manager	High school	30 years	*Expert 22*	Assistant manager	Master's	25 years
Expert 11	Manager	Bachelor's	20 years	*Expert 23*	Assistant manager	Master's	20 years
Expert 12	Manager	Bachelor's	20 years	*Expert 24*	Assistant manager	Master's	20 years

Table 5 shows the survey results for the first expert in this study. For example, the first expert considered Q1 to have a "high influence" on Q2 and evaluated the confidence level to be "very high", thus presenting the results of H, VH in Q1 vs. Q2. The paired-comparison processes between the other criteria were also conducted in the same way. Finally, the data in Table 5 were converted into Z-value membership functions as shown in Table 6.

Table 5. The first expert's linguistic terms.

	Q1	Q2	Q3	Q4	M1	...	E7
Q1	0	H, VH	VH, VH	M, VH	H, VH	...	M, VH
Q2	VH, H	0	VH, H	VH, H	M, H	...	L, H
Q3	H, M	VH, M	0	M, M	H, M	...	M, M
Q4	H, VH	VH, VH	M, VH	0	VH, VH	...	H, VH
M1	VH, M	H, M	H, M	VH, M	0	...	H, M
⋮	⋮	⋮	⋮	⋮	⋮	⋱	⋮
E7	M, VH	H, VH	M, VH	VH, VH	VH, VH	...	0

Table 6. The first expert's linguistic terms (Z membership functions).

	Q1	Q2	Q3	Q4	M1	...	E7
Q1	(0.00, 0.00, 0.00)	(1.90, 2.85, 3.80)	(2.85, 3.80, 3.80)	(0.95, 1.90, 2.85)	(1.90, 2.85, 3.80)	...	(0.95, 1.90, 2.85)
Q2	(2.51, 3.35, 3.35)	(0.00, 0.00, 0.00)	(2.51, 3.35, 3.35)	(2.51, 3.35, 3.35)	(0.84, 1.67, 2.51)	...	(0.00, 0.84, 1.67)
Q3	(1.41, 2.12, 2.83)	(2.12, 2.83, 2.83)	(0.00, 0.00, 0.00)	(0.71, 1.41, 2.12)	(1.41, 2.12, 2.83)	...	(0.71, 1.41, 2.12)
Q4	(1.90, 2.85, 3.80)	(2.85, 3.80, 3.80)	(0.95, 1.90, 2.85)	(0.00, 0.00, 0.00)	(2.85, 3.80, 3.80)	...	(1.90, 2.85, 3.80)
M1	(2.12, 2.83, 2.83)	(1.41, 2.12, 2.83)	(1.41, 2.12, 2.83)	(2.12, 2.83, 2.83)	(0.00, 0.00, 0.00)	...	(1.41, 2.12, 2.83)
⋮	⋮	⋮	⋮	⋮	⋮	⋱	⋮
E7	(0.95, 1.90, 2.85)	(1.90, 2.85, 3.80)	(0.95, 1.90, 2.85)	(2.85, 3.80, 3.80)	(2.85, 3.80, 3.80)	...	(0.00, 0.00, 0.00)

The direct relationship matrix (Table 7) of the 24 experts was integrated by using Equation (3), and the importance of all experts' opinions was determined to be the same in this step. The ASG could effectively identify the consistency of the experts' data, and an ASG of less than 5% indicated a consensus among the experts. In this study, the ASG was calculated as 3.77%, which meant that 96.23% of the confidence level indicated that there was a significant consensus among the experts.

Next, the survey data from all experts were normalized by using Equations (4) and (5) (Table 8), ensuring that the overall data range was between 0 and 1. Next, Equations (6)–(8) were used to obtain the total influential relationship matrix (Table 9).

Table 7. The direct relation matrix.

	Q1	**Q2**	**Q3**	**Q4**	**M1**	...	**E7**
Q1	(0.00, 0.00, 0.00)	(2.00, 2.85, 3.39)	(2.35, 3.19, 3.39)	(1.26, 2.11, 2.96)	(1.19, 2.03, 2.88)	...	(1.10, 1.86, 2.59)
Q2	(2.19, 3.03, 3.32)	(0.00, 0.00, 0.00)	(2.37, 3.20, 3.32)	(1.69, 2.52, 3.13)	(1.14, 1.97, 2.80)	...	(0.71, 1.54, 2.37)
Q3	(1.84, 2.66, 3.26)	(2.03, 2.85, 3.26)	(0.00, 0.00, 0.00)	(1.53, 2.34, 3.07)	(1.51, 2.33, 3.15)	...	(0.70, 1.51, 2.33)
Q4	(1.47, 2.32, 3.16)	(1.57, 2.42, 3.06)	(1.57, 2.42, 2.96)	(0.00, 0.00, 0.00)	(1.90, 2.75, 3.39)	...	(0.95, 1.69, 2.54)
M1	(1.33, 2.16, 2.79)	(1.23, 2.06, 2.89)	(1.13, 1.96, 2.79)	(1.56, 2.39, 3.01)	(0.00, 0.00, 0.00)	...	(1.19, 2.02, 2.85)
⋮	⋮	⋮	⋮	⋮	⋮	⋱	⋮
E7	(0.90, 1.76, 2.51)	(1.02, 1.78, 2.64)	(0.98, 1.84, 2.70)	(1.14, 1.90, 2.52)	(1.56, 2.42, 3.04)	...	(0.00, 0.00, 0.00)

Table 8. The normalized direct relation matrix.

	Q1	**Q2**	**Q3**	**Q4**	**M1**	...	**E7**
Q1	(0.00, 0.00, 0.00)	(0.04, 0.06, 0.07)	(0.05, 0.07, 0.07)	(0.03, 0.04, 0.06)	(0.03, 0.04, 0.06)	...	(0.02, 0.04, 0.05)
Q2	(0.05, 0.06, 0.07)	(0.00, 0.00, 0.00)	(0.05, 0.07, 0.07)	(0.04, 0.05, 0.07)	(0.02, 0.04, 0.06)	...	(0.02, 0.03, 0.05)
Q3	(0.04, 0.06, 0.07)	(0.04, 0.06, 0.07)	(0.00, 0.00, 0.00)	(0.03, 0.05, 0.07)	(0.03, 0.05, 0.07)	...	(0.01, 0.03, 0.05)
Q4	(0.03, 0.05, 0.07)	(0.03, 0.05, 0.07)	(0.03, 0.05, 0.06)	(0.00, 0.00, 0.00)	(0.04, 0.06, 0.07)	...	(0.02, 0.04, 0.05)
M1	(0.03, 0.05, 0.06)	(0.03, 0.04, 0.06)	(0.02, 0.04, 0.06)	(0.03, 0.05, 0.06)	(0.00, 0.00, 0.00)	...	(0.03, 0.04, 0.06)
⋮	⋮	⋮	⋮	⋮	⋮	⋱	⋮
E7	(0.02, 0.04, 0.05)	(0.02, 0.04, 0.06)	(0.02, 0.04, 0.06)	(0.02, 0.04, 0.05)	(0.03, 0.05, 0.06)	...	(0.00, 0.00, 0.00)

Table 9. The total influence matrix.

	Q1	**Q2**	**Q3**	**Q4**	**M1**	...	**E7**
Q1	(0.02, 0.09, 0.57)	(0.06, 0.15, 0.66)	(0.07, 0.15, 0.64)	(0.04, 0.13, 0.62)	(0.04, 0.13, 0.62)	...	(0.04, 0.11, 0.56)
Q2	(0.06, 0.15, 0.63)	(0.02, 0.09, 0.58)	(0.07, 0.15, 0.64)	(0.05, 0.14, 0.62)	(0.04, 0.12, 0.61)	...	(0.03, 0.10, 0.55)
Q3	(0.06, 0.14, 0.62)	(0.06, 0.14, 0.63)	(0.02, 0.09, 0.56)	(0.05, 0.13, 0.61)	(0.05, 0.13, 0.60)	...	(0.03, 0.10, 0.54)
Q4	(0.05, 0.13, 0.61)	(0.05, 0.13, 0.62)	(0.05, 0.13, 0.61)	(0.02, 0.08, 0.54)	(0.05, 0.13, 0.60)	...	(0.03, 0.10, 0.54)
M1	(0.04, 0.12, 0.57)	(0.04, 0.12, 0.59)	(0.04, 0.12, 0.58)	(0.05, 0.12, 0.57)	(0.01, 0.07, 0.51)	...	(0.03, 0.10, 0.52)
⋮	⋮	⋮	⋮	⋮	⋮	⋱	⋮
E7	(0.03, 0.11, 0.59)	(0.04, 0.12, 0.61)	(0.04, 0.12, 0.60)	(0.04, 0.12, 0.59)	(0.05, 0.12, 0.59)	...	(0.01, 0.07, 0.48)

$\otimes r_i$ and $\otimes s_i$ were obtained by summing the columns and rows of the total influence matrix through Equations (9)–(12). The results of the total influence $\otimes r_i + \otimes s_i$ and net influence $\otimes r_i - \otimes s_i$ are shown in Table 10. The total influence and net influence of each criterion can be obtained from Table 11. The net effect of emotional resilience (E2) was 0.337, which meant that emotional resilience (E2) was most likely to affect other criteria. The net effect of empowering (M1) was −0.313, which meant that empowering (M1) was most likely to be influenced by other criteria.

Table 10. Total influence and net influence of Z-numbers.

	$\otimes r_i$	$\otimes s_i$	$\otimes r_i + \otimes s_i$	$\otimes r_i - \otimes s_i$
Q1	(0.69, 2.00, 9.97)	(0.68, 1.98, 9.87)	(1.37, 3.99, 19.84)	(−9.18, 0.02, 9.29)
Q2	(0.69, 2.00, 9.87)	(0.72, 2.05, 10.18)	(1.41, 4.04, 20.06)	(−9.49, −0.05, 9.16)
Q3	(0.65, 1.89, 9.65)	(0.71, 2.04, 9.99)	(1.36, 3.93, 19.64)	(−9.35, −0.15, 8.94)
Q4	(0.59, 1.83, 9.51)	(0.67, 1.94, 9.75)	(1.26, 3.77, 19.26)	(−9.16, −0.11, 8.84)
M1	(0.51, 1.68, 9.02)	(0.64, 1.91, 9.69)	(1.15, 3.58, 18.71)	(−9.18, −0.23, 8.38)
M2	(0.50, 1.67, 9.06)	(0.62, 1.87, 9.60)	(1.12, 3.54, 18.66)	(−9.10, −0.20, 8.44)
M3	(0.48, 1.62, 8.76)	(0.49, 1.64, 8.97)	(0.97, 3.26, 17.73)	(−8.49, −0.02, 8.27)
M4	(0.46, 1.60, 8.67)	(0.56, 1.77, 9.40)	(1.02, 3.37, 18.07)	(−8.94, −0.17, 8.11)
M5	(0.44, 1.56, 8.69)	(0.56, 1.76, 9.29)	(0.99, 3.32, 17.98)	(−8.85, −0.21, 8.14)
M6	(0.57, 1.78, 9.39)	(0.45, 1.58, 8.76)	(1.01, 3.35, 18.15)	(−8.19, 0.20, 8.95)
E1	(0.51, 1.67, 9.00)	(0.38, 1.45, 8.28)	(0.89, 3.12, 17.28)	(−7.76, 0.23, 8.62)
E2	(0.61, 1.83, 9.53)	(0.47, 1.59, 8.80)	(1.07, 3.42, 18.33)	(−8.19, 0.24, 9.07)
E3	(0.52, 1.69, 9.07)	(0.50, 1.63, 8.88)	(1.02, 3.32, 17.95)	(−8.36, 0.05, 8.57)

Table 10. *Cont.*

	$\otimes r_i$	$\otimes s_i$	$\otimes r_i + \otimes s_i$	$\otimes r_i - \otimes s_i$
E4	(0.49, 1.62, 8.75)	(0.46, 1.56, 8.55)	(0.95, 3.18, 17.30)	(−8.06, 0.05, 8.29)
E5	(0.61, 1.86, 9.61)	(0.53, 1.71, 9.16)	(1.15, 3.57, 18.78)	(−8.55, 0.14, 9.08)
E6	(0.50, 1.62, 8.61)	(0.46, 1.58, 8.63)	(0.96, 3.20, 17.25)	(−8.14, 0.04, 8.15)
E7	(0.58, 1.80, 9.46)	(0.51, 1.65, 8.83)	(1.08, 3.45, 18.29)	(−8.26, 0.16, 8.95)

Table 11. Z-DEMATEL weighting and ranking analysis results after defuzzification.

	r_i	s_i	r_i+s_i	r_i−s_i	**Weight**	**Rank**
Q1	3.669	3.629	7.298	0.039	0.065	2
Q2	3.639	3.748	7.387	−0.108	0.066	1
Q3	3.521	3.695	7.216	−0.175	0.064	3
Q4	3.441	3.577	7.017	−0.136	0.062	4
M1	3.221	3.535	6.756	−0.313	0.060	6
M2	3.225	3.492	6.717	−0.267	0.060	7
M3	3.121	3.185	6.306	−0.064	0.056	14
M4	3.080	3.375	6.455	−0.296	0.057	11
M5	3.062	3.344	6.406	−0.282	0.057	12
M6	3.379	3.089	6.468	0.290	0.057	10
E1	3.217	2.888	6.104	0.329	0.054	17
E2	3.450	3.112	6.562	0.337	0.058	9
E3	3.242	3.162	6.404	0.080	0.057	13
E4	3.119	3.035	6.154	0.084	0.055	16
E5	3.484	3.281	6.765	0.204	0.060	5
E6	3.089	3.066	6.155	0.024	0.055	15
E7	3.4101	3.1580	6.568	0.252	0.058	8

In order to facilitate the interpretation of the representative meaning of the data, the original fuzzy data were transformed into crisp values through Equation (13) so that the weighting and ranking of the criteria could be clearly obtained, and the defuzzified Z-DEMATEL results are shown in Table 11. In addition, the influence weights of the criteria could be constructed by using Equation (14). The top five influencing criteria for leadership competencies of financial industry leaders in the COVID-19 epidemic were vision and imagination (Q2), critical analysis and judgment (Q1), strategic perspective (Q3), teamwork (Q4), and interpersonal sensitivity (E5). Vision and imagination (Q2) was the most important criterion with a weight of 0.066. The results for critical analysis and judgment (Q1), strategic perspective (Q3), teamwork (Q4), and interpersonal sensitivity (E5) were 0.065, 0.064, 0.062, and 0.060, respectively.

The elements of the total influence matrix (Table 9) could be defuzzified to obtain crisp values. To identify the most influential criteria, it was decided to extract the top 25 values after consulting the experts. Finally, the ICM among the criteria could be plotted by displaying the total and net influence of all criteria in Table 11, with the total influence $r_i + s_i$ as the horizontal axis and the net influence $r_i - s_i$ as the vertical axis as shown in Figure 1.

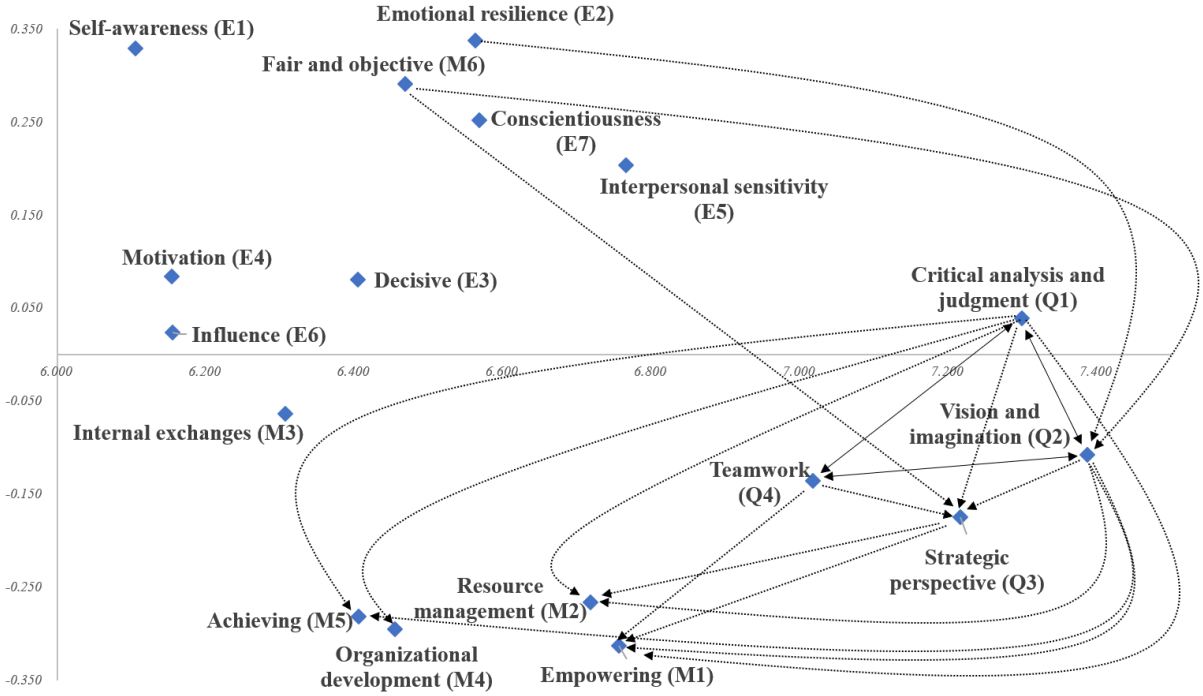

Figure 1. ICM of the leadership competencies.

6. Discussion and Conclusions

In today's ever-changing and uncertain environment, the financial industry places significant emphasis on leadership competencies, as they directly impact a company's operational performance and sustainability. Notably, the dimension of business strategy stands out as the most critical, particularly in the financial sector, in which leaders must constantly evolve their business strategies to adapt to internal and external changes [17–19]. To shed light on the interdependence and mutual influence relationships among leadership competencies, this study employed the Z-DEMATEL method.

The top five influencing criteria for leaders in the financial industry during the COVID-19 epidemic were identified as follows: vision and imagination (Q2), critical analysis and judgment (Q1), strategic perspective (Q3), teamwork (Q4), and interpersonal sensitivity (E5). Recognizing the importance of these criteria enables decision makers to devise targeted improvement strategies to enhance the competencies of financial industry leaders. For instance, companies can offer educational and creative training programs such as brainstorming and logical thinking and analysis activities to improve the vision and imagination of their leaders.

By incorporating the concept of digital transformation, this findings of this study underscore the necessity of developing dynamic leadership competencies that adeptly respond to the challenges and opportunities presented by the rapidly evolving financial landscape. Through the utilization of the Z-DEMATEL method, this research contributes to a deeper understanding of the interconnected nature of leadership competencies, ultimately facilitating more effective strategies for fostering leadership excellence in the financial industry during digital transformation.

The results of the ICM revealed the mutual influence relationships of several criteria. For example, critical analysis and judgment (Q1), vision and imagination (Q2), strategic perspective (Q3), and teamwork (Q4) were four criteria that had a high degree of mutual influence on one another. This was also consistent with the findings of Wei et al. [8]. These operational components are intertwined, and the absence of any one criterion may not be effective in meeting the target outcomes. Therefore, leaders must lead their organizations with the goal of sustainable management, establish clear strategic plans and performance goals, propose new management concepts and improvement techniques through innovative

models with multiple angles and perspectives, and lead their team members to work together to improve overall efficiency in order to solve possible obstacles and challenges in organizational management. In addition, empowering (M1), resource management (M2), organizational development (M4), and achieving (M5) were the four criteria that were mainly influenced. Therefore, how good the other criteria are can directly or indirectly affect these four criteria (which can also be referred to as effects), which means that these four criteria are the products of the practice of other criteria.

It is worth mentioning that emotional resilience (E2) and fair and objective (M6) mainly influenced vision and imagination (Q2) and strategic perspective (Q3). Emotional control and management are important for leaders in dealing with internal organizational issues, and fairness and objectivity do significantly influence strategic perspectives, which in turn influence leaders' vision and imagination. The ICM was divided into four quadrants: core, driving, independent, and impact, and the criteria and management recommendations for each quadrant are shown in Table 12. This classification will allow decision makers to develop improvement strategies more efficiently.

Table 12. Description of the four quadrants of the ICM.

Category	Criteria	Description	Management Recommendation
Core	E5 and Q1	High total influence and high net influence indicate that these criteria are core elements of the leadership competency evaluation system.	Invest proactively to strengthen the competitiveness of these criteria.
Driving	E1, E2, E3, E4, E6, E7, and M6	Low total influence and high net influence indicate that these criteria are drivers of other leadership competencies.	Track the performance of these criteria on an ongoing basis. No need to invest too many resources.
Independent	M3, M4, and M5	Low total influence and low net influence indicate that these criteria are primarily influenced.	Can neglect slightly because these criteria are less influential in the system.
Impact	M1, M2, Q2, Q3, and Q4	High total influence but low net influence indicates that these criteria have a high degree of mutual influence.	Develop improvement strategies to maintain the performance of these criteria.

On the other hand, a sensitivity analysis was conducted in this study to ensure the reliability of the research results. The number of experts was altered to test whether the analytical results changed. In each test, data from three randomly selected experts were excluded, and the Z-DEMATEL calculation was performed to record the ranking of the criteria. After repeating the experiment 15 times, there was no change in the ranking of the criteria, and there were no significant changes in the weights of the criteria.

In summary, this study addressed the gap in previous research on leadership competencies by incorporating the Z-DEMATEL technique, which identifies influential relationships among leadership competency criteria. By generating influence weights for the criteria combined with Z theory, the evaluation became more reliable in the context of uncertainty, such as in the digital transformation era. The Influence Classification Map (ICM) further categorized the criteria into four groups: core, driving, independent, and impact, offering valuable management implications and improvement suggestions. The study adopted a mixed-method approach by extracting professional judgment from senior executives through qualitative interviews and conducting a quantitative analysis using soft computing techniques. Moreover, this study provided insights into the characteristics of

leaders amidst the challenges of COVID-19 and uncovered the interrelationships among these leadership traits.

However, certain limitations exist in this study. While the survey involved 24 experts, variations in the sample size may have led to subtle differences in the analyzed results. Future studies could explore the impact of different sample sizes to observe potential additional findings. Additionally, the evaluation framework and research process can be adapted for application in other industries. For example, the service industry may require more emphasis on interpersonal sensitivity, self-awareness, and emotional resilience, given the significance of human interaction needs. Future research could consider incorporating additional factors to enhance the comprehensiveness and completeness of the framework to offer broader insights into leadership competencies across industries in the context of digital transformation. In terms of methodology, future research can focus on refining the algorithm of the study by identifying interdependencies among criteria, as inspired by the study of Traneva and Tranev [44]. By streamlining the criteria with slower or more costly measurements, the efficiency and practicality of Z-DEMATEL in real-world applications can be enhanced.

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