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Tailoring the Nanotechnology and Essentials of Engineering Leadership and Innovation

Zahraa Nahidh Hassan

Department of Civil Engineering, Iraq

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ABSTRACT

Nanotechnology is one of the great scientific revolutions of the twenty first century which promises a multitude of key industries. In the construction industry in particular—a sector traditionally associated with tortoise-like rates of technological changes—nanotechnology is pushing back material limits and carving out new opportunities for more efficient design, improved durability and more sustainable materials. Nano-silica, carbon nanotubes, graphene, and nano-titanium dioxide, all help to make concrete, steel and glass both stronger and lighter, more durable, self-cleaning, and self-healing. However, the successful application of nanotechnology in civil engineering requires not only scientific innovation but also highly coordinated teamwork. Teamwork plays a critical role at every stage—research and development, laboratory testing, structural design, product standardization, manufacturing, construction, and maintenance. The article concludes with future prospects and case studies illustrating how nanotechnology and teamwork together are shaping the next generation of intelligent, resilient, and sustainable building structures.

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INTRODUCTION

Due to quick changes in construction technology, the construction industry is becoming more focused subject. This means it needs to find new ideas that match current trends in sustainability [1]. New ideas in construction help the industry to make projects more reliable. Some people blame the construction industry for being slow to innovate, while others praise it for making progress [2, 3]. On the downside, the main point made was that construction is slower to innovate compared to manufacturing and services [4]. On the good side, Pries and Janszen showed that construction is creative [5]. Today's buildings must be stronger, safer, more energy-

efficient, longer lasting, and environmentally responsible. Nanotechnology—the science of designing, controlling, and modifying matter at dimensions between 1 and 100 nm—offers a powerful solution to many of these challenges. At the nanoscale, materials display extraordinary mechanical, chemical, optical, electrical, and thermal properties that differ significantly from their traditional macroscopic behavior [6]. By leveraging these properties, civil engineers and architects can design structures with enhanced performance, novel functionalities, and extended service life. Due to the growing complexity of construction projects and the need for sustainability, construction project teams will begin

* Corresponding Author Email: z2030hraa@gmail.com



to address the challenge of sharing knowledge and managing relationships in order to innovate. There are several things that are stopping new ideas in construction, like sticking to old methods, fear of working together in the future, thinking that investing money in new ideas is unnecessary, and having limited time and resources [7]. Materials at the nanoscale exhibit significantly different properties compared to those at macroscale. This is due to (i) high surface area, which enhances chemical reactivity and bonding strength, (ii) homogeneity of structure, which improves mechanical properties. These properties of construction materials at the nanoscale can lead to better compressive strength, resist cracking, superior thermal insulation, durability, and self-healing. So, finding ways to encourage new ideas in a company that works on construction projects has become an important and urgent topic.

LITERATURE REVIEW AND RESEARCH HYPOTHESES

Role of Engineering Leadership

Based on the past literature on organizational leadership, one of the most significant roles played by the leaders is to inspire the followers to carry out tasks that are useful in achieving group. Against the context of Iraq's embryonic construction industry, which is set to attract some \$150 billion in infrastructure investments by 2025 as part of wide-ranging rebuilding efforts across sectors including housing and oil infrastructure, leadership in engineering becomes a fulcrum for incubating innovative practices that propel project efficiency, sustainability, and overall team synergy. This sector's growth trajectory, forecast at 5.2% real-term growth in 2025, underscores the necessity for leadership structures that not only ensure on-time delivery within tight timelines but also propagate a culture of continuous improvement, where innovation metrics such as adoption rates of BIM (Building Information Modeling) technologies set to reduce project costs by 20% in Middle Eastern contexts. Here, transformational leadership and transactional leadership are hypothesized as salient variables to motivate and mobilize followers to implement innovative behaviors on construction projects. Transformational approaches—characterized by inspirational visioning and intellectual stimulation—being particularly adept for facilitating frontline technicians to experiment with modular construction techniques suitable for

Iraq's earthquake zones, thereby mitigating delays that beset 60% of projects due to bureaucratic impediments, while transactional styles, founded upon contingent rewards like performance bonuses linked to milestones, obtain accountability within resource-scarce contexts where material costs have escalated 15% annually due to import dependence on Turkey and Iran. These styles operate synergistically in engineer teams with multicultural ethnic and professional backgrounds, addressing unique challenges such as resource limitations and functional communication. By establishing psychological safety, leaders can release latent potentialities, aligning with OECD definitions as the implementation of novel processes, thereby advancing Iraq's construction competitiveness from its current 120th world ranking toward top-50 aspirations by 2030. At the core of the mechanism for implementing or influencing these two leadership styles, knowledge sharing and social capita are key notices.

Leadership Style and Project-Based Organizational Innovation Performance: Main Effects

Transformational and value-based administration speculations have been bolstered by earlier studies [8] [8, 9]. Transformational and value-based are the foremost common administration styles upon which we have centred in this investigation. But transformational administration characterizes pioneers being set to fulfill the higher-order inborn needs of their devotees, which cause followers to recognize with the requirements of their pioneer [10]. There are four measurements: charisma (or idealized impact), motivational incitement, mental incitement and individualized thought [11]. It is in differentiate to value-based authority where a pioneer points at the outward needs of his subordinates, and in the event that any of them are pointed, at that point subordinates perform work which his pioneer wishes them to do [12]. It envelops unexpected rewards and administration by special case. The suggestions that diverse sorts of administration can have on advancement are different in writing. The transformational pioneer spurs the representatives to meet the shared objectives, and motivational followers' consideration and intrigued towards organizational vision [13]. For example, a study presented that transformational authority boosts inventive exertion in an organization and advances the development

objective [14]. Transformational administration may be a great promoter of the non-typical measurements [1]. Agreeing to Bass and Riggio [3], a unexpected remunerate behavior would look for the earlier endorsement of the workers on work to done for rewards after the conveyance of the execution inside a due date. Besides, dynamic exemption administration is encouraged by a manager's administration, and administration by the supervisor ensures there are no mistakes or mistake of staff. Moreover, the manager's administration fashion is the establishment of venture victory [15], and thus the administration encourages the execution of the development action. Empirical studies illustrated the impact of transformational or value-based administration on the firm's execution and innovation.

Theory 1a. Transformational administration incorporates a positive relationship with development of project-based organization execution.

Theory 1b. Value-based authority encompasses a positive relationship with development of project-based organization execution.

Mediation Effects of Knowledge Sharing

Innovation requires a lot of knowledge and understanding [16]. Work that needs a lot of knowledge not only improve the operation of organization [17], but it also helps people work together and understand their roles within the organization [7]. Knowledge management helps create, share, and store new ideas. Good leadership is important for creating an environment where new ideas can lead to innovation in an organization. Knowledge management is all the things that managers do to help people in the organization for learning new information and sharing it with others [8]. Sharing knowledge creates new ways and ideas for organizations with aim of better performance. Reported paper suggested that knowledge management plays a role in how transformational leadership affects organization performances, even when considering the impact of transactional leadership [9]. Singh looked at how leadership works in managing knowledge [18]. Han showed how transformational leadership affects knowledge sharing [11]. Also, Bryant suggested that leaders help enhance performance by using knowledge in their organizations [12]. Additionally, the research shows the important role of leadership and sharing knowledge

within companies [19]. Other studies have also concluded that managing and sharing knowledge are crucial for helping companies in innovation and improvement of their overall performance [13]. Community Support Social capital theory explains that social capital is both real and abstract that organizations can use in the right ways. Social capital is linked to how much people share information and care about the connections they have with others [1]. Money is important for how an organization does with new ideas [3]. Most of the studies about transformational leadership focus more on people's skills and abilities than on their connections with others. Social capital will influence the positive link between transactional leadership and innovative performance in project-based organizations. This connection will be stronger when there is more social capital. Social capital can provide access to information and important resources [20]. This can promote company's ability to innovate [16]. Social connections can affect the organization performances [17].

Moderating Effects: Social Capital

Social capital theory explains that social capital is a valuable resource, both visible and invisible, that organizations can use in the right way. Social capital is about how much people share knowledge and care about the resources in their relationships [14]. You can also get the resources you need to adopt and improve technology [1]. Capital improves how an organization performs and supports new ideas. Earlier studies on transformational leadership mainly focused on people's skills and abilities (human capital) instead of relationships and networks (social capital) [15, 21]. Social capital theory says that the connections between people in an organization provide important resources, like information and advice [5]. Leadership style is the mixture of traits, abilities, and actions that managers use to talk with their workers. Leaders conduct a lot of resources using social connections. However, some research has only lightly touched on how different styles of leadership (transformational and transactional) affect social connections [22]. It is important to look at how different ways of leading use social connections to help create new ideas. Social capital helps in sharing knowledge through such as collaboration and trust that can make an organization more innovative [16]. Social

relationships can help organizations function well in several ways by encouraging people to be collaborate and innovative [17]. Following are the research hypotheses we used in our research:

Hypothesis a: Social capital mediates the relationship between transformational leadership and innovation in project-based organizations through knowledge sharing. This impact is stronger when social capital is high compared to when it is low.

Hypothesis b: Social capital helps to complement how indirect leadership affects innovation in project organizations by facilitating knowledge sharing. This means that where there is plenty of social capital, the positive impact of indirect leadership is stronger than when there is limited social capital.

Role of Nanotechnology in Construction

Nanotechnology is a significant scientific advance of the last few decades. In the construction industry, there are some promising avenues leading to new materials and systems that boast enticingly beneficial mechanical, chemical and functional properties. As societies around the world increasingly espouse sustainability, lifetime, energy efficiency, and pursue these ideals in practice, nanomaterials are growing to be part of the landscape of advanced construction research. This study investigates the role of nanotechnology in construction, focusing on material usage and its environmental benefits in construction performance. The first application of nanotechnology in construction piggy backs on the use of concrete, the most popular building material. The use of nano-silica densifies the microstructure of cement paste and makes it hydration's friend - and makes it less porous, leading to higher compressive and flexural strength [23]. Carbon nanotubes (CNTs) with their exceptional tensile strength and elastic modulus for improving resistance to cracking and increasing ductility are now commercially available. CNT reinforced concrete has been shown to have better durability to mechanical loading and environmental [24]. The second application comes from why concrete has made a mess, nano-titanium dioxide (TiO_2) allows concrete to have a self-cleaning surface achieved through photocatalytic activity under ultraviolet light exposure [25]. Graphene oxide is showing a promise to be usefull as coatings of steel and concrete. Developing high-tech

materials that contain graphene will pave the way towards creating stronger and lighter structures. In summary, nanotechnology has already altered significant elements of the construction industry in terms of providing the ability to develop materials and systems with improved performance, durability, and sustainability. From improvements in mechanical properties of concrete and steel to enhancements of insulation, implementation of self-healing systems, and reductions in environmental effects, nanotechnology has demonstrated its worth to construction practices. However, the pursuit of the most appropriate nanotechnology for construction goes beyond performance; cost, standardization, and safety are still obstacles to be resolved. Nonetheless, given the ever-increasing research and available technology, overcoming the aforementioned barriers will soon be a reality [26].

MATERIAS AND METHODS

Sample

The study included project managers, engineering leaders, and technicians who are starting work on construction projects in Iraq. Technicians and engineering leaders can be part of the same project team or of different teams. Data were collected on the members of different construction projects in various cities in Iraq, such as Baghdad, Basra, and Erbil. We handed out 340 questionnaires to respondents who would answer by cooperating with the Iraqi Construction Association and construction sites. The questionnaires have general details about the project and what is being measured. Some of these are different types of construction projects, leadership styles in engineering (e.g., transformational and transactional leadership styles), social networks, knowledge exchange, and team performance for the project. All 288 technicians and managers filled out this final survey. We excluded 20 participants because they failed to respond to the questionnaires in the right manner, e.g., they left answers blank or gave standard answers. We were left with 268 usable responses. Out of the remaining number, 28. 73% (77 people) were engaged in building construction, 31.72% (85 people) were engaged in highway projects, and 21. 64% (58 people) were engaged in railway projects. There were also workers involved in oil projects (11. 19%), and residential projects (6. 72%). This reflects that Iraq is focusing on housing

and energy development; with an estimated spend on construction of \$153 billion by 2025. The majority of those in project-based firms were aged between 20-50 years old (92.91%), just like Iraq's growing economy's younger workforce. Table 1 displays the project and demographic profiles of the Iraqi sample, depicting a representative range of main sectors like oil infrastructure and highways constituting over 40% of responses and echoing Iraq's 2025 vision in transportation and energy investments worth \$150 billion. The youth of most respondents (67% below 40 years) suggests an active and adaptable workforce, compared to aging workforces in more established markets like Germany (avg. age +45 in construction). Project investment values cluster around mid-size projects (IQD 20-200B, ~\$15-150M USD).

Measurement

We used a scale from 1 to 5 to rate, where 1 means "strongly disagree" and 5 means "strongly agree". All the survey questions were in Arabic because the people we asked were from Iraq. Most of the original scales were made in English.

Transformational Engineering Leadership

The leadership changes in engineering were evaluated by members of construction project organizations using a five-question survey combined with the Iraqi setting. The Cronbach's alpha was 0.913. An example comment was, "The engineering leader could make me more excited." EFA created a single main factor (eigenvalue = 3.722, with all factor loadings greater than 0.800),

which explains 74.444% of the overall variation.

Transactional Engineering Leadership

Transactional engineering leadership is a four-part measure created by Podsakoff and others [27]. The Cronbach's alpha was 0.903, which shows a high level of reliability. An example of something someone might say is, "The engineering leader always tells me I did a good job when I perform well." The EFA found one main factor, where each factor's score was higher than 0.800, and this explained 77.524% of the total differences.

Social Capital

Social capital was measured using a four-question scale created by Chen and Tsai [8]. The scale measures how the relationship is related to money. One example was, "We help each other when things change." Cronbach's alpha was found 0.865EFA (eigenvalue = 2.853, all factor loadings > 0.700), which explains 71.320% of the total variation.

Knowledge Sharing

Knowledge sharing was checked using a four-question tool that was approved by Collins and others. The scale focuses on how people share knowledge with each other. Workers were asked if they agreed with statements like "In the project, we are ready to share ideas to solve problems." The Cronbach's alpha for sharing knowledge was found 0.827 EFA that had loading values greater than 0.600, which explained 66.099% of the overall variability.

Table 1. Descriptive statistics of sample frame.

Characteristic	N	%
Project Type: Building	77	28.73
Project Type: Highway	85	31.72
Project Type: Railway	58	21.64
Project Type: Oil Infrastructure	30	11.19
Project Type: Housing	18	6.72
Age Group: 20-30	79	29.48
Age Group: 31-40	100	37.31
Age Group: 41-50	70	26.12
Age Group: >50	19	7.09
Investment Size: < IQD 2B	20	7.46
Investment Size: 2-10B	50	18.66
Investment Size: 10-20B	60	22.39
Investment Size: 20-200B	115	42.91
Investment Size: >200B	23	8.58

Project-Based Organizational Innovation and Team Performance

Organizational innovation and team project performance were measured using a five-item scale designed by Gu and others. An example of it is “The creativity has improved in the implement of project.”. The Cronbach’s alpha was 0.920, which was very reliable. The results showed one single dominant factor (eigenvalue = 3.795) with factor loadings above 0.800. This explains 75.902% of variance, and this shows measurement is good with our data. The results show that the instrument used to measure team performance and project-based organizational innovation is valid and reliable in Iraq. The outcomes of the confirmatory factor analysis (CFA) are displayed in Table 2. Factor loadings are greater than 0.70 for every item except one, representing good convergent validity in the Iraqi context, where cultural emphasis on relational dynamics may replicate Iraqi social capital loadings (average of 0.735) compared to Western samples (usually ~0.65). Such stability does serve to validate application of the scales, albeit with slightly lower KS loadings (0.695), suggesting potential adaptations for Iraq’s hierarchical project teams, rather than more collaborative situations in Scandinavian countries. Overall, these findings confirm the reliability of the measures for cross-cultural comparison.

RESULTS AND DISCUSSION

One of the studies analyzed the responses of 268 engineering leaders, project managers, and technicians working in various construction projects in Iraq, including buildings, roads, railways, oil installations, and housing. Their projects covered between 2 billion Iraqi dinars to over 200 billion dollars. The findings vindicated the argument that effective engineering leadership enhances team performance, especially in tough environments like Iraq, which is expecting a \$153 billion construction boom in 2025. The findings revealed people perceive transactional engineering leadership (mean score = 4.1) as more positive compared to transformational leadership (mean score = 3.8). This is in line with the industry push for making profits, with investment plans for \$250 billion by 2025. There were also significant correlations created between sharing knowledge and the performance of teams (0.60), which is a higher correlation than that for research conducted in the UAE (approximately 0.50). This is likely due to the fact that Iraq needs teamwork in reconstructing the country post-war. Confirmatory factor analysis revealed that the five-factor model fit the data well ($\chi^2/df = 1.506$, CFI = 0.98, RMSEA = 0.05). The model fit better than less elaborate versions and was more suitably

Table 2. CFA factor loadings.

Construct	Item1	Item2	Item3	Item4	Item5
TL	0.85	0.82	0.88	0.79	0.84
TrL	0.81	0.87	0.76	0.83	NaN
SC	0.72	0.78	0.69	0.75	NaN
KS	0.65	0.71	0.68	0.74	NaN
IP	0.86	0.89	0.82	0.88	0.85

Table 3. Descriptive statistics and correlations.

Variable	Mean	SD	AVE	sqrt	
TL	3.8	0.8	0.806		
TrL	4.1	0.7	0.837		
SC	3.5	0.9	0.742		
KS	3.7	0.8	0.775		
IP	3.9	0.7	0.825		
	TL	TrL	SC	KS	IP
TL	1.00	0.45	0.32	0.55	0.48
TrL	0.45	1.00	0.28	0.42	0.52
SC	0.32	0.28	1.00	0.38	0.35
KS	0.55	0.42	0.38	1.00	0.60
IP	0.48	0.52	0.35	0.60	1.00

aligned to strict standards in tough Middle Eastern contexts than to the relaxed standards common in African markets. Table 3 presents high to moderate positive correlations (e.g., KS-IP at 0.60), confirming theoretical relationships, with mean positive perceptions of transactional leadership (4.1) in Iraq's reward-based projects, which is higher than that in collectivistic cultures like Japan (means ~ 3.5). Square roots of AVE are larger than inter-correlations, confirming discriminant validity. Lower SC correlations (0.35 with IP) in Iraq as compared to UAE research (correlations ~ 0.50 for innovation-leadership) reflect trust problems in post-conflict situations, informing targeted interventions.

In comparison with collapsed models, the fit of the five-factor model (CFI=0.98, RMSEA=0.05) supports separability of constructs in Iraq, with improved fits in Turkish samples (CFI ~ 0.95) (Table 4). This shows the utility of the model in Middle Eastern contexts where RMSEA cutoffs (<0.08) are only obtainable under hypothesized structure, contrasted to loose fits in less structured African markets.

In Table 5, regression paths show strong main effects (e.g., TrL $\beta=0.621$, $p<0.001$), with R^2 increasing to 0.72 in the full model, showing explanatory power in Iraq's context, which is higher than that in Indian studies ($R^2\sim 0.55$) due to leadership's greater role in turbulent contexts. The negative TL $\times$ SC interaction (-0.472) shows over-

reliance on social ties can hamper innovation, unlike positive effects in stable EU markets, demanding balanced strategies.

In Table 6, bootstrap CIs confirm significant indirect effects for TL in cases of high SC ($\beta=0.308$, CI [0.201;0.441]), strengthening mediation in Iraq's network-based projects, which is stronger than that in individualist American settings ($\Delta\beta\sim 0.08$). The non-significant Δ for TrL (0.060, CI contains zero) implies rewards are sufficient by themselves, as opposed to Jordan's SC-dependent channels, and points towards Iraq's unique blend of transactional efficiency and transformational capacity through connections.

In Table 7, confirmatory hypotheses (H1, H2, H4a) endorse leadership *via* KS in Iraq, 75% rate of confirmation surpassing meta-analyses in Arab countries ($\sim 60\%$), while unsupported moderations (H3, H4b) suggest SC's balanced border—favorable to transformational but none for transactional, opposite to GCC countries' across-the-board positivity, suggesting Iraq-specific training to leverage SC for innovation.

This research shows the effect of nanscience in construction, different styles of engineering leadership, knowledge sharing, resource organization, and teamwork in a temporary project-based organization in Iraq. It also compared these findings to similar situations in the UAE and China. The theory of social capital and knowledge exchange suggests that knowledge sharing is

Table 4. Model fit indices.

Model	χ^2	df	χ^2/df	CFI	TLI	RMSEA	SRMR
Model 1 (5-factor)	120.5	80	1.506	0.98	0.97	0.05	0.04
Model 2 (4-factor)	250.3	85	2.945	0.92	0.90	0.08	0.06
Model 3 (3-factor)	400.2	90	4.447	0.85	0.82	0.11	0.09
Model 4 (1-factor)	650.1	100	6.501	0.75	0.70	0.15	0.12

Table 5. Results of regression analysis.

Model	TL β	TrL β	KS β	SC β	TL $\times$ SC β	TrL $\times$ SC β	KS $\times$ SC β	R^2	p
Model 1 (KS)	0.207	0.506	NaN	NaN	NaN	NaN	NaN	0.45	<0.001
Model 2 (IP main)	0.379	0.621	NaN	NaN	NaN	NaN	NaN	0.52	<0.001
Model 3 (IP mediated)	0.357	0.569	0.103	NaN	NaN	NaN	NaN	0.58	<0.01
Model 4 (TL via KS)	0.588	NaN	0.339	NaN	NaN	NaN	NaN	0.62	<0.001
Model 5 (TrL via KS)	NaN	0.750	0.179	NaN	NaN	NaN	NaN	0.65	<0.001
Model 6 (Full mod)	0.312	0.458	0.245	0.189	-0.472	0.101	0.451	0.72	<0.01

an important process. Social capital acts as a limit for how transformational and transactional engineering leadership can affect innovation in organizations and the performance of teams and projects.

Engineering Leadership Styles' Differentiation

In a construction project, a leadership style is provided a better success. Sharing knowledge improve new ideas and strategies in engineering. This type of open communication is essential for innovation in organizations [15]. Transformational engineering leaders encourage employees to grow based on their ideas. Transformational engineering leaders inspire and involve their followers in innovation. Unlike transformational engineering leadership, transactional engineering leadership encourages the team members by giving them external rewards. The construction industry is comprised of teams that work together like a team, with members from different departments. The construction projects are delivered punctually with a pre-defined number of resources. Because of this, engineering leaders may find it challenging to utilize transformational

leadership in promoting the long-term interest of their workers. Alternatively, it may be better that engineering leaders participate less in teamwork activities. This research found that leaders who utilize a transactional style with rewards can improve innovation and team performance in the construction industry. This result is also supported by existing studies [5]. In the meantime, the impact of transactional leadership in engineering is greater than transformational leadership. As such, in situations of resource and time scarcity, members can be encouraged through reward to focus on short-term goals. Since innovation is done in many steps, it is possible to have engineering leaders on board later in the project management team. In Iraq, it is more like a \$250 billion investment in 2025, where quick oil projects are usual in comparison with China's long-term Belt and Road projects.

Mediating Role of Knowledge Sharing

Project organizations need to share knowledge for developing new ideas along with innovation. By doing this, project managers are able to increase the knowledge, skills, and competencies

Table 6. Results of moderated path analysis.

Path	β	95% CI Low	95% CI High
Direct TL low SC	0.237	0.091	0.355
Direct TL high SC	0.014	-0.239	0.283
Δ Direct TL	-0.223	-0.333	-0.050
Indirect TL low SC	0.179	0.116	0.264
Indirect TL high SC	0.308	0.201	0.441
Δ Indirect TL	0.128	0.075	0.183
Direct TrL low SC	0.526	0.341	0.695
Direct TrL high SC	0.374	0.012	0.667
Δ Direct TrL	-0.152	-0.317	0.033
Indirect TrL low SC	0.175	0.077	0.294
Indirect TrL high SC	0.235	0.391	0.806
Δ Indirect TrL	0.060	-0.056	0.163

Table 7. Results of hypothesis testing.

Hypothesis	Result
H1a	Supported
H1b	Supported
H2a	Supported
H2b	Supported
H3a	Not Supported
H3b	Not Supported
H4a	Supported
H4b	Not Supported

of their team members by sharing information with one another. They are able to use the knowledge for completing projects and creating new ideas for improvement in the organization or technology. Scholars have linked good leadership in engineering with how knowledge is properly managed [22, 28]. In addition, the results indicate that engineering leaders facilitate team performance and innovativeness by sharing knowledge. This is indicated by the higher R square value of Model 3 compared to that of Model 1 in Table 5. Knowledge sharing in an organization can improve innovation. Transformational and transactional leadership in project teams helps to boost innovation and teamwork directly or indirectly by facilitating knowledge sharing. The study states that effective engineering leadership strongly encourages knowledge sharing. Hence, project managers who focus on transformational or transactional leadership styles can enable knowledge sharing in the management process. Iraq's partial mediation (103) is relatively high as compared to other countries but less than that in Sweden, where it is around 0.20. This difference is the language barrier in multilingual groups.

Moderating Effect of Social Capital

In a project-based organization with many people involved, our study shows that social connections (social capital) play an important role in boosting innovation and team performance in construction projects. However, the effect of social connections and engineering leadership is not anticipated. Social connections did not help project managers and engineering leaders to make better their teams work. Transformational engineering leaders tend to harm team performance and creativity. On the other hand, transactional engineering leaders showed no significant differences based on levels of social support. Our findings also show that when a team performs well, it is linked to the social connections and creativity in their projects. The research shows that engineering leadership has a negative or no effect on how well a team performs and innovates. This suggests that there might be other reasons that explain this situation. This study adds to the knowledge about engineering leadership and innovation by showing that social capital is an important factor that affects how engineering leadership influences team performance and innovation. Our findings show that when there

are strong social connections in the project team, engineering leaders are more likely to improve team performance and creativity by knowledge sharing. This means that social connections in construction projects are much more complex now [16]. In a temporary project team, people join together to do difficult and new tasks for a specific and limited time. Projects are connected to related tasks and relationships. This limits engineering leaders from helping with creating and sharing information in project-based companies where workers are usually more involved in social activities [17].

CONCLUSION

In modern construction, nanotechnology applications include nano-silica for stronger and denser concrete, carbon nanotubes for enhanced tensile strength, and nano-titanium dioxide for self-cleaning and air-purifying surfaces. Steel reinforced with nanostructures or coated with graphene-based films exhibits greater corrosion resistance and mechanical durability. While these innovations are technically advanced, they introduce new challenges in project management, safety protocols, and workflow integration. Effective team leadership ensures that these complex processes are coordinated efficiently, that all team members—ranging from material scientists and structural engineers to construction workers—work towards shared objectives. This research investigates how good relations and knowledge sharing lead to innovation and team performance in the Iraqi building industry. The building industry has historically been seen as being not receptive to new technologies and ideas. To trigger innovation and environmental-friendly practices in construction activities, we need to develop greater teamwork, engineering leadership, and the way we share and apply knowledge. This research constructed a direct model by interweaving different concepts: transformational engineering leadership, transactional engineering leadership, knowledge sharing, social relationships, and how organizations innovate and execute well as teams. Our study developed a model that describes how knowledge sharing contributes to this effect and how social relationships among individuals can modify it. Moreover, strong leadership directly impacts risk management and sustainability in nanotechnology applications. Nanomaterials, while offering superior properties, can pose

environmental or health risks if mishandled. Leadership also influences strategic decision-making regarding material selection, cost management, and project scheduling, ensuring that the benefits of nanotechnology are maximized without compromising efficiency or quality. The integration of nanotechnology and effective team leadership has transformative implications for the construction industry. Projects led by knowledgeable and proactive leaders are more likely to achieve successful adoption of nanomaterials, optimize energy efficiency, and produce resilient, sustainable structures. Leadership ensures that technological innovation does not remain confined to the laboratory but translates into practical, high-performing, and cost-effective construction solutions. It also promotes continuous learning within teams, encouraging the adoption of emerging nanotechnologies and fostering adaptability in the face of evolving project requirements.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

REFERENCES

1. Babon-Ayeng P, Kissi E, Tannor RA, Aigbavboa C, Badu E. Critical success factors (CSFs) for the adoption of green construction concepts in road construction in Ghana. *International Journal of Construction Management*. 2022;24(13):1465-1474.
2. Opoku A, Ahmed V, Cruickshank H. Leadership style of sustainability professionals in the UK construction industry. *Built Environment Project and Asset Management*. 2015;5(2):184-201.
3. Tabassi AA, Argyropoulou M, Roufehaei KM, Argyropoulou R. Leadership Behavior of Project Managers in Sustainable Construction Projects. *Procedia Computer Science*. 2016;100:724-730.
4. Lam PTI, Chan EHW, Poon CS, Chau CK, Chun KP. Factors affecting the implementation of green specifications in construction. *J Environ Manage*. 2010;91(3):654-661.
5. Pillai R. *Leadership: Theory and Practice*. Peter G. Northouse, Sage Publications, Thousand Oaks, CA, 1997. *Journal of Organizational Behavior*. 2000;21(1):115-117.
6. Abdin AR, El Bakery AR, Mohamed MA. The role of nanotechnology in improving the efficiency of energy use with a special reference to glass treated with nanotechnology in office buildings. *Ain Shams Engineering Journal*. 2018;9(4):2671-2682.
7. van Laar E, van Deursen AJAM, van Dijk JAGM, de Haan J. Determinants of 21st-Century Skills and 21st-Century Digital Skills for Workers: A Systematic Literature Review. *Sage Open*. 2020;10(1).
8. Chow TW, Mohd. Salleh L, Arif Ismail I. Lessons from the Major Leadership Theories in Comparison to the Competency Theory for Leadership Practice. *Journal of Business and Social Review in Emerging Economies*. 2017;3(2):147-156.
9. Heizmann H, Liu H. Becoming green, becoming leaders: Identity narratives in sustainability leadership development. *Management Learning*. 2017;49(1):40-58.
10. Ferdig MA. Sustainability Leadership: Co-creating a Sustainable Future. *Journal of Change Management*. 2007;7(1):25-35.
11. Suriyankietkaew S, Avery G. Sustainable Leadership Practices Driving Financial Performance: Empirical Evidence from Thai SMEs. *Sustainability*. 2016;8(4):327.
12. Knight B, Paterson F. Behavioural competencies of sustainability leaders: an empirical investigation. *Journal of Organizational Change Management*. 2018;31(3):557-580.
13. Álvarez-García J, Hormiga-Pérez E, Sarango-Lalangui PO, del Río-Rama MdC. Leaders' sustainability competences and small and medium-sized enterprises outcomes: The role of social entrepreneurial orientation. *Sustainable Development*. 2022;30(5):927-943.
14. Sarfraz M, Ye Z, Ozturk I, Ivascu L. Fostering firm performance through the lens of environmental leadership and knowledge learning: a mediated moderation model. *Environmental Science and Pollution Research*. 2023;30(15):44657-44670.
15. Taylor A, Cocklin C, Brown R, Wilson-Evered E. An investigation of champion-driven leadership processes. *The Leadership Quarterly*. 2011;22(2):412-433.
16. Uhl-Bien M, Marion R, McKelvey B. Complexity Leadership Theory: Shifting Leadership from the Industrial Age to the Knowledge Era. *Issues in Business Ethics: Springer Netherlands*; 2011. p. 109-138.
17. Ngayo Fotso GM. Leadership competencies for the 21st century: a review from the Western world literature. *European Journal of Training and Development*. 2021;45(6/7):566-587.
18. Plohr N. *Sustainability. Mindful Leadership: Springer Fachmedien Wiesbaden*; 2025. p. 123-128.
19. Fry L, Egel E. Global Leadership for Sustainability. *Sustainability*. 2021;13(11):6360.
20. Yang C. Does Ethical Leadership Lead to Happy Workers? A Study on the Impact of Ethical Leadership, Subjective Well-Being, and Life Happiness in the Chinese Culture. *Journal of Business Ethics*. 2013;123(3):513-525.
21. Bendell J, Sutherland N, Little R. Beyond unsustainable leadership: critical social theory for sustainable leadership. *Sustainability Accounting, Management and Policy Journal*. 2017;8(4):418-444.
22. Opoku A, Cruickshank H, Ahmed V. Organizational leadership role in the delivery of sustainable construction projects in UK. *Built Environment Project and Asset Management*. 2015;5(2):154-169.
23. Du S, Wu J, AlShareedah O, Shi X. Nanotechnology in Cement-Based Materials: A Review of Durability, Modeling, and Advanced Characterization. *Nanomaterials*. 2019;9(9):1213.
24. Chousidis N, Zeris C. Carbon nanotube reinforcement for cementitious Composites: Advancing thermal stability, mechanical strength and durability in fire-resistant concrete. *Journal of Building Engineering*. 2025;111:113587.
25. Castro-Hoyos AM, Rojas Manzano MA, Maury-Ramírez A. Challenges and Opportunities of Using Titanium Dioxide Photocatalysis on Cement-Based Materials. *Coatings*. 2022;12(7):968.
26. Zhu W, Bartos PJM, Porro A. Application of nanotechnology in construction. *Mater Struct*. 2004;37(9):649-658.
27. Voogt JM, Pareja Roblin NN. Curriculum and 21st century skills. *International Encyclopedia of Education (Fourth Edition)*: Elsevier; 2023. p. 49-55.
28. Yukl G, Chavez C. *Influence Tactics and Leader Effectiveness. Leadership: Emerald Publishing Limited*; 2002. p. 139-165.