Network Analysis of Iraq's Construction Ecosystem: Identifying Pivotal Construction Enabling Sectors for Sustainable Economic Development (2004–2023)

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ABSTRACT

Network analysis in recent years has emerged as modern technique of analysis used to examine the interaction among complex supply networks and structural configuration of productive systems. The main aim of the present research is to examine the structural interdependencies within the ecosystem of Iraq in terms of supply chain by using approach of network analysis with purpose to identify the intensity and nature of linkages among oil-based financing, industrial production, transportation systems and electricity provision. Present study uses network analysis of construction enabling sector of Iraq including services, transportation, electricity, agriculture, manufacturing and oil for the period 2004 to 2023. This research used data of input and output from development indicators from world bank and Iraqi central Bureau of statistics. Present study models these sectors in the form of integrated network of infrastructure supply chain. The findings reveal a high degree of structural centralization around oil-based financing, which acts as the dominant hub influencing the rest of the construction ecosystem. In contrast, manufacturing, agriculture, electricity, and transportation sectors have lower interconnections, which have resulted in moderate network density. This suggests that the infrastructure development in Iraq is financially centralized but operationally decentralized. Therefore, the construction supply chain is vulnerable to oil price volatility. Weak intersectoral density constrains the diffusion of development gains across sectors and limits progress toward sustainable infrastructure expansion. Based on findings, this research proposed institutionalizing of network-based tools, promotion of renewable energy investment, and upgradation of electricity and transportation infrastructure to enhance resilience of construction supply chain.

Keywords: Network Analysis, Construction supply Chain, Infrastructure Supply Chain, Sustainable Infrastructure development, Construction ecosystem

INTRODUCTION

Since last few years analytical thoughts in construction and infrastructure development has moved towards the adoption and usage of quantitative approaches with purpose to explain complex factors that shape large project ecosystems (Vigren, 2023). Therefore, supply chain analysis that is network based is considered as vital tool for analysis with purpose to understand the ecosystem of construction. In this aspect different sectors are conceptualized in the form of interconnected factors that exchanges industrial inputs, logistic services, financial resources, energy and materials. From this perspective, construction should not be viewed as activity alone (Choudhary et al., 2022). Whereas it must be recognizing infrastructure development as oil based public financing, industrial production capacity, transportation systems and electricity provisions that collectively determine the sustainability and viability of the project.

At the global level, network analysis supply chain is recognized as important aspect of strategic planning with purpose of development of infrastructure specifically in areas where energy reliability, industrial linkages and public investment has strong impact on construction performance (Huang & Li, 2024). This analysis system is used mostly for the diagnosis of problems at the stage of assessing vulnerability of system to the external shocks, evaluation of industrial dependencies and execution of projects. Whereas, in the context of Iraq, there is limited adoption of such integrated ecosystem of construction (Altememy et al., 2023). Despite the availability of input output structures and sectoral data since last two decades, analytical applications have remained limited to macroeconomic assessments, without mapping the way oil financed public expenditures, industrial production capacity, transportation efficiency and electricity stability interacts to develop construction supply chains.

In Iraq, infrastructure and construction projects basically rely on four pillars including oil revenue with purpose to finance public infrastructure, domestic industrial capacity with purpose of construction inputs (Bekheet et al., 2023), transportation network with purpose of material mobility, and electricity supply for execution of projects. Structural disruption or imbalances in one of these pillars has negative effect in the ecosystem supply chain of construction that results in reduced development impact, cost overruns, and project delays (Malik et al., 2022). So, understanding of these factors as integrated networks of supply chain provides accurate information about missing links and diagnosis of systematic constraints that creates hurdle in development of infrastructure. Such study is important in context of Iraq as it helps in reconceptualizing the developing challenges from the lens of macroeconomic to construction ecosystem supply chain framework. Instead of analyzing oil financing, industry, transportation, and electricity as exogenous sectors, present research adopts more wholistic approach with purpose to examine collective role and interconnectivity to enable sustainable expansion of infrastructure (Xiaoying et al., 2026). Reliance on oil financing is not enough with purpose to achieve diversified development and long-term infrastructure resilience. The sustainable progress needs to strengthen the interpersonal linkage within the ecosystem of construction to ensure the industrial depth, logistic efficiency and energy reliability function cohesively to support growth of infrastructure (Semenova & Martínez Santoyo, 2024).

The main purpose of the present study is to assess the structural interdependencies within the ecosystem of Iraq in terms of supply chain by using approach of network analysis with purpose to identify the intensity and nature of linkages among oil-based financing, industrial production, transportation systems and electricity provision. Present research further seeks to identify the way these sectors are interconnected, and they collectively effect the development capacity of infrastructure. This research also seeks to explore strategic pathway to strengthen integration of internal supply chain to achieve resilient and sustainable construction-based development in Iraq. In other words, this research tries to answer to what level can network analysis of construction sector of Iraq provide a diagnostic tool to find out structural weaknesses and look for targeted intervention of policy to improve infrastructure supply chain resilience and integration.

LITERATURE REVIEW

Construction Supply Chain Management

Construction Supply Chain Management (CSCM) refers to the strategic coordination of material flows, information exchange, and stakeholder relationships across the lifecycle of construction projects. Unlike traditional manufacturing supply chain networks, construction supply chain networks are project-based, fragmented, and highly temporary in nature, involving various contractors, subcontractors, suppliers, and government bodies. Effective CSCM requires integration, cooperation, and transparency to mitigate issues of cost overruns, delays, and operational inefficiencies. Recent literature has emphasized the significance of digital technologies like Building Information Modeling (BIM), blockchain, and IoT in enhancing real-time coordination and transparency in construction project networks (Behera et al., 2015). Moreover, sustainable CSCM has become increasingly important with its emphasis on green purchasing, waste reduction, and circular flows of materials. Risk management, relationship management between suppliers, and performance measurement systems are also recognized as important enablers for construction ecosystems' resiliency. CSCM research underscores the shift from transactional procurement practices toward long-term strategic partnerships that enhance project performance and supply chain competitiveness**.**

Past studies on network analysis and diversification have shown strong analytical base to understand the systematic resilience and inter-sectional interdependence. The base work plays key role of conceptualizing the production systems as vital networks to connect that linkages (Meisel et al., 2022). This concept further shows that higher diversified productivity linkages and network density are strongly linked to export performance and growth potential (Bodin et al., 2019).

From the point of view of methodology, internal, backward and forward linkages are derived from the matrices of input and output that provides a framework to trace value flows among all interconnected production systems (Dutta, 2025). Past studies from the perspective of different geographical locations have confirmed that approached of network-based analysis are important tool in order to diagnose issues of structural integration and informing policies of strategic development (Trasciani et al., 2026). Past studies have revealed that there is high density in system for the production network showing stronger resilience in terms of economic shock and higher progress towards the objectives of sustainable development. The implication of such network lies directly to the ecosystem of construction. It is not possible to work on infrastructure development in isolation (Hosseini Shekarabi et al., 2025). Whereas it depends on collection of construction that enable sectors to support execution of projects and sustainability of the assets. Interconnections of high density among mentioned sectors enhances resilience and minimizes vulnerability to supply disruptions.

In the context of Iraq, the economy of country is mainly dependent on the revenues of oil. Studies mentioned that oil industry make 90% of the Iraqi industry and 60% of its GDP (Al-Tamimi, 2012). Scholars further mentioned weak linkages between non-oil economic factors of country with diversification of 0.32. This type of structural concentration shows high level of vulnerability of the economic system and heavily dependence on oil financing. Whereas there is high level of gap in present studies. Present studies do not mention and modelled the importance of construction sector of Iraq and its integration with supply chain network (Rahim & Hassan, 2025). Limited application of this sector in research has restricted the understanding of the way oil financing, agriculture, services, manufacturing, transportation efficiency and electricity reliability collectively shapes infrastructure delivery (UNEPFI, 2024). Furthermore, there are very limited studies that has mentioned linkage between centrality measures and network density to infrastructure sustainability and construction supply chain resilience in Iraq.

The Concept of Network Analysis in Construction Ecosystems

Network analysis helps in gathering quantitative framework to reveal connectivity structure by using different tools such as input output tables to examine service flows, financial, energy, and material between construction enabling sectors (Möller et al., 2020). Through transformation of intersectoral relationships into graphs of networks it becomes possible to measure vulnerability indicators, density, and quantify centrally. Therefore, it becomes possible to find out the sector that is exerting more pressure (Pirbhulal et al., 2021). In the ecosystem of construction, the network approach predicts that development of infrastructure is based on complex adaptive system rather than a series of isolated activities of sector. Provision of electricity, professional services, agriculture raw materials, transportation logistics, and manufacturing outputs plays the role of interconnected nodes withing supply chain infrastructure. Problem in one node creates a significant effect throughout the long-term asset sustainability, cost structures and execution timelines (Choudhary et al., 2025). Thus, network analysis is not only a tool of diagnosis, infact it can be used as tool for strategic planning with purpose of assessing adaptive Capacity and supply chain resilience in response to external and internal shocks (Das & Perona, 2025).

Economic Network Analysis as A Tool for Construction Supply Chain Planning

Coordinated interaction is required in construction supply chains among different enabling sectors. In the case of Iraq, the projects infrastructure is mainly dependent on revenue of oil for infrastructure programs that are capital intensive and financing of public works; manufacturing capacity with purpose to supply construction materials; electricity provision for the onsite project operations and industrial production; transportation networks for logistic efficiency and material mobility; and service sectors that includes technical supervision, contracting and engineering (Fadhil & Burhan, 2021). All these sectors can be classified into economic sectors within ecosystem of construction network as they function in the form of support sectors of supply chain. Their interdependence determines delivery speed, cost stability and project continuity (Cataldo et al., 2022). The network-based approach helps policy makers for the evaluation of centrality and density of these sectors. It also helps in detection of different weaknesses and designing targeted interventions for the enhancement of construction supply chain integration (Ma et al., 2024). By using network analysis in the context of supply chain, studies are able to diagnose problem in the infrastructure planning. Therefore, they strengthen their relevance to supply chain management in sector of construction.

Network Analysis Indicators

A set of quantitative indicators derived from network science (Network Science) are used in network analysis, the most prominent of which are:

- Degree of centralization (Degree Centrality): Represents the number of links each sector has with the rest of the sectors and is used to identify the sectors that mediate the network of the economy (DePaolis et al., 2022).

- Centralization indicators can be calculated according to the following formula:

$$CD(i) = \sum_{j=1}^{n} w_{ij}$$

- Centralization of direction (Betweenness Centrality): Shows how important the sector is in passing economic influences among other sectors, that is, being a channel for transmitting influences.

$$C^*_{in}(i) = C_{in} \backslash n - a; \; C^*_{out}(i) = C_{out} \backslash n - b$$

- Closeness Centrality: In infrastructure ecosystems, sectors with high closeness centrality—such as electricity—can rapidly transmit productivity effects across industrial production and project execution stages.

$$C_C(i) = n\text{-}1 \backslash \sum \quad j \neq i \; d(i, j)$$

- Network density Higher density indicates stronger integration among construction enabling sectors and greater structural cohesion. In the context of infrastructure development, dense networks enhance resilience by reducing overdependence on a single node, such as oil financing (Liu et al., 2021).

$$\text{Density}_{unw} = 2E \backslash n(n\text{-}1)$$

Depending on the interconnection matrix used in the study (not counting self-loops), the unweighted density of the network indicates that all sectors are assumed to have links between them. Weighted density, which measures the average strength of these bonds across possible pairs.

Hub Analysis: Hub analysis identifies key backbone sectors within the construction ecosystem supply chain (Li et al., 2020). A hub sector frequently lies on the shortest paths connecting other sectors, thereby controlling the circulation of financial, material, and service flows. In Iraq, oil revenues, electricity, and transportation infrastructure are potential hub sectors that determine the continuity and scalability of infrastructure projects (Li et al., 2020).

Classification Of Construction Supply Chain Linkages

Within the construction ecosystem framework, intersectoral linkages can be classified into three principal forms:

- **Forward linkages:** When a construction enabling sector supplies essential inputs to other sectors. For example, oil revenues financing electricity generation and public infrastructure projects.
- **Backward linkages:** When a sector depends on inputs from upstream enabling sectors. For instance, manufacturing of cement and steel depending on energy supply and transportation logistics.
- **Internal linkages:** Interactions within a sector itself, such as coordination among engineering firms, contractors, and subcontractors within the services sector.

This classification enables a structured mapping of infrastructure supply chain interdependencies and allows policymakers to identify bottlenecks in project delivery systems.

Network Analysis and Sustainable Development

Network analysis is closely aligned with the Sustainable Development Goals (SDGs), particularly those related to infrastructure (SDG 9), clean energy (SDG 7), sustainable cities (SDG 11), and responsible production (SDG 12) (Dalampira & Nastis, 2019).

Within a construction ecosystem context, network analysis helps evaluate how effectively construction enabling sectors integrate economic, environmental, and social objectives. Strong interconnections among electricity, manufacturing, transportation, and services enhance infrastructure resilience and support sustainable project delivery (Gong et al., 2024).

Sustainable development in infrastructure systems encompasses three interrelated dimensions (Figure 1) (Abdul-Abbas et al., 2024):

1. **Economic sustainability** – efficient allocation of oil revenues and industrial resources for long-term infrastructure growth.
2. **Environmental sustainability** – integration of clean energy and reduced material waste in construction processes.
3. **Social sustainability** – improved accessibility, employment generation, and community development through infrastructure expansion.

A fourth dimension relates to **institutional and municipal decision-making capacity**, which governs regulatory alignment and infrastructure planning efficiency.

Figure 1: 3E Principles of Sustainability

Studies by sustainability as Alshammari and Alshammari (2023) and Hussain et al., (2024) indicate that sustainable solutions promote green Innovative that has a positive impact on sustainability. Wang et al. (2021) and Alabdily et al., (2025) found that green process innovation improves the level of sustainability. emphasizing the importance of innovative approaches to achieve sustainability goals. They're for the organizations should carefully manage environmental stewardship, social responsibility, and economic viability to achieve sustainable development (Abdulameer et al., 2023; Alsharifi et al., 2026). There are numerous reasons why sustainability is crucial for the future of our planet: **Climate change:** Climate change is one of the most urgent threats facing humanity (Majedul Islam, 2022). Sustainability is essential to mitigate the effects of climate change and adapt to its impacts. **Resource depletion:** The unsustainable exploitation of natural resources, such as water, forests and minerals, is putting at risk the planet's ability to meet the planet's needs. future needs. Sustainability works towards the availability of resources to be used by future generations. Environmental degradation such as pollution, deforestation, and biodiversity loss is some of the most serious environmental issues the world is currently facing. Sustainability works towards the restoration and preservation of the environment to be used by future generations. The Sustainable Development Goals are vital to the development of sustainable, inclusive, stronger, and more resilient societies. Sustainability is the key to solving the problems of climate change and adapting to the effects of climate change. Additionally, the excessive use of resources such as water, forests, and minerals by the planet makes it unable to meet its needs (Yang et al., 2020).

International Applications in The Field of Network Analysis

This methodology is used in a variety of different countries, both in the developed world and in the developing world. For instance, in South Korea, network analysis has shown that the high-tech sector is the most influential sector in terms of driving economic growth. In China, this same methodology has shown that the manufacturing sector is the sector that plays the most important role in triggering the growth of other sectors. In Germany, this methodology has shown the importance of promoting further integration between the energy sector and the green sector. All of these examples serve to demonstrate the importance of this methodology in Iraq in terms of identifying which sector is likely to drive growth in the country.

On the basis of above literature review following hypothesis are developed

H1: The infrastructure supply chain network in Iraq is highly centralized around oil-based financing, resulting in weak interconnectedness among other construction enabling sectors (electricity, manufacturing, transportation, services, and agriculture).
H2: Weak density and low diversification of linkages among construction sector enables negatively impact sustainable infrastructure development in Iraq.
H3: The applications of indicators of network analysis enables the identification of important construction enable sectors that must be strengthened strategically to improve construction infrastructure sustainability and supply chain resilience.

METHODOLOGY

Present study adopted quantitative network analysis approach in order to explore structural interdependencies in the construction sector of Iraq. The main purpose of using this approach as it helps in integration of supply chain networks. Moreover, it also helps in evaluation of structural cohesion, density and relative centrality of these support networks. The analysis is mainly dependent on secondary data that is obtained from UNDP, Iraq sustainable goal report (2023), world bank development indicators database (2024), and Iraqi central Bureau of Statistics (2024), and Economic input output tables (2023). These data sources were used to collect intersectoral flow matrices and development indicators that are necessary to develop infrastructural supply chain network for certain period. In this study, six major sectors in context of construction were analysed in the form of nodes within the infrastructure network of supply chain. These sectors included transportation, electricity, agriculture, manufacturing, oil and services. From the perspective of this framework, these sectors were conceptualized not only in terms of economy whereas in the form of independent pillars to support construction project and infrastructure delivery.

Keeping in view the methodological approach mentioned by Liu et al. (2022), backward and forward linkage indicators were delivered from output and input matrices which were used to measure relative interdependence and centrality of each construction enabling sector within the network of infrastructure supply chain. Forward linkage was used to capture the level to which different sectors supply important inputs to other sectors that were construction enabler. On the other hand, backward linkages measure the level to which a sector depends on upstream inputs for continuity of operations. Through transformation of intersectoral matrix into structure of networks, the analysis was used to evaluate hub positioning, network density, closeness centrality, betweenness centrality and degree centrality.

Network Analysis Results

The network analysis results indicate that Iraq's construction ecosystem supply chain is structurally centralized around oil-based financing rather than diversified production linkages among construction enabling sectors. Infrastructure development is therefore predominantly dependent on oil-generated public revenues, while operational interconnections among manufacturing, electricity, transportation, agriculture, and services remain comparatively weak. This reflects a financially centralized but operationally fragmented construction supply chain structure.

The high degree centrality score of the oil sector, 0.92, followed by the services sector, 0.81, then manufacturing, 0.67, reveals that infrastructure activities are maintained mainly through fiscal flows originating from oil revenues, rather than dense production chains within the country. In terms of the construction supply chain, this reveals that capital expenditure for public works, infrastructure projects, and maintenance activities is highly dependent on changes in oil prices worldwide. Any decrease in oil revenues will, therefore, constrain infrastructure activities, leading to instability within the system.

Further, the betweenness centrality results reveal that oil and services account for 72% of the network's transmission capacity. The oil sector, within the context of the construction supply chain, is the primary financial channel, while the services sector, which includes engineering, contracting, and project supervision, is the primary coordinating center for infrastructure delivery activities. Although the high service centrality score reveals high intermediation capacity, the over-reliance on oil as a bridging node reveals vulnerability, as the system is dependent on only one source of revenue, which controls systemic influence.

Finally, the network density of 0.53 reveals moderate levels of integration between the different enabling sectors of the construction infrastructure system. Although there are links between electricity, manufacturing, transportation, services, and agriculture, there is not sufficient density within the network to reveal high levels of system robustness, which would be revealed by infrastructure supply chain activities.

In terms of supply chain theory, this level of density reveals limited backward and forward production links within the country, with continued dependence on imported goods for infrastructure activities.

Moreover, the results of the hub analysis verify the prominent position of oil in the infrastructure supply chain network, while the positions of agriculture, electricity, and transportation sectors remain peripheral. The weak level of manufacturing sector integration implies the need to import cement, steel, and construction materials, which makes infrastructure projects prone to international supply chain disruptions and currency fluctuations. The peripheral position of transportation implies the presence of logistics chain disruptions and lower material flow efficiency, which could negatively affect construction project completion times and costs. The peripheral position of the agriculture sector implies insufficient development of this sector in relation to the construction industry, which negatively affects balanced expansion of the territory.

The results of the calculation of directional centrality indicate that the services sector has the highest outward influence on the infrastructure supply chain network, 0.566, while the oil sector has the second highest outward influence, 0.560, implying high efficiency in the transmission of operational impacts from the construction industry. However, services and manufacturing have the highest inward dependencies, 0.524 and 0.506, respectively, implying their vulnerability to disruptions in the financing of oil and electricity supply. The agriculture sector has the lowest inward and outward integration values, 0.382 and 0.324, respectively, implying its peripheral position in the infrastructure supply chain network.

The results of the calculation of closeness centrality indicate that the services sector has the highest value, 0.534, implying its higher potential to influence and be influenced more rapidly than other construction enabling sectors. This implies the importance of institutional coordination, project management, and technical expertise in stabilizing infrastructure supply chain systems.

Overall, the results indicate that Iraq's construction environment is financially centralized in its oil revenues, integrated into its production sectors to a limited degree, logistically limited in its transportation linkages, and structurally vulnerable to changes in imported oil prices and supplies. All of these features collectively suggest that supply chain resiliency in Iraq's construction environment may be limited and that strengthening its manufacturing sector, electric supply, transportation integration, and intersectoral integration would be important to sustainable infrastructure growth (Table 1).

Table 1: How quickly sector interacts with the rest of proximity-centric sectors within the network

Sector	Proximality central	Standard proximity
Services	0.534	1,000
Industry	0.486	0.909
Oil	0.477	0.892
Electricity	0.449	0.841
Transportation	0.441	0.825
Agriculture	0.345	0.645

This pattern further reiterates the structural configuration of Iraq's construction ecosystem's supply chain. The position of industry, followed by oil, in terms of the most central sectors, reiterates that oil, in this context, does not only serve the purpose of a financial backbone but also represents a rapidly influential sector in the infrastructure supply chain network. This, in turn, reiterates the potential of oil to diffuse its impacts rapidly across manufacturing, electricity, and construction services, courtesy of fiscal transfers, investment channels, and services. In this respect, this reiterates, in terms of construction supply chain network, that oil represents not only a financial backbone but also a transmission accelerator in the infrastructure supply chain network (Table 2).

On the other hand, the sector of agriculture has the least centrality value, approximately 0.345, reiterating its peripheral and least integrated position in the infrastructure supply chain network. This reiterates the potential of this sector to have longer network paths, implying limited potential for transactional and production linkages with key construction-enabling sectors like manufacturing, electricity, and transportation.

From a construction SCM perspective, this suggests that rural infrastructure development and agro-based value chains remain insufficiently connected to national infrastructure planning and material supply systems. The marginal integration of agriculture signals weak incorporation into domestic value chains that could otherwise support regional construction demand, land development, and localized infrastructure expansion. Such structural distance reduces multiplier effects and limits balanced territorial development within the broader construction ecosystem (Table 2).

Table 2: Centralization of entry and exit for sectors

Proximity centrality	Weighted out	Centralized exit (Weighted In)	Sector
0.534	0.524	0.566	Services
~0.477	0.500	0.560	Oil
0.486	0.506	0.590	Industry
0.345	0.382	0.324	Agriculture

DISCUSSION

The results mentioned in Table 2 shows that service sector has achieved the maximum values in exit and entry centrality along with highest closeness centrality. From the perspective supply chain in construction ecosystem, the findings suggest that technical service, supervision, contracting and engineering activities plays the role of primary coordination interface of delivery infrastructure. Services not only helps in absorption of productive and financial influence from transportation, electricity, manufacturing and oil, but transmit these impacts rapidly across the networks of infrastructure. In other words, services help in connection of oil based public revenues in terms of distribution activities and execution of activities. Oil is used as main source of financing have rapid system wide influence and maintain high centralization outward through service mediated capital flow and public expenditure. The foregoing is consistent with the study of both (Alaarajy et al.,2024; Shani et al.,2024)

The combined results of services and oil sector confirms that these two roles are important for the Iraq based construction supply chain. Different services operate as operational hub of transmission. Whereas oil plays the role of dominant financial anchor to sustain infrastructure investment. From the point of view of construction supply chain resilience, structural imbalance is created through this dual concentration. On the other hand, coordination capacity is present within the services, and their productive depth remains insufficient because agriculture, transportation, electricity and manufacturing do not show strong integration.

The weighted density of network of 0.53 shows that there is moderate structural integration among sectors of construction. Though, there exists formal connection between all sectors of construction, there is limited strength of productive interlinkages. In terms of construction supply chain management, it shows partial integration at the domestic level. The projects of infrastructures are connected to each other but lack forward and backward production linkages. The network-based diagnosis helps in providing a more interaction and structural focused understanding of delivery of infrastructure as compared to traditional indicators of economy. This approach also reveals the way service flows, energy, material and financials interact within the architect of supply chain.

This analysis also shows that there is weak intersectoral density that impacts the ability of Iraq to achieve sustainable development of infrastructure. The ecosystem of construction that is highly centralized around the revenues of oil that becomes fragile when it is exposed to volatility of commodity price. It limits the capacity to sustain objectives of long-term development. Fragility of this infrastructure has direct impact on progress of different SDGs. Infrastructure employment and growth generation is closely related to oil performance (SDG 8). Limited diversification and weak manufacturing integration impacts progress towards industrial and infrastructural development (SDG 9). Challenges of fossil fuel impacts the cleaner energy (SDG 7). On the other hand, agriculture integration also impacts the development of food system (SDG 2). In the end, moderate network density impacts employment outcomes (SDG 1 and SDG8).

Weak interconnection of network is compared with metrics of national sustainable development in this study. The real growth rates are mainly dependent on oil sector, there is low economic diversification index, dependence on fossil fuel energy is also very high, unemployment is at 14.6% and there is marginal agricultural investment.

LIMITATIONS AND FUTURE DIRECTIONS

There are few limitations in the study that must be acknowledged. Firstly, the analysis mainly depend on data of different sectors that may not present full picture of informal supply chain activities and firm level dynamics within the construction ecosystem of Iraq. The integration of different sectors masks regional disparities and micro-level interdependence in development of infrastructure. Secondly, the usage of network indicators such as density and centrality provides structural insights. But it does not measures performance outcomes directly such as project completion rates, cost efficiency, and productivity. Thirdly, constraints at the level of data, including availability of flow information at the real time, that may affect accuracy of network estimations. In the end, the study focuses on economic linkages and do not integrate institutional, regulatory and political uncertainty that impacts supply chain coordination and investment decisions.

There are few recommendations in light of these mentioned limitations. Decision makers and policymakers should give priority to the diversification of construction supply chain in Iraq.

They must look for financial contribution from other sectors than oil. In other words, the financial contribution from sectors like agriculture and manufacturing should be strengthened. Government from the perspective of public investment should target different projects that creates strong backwards and forward linkages, specifically integrated production zones, logistic corridors, and industrial clusters. Electricity and transportation infrastructure should be treated as basic enabler to reduce operational bottlenecks and enhance network density. The strategic investment systematic integration and prioritization will be improved through institutional planning and network analysis.

CONTRIBUTION

This research enhances and improves the literature of supply chain management by enhancing network analysis to supply chain of infrastructure in economies that are resource dependent. On the contrary of adopting conventional perspectives of macroeconomic, this study conceptualizes services, agriculture, transportation, electricity, manufacturing, and oil sectors as interdependent factors that collectively shapes construction infrastructure sector. Through application of quantitative network technique in context of Iraq and data from different sectors from two decades starting from 200 to 2023. The study transforms transactions of different sectors into structural networks that are measurable. Density and centrality indicators are used to find out vulnerability points, structural bottlenecks, and pivotal nodes within the ecosystem of infrastructure. This approach provides a framework of novel diagnostic for evaluation of concentration patterns and systematic risk in construction supply chains. The results contribute theoretically by integration of network science with supply chain resilience in construction and sectoral rebalancing.

POLICY IMPLICATIONS

Results of this study shows significant policy implications for the construction supply chain management of Iraq. Significant reliance of Iraq on oil-based financing procurement of public exposes projects of infrastructure to price volatility of oil that results in project delay and financial uncertainty. Minimizing such vulnerability needs to strengthen manufacturing capacity at the domestic level specifically in construction materials, steel, and cement to minimize dependence on import and deepen linkages. Upgradation of transportation infrastructure is important to control the cost of projects and remove logistics bottlenecks. Equally, it is important to reinforce the electricity sector to sustain production of electricity and efficient execution of projects. Integration of these sectors in infrastructure at national level will promote diversity, reduce systematic risk, enhance resilience and promote construction led development. From a policy perspective, governments should institutionalize diversified procurement strategies and encourage supplier diversification mechanisms to reduce systemic vulnerability and enable risk pooling across large-scale infrastructure portfolios. Furthermore, promoting domestic value chain clustering through localized manufacturing hubs and backward linkages can strengthen supply resilience, enhance economic spillovers, and reduce dependence on volatile external supply markets.

CONCLUSION

In the ecosystem of Iraq construction supply chain, there is clear dominance of oil sector because there is high degree centrality in this sector (0.92). This sector is followed by services and manufacturing sector as 0.81 and 0.67. It shows that infrastructure development is mainly dependent on financing of oil. The overall density of network of 0.53 shows the moderate integration between the sectors that are liked to construction. On the other hand, there is formal connection where productive linkages are not sufficient for the generation of resilient and deeply integrated infrastructure supply chain. Different service sectors including electricity, transportation, manufacturing and agriculture show limited collective capacity to develop a structurally and cohesive robust network of infrastructure.

The main source of financing of infrastructure from the revenue of oil also minimizes the adaptive flexibility. In case of fluctuation in the prices of oil, the expenditure is directly affected. It limits the ability of system to maintain stable growth and absorb external shocks. Insufficient investment in the non-oil sectors that impacts infrastructure impacts the development of domestic production, specifically in inputs of energy reliability, logistics systems and manufacturing inputs. The infrastructure network of supply chain shows significant reliance in the field of oil sector. From the perspective of construction supply chain resilience, such findings have negative effect on the long-term sustainability. Weak interlinkages between construction sectors creates slow diversification of inputs of infrastructure and minimize generation of jobs. As a result, poverty is enhanced. Lack of coordinated policies integrates services, transportation, electricity, agriculture, and manufacturing into a single infrastructural strategy. Findings show that strengthening of network density between different sectors can enhance growth of GDP more than 2 person every year. Development of sustainable infrastructure in Iraq needs restructuring the ecosystem of construction on integrated foundations that enhances logistics efficiency, energy reliability and diversified production linkages. The results show that infrastructure delivery system of Iraq need comprehensive structural recreation for balancing sectors of construction, providing strength to the networks at the domestic level and minimize dependence on financing generated from oil.

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