

Economic Sciences

UDC 658.7:658.5:624.014

Avetisyan Norayr

Owner and Director

LLC “Kharkiv Steel”

ORCID: 0009-0007-9654-318X

DOI: <https://doi.org/10.25313/2520-2057-2026-4-12097>

INTEGRATED SUPPLY AND FABRICATION MODEL IN STEEL CONSTRUCTION: A CASE STUDY OF SMALL AND MEDIUM ENTERPRISE OPERATIONAL PRACTICE

Summary. *Small and medium enterprises in steel construction typically specialize in a single function, specifically trading, fabrication, or installation, creating information and quality gaps between supply chain stages that increase defect risk and reduce client accountability. Integrated models combining these functions within a single organizational structure have been documented for large corporations but remain under-represented in academic literature for SME contexts where resource constraints and management concentration create different operational dynamics. A longitudinal case study of Kharkiv Stal LLC (Kharkiv, Ukraine), documenting the enterprise’s twelve-year evolution (2013–2025) from a steel trading startup to an integrated supply-fabrication-service (ISFS) operation encompassing certified material procurement, structural steel fabrication, profiled sheeting production, and post-delivery client support. Operational data spanning four development phases demonstrate that vertical integration of supply and fabrication functions within a single SME enabled 100% certified material sourcing,*

repeat client revenue exceeding 60% of annual turnover, and revenue growth from startup levels to over UAH 40 million annually with a diversified portfolio spanning trading, fabrication, and finishing services. As a contribution, the ISFS model is proposed as a potentially transferable framework, subject to validation in other SME contexts, identifying the preconditions, integration mechanisms, and performance indicators relevant to small enterprises pursuing vertical integration strategies in steel construction markets.

Key words: *steel construction, small and medium enterprise, supply chain integration, fabrication management, quality assurance, case study, vertical integration, client service model.*

Introduction. Global steel production reached 1.9 billion tons in 2023, with construction applications consuming over 50% of total output [12]. Structural steelwork, metal cladding, and associated fabrication services serve industrial, commercial, agricultural, and infrastructure sectors across every national market. In most countries, the sector is populated by a large number of small and medium enterprises that collectively process most of the structural steel tonnage, even where a few large fabricators dominate high-profile project segments. Ukraine’s steel construction market follows this pattern: alongside several large fabricators with capacities exceeding 10,000 tons per year, hundreds of SMEs operate in the 500–5,000 ton range, serving regional demand for warehouses, workshops, agricultural buildings, commercial premises, and light industrial structures [13; 14].

A distinguishing feature of the SME segment is functional fragmentation. Steel trading companies purchase material from mills and distributors, maintaining inventory for resale to fabricators and construction firms. Fabrication workshops receive material from trading companies or directly from mills, converting it into structural components through cutting, welding, and assembly operations.

Installation contractors erect the fabricated structures at construction sites. Each entity operates within its own commercial and quality management boundaries, and the interfaces between them represent points where information is lost and accountability is diluted. A trading company delivering steel to a fabricator transfers a mill certificate; whether that certificate is consulted during welding procedure selection depends on the fabricator’s internal practices. A fabricator shipping structural components to an installation site provides dimensional drawings; whether those drawings account for actual (rather than nominal) member dimensions depends on the fabricator’s measurement discipline. At each handover point, quality information degrades unless formal protocols preserve it; a pattern the author has observed consistently across two decades of professional engagement with the steel supply chain.

Published research on supply chain integration in manufacturing draws extensively on value chain theory originated by Porter [1], who identified primary and support activities as the building blocks of competitive advantage. Womack and Jones [2] extended this framework through lean thinking, emphasizing the elimination of waste across the value stream from raw material to end customer. Gunasekaran et al. [3] developed performance measurement frameworks for supply chain management, identifying metrics at strategic, tactical, and operational levels. More recent research has refined these foundations: Mittal et al. [15] examined enabling factors for smart manufacturing in SMEs, while Chiarini [8] linked sustainable manufacturing practices to supply chain configuration. All of these works, however, address supply chain integration primarily from the perspective of enterprises with dedicated functional departments and formalized inter-organizational relationships, leaving the SME configuration, where a single owner-manager may simultaneously oversee procurement, production, sales, and quality, largely outside their analytical scope.

Individual case studies of steel enterprises have examined lean implementation in large-scale steel production [5], quality management systems as organizational frameworks [10], and digital transformation pathways for manufacturing [15], but none has documented the operational mechanics and performance outcomes of an integrated supply-fabrication-service model in an SME context over a multi-year development trajectory. Yin [4] identifies the “revelatory case” as a legitimate rationale for single-case study design: a situation where the researcher has access to a phenomenon previously unavailable for scientific observation. An SME founder documenting the complete operational history of an enterprise from inception through twelve years of growth, diversification, and wartime adaptation constitutes such a case.

Kharkiv Stal LLC (Kharkiv, Ukraine), founded in 2013, provides the empirical basis for this study. Starting as a steel trading operation with minimal initial capital, the enterprise evolved through four distinct development phases over twelve years into an integrated operation with certified supplier relationships, in-house fabrication capacity, and a client base generating over UAH 40 million in annual revenue. Having served as both founder-director and researcher enables the author to have access to complete operational records from inception, while also requiring explicit methodological safeguards against confirmation bias, which are addressed in the Methods section. Operations spanned a period that included rapid market growth (2017–2021), the full-scale military conflict beginning in February 2022, and subsequent wartime adaptation, a trajectory that tested the resilience of the integrated model under conditions that no controlled study could replicate.

Presented here is a documentation and systematization of the Integrated Supply-Fabrication-Service (ISFS) model as implemented at Kharkiv Stal LLC, analyzing its operational structure, quality assurance mechanisms, client interaction patterns, and quantitative performance over the 2013–2025 period. Results and

Discussion sections are presented separately to distinguish factual operational data from their interpretation. Scientific novelty lies in the formalization of a vertically integrated SME operational model in steel construction, documented through longitudinal data from a single enterprise across multiple market conditions including peacetime growth and wartime adaptation. Practical contribution consists in identifying the preconditions, integration mechanisms, and measurable performance outcomes that other SMEs can evaluate when considering similar vertical integration strategies.

Literature review. Supply chain integration as a competitive strategy has been studied across manufacturing sectors for over three decades, generating theoretical frameworks, empirical evidence, and prescriptive models at varying scales of enterprise. For the steel construction SME context examined in this study, four research streams are directly relevant: vertical integration theory and its application to manufacturing, supply chain quality management, SME operational models, and industry-specific case studies in steel and metalworking.

Vertical integration refers to the extent to which a firm owns or controls successive stages of the value chain for its products. Harrigan [17] distinguished between full integration (complete ownership of adjacent stages), taper integration (partial ownership supplemented by market transactions), and quasi-integration (long-term contracts or equity stakes without full ownership). For manufacturing SMEs, full vertical integration is typically constrained by capital requirements: owning a steel mill, a fabrication workshop, and a construction crew simultaneously exceeds the financial capacity of most small enterprises. What becomes feasible is selective integration of adjacent stages, for example, combining trading and fabrication, or fabrication and installation, where the capital requirement for adding the adjacent function is proportionate to the enterprise’s existing resource base. A strategic question is which combination of stages generates the greatest competitive

advantage for a given investment, and the answer depends on where in the value chain the most significant quality and information losses occur [1; 2].

Supply chain quality management (SCQM) examines how quality practices extend beyond the boundaries of a single firm to encompass supplier relationships, inter-organizational information flows, and customer feedback loops. Kuei et al. [18] identified six dimensions of SCQM: leadership commitment, strategic planning, human resource focus, supplier focus, customer focus, and quality information availability. Their empirical analysis of 214 firms in Taiwan found that quality information availability, specifically the degree to which quality data flows freely across organizational boundaries, was the strongest predictor of supply chain performance. Robinson and Malhotra [19] conducted a comprehensive literature review of SCQM, concluding that the field had evolved from a narrow focus on supplier quality auditing toward a broader view encompassing collaborative quality planning, joint problem-solving, and shared performance metrics. For steel construction, where material quality at the procurement stage propagates through fabrication into the finished structure’s performance over decades of service, the availability and continuity of quality information across supply chain stages is particularly consequential.

ISO 9001:2015 [10] provides the management system architecture within which SCQM operates at the firm level, requiring documented processes for supplier evaluation, incoming material verification, in-process control, and customer feedback management. ISO 3834-2:2021 [11] adds welding-specific quality requirements that link material properties (chemical composition, mechanical characteristics) to fabrication process parameters (welding procedures, preheat temperatures, interpass constraints). EN 1090-2:2018 [9] establishes execution classes that determine the minimum levels of material traceability, dimensional tolerance, and inspection intensity for steel structures. Individually, these standards

define what must be controlled at each stage; collectively, they create a quality framework that spans the material-to-structure chain. For a fragmented supply chain where different enterprises hold different certifications, compliance is verified at organizational boundaries through document exchange. For an integrated enterprise holding all three certifications, compliance is verified through internal processes with no inter-organizational information gaps.

SME operational models in manufacturing have been characterized by several distinguishing features that differentiate them from large-enterprise models. Ghobadian and Gallear [20] compared total quality management implementation between large and small firms, identifying that SMEs benefit from shorter communication lines, faster decision cycles, and direct owner involvement in quality, but suffer from limited specialist expertise, informal documentation, and vulnerability to key-person dependency. Srinivasan et al. [5] applied Lean Six Sigma methodology to a steel industry context using Yin’s case study approach, demonstrating that structured improvement frameworks originally developed for automotive and electronics manufacturing can be adapted to steel processing environments with measurable gains in cycle time and defect reduction. Their study, conducted at a galvanizing line within a larger steel operation, documented a 42% reduction in non-value-added time and significant improvement in process cycle efficiency through targeted application of value stream mapping and statistical process control.

Distinctions between SME integration in stable markets and in volatile or conflict-affected environments has received limited academic attention. Ates et al. [16] noted that emerging economy SMEs face institutional voids, specifically gaps in market infrastructure, regulatory enforcement, and financial services, that simultaneously constrain growth and create opportunities for enterprises willing to internalize functions that market institutions would otherwise provide. Such

dynamics resonate with the Ukrainian steel construction context, where supply chain fragmentation is partly a consequence of market immaturity: the institutional mechanisms that enable reliable inter-firm quality coordination in mature markets (industry-wide certification bodies, established reputational networks, enforceable quality warranties) are less developed, creating an incentive for individual enterprises to integrate functions rather than depend on external coordination.

Digital transformation offers SMEs potential tools for achieving integration benefits without full vertical ownership. Moeuf et al. [6] found that SMEs adopting Industry 4.0 technologies tended to implement cloud-based ERP systems, basic IoT sensors, and digital quality records before attempting more advanced technologies like digital twins or artificial intelligence. Matt and Rauch [7] proposed an SME 4.0 framework emphasizing that technology adoption in small firms follows a pragmatic path driven by immediate return on investment rather than comprehensive digital strategy. For steel construction SMEs, ERP-based integration of procurement, inventory, production, and delivery data represents the most accessible digitalization pathway, enabling information continuity across supply chain stages without requiring the sensor infrastructure and data analytics capability that large-enterprise Industry 4.0 implementations demand [15].

Figure 1 positions the ISFS model within Porter’s value chain framework, illustrating which primary and support activities are internalized within the integrated SME versus outsourced or absent in the fragmented model.

(a) Fragmented supply chain



(b) Integrated Supply-Fabrication-Service (ISFS) model

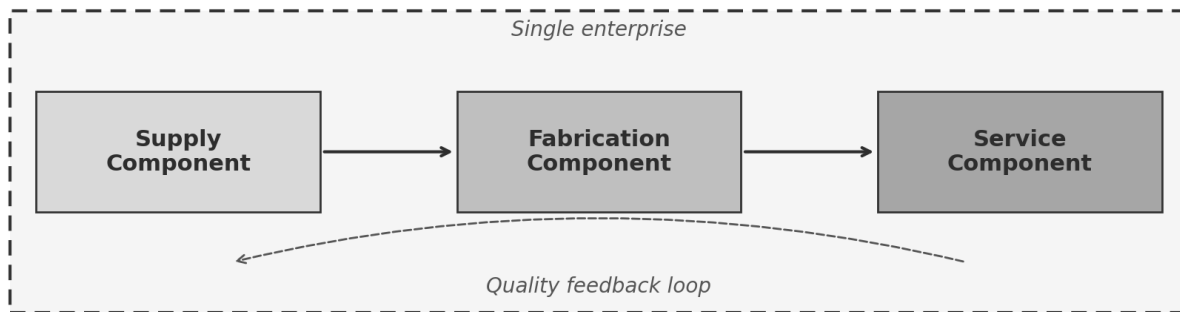


Fig. 1. Porter’s value chain adapted: fragmented supply chain versus integrated ISFS model in steel construction SME

Source: developed by the author based on Porter [1] and operational practice

In the fragmented model, inbound logistics (material procurement and inventory) resides with the trading company, operations (fabrication) with the workshop, outbound logistics and service with the installation contractor, and quality information transfers between entities through documents that may or may not be consulted at the receiving end. In the ISFS model, all primary activities from procurement through service reside within a single enterprise, enabling continuous quality information flow, unified performance metrics, and direct feedback from client experience to procurement and fabrication decisions. Support activities (firm

infrastructure, human resource management, technology) similarly operate under unified management rather than being distributed across independent entities with potentially conflicting priorities.

Across the reviewed literature, supply chain integration theory provides the strategic rationale for combining adjacent value chain stages. SCQM research identifies quality information continuity as the critical enabler of supply chain performance. SME studies document the specific constraints and opportunities that small enterprises face when pursuing integration. Steel industry case studies demonstrate that structured improvement methodologies can deliver measurable gains in metalworking environments. No identified source, however, documents the complete operational trajectory of a steel construction SME that progressively integrated trading, fabrication, and service functions over a multi-year period, tracking the preconditions for each integration step, the mechanisms through which integration produced operational benefits, and the quantitative performance outcomes across changing market conditions. Such a longitudinal integration gap defines the contribution of the present case study.

Materials and methods. This study employs a single-case embedded design following Yin’s [4] case study methodology. Yin identifies five rationales for single-case design: the critical case (testing a well-formulated theory), the extreme or unique case, the representative case, the revelatory case (previously inaccessible to observation), and the longitudinal case (same case at multiple time points). By combining the revelatory and longitudinal rationales: the author’s position as founder and director of Kharkiv Stal LLC provides access to complete operational data from the enterprise’s inception, data that would be unavailable to an external researcher, while the twelve-year observation period (2013–2025) enables analysis of the enterprise’s evolution across distinct market phases.

An embedded design with three units of analysis corresponding to the three components of the ISFS model: the supply component (procurement practices, supplier relationships, material quality assurance), the fabrication component (production capabilities, process organization, in-process quality control), and the service component (client interaction patterns, post-delivery support, feedback mechanisms). Each unit is analyzed through its own set of data sources and performance indicators, while cross-unit analysis examines how integration between components generates outcomes that the individual components could not achieve independently.

Data sources comprise four categories. Operational records include procurement logs (supplier, product, quantity, certification type, and price for every incoming shipment), production records (order specifications, cutting plans, welding protocols, inspection results, and delivery documentation), and client records (order history, delivery dates, complaint logs, and repeat purchase patterns). Financial summaries include annual revenue, cost structure breakdowns, and margin analysis aggregated from the enterprise’s accounting system (data are presented in ranges rather than exact figures to maintain commercial confidentiality while preserving analytical value). Quality records include incoming material inspection results, in-process rework logs, final inspection outcomes, and post-delivery client feedback collected since the formalization of the quality management system in 2017. Contextual records include supplier correspondence, client meeting notes, and the author’s contemporaneous observations documented in operational notes maintained since 2013, formalized into structured journals from 2015 when the enterprise’s operational complexity warranted systematic documentation.

Analytically, the approach follows a pattern-matching logic [4], comparing the observed enterprise trajectory against two alternative theoretical predictions: (a) that vertical integration in an SME creates bottlenecks and management overload

that limit growth beyond a certain threshold, and (b) that vertical integration creates synergies that enable sustainable growth through quality differentiation and client retention. Performance indicators were selected to discriminate between these predictions: revenue trajectory (growth versus plateau), client retention rate (increasing versus stable versus declining), quality metrics (improving versus stable versus deteriorating), and product portfolio breadth (expanding versus static). Convergent evidence across multiple indicators toward prediction (b) would support the proposition that the ISFS model generates sustainable competitive advantage for the SME; mixed or contradictory evidence would suggest conditional applicability.

Methodological limitations require explicit acknowledgment. A dual role as enterprise founder and researcher creates inherent risk of confirmation bias: a natural tendency to interpret ambiguous data in ways that validate the model one has built. Three safeguards mitigate this risk without eliminating it. First, quantitative performance data (revenue, order counts, rejection rates, client retention percentages) are drawn from accounting and quality management records that were created for operational purposes before the research was conceived, reducing the possibility of retrospective data selection. Second, negative evidence is actively reported: instances where integration created problems (management overload during peak periods, capital concentration risk, wartime supply disruptions) are documented alongside successes. Third, the Discussion section explicitly addresses alternative explanations for observed outcomes, including market conditions, geographic advantages, and competitive dynamics that may have contributed to the enterprise's trajectory independently of the ISFS model. No causal proof is claimed that the ISFS model produced the observed results; it documents the co-occurrence of the model's implementation with specific performance outcomes and proposes the integration mechanisms through which the model may have contributed to those outcomes.

Results

1. Company profile and evolution

Kharkiv Stal LLC was registered in Kharkiv, Ukraine in 2013 as a steel trading enterprise. With over a decade of prior experience in the metal products market, having worked in steel procurement and sales since the early 2000s. Initial operations comprised purchasing structural steel from regional distributors and reselling it to construction firms and small fabrication workshops in the Kharkiv region. Starting capital was minimal, the team consisted of the founder and one assistant, and the enterprise operated without its own warehouse, arranging deliveries directly from distributor stock to client sites.

Development over the subsequent twelve years can be characterized through four distinct phases, each marked by a qualitative shift in operational capability and market positioning. Table 1 summarizes these phases.

Table 1

Development phases of Kharkiv Stal LLC (2013–2025)

Phase	Period	Primary activity	Key capability milestones
1. Trading startup	2013–2015	Steel resale from distributor stock	First direct mill contracts; client base formation; first leased warehouse
2. Trading + basic fabrication	2015–2017	Steel trading with cutting and light fabrication	Plasma cutting equipment; first production zone; EN 10204 type 3.1 policy
3. Integrated supply-fabrication	2017–2020	Certified trading, structural fabrication, profiled sheeting	3 production zones; ISO 3834 welding; sheeting line; 5 certified suppliers
4. Full ISFS + wartime adaptation	2020–2025	Integrated supply, fabrication, service, support	ERP order management; wartime restructuring; geographic expansion

Source: compiled by the author based on operational records, Kharkiv Stal LLC. Revenue, staff, and other quantitative indicators are consolidated in Table 5 (Section 4.6)

Phase 1 (2013–2015) established the commercial foundation. Revenue grew steadily during this phase, driven by the founder’s existing relationships in the regional construction market. During this phase, the enterprise functioned as a pure intermediary: purchasing steel at wholesale prices and reselling with a trading margin. Quality control was limited to verifying delivery documentation against order specifications. In retrospect, two operational patterns during this phase created the conditions that motivated subsequent integration. First, the enterprise had no control over the quality of material it sold: when a client reported that the delivered plate did not match the specified grade, the trading company could only relay the complaint to the distributor, with resolution depending on the distributor’s willingness to investigate. Second, margins on pure trading were thin and vulnerable to price competition from other traders offering identical products from the same distributors at marginally lower prices.

Phase 2 (2015–2017) added basic fabrication capability. Initial production space (~800 m²) was leased, and the enterprise acquired production space (~800 m²) and acquired plasma cutting equipment, enabling it to offer cut-to-size plates and sections alongside standard trading inventory. Two consequences followed from this capability shift. Commercially, it allowed the enterprise to capture fabrication margin on top of trading margin, increasing gross margins on orders that included cutting services (specific margin data are reported in Table 5). Operationally, it created the first direct contact between the enterprise and the physical properties of the material it handled: operators cutting steel plates discovered dimensional inconsistencies and surface defects that were invisible in the documentation-only trading model. This hands-on quality feedback motivated the decision in 2017 to adopt a 100% certified sourcing policy, requiring EN 10204 type 3.1 mill certificates for every incoming shipment of structural steel, and transitioning supplier

relationships from ad hoc purchasing to formal agreements with five certified mills and primary distributors.

Phase 3 (2017–2020) represented the core integration period. Production capacity expanded to three working zones totaling approximately 4,100 m². The product portfolio expanded from steel trading with cutting services to include fabricated structural components (trusses, frames, platforms, canopies, stairways), custom metalwork (conveyor supports, equipment frames, agricultural structures), and profiled sheeting in multiple profiles and coatings. Welding quality was formalized under ISO 3834 requirements, and execution class EXC2 per EN 1090-2 became the standard for structural work. By the end of Phase 3, the enterprise was processing 5–8 concurrent orders across its three zones, with annual throughput of approximately 800–1,200 tons of structural steel and 150,000–200,000 m² of profiled sheeting.

Phase 4 (2020–2025) added the service dimension and tested the model under extreme conditions. Client interaction evolved from transactional (deliver and invoice) to relational (consult, specify, fabricate, deliver, follow up). An ERP-based order management system replaced manual tracking, enabling real-time visibility of order status from material procurement through production to delivery. When full-scale military conflict began in February 2022, the enterprise’s operations were directly affected: Kharkiv experienced sustained shelling, supply routes were disrupted, some clients suspended construction activity, and several employees were mobilized.

The integrated model proved more adaptable than a fragmented alternative would have been: because the enterprise controlled its own material inventory rather than depending on just-in-time deliveries from external traders, production could continue using existing stock during periods when incoming supply was interrupted. Supplier relationships were restructured to accommodate altered logistics (western

routing replacing disrupted eastern corridors), and the product mix shifted toward military-adjacent construction (fortification elements, rapid-assembly shelters, repair components for damaged structures). By 2024–2025, revenue had recovered to pre-conflict levels and the enterprise was serving clients across a wider geographic area than before the conflict, having established delivery capability beyond the Kharkiv region.

2. Supply component: procurement and material management

The supply component of the ISFS model encompasses supplier selection, procurement execution, inventory management, and incoming quality verification. Since Phase 3 (2017 onward), five certified suppliers have constituted the core procurement portfolio, each contributing specific product categories. Table 2 presents the supplier structure.

Table 2

Supplier portfolio: product categories, certification, and relationship duration

Supplier	Product categories	Certificate type	Relationship since
Metinvest-SMC	Hot-rolled plate, sections, rebar, wire	EN 10204 type 3.1	2015
ArcelorMittal Kryvyi Rih	Structural sections, merchant bar	EN 10204 type 3.1	2016
Cascade	Hot-rolled and cold-rolled coil, sheet	EN 10204 type 3.1	2017
Slavsant	Galvanized and polymer-coated coil	EN 10204 type 3.1	2017
AV Metal Group	Profile tubes, hollow sections	EN 10204 type 3.1	2018

Source: compiled by the author based on procurement records, Kharkiv Stal LLC

The current product range exceeds 2,000 SKU spanning seven categories: structural plate and sheet (S235JR through S355J2, thickness 3–20 mm), structural sections (angles, channels, I-beams from 50 mm to 400 mm), profile tubes (rectangular, square, and circular, 15×15 mm to 200×200 mm), rebar and reinforcing mesh (diameter 6–32 mm), galvanized and polymer-coated coil (0.35–0.85 mm, zinc

coating Z100–Z275, polymer in RAL color range), welding consumables (wire, electrodes matched to base material grades), and fasteners (bolts, nuts, washers, anchor assemblies for structural connections).

Incoming quality verification follows a standardized protocol for every shipment. Mill certificates are checked against order specifications before unloading: supplier name, steel grade, heat number, chemical composition, and mechanical test results are verified against EN 10025 requirements. Dimensional verification includes spot thickness measurements at 4–6 points per plate or coil using a calibrated ultrasonic gauge. Surface condition is assessed visually during unloading, with any material showing corrosion, mechanical damage, or coating defects segregated for evaluation before acceptance. Since the transition to 100% certified sourcing in 2017, incoming rejection rates have remained below 1% of deliveries, with rejections primarily attributable to transport damage rather than material non-conformance.

Inventory management balances two competing objectives: maintaining sufficient stock to enable rapid order fulfillment (clients in construction frequently require material within 1–3 days rather than the 2–4 week lead time for mill orders) and minimizing capital locked in inventory. The enterprise maintains a rolling stock valued at approximately UAH 5–8 million, comprising high-turnover items (S235/S275 plate 4–10 mm, profile tubes 40×40 through 100×100, rebar 10–16 mm, galvanized coil 0.45–0.55 mm) that account for 70–80% of order volume. Lower-turnover or project-specific material is procured against confirmed orders.

3. Fabrication component: production capabilities and processes

Fabrication operations occupy three production zones that were established progressively as the enterprise’s capability expanded. Cutting capability, acquired in Phase 2 with the lease of initial production space, grew into a dedicated zone of approximately 1,200 m² housing plasma cutting equipment (capacity up to 40 mm

carbon steel), oxy-fuel cutting stations for heavy plate, and mechanical cutting tools (band saws, shears) for sections and tubes. Welding and assembly capability, added during Phase 3, occupies approximately 1,800 m² containing MIG/MAG and manual arc welding stations, assembly jigs, and overhead crane capacity for handling structural assemblies up to 5 tons. The finishing zone, also established in Phase 3, encompasses approximately 1,100 m² incorporating the profiled sheeting line, surface preparation equipment (grinding, primer application), and the dispatch area. Combined production area of approximately 4,100 m² represents a facility that was built incrementally through reinvested operating cash flow rather than designed as a greenfield layout.

The production flow from material receipt to dispatch follows six stages, with quality verification integrated at each transition. Figure 2 presents this flow schematically.

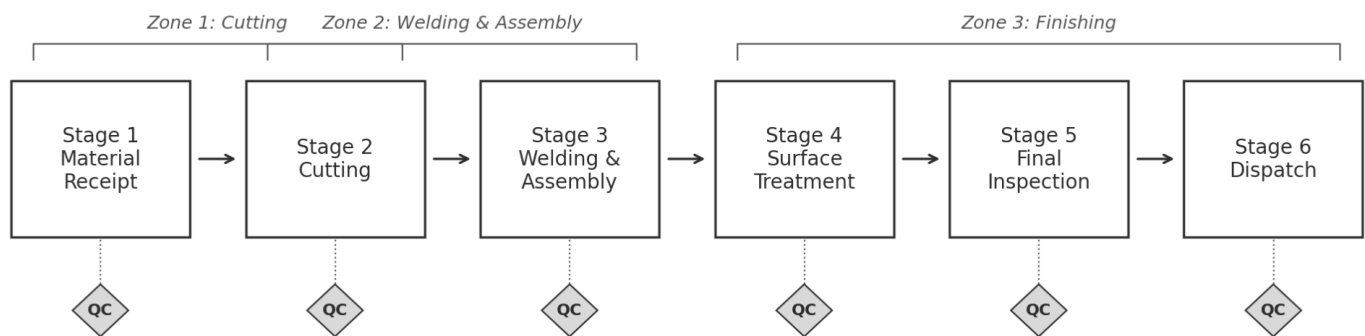


Fig. 2. Production flow: six stages with integrated quality checkpoints

Source: developed by the author based on operational practice, Kharkiv Stal LLC.

Stage 1 (material receipt and incoming inspection) verifies identity, grade, dimensions, and surface condition against the order specification and mill certificate. Stage 2 (cutting) converts raw material into components per cutting plans; cut parts

are checked for dimensional accuracy against tolerances specified in the order. Stage 3 (welding and assembly) joins cut components into structural assemblies per welding procedure specifications matched to the base material grade and thickness; visual inspection of every weld and dimensional verification of completed assemblies occur before the assembly advances. Stage 4 (surface treatment) applies primer, paint, or other protective coating as specified; coating thickness is verified by gauge measurement. Stage 5 (final inspection) conducts a comprehensive check covering dimensions, weld quality, surface treatment completeness, and documentation accuracy. Stage 6 (packaging and dispatch) prepares the product for transport with appropriate protective measures.

The profiled sheeting line operates as a parallel production stream, converting galvanized or polymer-coated coil into finished roofing tiles, corrugated wall panels, and flat profiled sheet. Machine parameters (roller pressure, forming speed, cut length) are verified at the start of each production run using sample pieces inspected for coating integrity at all bend radii before full production proceeds.

Production capacity allows concurrent processing of 5–8 fabrication orders and continuous sheeting production during standard working hours. During peak demand periods (typically spring and early summer in the Ukrainian construction season), capacity utilization reaches 85–90%. During the wartime period (2022 onward), production scheduling adapted to intermittent electricity supply and periodic operational pauses during active shelling. A diesel generator maintained power for critical operations (plasma cutting, welding, crane systems), and flexible shift patterns concentrated production during periods of stable grid supply.

4. Quality assurance across the supply-fabrication chain

Quality assurance at Kharkiv Stal operates through four sequential levels spanning the material-to-delivery chain. Rather than describing inspection procedures at each level (which follow standard industry practice per EN 1090-2 [9]

and ISO 3834-2 [11]), this section focuses on the integration-specific advantages that arise from conducting all four levels within a single enterprise.

At Level 1 (incoming material quality), the critical integration benefit is that quality information gathered during inspection, specifically actual thickness readings, chemical composition from the mill certificate, surface condition observations, transfers directly into production planning within the same organization. A fabricator purchasing material from an external trader receives a mill certificate as a document; an integrated enterprise receives the same data as operational input already embedded in its quality system.

At Level 2 (in-process fabrication quality), the integration benefit operates bidirectionally. When a production issue is detected, for example, inconsistent weld penetration on a plate that met all incoming specifications, the quality system traces backward to the specific shipment, supplier, and heat number, and forward to any other orders using material from the same batch. In a fragmented chain, backward tracing requires cross-organizational communication that may take days; in the integrated model, it takes minutes.

At Level 3 (final product quality), integration ensures that inspection criteria reflect actual material properties rather than nominal specifications. Final dimensional checks account for the actual thickness measured at incoming (Level 1), not the nominal thickness on the drawing, because the same system holds both data points.

At Level 4 (post-delivery quality and client feedback), integration closes the information loop. Client feedback on structural performance, assembly fit, and coating durability during service feeds back into procurement decisions (supplier performance rating), production adjustments (process parameter refinement), and product development, creating a continuous improvement cycle that spans the entire supply-fabrication-service chain.

Table 3 presents quantitative quality metrics across the four levels for the most recent three-year period (2023–2025).

Table 3

Quality metrics by assurance level (2023–2025 averages)

Quality level	Metric	Target	Actual (2023–2025)
Level 1: Incoming	Shipment rejection rate	< 2%	0.8%
Level 1: Incoming	Certificate non-conformance	0%	0%
Level 2: In-process	Rework rate (cutting)	< 3%	1.8%
Level 2: In-process	Rework rate (welding)	< 5%	2.9%
Level 2: In-process	Rework rate (assembly)	< 3%	1.4%
Level 3: Final	First-pass inspection rate	> 90%	94.2%
Level 3: Final	Documentation completeness	100%	99.6%
Level 4: Post-delivery	Complaint rate (per 100)	< 2	0.4
Level 4: Post-delivery	Repeat order rate	< 50%	62%

Source: compiled by the author based on quality management records, Kharkiv Stal LLC, 2023–2025

The complaint rate of 0.4 per 100 deliveries merits contextual interpretation. During Phase 1 (2013–2015), when the enterprise functioned as a pure trader without fabrication capability, complaint resolution depended on the upstream distributor’s cooperation and could take weeks. During Phase 4 (2023–2025), complaints are resolved internally within 1–3 working days because the enterprise controls the full production chain and can identify whether the issue originated in material (Level 1), fabrication (Level 2), inspection (Level 3), or transport/handling (post-Level 3). This resolution speed is itself a competitive advantage: construction clients operating

under tight schedules value rapid problem resolution over zero-defect promises that cannot be verified until after the project deadline.

5. Client interaction and market development

The service component of the ISFS model encompasses client acquisition, order specification, delivery logistics, post-delivery support, and long-term relationship management. Evolution of this component parallels the enterprise’s four development phases, shifting from transaction-based interaction (Phase 1–2) to relationship-based engagement (Phase 3–4).

During the trading-only period (Phase 1), client interaction was transactional: price quotation, order acceptance, delivery, and invoicing. Differentiation from competing traders was limited to delivery reliability and personal relationships, with no quality or technical advantage available.

Addition of fabrication capability (Phase 2–3) transformed the client interaction model. Clients could now request material as well as processing services, including cut-to-size plates, welded assemblies, custom brackets, and complete structural components designed to their specifications. Technical consultation became part of the sales process: the enterprise’s production staff could advise clients on material selection (which grade and thickness for a given structural application), connection design (welded versus bolted, detail geometry), and surface protection (appropriate coating system for the intended service environment). This consultative capability attracted a different client profile, specifically construction companies and industrial enterprises that valued engineering input alongside material supply, and shifted the competitive basis from price per ton to value per project.

Client segments span industrial enterprises, construction companies, agricultural enterprises, and individual clients. Industrial and construction segments generate approximately 75% of annual revenue.

Geographic market reach expanded progressively from the immediate Kharkiv area (Phase 1) to the broader Kharkiv Oblast (Phase 2–3) and, following wartime disruption, to a national scope including central and western Ukrainian regions where the enterprise had no prior presence.

Repeat client revenue grew from an estimated 25–30% of annual turnover in Phase 1 (when the enterprise was new and client relationships were forming) to over 60% in Phase 4. This growth trajectory developed in parallel with the enterprise’s expanding service scope, as the share of clients utilizing multiple services (trading + fabrication, or fabrication + delivery + consultation) grew relative to clients purchasing a single product category.

6. Quantitative performance assessment

Growth was not without setbacks. During the Phase 2–3 transition (2016–2018), concurrent management of expanding supplier negotiations, production scheduling, client quotations, and quality documentation created operational bottlenecks: client response times periodically exceeded 48 hours and scheduling conflicts resulted in delivery delays on an estimated 10–15% of orders during peak periods. The 2022 conflict onset produced a sharper disruption: revenue declined by an estimated 40–50% in the first six months before adaptation measures restored operational continuity.

Table 4 aggregates the key performance indicators across the enterprise’s twelve-year trajectory, organized by development phase. Figure 3 visualizes the revenue and order volume trends.

Table 4

Key performance indicators by development phase (2013–2025)

Indicator	Phase 1 (2013–15)	Phase 2 (2015–17)	Phase 3 (2017–20)	Phase 4 (2020–25)
Revenue (UAH M)	2–8	8–15	15–30	30–45

Orders/year	50–150	150–400	400–800	600–1,000
Product categories	1	3	5	7
Staff (year-end)	2–4	5–10	10–20	15–25
Supplier certification	Mixed	~60% type 3.1	100% type 3.1	100% type 3.1
Gross margin	8–12%	15–22%	18–28%	20–30%
Repeat client share	25–30%	35–45%	50–58%	60–65%
Complaint rate (/100)	Not tracked	~3	~1	0.4
Capacity (tons/yr)	N/A	~200	800–1,200	1,000–1,500

Source: compiled by the author based on financial and operational records, Kharkiv Stal LLC. Revenue in ranges for commercial confidentiality

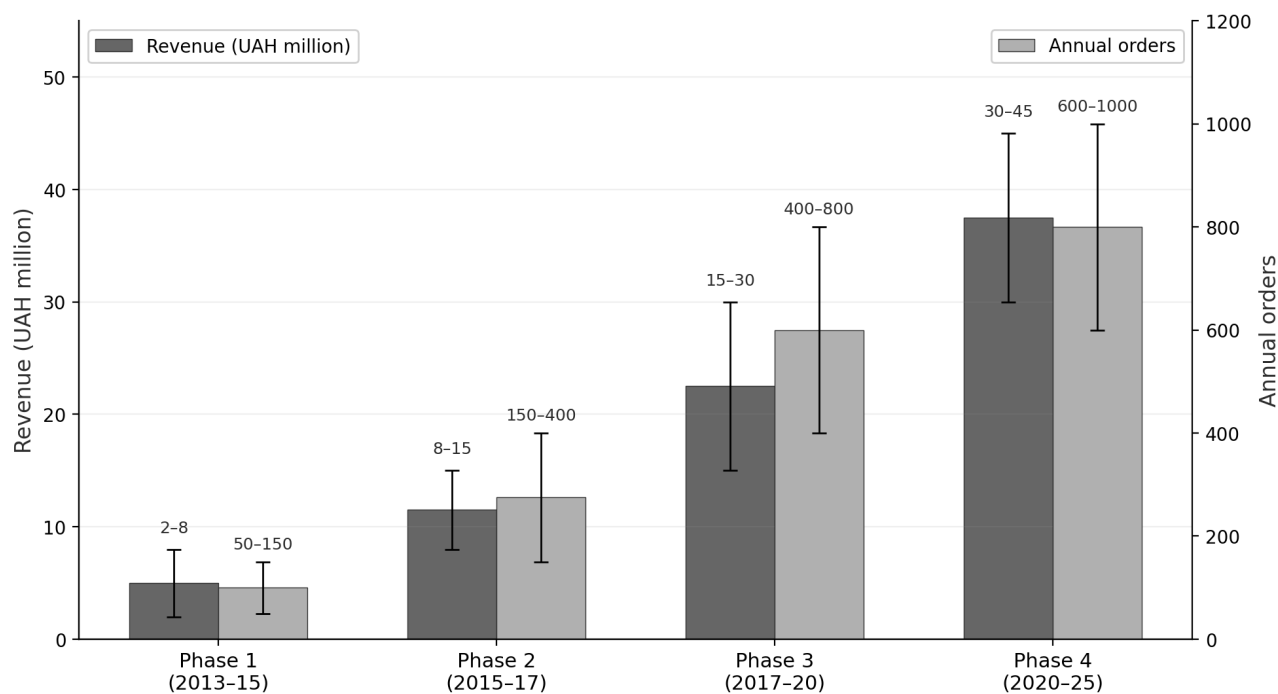


Fig. 3. Revenue trajectory and order volume growth (2013–2025) by development phase

Source: compiled by the author based on financial records, Kharkiv Stal LLC

Several patterns emerge from the longitudinal data. Revenue growth was not linear: Phase 1 showed rapid percentage growth from a low base (approximately 4× over three years), Phase 2 showed moderate growth (approximately 2× as fabrication margins supplemented trading), Phase 3 showed accelerating growth (approximately 2× as the integrated model attracted higher-value orders), and Phase 4 showed resilience and recovery (dip during 2022 conflict onset, followed by recovery to pre-conflict levels by 2024 and continued growth in 2025).

Gross margin expansion from 8–12% (pure trading) to 20–30% (integrated ISFS) reflects the progressive capture of value-added stages. Each integration step, from resale to cutting, from cutting to welding, from welding to complete fabrication, from fabrication to sheeting, from product delivery to technical consultation, added margin layers that cumulatively transformed the enterprise from a low-margin intermediary into a differentiated service provider competing on capability rather than price alone.

Client complaint rate declined from approximately 3 per 100 deliveries in Phase 2 (when fabrication capability was newly established) to 0.4 per 100 in Phase 4, a trajectory that coincided with quality system maturation, supplier base stabilization, and workforce experience accumulation documented in Sections 4.2–4.4.

Discussion. The operational trajectory documented in Sections 4.1–4.6 can be interpreted through the theoretical lenses established in the literature review, while also identifying empirical findings that extend or qualify existing theoretical predictions.

Porter’s value chain framework [1] predicts that competitive advantage arises from configuring primary and support activities in ways that create value for the buyer at acceptable cost to the firm. The ISFS model demonstrates a configuration where inbound logistics, operations, outbound logistics, and service are unified

under single management within an SME structure. Harrigan’s [17] integration typology classifies this as selective full integration: the enterprise fully owns and controls the trading-fabrication-service chain but does not extend into upstream steel production or downstream construction installation. The empirical data suggest that for SMEs in steel construction generally, this selective boundary is strategically rational: extending into steel production would require capital investment orders of magnitude beyond SME reach, while extending into construction installation would require a different workforce skill set and regulatory framework. This finding can be generalized to SMEs operating in fragmented manufacturing sectors: the trading-fabrication-service segment represents value chain territory where SME-scale capital and management capacity can achieve integration benefits without exceeding resource constraints.

Kuei et al. [18] identified quality information availability as the strongest predictor of supply chain performance among the six SCQM dimensions they studied. The present case provides a mechanism-level illustration of this finding. When procurement and fabrication reside within a single enterprise, quality information flows directly into production parameters without crossing an organizational boundary. In a fragmented chain, this transfer depends on multiple handoffs, each representing a potential failure point. The quality metrics documented in Section 4.4 are consistent with the SCQM prediction that information continuity reduces defect generation. This suggests that SMEs capable of internalizing the procurement-fabrication interface gain a quality advantage that is structural rather than dependent on individual vigilance. The decline in complaint rates from early fabrication to mature ISFS operation reflects concurrent quality mechanisms: system formalization, supplier stabilization, and experience accumulation. For other SMEs considering similar integration, this trajectory suggests that quality benefits

compound over time rather than appearing immediately at the point of structural change.

Ghobadian and Gallear [20] characterized SMEs as benefiting from short communication lines and direct owner involvement but suffering from limited specialist expertise and key-person dependency. The Kharkiv Stal case confirms both sides of this characterization. Short communication lines enable direct owner oversight across procurement, production, and client relationships simultaneously, an integration capability that larger enterprises achieve only through formal coordination mechanisms. This concentration of quality authority in a single decision-maker accelerates quality culture development in ways that formal documentation alone cannot replicate, a pattern likely generalizable to owner-managed SMEs across manufacturing sectors. Conversely, key-person dependency is the model’s primary vulnerability: during the most intense period of the 2022 conflict, when the founder was directly managing evacuation logistics, supply chain restructuring, and client communication simultaneously, production coordination suffered until additional management responsibility was delegated to senior production staff. The wartime period forced an acceleration of organizational development that had been deferred during peacetime growth, transitioning from founder-centric to team-distributed decision-making for routine operations while retaining founder oversight for strategic and quality-critical decisions. Repeat client share exceeding 60% suggests that integrated service offerings create relationship continuity through switching costs, a retention mechanism available to any SME that combines multiple value chain stages rather than specializing in one.

The competing prediction, that vertical integration creates bottlenecks limiting growth, found partial support. Phase transitions and the 2022 conflict exposed two stress points: management overload during capability expansion, and financial exposure from capital concentration during demand shocks. These findings

suggest that SMEs pursuing vertical integration should anticipate management capacity constraints at each growth phase and build delegation mechanisms before they become urgent rather than after crisis forces the transition. The founder’s initial resistance to delegating procurement and quality decisions, overcome by operational necessity during wartime, illustrates the key-person dependency risk that Ghobadian and Gallear [20] identified as characteristic of SME quality management.

Transferability of the ISFS model to other SMEs requires assessment of preconditions. The empirical evidence suggests four necessary conditions for successful implementation: (1) foundational market knowledge: the founder’s pre-existing experience in steel trading provided client relationships and supplier contacts without which the startup phase would have been significantly longer; (2) incremental capital investment, each integration phase was funded from operating cash flow rather than external investment, making the model accessible to bootstrapped enterprises but requiring patience in the growth trajectory; (3) quality commitment preceding capability expansion, the transition to 100% certified sourcing in Phase 2, before full fabrication capability was established, created the quality foundation on which subsequent integration was built; and (4) management willingness to learn adjacent functions, the founder transitioned from trader to production manager to quality system designer to client relationship manager progressively, acquiring competencies that a specialist in any single function might not pursue. SMEs that lack any of these preconditions may find specific integration steps more difficult, though not necessarily impossible, to execute.

Conclusions. The Integrated Supply-Fabrication-Service model documented in this case study demonstrates that a steel construction SME can achieve competitive advantage through progressive vertical integration of trading, fabrication, and client service functions within a single organizational structure. Over twelve years and four development phases, Kharkiv Stal LLC evolved from a

two-person steel trading startup into an integrated operation with certified supplier relationships, multi-zone fabrication capability, diversified product portfolio, and a service-oriented client model generating over UAH 40 million in annual revenue with repeat client share exceeding 60%.

Quality assurance across the integrated supply-fabrication chain represents the model’s primary operational advantage. Continuous information flow from incoming material inspection through production stages to post-delivery client feedback, managed within a single quality management system without inter-organizational boundaries, produced measurable outcomes: incoming rejection rates below 1%, in-process rework rates of 1.4–2.9% depending on operation type, first-pass final inspection rate of 94.2%, and client complaint rate of 0.4 per 100 deliveries. These metrics are consistent with the supply chain quality management prediction that quality information continuity is the strongest driver of supply chain performance, and they provide SME-specific quantification that the SCQM literature has lacked.

Wartime adaptation (2022–2025) provided an unplanned but empirically valuable test of the model’s resilience. The integrated structure offered specific advantages, specifically inventory buffering, prioritized supplier relationships, and product-mix flexibility, that enabled operational continuity under conditions that would have fragmented a non-integrated supply chain. While this finding is specific to the Ukrainian conflict context, the underlying principle, that enterprises controlling more stages of their value chain have more response options during disruption, is consistent with supply chain resilience theory and has implications for SMEs operating in any volatile market environment.

As a single-case study documenting one enterprise’s trajectory in a specific market and conflict context, the findings represent a single data point rather than a generalizable law. The author’s dual role as founder and researcher, while enabling

unprecedented data access, introduces interpretation risks that the methodological safeguards described in Section 3 mitigate but cannot eliminate. Quantitative performance outcomes reflect the combined effect of the ISFS model and numerous concurrent factors (market conditions, competitive dynamics, macroeconomic trends, wartime disruption) that cannot be isolated through observational methodology.

Four preconditions for ISFS model implementation emerged from the longitudinal analysis: foundational market knowledge, incremental capital investment, quality commitment preceding capability expansion, and management willingness to acquire adjacent-function competencies. These preconditions define the boundary conditions within which the model is likely to be replicable, and they suggest that successful integration is a multi-year developmental process rather than a configuration that can be designed and implemented at a single point in time.

Further research should pursue three complementary directions: multi-case comparative studies examining whether the ISFS model produces similar outcomes at other steel construction SMEs in different market contexts; quantitative modeling of the relationship between integration depth and performance metrics across a sample of enterprises at varying integration levels; and longitudinal studies of SME adaptation in conflict-affected markets, where the interplay between supply chain structure and operational resilience can be examined with the analytical rigor that the single-case design of the present study cannot provide.

References

1. Porter M. E. *Competitive Advantage: Creating and Sustaining Superior Performance*. New York : Free Press, 1985. 557 p. ISBN 978-0-02-925090-7. URL: <https://www.hbs.edu/faculty/Pages/item.aspx?num=193>

2. Womack J. P., Jones D. T. Lean Thinking: Banish Waste and Create Wealth in Your Corporation. Revised and updated ed. New York : Free Press, 2003. 397 p. ISBN 978-0-7432-4927-0. URL: <https://www.simonandschuster.com/books/Lean-Thinking/James-P-Womack/9780743249270>
3. Gunasekaran A., Patel C., McGaughey R. E. A framework for supply chain performance measurement. *International Journal of Production Economics*. 2004. Vol. 87, No. 3. P. 333–347. DOI: <https://doi.org/10.1016/j.ijpe.2003.08.003>.
4. Yin R. K. Case Study Research and Applications: Design and Methods. 6th ed. Thousand Oaks, CA : SAGE Publications, 2018. 352 p. ISBN 978-1-5063-3616-9. URL: <https://collegepublishing.sagepub.com/products/case-study-research-and-applications-6-250150>
5. Srinivasan K., Sarulkar P., Yadav V. K. Operational excellence of the steel industry using the Lean Six Sigma approach: a case study. *International Journal of Quality & Reliability Management*. 2024. Vol. 41, No. 3. P. 826–849. DOI: <https://doi.org/10.1108/IJQRM-08-2022-0250>
6. Moeuf A., Pellerin R., Lamouri S., Tamayo-Giraldo S., Barbaray R. The industrial management of SMEs in the era of Industry 4.0. *International Journal of Production Research*. 2018. Vol. 56, No. 3. P. 1118–1136.
7. Matt D. T., Rauch E. SME 4.0: the role of small- and medium-sized enterprises in the digital transformation. Industry 4.0 for SMEs: Challenges, Opportunities and Requirements / ed. by D. T. Matt, V. Modrák, H. Zsifkovits. Cham : Palgrave Macmillan, 2020. P. 3–36. DOI: https://doi.org/10.1007/978-3-030-25425-4_1.
8. Chiarini A. Sustainable manufacturing-greening processes using specific Lean Production tools: an empirical observation from European motorcycle

component manufacturers. *Journal of Cleaner Production*. 2014. Vol. 85. P. 226–233. DOI: <https://doi.org/10.1016/j.jclepro.2014.07.080>.

9. EN 1090-2:2018+A1:2024. Execution of steel structures and aluminium structures. Part 2: Technical requirements for steel structures. Brussels : European Committee for Standardization, 2024. URL: <https://www.dinmedia.de/en/standard/din-en-1090-2/379469336>

10. ISO 9001:2015. Quality management systems — Requirements. Geneva : International Organization for Standardization, 2015. URL: <https://www.iso.org/standard/62085.html>

11. ISO 3834-2:2021. Quality requirements for fusion welding of metallic materials. Part 2: Comprehensive quality requirements. Geneva : International Organization for Standardization, 2021. URL: <https://www.iso.org/standard/81651.html>

12. World Steel in Figures 2024. Brussels : World Steel Association, 2024. URL: <https://worldsteel.org/wp-content/uploads/World-Steel-in-Figures-2024.pdf>

13. Ukrmetallurgprom. Metal Products Production and Consumption in Ukraine in Jan–Dec 2024. 2025. URL: <https://www.ukrmetprom.org/metal-products-production-and-consumption-in-ukraine-in-jan-dec-2024/>

14. Structural Changes and Challenges in the Construction Industry of Ukraine: Analysis and Forecasts. Kyiv : Kyiv School of Economics, 2024. 111 p. URL: https://kse.ua/wp-content/uploads/2024/09/02_09_24_Zvit_Strukturni_zmini_ta_vikliki_v_budivelni_i--_industrii--.pdf

15. Mittal S., Khan M. A., Romero D., Wuest T. Smart manufacturing: characteristics, technologies and enabling factors. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*. 2019. Vol. 233, No. 5. P. 1342–1361.

16. Ates A., Garengo P., Cocca P., Bititci U. The development of SME managerial practice for effective performance management. *Journal of Small Business and Enterprise Development*. 2013. Vol. 20, No. 1. P. 28–54. DOI: <https://doi.org/10.1108/14626001311298402>
17. Harrigan K. R. Vertical Integration, Outsourcing, and Corporate Strategy. Washington, DC : Beard Books, 2003. 392 p. ISBN 978-1-58798-190-6. URL: <https://books.google.com/books?id=3JH0LVv0ohoC>
18. Kuei C.-H., Madu C. N., Lin C. The relationship between supply chain quality management practices and organizational performance. *International Journal of Quality & Reliability Management*. 2001. Vol. 18, No. 8. P. 864–872. DOI: <https://doi.org/10.1108/EUM00000000006031>
19. Robinson C. J., Malhotra M. K. Defining the concept of supply chain quality management and its relevance to academic and industrial practice. *International Journal of Production Economics*. 2005. Vol. 96, No. 3. P. 315–337. DOI: <https://doi.org/10.1016/j.ijpe.2004.06.055>
20. Ghobadian A., Gallea D. TQM and organization size. *International Journal of Operations & Production Management*. 1997. Vol. 17, No. 2. P. 121–163. DOI: <https://doi.org/10.1108/01443579710158023>