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Designing a Measurement Model and Continuous Improvement of Social Capital Based on the Compound Eye Metaphor in “Water and Sewage of Tehran Province”

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ABSTRACT

Most previous research on social capital has used cross-sectional surveys, and no model or framework has been proposed for continuous measurement and improvement over time. The purpose of this research is to introduce and implement the “compound eye metaphor” using various information systems or platforms that can continuously measure and improve social capital. The five-stage model of “Lynham's theory building” was used to conduct the research, and the “Krishna and Shrader” model was used for measurement. This research is developmental-applied in purpose and was conducted using allegorical logic (questioning and analogy) through the metaphor of the compound eye. To collect quantitative and qualitative data, this research adopted a simultaneous mixed-methods approach, drawing on three sources (interviews, questionnaires, and compound eye platforms) and analyzing and modeling the data. The findings of the research show the status of social capital on platforms (2.50) and in the questionnaire (3.15). Also, in terms of time, social capital is weekly on the platform, with an average of 2.24 in the first week and 2.90 in the last week, and in the questionnaire, with 2.37 and 3.62, which show an increasing trend. In the end, through the analysis of the similarities and differences of the compound eye, a model for measuring and continuously improving social capital was presented. Therefore, the metaphor of the compound eye has succeeded in continuously and daily measuring and improving social capital.

Keywords: Compound eye, metaphor, measurement, social capital, improvement

Introduction

The concept of social capital has evolved over more than a century, reflecting the changing intellectual paradigms used to understand collective life, organizational functioning, and societal development. Early conceptualizations, such as Hanifan’s emphasis on “goodwill, fellowship, mutual sympathy, and social intercourse” within local communities, framed social capital as an essential social resource embedded in human relationships that support collective prosperity (1). Subsequent theoretical advancements deepened the foundations of this concept, with

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Tocqueville drawing attention to the importance of civic associations and participatory structures in democratic societies (2). These foundations eventually shaped the modern view of social capital as a multi-dimensional phenomenon comprising structures, networks, norms, trust, and shared values. In Bourdieu's formulation, social capital is a durable resource gained through membership in networks of mutual recognition (3, 4). Coleman later expanded this perspective to emphasize the functional value of social structures in enabling coordinated actions and cooperative behaviors (5).

Over time, scholars increasingly recognized social capital as an asset not only of communities, but also of organizations and economic systems. Discussions on structural holes by Burt highlighted how network configurations create opportunities and constraints for information flow and resource access (6). Similarly, Kogut and Zander's foundational work linked knowledge replication and combinative capabilities to organizational networks, illustrating how collective expertise represents an intangible capital that improves firm performance (7). These early contributions established that social capital, like financial or human capital, can significantly enhance an organization's ability to innovate, solve problems, and adapt to environmental turbulence.

By the late 1990s, social capital had become central to organizational research, development studies, and economic policy analysis. Putnam's widely cited examination of declining civic engagement in the United States underscored how the erosion of trust and social cohesion undermines institutional effectiveness and societal well-being (8). Dasgupta and Serageldin's multi-volume work for the World Bank further established social capital as a developmental asset critical for economic growth and governance reforms (9). At the same time, Woolcock and Narayan emphasized the multidimensional nature of social capital—bonding, bridging, and linking—and its significance for policy frameworks aimed at poverty alleviation and community empowerment (10). These multiple streams converged into a broader recognition that social capital enables trust, cooperation, collective action, and performance across different levels of analysis.

The organizational domain, in particular, witnessed notable conceptual expansion. Nahapiet and Ghoshal underscored how social capital contributes to intellectual capital formation and creates organizational advantage through shared norms, trust-based relations, and dense communication networks (11). Leana's work similarly clarified the relationship between employment practices and organizational social capital, revealing how high-trust structures promote collaborative problem-solving (12). As social systems within organizations became more complex, Robbins' organizational theory and Hatch's symbolic and postmodern perspectives offered analytical tools to understand how relationships, communication patterns, and shared meanings shape organizational functioning (13, 14). Morgan's paradigm-shifting work on metaphors emphasized that organizations can be understood through multiple lenses—organisms, cultures, political systems, and even living brains—foregrounding the interpretive and symbolic nature of organizational life (15-17). Rodgers added that metaphors not only describe but shape the way scholars and practitioners think about organizational phenomena (18).

Parallel to these conceptual developments, efforts to measure social capital have intensified, though measurement remains a contested and evolving domain. Krishna and Shrader developed a practical assessment tool to capture structural and cognitive dimensions of social capital in communities (19). Coleman, Narayan, and Cassidy also contributed a dimensional inventory to measure social capital with methodological rigor (5). Yet a recurring challenge persists: compared to financial or human capital, social capital is more abstract, relational, context-dependent, and dynamic, making it difficult to measure accurately and continuously (20). Recent contributions aim to address this challenge. For example, Chen et al. introduced scales for assessing social capital

investment and its psychological correlates (21). DeFilippis provided critical insights into how the concept is often misapplied in community development without adequate operationalization (22). Chetty and his colleagues advanced the field by producing large-scale empirical measures of social capital using economic mobility datasets, highlighting how social connectivity patterns influence long-term outcomes at regional and national levels (20). At the same time, Haldane and Halpern, in their 2025 report, emphasized that nations often overlook the economic value embedded in social networks, trust structures, and collective norms—what they term the "hidden wealth of nations" (23). These contributions collectively reaffirm that social capital is both measurable and essential for societal and organizational prosperity, but robust frameworks and continuous measurement tools remain scarce.

Within organizational research, the recognition of internal social capital as a driver of performance has been particularly salient. Maurer and Ebers demonstrated how dynamic social capital processes support organizational growth, knowledge exchange, and strategic advantage in entrepreneurial firms (24). Sanchez-Famoso and colleagues synthesized decades of research to highlight the powerful role of internal social capital in fostering resilience, innovation, and participation, while identifying significant methodological gaps in existing studies (25). Gholipour's examination of social capital in Iranian organizations similarly revealed how trust, participation, and shared norms influence entrepreneurship and organizational effectiveness (26). Moreover, Zolfaghari's meta-analysis confirmed strong empirical linkages between social capital and job performance over a decade of longitudinal studies (27). Collectively, these findings reaffirm that internal social capital is not merely a cultural or relational attribute but a strategic organizational resource.

Despite these advances, most studies rely heavily on periodic surveys, cross-sectional designs, or one-time assessments, failing to capture the dynamic, fluctuating, and temporal nature of social capital. The lack of continuous measurement inhibits managers' ability to detect early signs of relational deterioration, declining trust, or weakening networks. This limitation creates a pressing need for approaches that enable organizations to track social capital in real time or near-real-time, interpret emerging patterns, and intervene proactively. Jha's work on the influence of financial reporting on social capital demonstrates the complexities of how organizational transparency shapes trust and relational dynamics over time (28). Kama and Weiss's research on managerial incentives and sticky costs also illustrates how internal relational structures influence managerial behaviors and decision-making patterns (29). These broader insights underscore the importance of understanding social capital as a dynamic construct requiring continuous monitoring and responsive systems.

Metaphors have long been recognized as powerful tools for organizational knowledge creation, enabling researchers to conceptualize abstract or complex phenomena through familiar analogies (30). Lynham's methodological contributions emphasize that theory-building in applied fields must integrate conceptual development, operationalization, empirical testing, and continuous refinement (31, 32). Danaeifard's comparative studies on theory-building methodologies further illustrate how inductive and allegorical reasoning can support conceptual innovation in organizational sciences (33). Within this intellectual lineage, metaphor-based organizational models—such as Morgan's images of organizations—have allowed researchers to re-envision core processes such as learning, knowledge sharing, coordination, and adaptation (15). Building upon this tradition, the metaphor of the compound eye offers a unique analytical and operational framework for conceptualizing continuous measurement.

The compound eye metaphor draws inspiration from entomological studies describing the multi-faceted visual capacity of insects, which perceive their environment through thousands of independent visual units, or ommatidia

(34). The optical and neurological sophistication of compound eyes—characterized by wide-range vision, sensitivity to rapid motion, parallel information processing, and composite image formation—illustrates the potential for organizations to observe, record, and interpret complex social environments in distributed and continuous ways (35). Transposed into organizational contexts, each employee can be envisioned as an ommatidium contributing unique perceptions, experiences, and signals that collectively generate a composite representation of organizational social capital.

This metaphor extends beyond symbolic interpretation to offer a methodological pathway for operationalizing continuous measurement. By treating employees as distributed perceptual nodes, organizations can develop interconnected platforms—surveys, feedback systems, internal networks, interviews, and digital channels—that continuously capture micro-level indicators of values, norms, trust, participation, collaboration, and accountability. Such a metaphor aligns with contemporary perspectives that emphasize the value of distributed cognition and the need for organizations to operate as adaptive, sensing entities (14, 15). Moreover, it directly addresses the methodological gap identified by Woolcock, Narayan, Chetty, Sanchez-Famoso, and others, who highlight the absence of tools for high-frequency, systemic measurement of social capital (10, 20, 25).

The uploaded study, which develops and implements a compound-eye-based model for measuring social capital in a large public utility, offers an empirical basis for advancing continuous monitoring approaches within organizational contexts. It demonstrates how multi-platform information systems can capture both cognitive and structural dimensions of social capital over time and how these data can be integrated to support managerial decision-making. By using repeated-measures analysis, comparative platform data, and metaphor-based operationalization, the study illustrates how social capital fluctuates over weeks and how a multi-source system can detect patterns that traditional survey methods overlook.

Furthermore, the integration of theory-building frameworks such as Lynham's five-stage model underscores the methodological robustness of the approach (31). The compound eye metaphor also aligns with Gholipour's emphasis on improving organizational entrepreneurship through relational infrastructures (26), with Maurer and Ebers' emphasis on dynamic social capital (24), and with Zolfaghari's findings on the central role of social capital in job performance (27). This convergence suggests that continuous measurement is not merely a diagnostic exercise but a strategic necessity.

In today's organizational environments—characterized by rapid change, digital transformation, and increasing interdependence—trust, collaboration, shared values, and relational cohesion are indispensable. As Huysentruyt and colleagues argue, bridging forms of social capital and trust are essential to overcome fragmentation and build resilient systems (36). Similarly, Morgan and Burrell's sociological paradigms highlight the importance of integrating structural, interpretive, and critical perspectives when analyzing organizational life (17). Considering the complex interplay between relational networks, cognitive frames, and organizational performance, a transformative measurement framework is required—one capable of capturing both micro-level perceptions and macro-level trends continuously.

Despite impressive theoretical progress, most organizations lack practical mechanisms to implement such frameworks. Continuous measurement requires not only conceptual innovation but also technological infrastructure, methodological clarity, and organizational commitment. The compound eye metaphor explicitly addresses these challenges by integrating distributed sensing, multi-source data collection, conceptual modeling, and interpretive analysis into a coherent system. It reflects Adler and Kwon's insight that social capital is an asset rooted in social

relations, yet requiring sustained investment and systematic management to yield returns (30). Equally, it resonates with Morgan's call for imaginative and holistic organizational models that can capture complex, emergent dynamics (16).

Given this landscape, the current study positions itself at the intersection of classical theory, contemporary measurement challenges, organizational metaphor, and applied management innovation. By integrating foundational theories of social capital with the compound eye metaphor and building upon the empirical findings of the uploaded document, the study contributes to a growing body of knowledge focused on operationalizing social capital as a measurable, manageable, and improvable organizational resource.

Accordingly, the aim of this study is to develop a comprehensive, continuous, and metaphor-based model for measuring and enhancing social capital within organizations, grounded in the compound eye metaphor and supported by rigorous theoretical and empirical foundations.

Methods and Materials

In terms of purpose, this research is developmental–applied, as the compound eye metaphor presents a novel state-measurement model in the field of social capital and is practical insofar as it improves social capital within organizations. The study also employs allegorical logic through the metaphor of the compound eye. This research can be situated within the Interpretative paradigm, since the compound eye metaphor is an innovative model in management sciences and lacks theoretical consensus. In Saunders' "onion" model, a six-layer framework is presented that specifies philosophy, approach, strategy, choice, time horizon, and data collection methods. In the present study, each of those layers is defined and operationalized as follows:

Layer One: Research Philosophy: This study is grounded in a positivist philosophy and is based on the principles of the empirical sciences, with an objectivist approach. Using data analysis software and the compound-eye metaphor, social capital is measured. Because this metaphor is being applied for the first time as a measurement model within an organization, it also constitutes a novel empirical experiment from a philosophical viewpoint.

Layer Two: Research Approach: Data were collected via three methods (employee feedback platforms, questionnaires, and interviews). Thus, the approach is inductive—moving from parts to wholes—consistent with empirical philosophy.

Layer Three: Research Strategy: The research strategy is practical and development-oriented, aligned with its objectives. It is expected that managers and decision-makers at the Tehran Province Water and Wastewater Company will be able to use the research findings to continuously measure, improve, and enhance social capital over time. This study employs descriptive-survey research methods.

Layer Four: Research Choice: Regarding the type of data, the present study is quantitative, and data were collected and analyzed using platforms and information systems for employee feedback, questionnaires, and interviews.

Layer Five: Time Horizon: The study's time horizon covers 2024 and measures social capital during that period; therefore, it is a cross-sectional study in terms of its temporal frame.

Layer Six: Data Collection Methods: There is a direct relationship between the research approach and the data collection methods. Because our approach is inductive, the data collection methods used are survey-based instruments—questionnaires and interviews—implemented through platforms and information systems.

In management science, various methods exist for theorizing, designing, and implementing a model. The application of these methods operationalizes a model based on standard elements. Therefore, to implement the compound eye in this study, we employed Lynham's method (31), which is a methodology for applied research in management. According to experts in this methodology, one can use grounded theory, meta-analytic, social construction, and case study research (33).

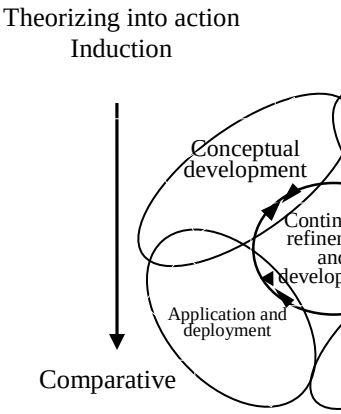

Figure 1. Conceptual model and stages of the general theory-building method for applied disciplines (31)

The present research applies the "case-study" method in the Tehran Province Water and Wastewater Company to understand the complexities of social capital's impacts on the organization over time. In Lynham's approach, the research implementation process comprises five stages (33), which, in terms of explicating the compound eye, are described as follows:

Stage One: Conceptual Development: At this stage, the key elements and components of the Compound Eye Metaphor—such as ommatidia, rhabdoms, independent visual units, communication networks, organizational structure, platforms, measurement and evaluation mechanisms, employee status, and processes of recording and transmission—were identified within the organization under study. Their interrelations were described, the correspondence between the two natural and organizational constructs and their respective conditions was specified, and the conceptual model was designed. The answer to the first research question lies within this stage. Therefore, to implement the Compound Eye metaphor in an organization, a package of platforms—as shown in Figure 2—must be designed and deployed.

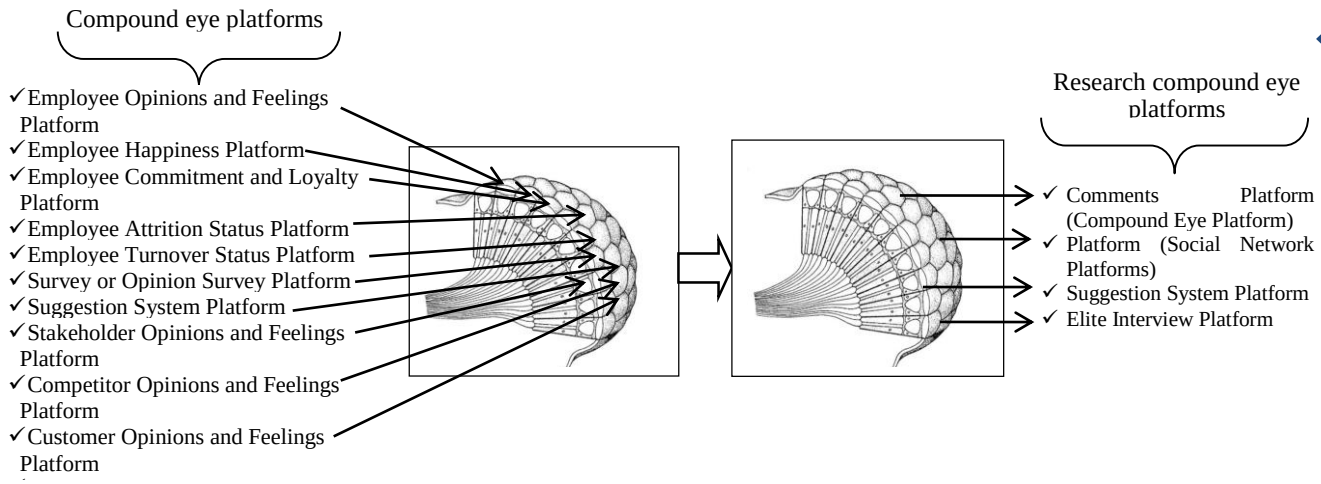

Figure 2. Conceptual Model of the Compound Eye

Stage Two: Operationalization: At this stage, the concepts were tested in practice; in other words, the conceptual model was examined using an operational model to determine whether it was confirmed or disconfirmed. Figure 3 below presents the executive model of the research through two approaches.

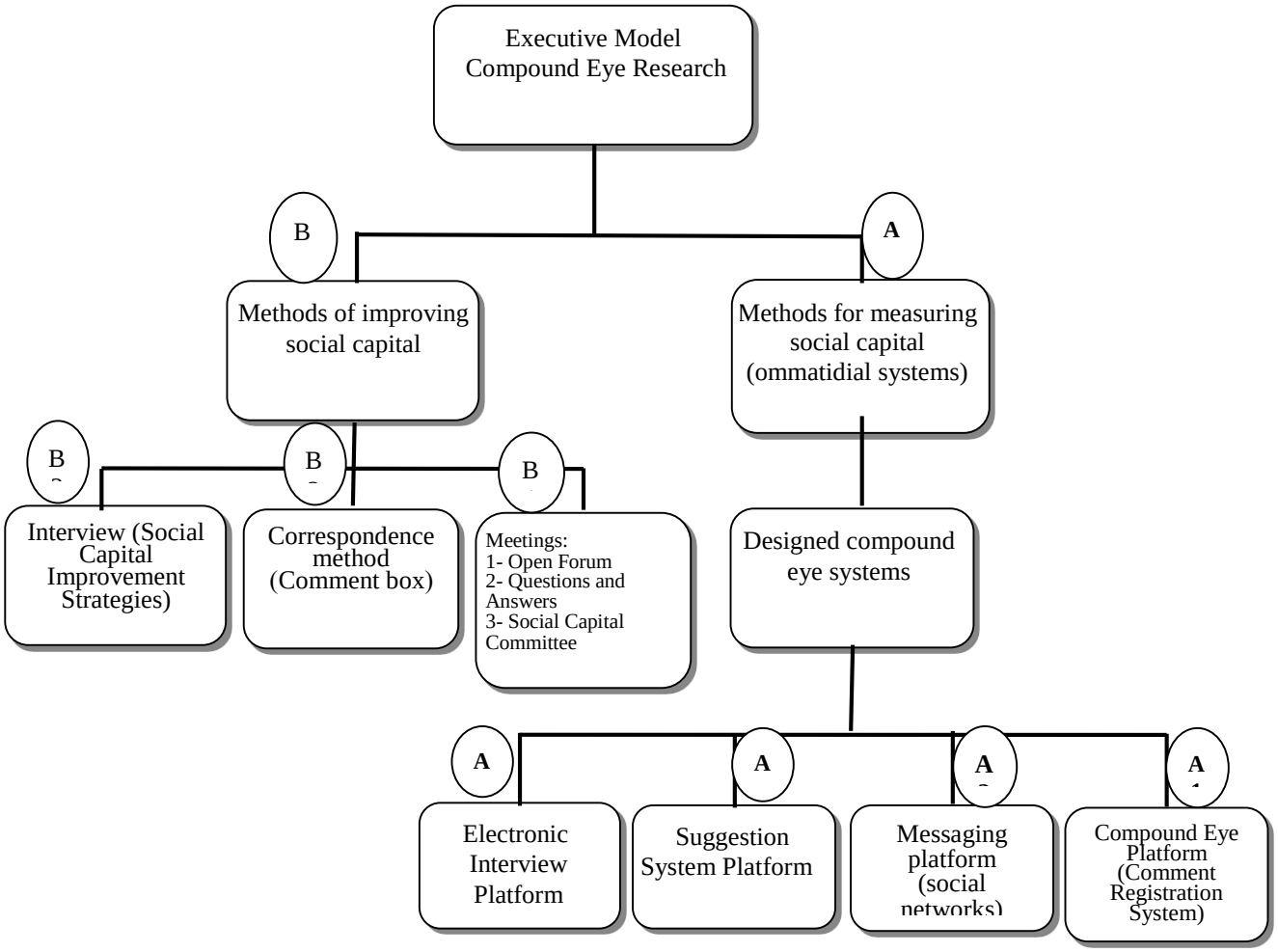

Figure 3. Operationalization Model of the Research

To conduct this stage of the research (measurement and improvement of social capital), the following steps were implemented:

A. Methods for measuring social capital by designing and launching the required research platforms, including:

- ✓ **A1.** Opinion Registration Platform – providing the statistical population with access for over three months to record their viewpoints.
- ✓ **A2.** Internal Social Network Platform – enabling employees to share their opinions freely within a diverse internal network. The more networks available for recording employee opinions, the more reliable the measurement process becomes.
- ✓ **A3.** Suggestion System Platform – another mechanism for submitting comments and suggestions from colleagues.
- ✓ **A4.** Improvement Platform (interviews with managers to propose improvement strategies) – aimed at determining the priority of social capital dimensions based on the measurement model of Krishna and Schrader for enhancement within the company, and comparing these priorities with data from the opinion registration platform and questionnaire. This means identifying whether there is a significant relationship between the improvement model's priorities and the employees' viewpoints gathered through the questionnaire and opinion platform.

B. Methods for Improving Social Capital

- ✓ **B1.** Holding Sessions: (1) Open Forum, (2) Q&A Sessions, (3) Social Capital Committee.
- ✓ **B2.** Correspondence Method: Receiving employees' opinions via suggestion boxes.
- ✓ **B3.** Conducting managerial interviews to propose strategies for enhancing social capital.

Electronic Questionnaire: An electronic questionnaire was designed and implemented to measure social capital via a survey, to compare its results with those from the Compound Eye opinion registration platform. This standardized questionnaire, developed by Chen et al. (2016, pp. 669–687), includes 15 items that assess social capital in the organization across nine indicators—values, norms, commitments, participation, trust, accountability, sound decision-making, participation in decision-making, and group collaboration—under two major dimensions: structural and cognitive, based on the Krishna and Schrader model. The questionnaire applies a five-point Likert scale. The mean t-test (t = 3) determines the significance level in three conditions (high, medium, and low). In terms of validity and reliability, the Cronbach's alpha coefficient is 0.85, the composite reliability is 0.896, and the convergent validity is 0.62.

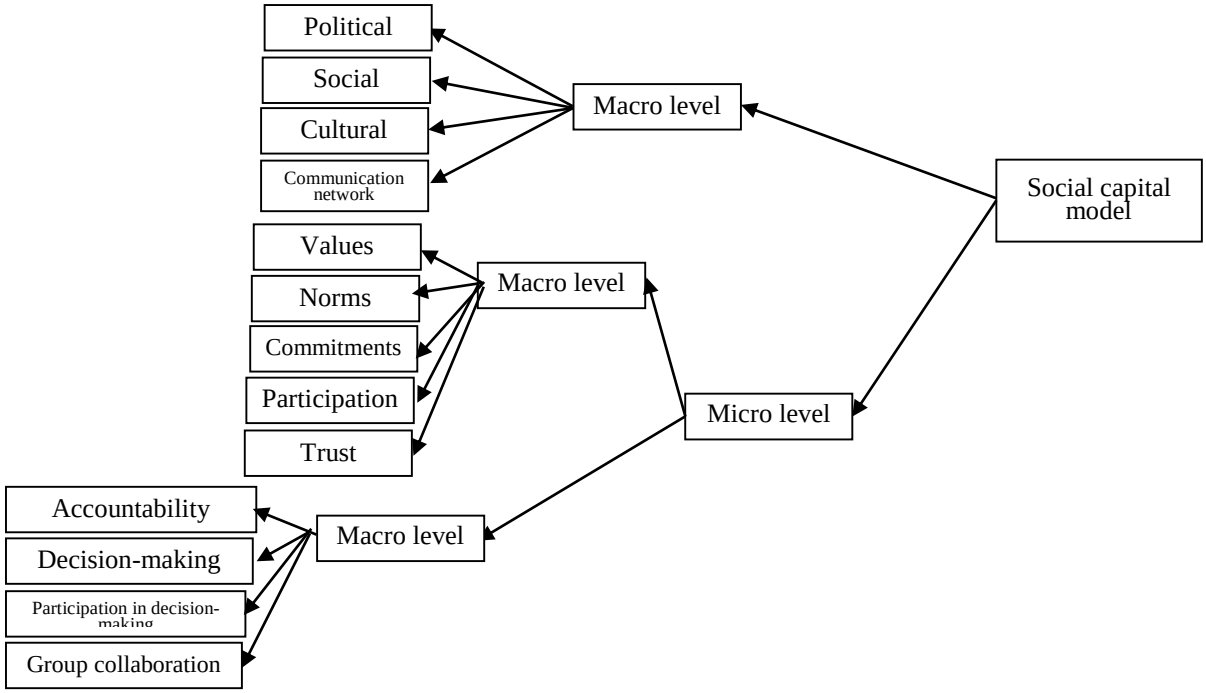

Figure 4. Measurement Model of Krishna and Schrader

Stage Three: Confirmation or Disconfirmation: At this stage, the operational framework (designed based on the conceptual model) was tested in the real world. The key finding of this stage—after conducting the research and confirming the applicability of the Compound Eye metaphor within the Tehran Water and Wastewater Company—was that the metaphor possesses the capability to measure social capital effectively. In addition to the data collected through the questionnaire, this stage also included data from both platforms and other improvement strategies. Through these combined approaches, social capital was measured, improvement actions were proposed, and the efficiency of the Compound Eye model was evaluated. (The results of this stage correspond to the first and second research objectives.)

Stage Four: Application: Based on the research findings, this stage determined whether the developed model improved individual or organizational behavior and addressed issues facing the organization. The study successfully demonstrated that implementing the Compound Eye metaphor and measuring social capital using the Krishna and Schrader model confirmed the efficiency of the Compound Eye model. Therefore, the results of this research will be made available to the Tehran Water and Wastewater Company for full implementation.

Stage Five: Ongoing Refinement and Development: At this stage, continuous updates and timely improvements to the tested model were ensured. The Compound Eye model, or applied theory, inherently possesses a “feedback” nature, requiring ongoing attention to its suitability and effectiveness to ensure its validity. In this phase, strategies for strengthening social capital, along with proposed recommendations, challenges, and limitations, were presented using the Compound Eye model.

The present study was operationalized within a statistical population of 220 employees from the headquarters and two subsidiary regions of the Tehran Water and Wastewater Company over five months (two months for preparation and three months for implementation). The Tehran Water and Wastewater Company is one of the largest service organizations in Iran, responsible for the transmission, treatment, and distribution of clean and safe drinking water in the capital. Distortions or disruptions in the service delivery process to customers and consumers,

or any negligence or inefficiency within this process, can, in some cases, turn water quality and public health issues into a social crisis or catastrophe. Studies within the European Union have shown that companies, organizations, and communities with higher levels of social capital demonstrate better performance and even exert a greater impact on economic growth. Moreover, social trust—one of the most significant dimensions of social capital—drives high-quality service delivery, increased productivity, and enhanced performance (Haldane & Halpern, 2025, p. 9). Therefore, monitoring the status of social capital in this company can be a key factor in delivering high-quality services to the capital's residents.

Findings and Results

The findings of this research were extracted from the analysis of three primary data sources: the Opinion Registration Platform, the Interview Platform, and the Electronic Questionnaire. In addition, the implementation status of the Compound Eye metaphor, the organizational and structural conditions, and the information systems of the Tehran Water and Wastewater Company were examined. The findings were derived in accordance with the five-stage executive process of the Lynham Model, as detailed below.

Stage One: Conceptual Development: The information in this stage identifies key elements and components, describes relationships and how the compound eye works, and was obtained by studying library documents (structure, information, and communication systems) and information available in interviews with senior managers (explained in the third objective). In this stage, the first research question is answered.

Objective One: The analogies between the compound eye of insects and the organizational compound eye and social capital, as well as the discovery of key components and relationships, are evident in Table 1 and Figures 5 and 6.

Table 1: Correspondence between Insect Compound Eye and Organizational Compound Eye and Social Capital

Insect Compound Eye	Organizational Compound Eye
Ommatidia (small units composed of independent photoreceptors, including cornea, lens, and photoreceptive cells)	Organization employees (with diverse perspectives, interests, knowledge, experience, attitudes, and worldviews)
Ability to distinguish colors and light	Ability to distinguish events from different viewpoints
Each ommatidium has a different orientation and sees a unique direction	Employees view phenomena from their own perspectives, different from those of others
Ability to detect rapid movements	Ability to detect organizational environmental changes and fluctuations from multiple perspectives
Ability to perceive and detect ultraviolet rays	Ability to recognize and identify unknown environmental factors
Detect the slightest movement in the fastest time.	Identify and understand the most minor and quickest environmental changes from various perspectives.
Some insects' compound eyes can differentiate 265 images per second	The central core can rapidly analyze opinions and perspectives recorded in the system through managerial decision-support tools
Distinguish very similar colors.	Distinguish the nature of events and unique interpretations by employees.
Rapid transmission of images and motion frequency through axons	Rapid transmission of employees' opinions and perspectives via communication networks
The brain integrates independently received images into a complete picture of the object.	The central core (platforms, decision-support systems, or expert systems) provides analytical and cognitive models to managers.

The analogies between the 10 components of the insect compound eye and the organizational compound eye, shown in the table above, result from examining complex organizational structures and inter-unit relationships.

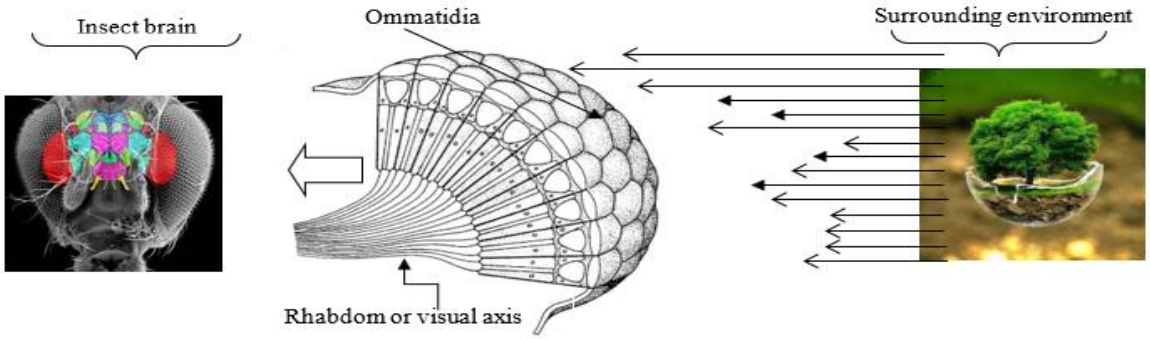

Figure 5. Function of the compound eye of insects

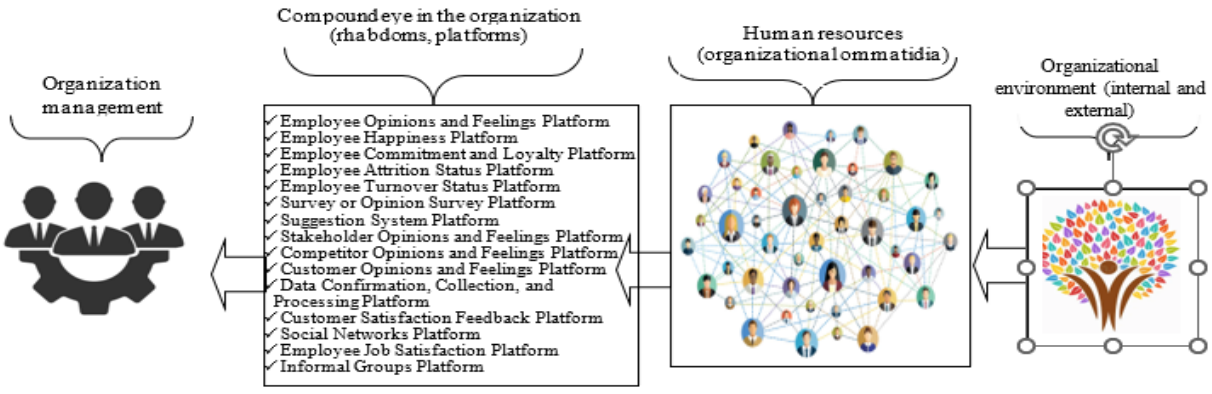

Figure 6. Function of the compound eye metaphor in the organization

Thus, the compound eye metaphor can be applied to various and diverse organizational situations. As observed, the correspondence between the characteristics of these two constructs (the insect compound eye and its organization) is clear. The five-step operational process in both constructs is: (1) Observing the surrounding

environment in pieces, like a puzzle; (2) Recording each piece by an ommatidium or employee; (3) Transferring it via neural systems or communication networks; (4) Analyzing and assembling images in the brain or by managers; (5) Decision-making and rapid response to environmental changes.

Stage Two: Implementation. In this stage, the research was operationalized, and, through the analysis of data from three sources—"Opinion Recording Platform," "Interview Platform," and "Electronic Questionnaire"—objectives 2 to 4 and the main research objective were described and addressed.

Objective Two: In this section, the data analysis shows how social capital is continuously measured using the compound eye metaphor and its correspondence with the conventional survey method (questionnaire). The findings were extracted and modeled in the following sections:

Table 2: Social Capital Dimensions Data from the Opinion Recording Platform

Social Capital Level	Mean	Social Capital Dimension	N	Mean	Std. Dev.	T=3	Significance	Social Capital Status	Friedman Test Result	Friedman Mean Rank
Cognitive	2.67	Values	114	2.59	0.84990	-5.179	0.000	Low	0.000	5.88
		Norms	139	2.84	0.80090	-2.330	0.021	Low		6.42
		Commitment	169	2.63	0.92426	-5.243	0.000	Low		4.04
		Participation Inclination	138	2.46	0.94459	-6.759	0.000	Low		5.00
		Trust	223	2.62	0.99684	-5.710	0.000	Low		3.83
Structural	2.51	Accountability	151	2.13	0.89201	-11.951	0.000	Low		2.08
		Correct Decision-Making	114	2.34	0.93911	-7.480	0.000	Low		5.33
		Participation in Decision-Making	173	2.66	0.89857	-4.992	0.000	Low		5.46
		Teamwork	162	2.72	0.94224	-3.836	0.000	Low		6.96

The results of descriptive statistics, the T=3 test, and the Friedman test in Tables 2 and 3, based on the social capital opinion registration platform, indicate that the T test for all dimensions of social capital is significant at the 5% level. Therefore, in Table 2, because the test statistic is negative, all dimensions of social capital are evaluated as low. The results of the Friedman test indicate a significant difference among the dimensions of social capital, and, according to the commenters' opinions, the two indicators "group cooperation and norms" are the most important.

Table 3: Descriptive Statistics / Mean of Social Capital Dimensions from Electronic Questionnaire

Social Capital Level	Mean	Social Capital Dimension	N	Mean	Std. Dev.	T=3	Significance	Social Capital Status	Friedman Test Result	Friedman Mean Rank
Cognitive	3.17	Norms	173	3.57	1.02437	7.27	0.00	High	0.000	6.26
		Values	173	3.49	0.94005	6.92	0.00	High		6.00
		Commitment	173	3.38	0.93254	5.30	0.00	High		5.66
		Participation Inclination	173	3.00	0.90701	0.00	1.00	Medium		4.34
		Trust	173	2.44	1.05272	-7.01	0.00	Low		2.83
Structural	3.13	Teamwork	173	3.52	0.72270	9.41	0.00	High		6.03
		Participation in Decision-Making	173	3.50	0.91974	7.15	0.00	High		6.21
		Correct Decision-Making	173	2.90	1.01766	-1.34	0.18	Medium		4.27
		Accountability	173	2.60	1.15002	-4.56	0.00	Low		3.40

The results in Table 3 and Figure 7 from the electronic questionnaire show that, among the nine dimensions of social capital, Trust (between managers and colleagues) with 2.44 at the cognitive level ranks lowest, followed by Accountability (managers) with 2.60 and Correct Decision-Making (managers) with 2.90, both at the structural level. Norms (adherence to religious and social codes) at 3.56 ranks first, followed by Teamwork at 3.52 and Participation in Decision-Making at 3.50. The cognitive level average of 3.17 is slightly higher than the structural level average of 3.13. Overall, the mean social capital from the questionnaire is 3.15, indicating a moderate level of social capital based on a T-test (T=3, significant, positive deviation from the mean).

The combined status of social capital based on the platform and questionnaire results is illustrated in the radar chart below.

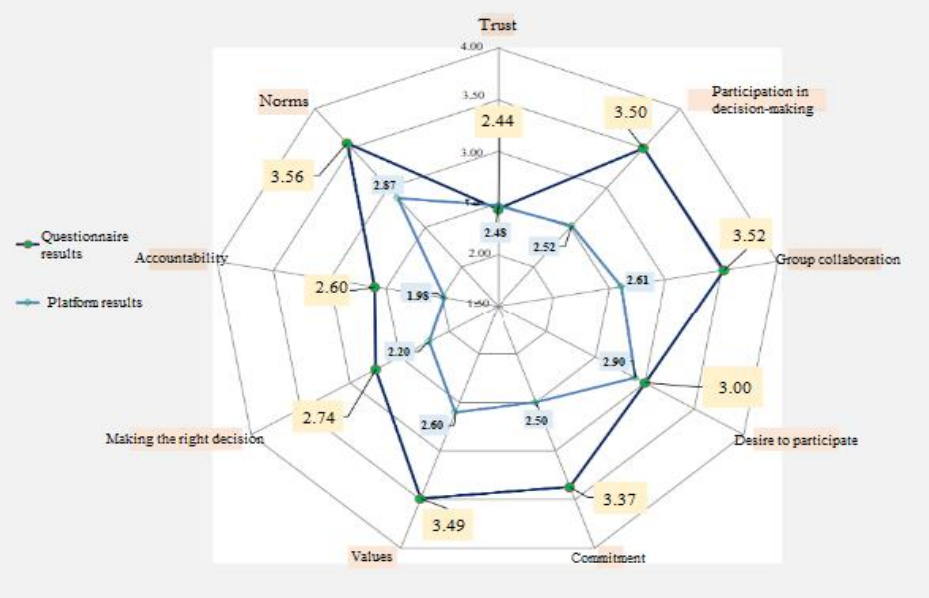

Figure 7 Radar Chart of Average Social Capital Dimensions from Platform and Questionnaire

As observed in Table 2 and Figure 7, among the nine dimensions of social capital, Accountability (managers) at the structural level ranks lowest with 1.98, followed by Correct Decision-Making (managers) at 2.20. Then, Trust (towards managers and colleagues) at the cognitive level with 2.48, ranked second and third. Participation Inclination (employees) at 2.90 indicates a high willingness of respondents to engage in organizational activities. However, it is crucial to consider the extent to which managers create a conducive environment and organizational climate for such engagement. Norms (observance of religious and social codes) at 2.87 and Teamwork (employees) at 2.61 are ranked second and third, respectively. The cognitive level (2.67) received slightly more attention from respondents than the structural level (2.50). Overall, the average social capital from the Opinion Recording Platform is 2.5, which, based on the T-test (T=3), is significant and indicates a negative deviation from the mean, suggesting low social capital. Comparison of the platform and questionnaire data shows an average social capital of 2.5 for the platform and 3.15 for the questionnaire. In both data sources, the cognitive level of social capital is slightly higher than the structural level.

Social capital was measured over time to assess changes and fluctuations using two data sources (Opinion Recording Platform and Questionnaire). This stage shows the temporal changes and fluctuations in social capital over 12 weeks (platform) and 7 weeks (questionnaire), as presented in Table 4 and Figure 8. This comparison aims to demonstrate the validity and reliability of the platform results relative to the questionnaire results over time.

Table 4: Comparison of Social Capital Growth Over Time in the Opinion Recording Platform and Questionnaire

Feedback platform results				Questionnaire Results		
Time (Week)	Platform Mean	Std. Dev.	T-test	Questionnaire Mean	Std. Dev.	T-test
1	2.2	0.3532	-6.433	-	-	-
2	2.1	0.4827	-5.399	-	-	-
3	2.2	0.4406	-5.421	-	-	-
4	2.1	0.6019	-4.430	2.37	-5.698	0.000
5	2.3	0.4542	-4.430	2.72	-1.435	0.189
6	2.4	0.2736	-7.022	2.94	-0.306	0.767
7	2.5	0.3058	-5.257	2.97	-0.130	0.900
8	2.6	0.2478	-5.066	2.96	-0.204	0.844
9	2.6	0.2168	-5.057	3.70	4.775	0.001
10	2.7	0.2304	-4.102	3.62	5.934	0.000
11	2.8	0.1456	-4.909	-	-	-
12	2.9	0.2103	-1.403	-	-	-

The results in both data sources show an increasing trend in social capital during the research period. Therefore, it can be claimed that the online compound eye platform can continuously and permanently measure social capital, and its results are valid and reliable compared to previous survey-based methods. The results of the above table show that social capital in the questionnaire based on the T-test for the fourth week is a significant value of less than 5 percent, so at a confidence level of 95 percent and considering the negative value of the social capital test statistic, it is evaluated as low on average in this week. For the fifth, sixth, seventh, and eighth weeks, the significance value is greater than 5 percent, and the test statistic is not significant, indicating that the average social capital in these weeks is not significantly different from the average. For the ninth and tenth weeks, considering that the critical value is less than 5 percent and the test statistic is positive, the average social capital in these two weeks is inferred to be high.

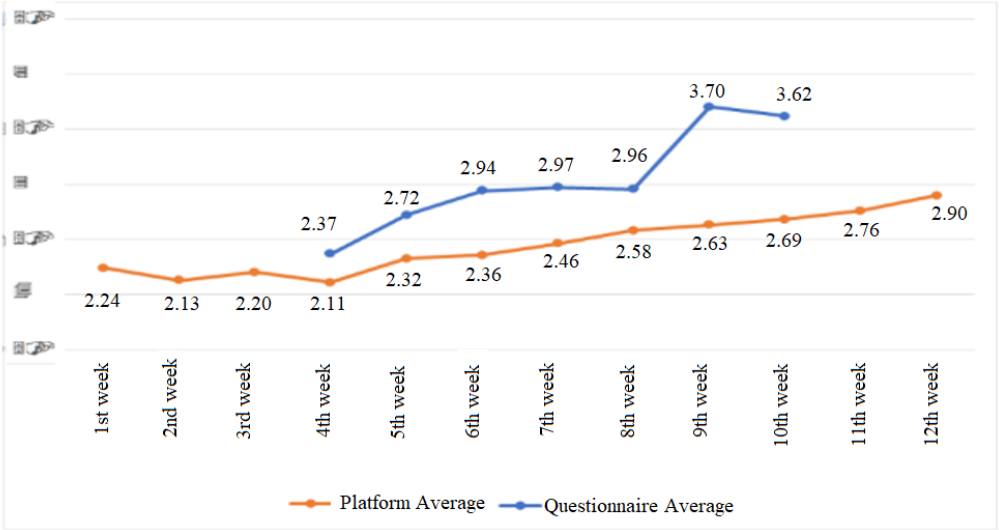

Figure 8. Comparison of Social Capital Trends in the Compound Eye Opinion Recording Platform and Electronic Questionnaire

To assess the effect over time, a Repeated Measures Test was conducted on social capital from the platform and questionnaire. The results are presented in Table 5.

Table 5: Repeated Measures Test Results for the Opinion Recording Platform and Electronic Questionnaire

Data Source Type	Source	Greenhouse-Geisser	Significance	Huynh-Feldt	Significance	Eta Squared
Opinion Recording Platform	Time (12 weeks)	9.567	0.000	9.567	0.000	0.545
Electronic Questionnaire	Time (7 weeks)	40.656	0.000	40.656	0.000	0.836

The repeated-measures test for the platform indicates that time has a significant main effect on social capital. As Mauchly's test indicated a violation of sphericity, the Greenhouse-Geisser and Huynh-Feldt corrections were applied. Pairwise comparison with Bonferroni adjustment shows no significant differences from Week 1 to Week 8, but from Week 8 onward, a significant temporal difference in social capital emerged.

The repeated measures test for the electronic questionnaire also shows a significant main effect of time on social capital. Due to Mauchly's test indicating a sphericity violation, Greenhouse-Geisser and Huynh-Feldt corrections were applied. Pairwise comparisons with the Bonferroni adjustment indicate no significant difference between Weeks 6 and 7, but important differences compared to the first five weeks.

The purpose of the interview is to determine respondents' priorities based on the nine indicators mentioned. The interview consists of 8 questions on improvement solutions for this platform, covering all nine indicators based on the Krishna and Schrader model, so that they can answer the questions in free text. The results of this table can serve as a basis for developing and implementing policy programs to improve and promote the company's social capital. In this research, the improvement interview platform was used, and a semi-structured interview model with identical questions was employed. The structural analysis method was used to analyze the data. Therefore, the components of the written text structure of the interview, extracted from the improvement platform and including words, concepts, and their relationships, were counted and examined for the number of times they appeared in sentences and their frequency. Then the patterns in the answers' texts were discovered. The relationships among the topics were identified and introduced using the relational analysis method. In response to the questions, what definition of social capital did the interviewees provide, and which of the nine dimensions of the Krishna and Schrader model did they prioritize in improvement programs to promote or improve social capital? These are shown in Table 6 and Figure 9.

In the table and diagram of the improvement model based on the results of the improvement platform and its comparison with the opinion registration platform model, the results of the interview data with managers to determine a model for improving social capital in the Tehran Province Water and Wastewater Company, and its comparison with the results of the opinion registration platform are shown. The purpose of this comparison is to discover the meaningful relationship between these two models. This means determining whether the exact dimensions that employees considered in the opinion registration platform were also considered by managers when presenting the improvement model.

Table 6: Results of the Improvement Platform (Interview) Compared with Opinion Recording Platform

Row	Dimension	Ratio of Mentions in Interview	Ratio of Mentions in Opinion Platform	Rank in Interview	Rank in Platform
1	Trust	0.78	0.87	1	1
2	Values	0.71	0.61	2	5
3	Teamwork	0.57	0.63	3	4
4	Participation in Decision-Making	0.54	0.68	4	2

5	Accountability	0.54	0.59	5	6
6	Participation Inclination	0.46	0.53	6	8
7	Commitments	0.45	0.66	7	3
8	Norms	0.41	0.54	8	7
9	Correct Decision-Making	0.39	0.45	9	9

Given the interview and comment recording platform data, frequency analysis was used to compare the two methods. For example, in the table above, the total number of people participating on the platform was 256, and of these, 223 mentioned the trust dimension of social capital in their comment recordings. The same method was used to calculate the other dimensions.

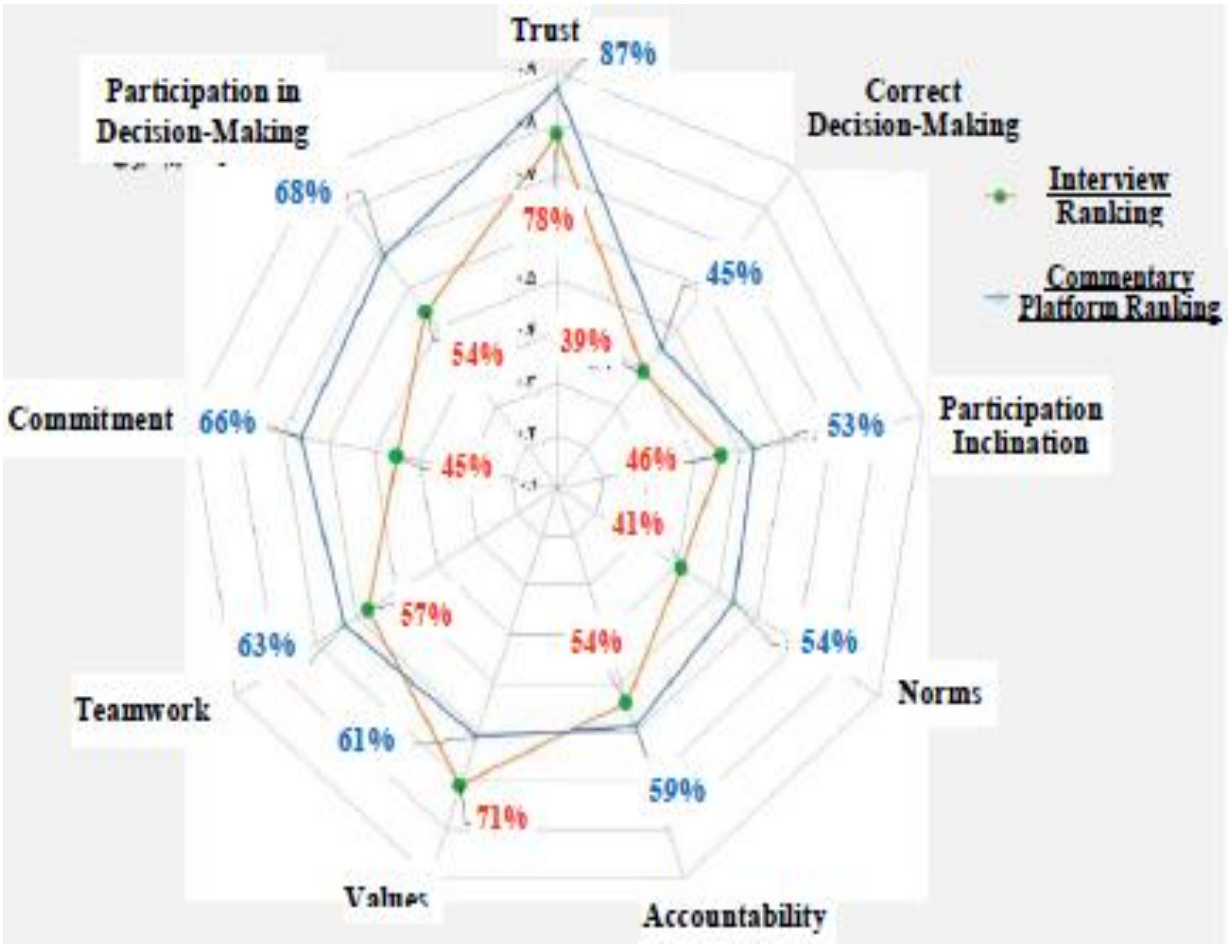

Figure 9. Prioritization of Social Capital Dimensions from Platform and Interviews

The comparison of the two platforms in Table 6 and Figure 9 shows that both interviewees and employees placed the highest emphasis on the Trust dimension (78% and 87%, respectively), indicating its importance to both groups. This means that the interviewees identified trust as the top priority for improving social capital, while employees highlighted the lack of trust between managers and staff on the opinion platform. Therefore, managers' recognition of trust as a priority aligns meaningfully with employees' opinions. Next in priority for improvement are Values (71%) and Teamwork (57%), suggesting that the company should plan programs to strengthen these dimensions. The interview platform results show that managers prioritize the cognitive level (0.47) over the structural level (0.41) for improvement.

Social capital can be converted into economic capital. Therefore, it is a productive factor. In a meta-synthesis of 27 studies, it was found that social capital directly affects job performance. In this study, by selecting nine key

human resource performance indicators (participation of senior managers, incentive systems, proposals from permanent and fixed-term contract employees, participation of permanent and fixed-term contract employees, approval of proposals, employee job satisfaction, satisfaction with medical services and employee welfare, succession planning, per capita employee participation and innovation) whose measurement is conceptually and operationally most similar to the measurement of social capital indicators, we were able to measure them among the statistical population at two time points, namely before the research (beginning of 2024) and (end of the first six months of 2024) and determine the effectiveness of the relationship between this sector, the results of which can be seen in Figure 10.

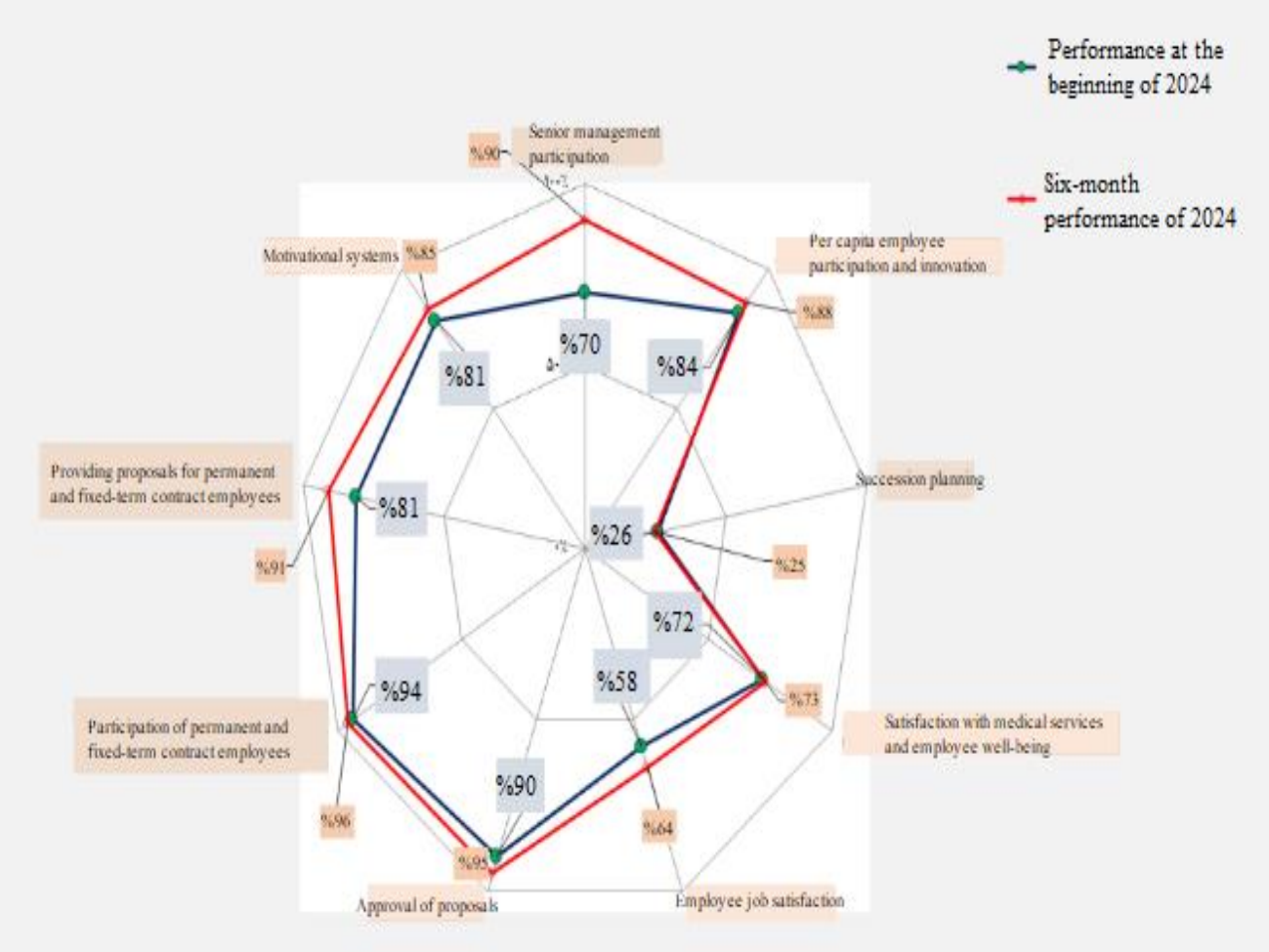

Figure 10. Human Resource Performance Report for the Sample Population at Two Time Points: Before and After the Study

The human resource performance report shows that the average achievement percentage in 7 out of 9 indicators increased from 0.41 at the start to 0.44 at the end of the study.

The compound eye functions as a system that records, analyzes, and transmits information. In this model, all employees within organizational units act as ommatidia, forming a coherent, interconnected whole through multiple communication networks, thereby creating the structure of a compound eye. Each individual, as part of the collective, has a distinct organizational role, perspective, knowledge, experience, and opinion, allowing them to observe and evaluate phenomena from their unique viewpoints. This is how the compound eye of an organism is formed.

Table 8. Comparison of Three Data Sources and Ranking of Social Capital Status

Row	Dimension	Most Frequent Mentions in Interview	Mean Opinion Platform	Mean Questionnaire	Rank in Interview	Rank in Platform	Rank in Questionnaire
		INT	VRP	QUES	R-INT	R-VRP	R-QUES
1	Norms	0.41	2.87	3.56	8	2	1
2	Values	0.71	2.60	3.49	2	4	4
3	Commitment	0.45	2.50	3.38	7	6	5
4	Participation Inclination	0.46	2.90	3.00	6	1	6
5	Trust	0.78	2.48	2.44	1	7	9
6	Teamwork	0.57	2.61	3.52	3	3	2
7	Participation in Decision-Making	0.54	2.52	3.50	4	5	3
8	Correct Decision-Making	0.39	2.20	2.90	9	8	7
9	Accountability	0.54	1.98	2.60	5	9	8

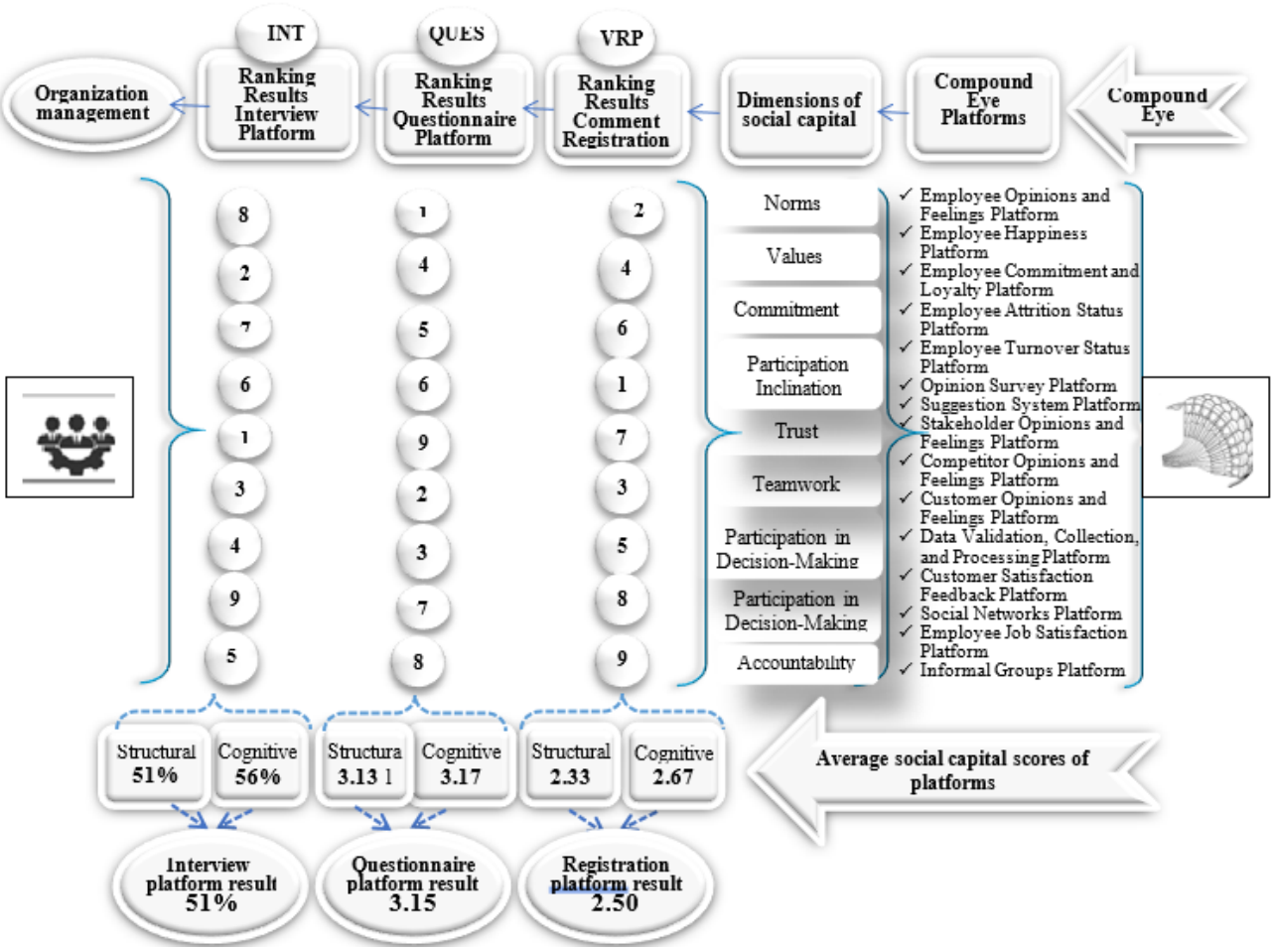

Figure 11. Relationships among the Three Data Sources and Final Ranking of Social Capital Status

Figure 11 presents the final ranking of social capital measurement using the Compound Eye Platform, Electronic Questionnaire, and Improvement Platform, and the relationships among social capital dimensions, summarized as follows:

1. Cognitive Level: Based on both data sources (questionnaire and platform), the mental level has the highest mean (3.17 in the questionnaire and 2.67 in the platform). This indicates that employees of the Tehran Province Water and Wastewater Company perceive the cognitive level as higher than the structural level. The cognitive level reflects employees' mental frameworks, perceptions, and thought patterns relative to

one another and the organization, enabling high potential for resource exchange. Strong connections, adherence to values and norms, and shared sentiments among members are considered organizational assets that managers can manage to improve decision-making and performance without relying on costly control and monitoring processes.

Among the five cognitive dimensions, Trust has the lowest level in both measurement methods (2.48 in the platform and 2.44 in the questionnaire), indicating that employees' confidence in the goodwill and reliability of colleagues, managers, and the organization is insufficient.

2. Structural Level: The structural level ranks second, with a mean of 2.33 in the platform and 3.13 in the questionnaire. Structurally, this dimension measures the size and scope of relationship networks, communication breadth, and employee engagement in formal and informal social networks, which depend on managers' willingness to facilitate such conditions. Low structural level indicates limited managerial inclination to ensure accountability, encourage employee participation, or promote effective decision-making. Structural social capital, defined as the configuration of links among employees and units, affects workforce efficiency and productivity in multiple ways.

In both the platform and questionnaire, managerial accountability ranks lowest (1.98 and 2.60, respectively). Lack of accountability among managers undermines perceptions of responsibility, which can negatively affect other dimensions, including trust.

3. Interview Platform Results: The Trust dimension (0.78) attracted the most attention from managers, indicating that they believe trust should be strengthened first to improve social capital. While Trust was the lowest-ranked dimension in both the opinion platform and questionnaire, managers' emphasis on it in the interview demonstrates a meaningful alignment among the three measurement and improvement methods. Values (0.71) and Teamwork (0.57) follow as the second and third priorities, respectively. Strengthening values and encouraging teamwork are strategies managers intend to implement to enhance social capital.

Third stage: Now the research has entered a new paradigm, namely, a complete understanding of the status of social capital using the compound eye. In this research, this paradigm is named "cognition" for two reasons: 1. Based on the methodological criteria and assumptions set, we were able to achieve the research objectives; 2. It was discovered that the compound-eye metaphor can be used to measure social capital. Therefore, after determining the results of measuring and improving social capital in the Tehran Province Water and Wastewater Company, the final report was presented in a meeting attended by the members and the chairman of the Social Capital Committee, and after discussing and examining the confidence and trust in the efficiency and success of the compound eye metaphor for measuring social capital, it was approved by the committee. The final report should be presented at the company's council of deputies, and a decision should then be made on the continuation of the fourth and fifth stages.

Stage Four: Having determined and confirmed the applicability of the compound eye in practice, we now have a world of "experience and knowledge" (Lynham, 2002, p. 233) for continuous development, and feedback on the applicability of the compound eye metaphor must be determined. At this stage, after presenting the final report to the Council of Deputies, three points were emphasized: 1. Measuring social capital is necessary because of its impact on individual and organizational performance; 2. Determining the strengths and weaknesses of social capital dimensions requires its improvement; 3. Establishing and implementing the compound eye model for one year by

the Council members with a “franchise strategy or selective approach”, i.e., a method in the form of separate platforms and step by step.

Step Five: The compound eye must demonstrate that it will work in the future, so “continuous attention to the reliability and substantive quality of the [compound eye] model” (Lynham, 2002, p. 234) is of particular importance. For this reason, the responsibility for implementing, developing, overseeing, and continuously monitoring the compound eye model was assigned to the Social Capital Committee, and the preparation of periodic reports on the status of social capital was transferred to the corporate planning and budget office.

Discussion and Conclusion

The findings of the study revealed that social capital within the organization is not static but fluctuates across time, platforms, groups, and relational contexts. The compound-eye model demonstrated that employees’ perceptions of values, trust, cooperation, and accountability vary significantly across the multiple sensing nodes embedded in the model. The strength of social capital indicators improved during periods marked by transparent communication, collaborative interaction, and strong network cohesion, while declining when organizational ambiguity increased or when inter-unit coordination weakened. These results affirm the conceptualization of social capital as a dynamic and context-sensitive construct, influenced by structural configurations, cognitive interpretations, and ongoing relational exchanges (3, 5). The distributed sensing capability of the compound-eye system allowed for the continuous capture of micro-level changes, providing an empirical demonstration of how organizational dynamics evolve more rapidly than traditional cross-sectional surveys can detect.

Interpreting the results within the broader literature indicates that the fluctuations observed in the study are consistent with foundational theories describing social capital as embedded in relational patterns and institutional contexts. Bourdieu’s conceptualization of capital as a function of durable networks and collective recognition directly aligns with the finding that periods of strong interdependence corresponded with higher social capital indices (4). Similarly, Coleman’s functionalist view that social structures facilitate coordinated action explains why departments with more cohesive communication patterns exhibited higher social capital scores (5). Putnam’s observations on the decline or strengthening of civic networks in response to social cohesion also resonate with the observed variations in trust and collaboration across different organizational units (8). These theoretical frameworks collectively support the study’s conclusion that social capital must be understood as relational, emergent, and sensitive to internal organizational processes.

The study’s findings further reinforce the role of social capital in shaping employee engagement, performance, and organizational functioning. Research has shown that high-trust environments facilitate cooperation, knowledge sharing, and collective responsibility, leading to improved performance outcomes (11, 24). Similarly, the association between positive relational climates and constructive workplace behaviors has been highlighted in prior empirical studies, including Jha’s work linking transparent reporting practices to enhanced trust networks (28). The results of the current study echo these insights: during intervals where communication clarity and cross-functional collaboration were reported as strong, employees’ perceptions of shared values, accountability, and relational cohesion improved. Conversely, during periods marked by managerial turnover, process reorganization, or reduced communication, the social capital indicators declined. This reinforces the bidirectional relationship between organizational change and social capital, a relationship extensively addressed in symbolic and postmodern

organizational theory (14) and in Morgan's metaphorical conceptualization of organizations as living systems continually adapting to environmental turbulence (15, 16).

The compound-eye model's capacity to detect heterogeneity across platforms also provides important insights into the nature of internal social capital. The results showed that employee perceptions differed depending on the medium of interaction—surveys, feedback channels, network data, or direct communication measurements—which aligns with Adler and Kwon's assertion that social capital arises from both structural and relational sources (30). The differential signals across platforms reflect Nahapiet and Ghoshal's tri-dimensional model of social capital—structural, relational, and cognitive—which suggests that no single instrument can fully capture the complexity of social capital within organizations (11). The compound-eye metaphor operationalizes this multidimensionality by integrating distributed, parallel sensing nodes, reminiscent of the capabilities of biological compound vision systems, which collect numerous micro-impressions to form a composite understanding of the environment (34, 35).

This alignment between the model and prior theory extends to the dynamic measurement aspect of the study. One of the core contributions of the compound-eye system is its ability to continuously monitor social capital, generating temporal trajectories rather than isolated snapshots. Woolcock and Narayan argue that social capital fluctuates with changes in institutional conditions, power relations, and community interactions (10). Chetty's large-scale measurement studies similarly demonstrate that social capital characteristics vary significantly across geographies, time periods, and social contexts, affecting mobility and long-term outcomes (20). The findings of the current study support these assertions by revealing short-term oscillations in trust and cooperation that traditional static measures would fail to detect. Thus, the empirical patterns emphasize the necessity of dynamic, multi-source measurement systems for organizations seeking to manage relational capital strategically.

The results also confirm that internal social capital is an important driver of job performance and organizational effectiveness. This is consistent with Zolfaghari's meta-analysis, which synthesized evidence across a decade of longitudinal studies and reported strong correlations between social capital and performance outcomes among Iranian organizations (27). Gholipour's findings similarly highlight that organizations with strong relational networks, shared norms, and trust structures are better able to foster entrepreneurial behavior and operational success (26). The compound-eye model, by detecting patterns of relational deterioration or improvement, provides organizations with a diagnostic capability that supports timely interventions to maintain or strengthen these performance-enhancing relational structures.

Moreover, the distributed sensing design aligns with the knowledge-based view of the firm. Kogut and Zander's theory posits that knowledge replication and innovation occur through networks of interaction rather than through isolated individuals (7). Burt's structural holes concept reinforces this by illustrating how individuals positioned between disconnected groups can facilitate knowledge transfer and organizational advantage (6). The results of the study, which show that relational gaps or fragmentation correlate with lower social capital scores, underscore the importance of network integrity for organizational learning and innovation. Similarly, Morgan and Burrell's sociological paradigms emphasize that organizations are socially constructed realities shaped by interaction patterns and interpretive processes (17). The compound-eye model, by monitoring these patterns continuously, offers a practical mechanism for tracking the conditions that support or undermine organizational learning.

The findings also resonate with the literature on organizational metaphors and theory-building. The conceptual framework used in the study draws from Lynham's general method of theory-building, which emphasizes the iterative development of conceptual, operational, and empirical components (31, 32). Morgan's metaphorical

approach supports the use of imagery to illuminate complex organizational processes and generate analytical leverage (15). Rodgers' examination of metaphors in education also highlights how figurative thinking enables researchers to understand abstract constructs such as trust, cohesion, or values (18). The findings demonstrate that metaphors, when operationalized properly, can bridge conceptual and empirical insights, enabling organizations to both understand and measure intangible constructs such as social capital.

The results additionally suggest that organizations benefit from bridging forms of social capital, consistent with the perspectives of Huysentruyt and colleagues who emphasize the role of bridging ties in fostering trust across diverse groups and reducing fragmentation (36). Periods during which cross-departmental collaboration increased were associated with higher indices of shared values and trust, reflecting bridging social capital's function as a link between otherwise disconnected units. This is further supported by Leana's early work showing that cooperative employment practices strengthen internal social capital (12). Sanchez-Famoso's review also emphasized that internal social capital is central to fostering resilience, innovation, and organizational continuity (25). The compound-eye model captured these effects by identifying increases in collaboration and trust during periods of cross-functional coordination.

The study's interpretation of relational and perceptual variations is also aligned with the work of Chen and colleagues, who showed that individuals' investments in social capital directly affect their levels of perceived stress and well-being (21). This reinforces the findings that employees who perceived stronger relational climates reported higher levels of alignment with organizational values and norms. Moreover, the study's evidence that managerial behaviors influence social capital aligns with the research of Kama and Weiss, who identified how incentives and managerial targets can distort relational structures and induce reactive behaviors (29). Taken together, these insights underscore the interconnectedness of managerial practices, relational networks, and the psychological climate of the organization.

Finally, the results demonstrate the significant value of using a multi-method, multi-platform model to measure social capital. Traditional measurement tools, such as surveys or inventories like those developed by Krishna and Shrader or by Coleman, Narayan, and Cassidy, provide foundational insights but lack the temporal resolution needed to capture rapid relational changes (5, 19). The compound-eye model addresses this by incorporating continuous data streams, aligning with contemporary recommendations for integrating methodological pluralism in organizational research (33, 37). The study's findings suggest that this pluralistic, multi-platform approach improves the accuracy of social capital diagnosis and strengthens managers' capacity to respond to emerging relational risks.

The study, despite its contributions, faces several limitations. First, continuous measurement systems require consistent employee engagement, and fluctuations in participation rates may influence the completeness or accuracy of the collected data. Second, the compound-eye model depends on technological infrastructure that may not be uniformly accessible or easily integrated into all organizational environments. Third, the interpretation of social capital indicators is inherently context-dependent, meaning that findings may not fully generalize to organizations with significantly different cultures, structures, or operational environments. Additionally, the distributed sensing approach may capture perceptions more readily than deeper structural dynamics, potentially underrepresenting hidden tensions or informal networks that are less visible to formal measurement instruments.

Future research should explore the integration of artificial intelligence and machine learning to enhance real-time pattern detection within social capital measurement systems. Longitudinal comparative studies across industries can reveal how different contextual variables shape social capital trajectories. Further investigation into the

relationship between digital communication patterns and social capital would also expand understanding of how virtual environments influence relational dynamics. Research should also examine how continuous measurement models can be combined with organizational interventions to test causal effects, thereby transitioning from descriptive monitoring to predictive and prescriptive analytics.

Organizations should implement continuous social capital monitoring systems to detect relational shifts early and intervene promptly. Managers should prioritize transparent communication, consistent cross-functional collaboration, and supportive leadership behaviors to strengthen internal networks. Training programs can be developed to help employees understand the value of shared norms, trust, and cooperation. Finally, organizations should treat social capital as a strategic resource, integrating its measurement into performance dashboards and decision-making processes to improve resilience, innovation, and organizational effectiveness.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

All ethical principles were adheried in conducting and writing this article.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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