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Workforce Competency Development and Production Efficiency in Textile Manufacturing: An Integrated Assessment Framework

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Abstract: The competitiveness of textile manufacturing increasingly depends on the competencies of its workforce, as enterprises move from the primary processing of raw materials towards products with higher value added, automated equipment and international quality and social compliance standards. In practice, however, workforce development and production efficiency are usually assessed separately: personnel departments record training hours, while production units monitor output, downtime and defects. This article proposes an integrated assessment framework that links the two. Drawing on a structured review of human capital and competency theory, experimental and firm-level evidence on the returns to training, industrial engineering methods and official data on the textile industry of Uzbekistan, the study constructs an Integrated Competency Index based on weighted competency domains, a Production Efficiency Index that combines overall equipment effectiveness, line efficiency, labour productivity and first-pass quality, and a diagnostic matrix that relates the two indices. The evidence reviewed shows that well-designed training can raise productivity by 13.5–23% and yield a net return of 256% to the firm, while the scale of the task is considerable: employment in the textile industry of Uzbekistan grew from about 188,000 in 2018 to 623,000 in 2025, and globally 59 of every 100 workers will need training by 2030. The framework allows managers to determine whether efficiency gaps stem from competency deficits or from technical and organisational constraints, and to target investment in training accordingly.

Keywords: workforce competency, competency model, production efficiency, textile industry, overall equipment effectiveness, labour productivity, training evaluation, Uzbekistan.

1. Introduction

Textile and apparel manufacturing remains one of the most labour-intensive branches of industry, yet its technological basis is changing rapidly. Automated spinning, weaving and knitting equipment, computer-aided design and cutting, enterprise resource planning systems and international requirements for product quality, traceability and working conditions all raise the demands placed on operators, technicians and supervisors. Whether expensive equipment is used at its full potential, how many defects occur and how quickly orders are

completed depend to a large extent on the knowledge, skills and behaviour of the people who run production. Human capital theory explains why investment in such capabilities is a source of productivity growth for both workers and firms [1].

The pressure to develop workforce competencies is global. According to the World Economic Forum, 39% of workers' core skills are expected to change or become outdated over 2025–2030; of every 100 workers, 59 will need training by 2030, and 63% of employers regard skill gaps as the main barrier to business transformation [2]. In the textile and apparel sector, the adoption of Industry 4.0 technologies is still at an early stage and focuses mainly on automation aimed at higher productivity and lower costs [3], while a shortage of qualified workers is identified as one of the key obstacles to the digital transformation of clothing production [4].

For Uzbekistan these questions are of particular importance. Within a few years the country has moved from exporting raw cotton to processing it domestically: since 2023 it has been able to convert 100% of its raw cotton into yarn, and employment in the textile industry increased from about 188,000 people in 2018 to about 600,000 in 2024 [5]. The "Uzbekistan-2030" strategy sets the goal of accelerating industrial development and increasing the output of products with high added value [6]. Entry into demanding export markets also requires compliance with international labour and social standards, which is supported by the Better Work programme launched in the country in 2023 [7]. Such rapid growth means that a large proportion of the workforce consists of recently hired employees whose competencies must be developed on the job.

At the enterprise level, however, the development of personnel and the efficiency of production are usually managed and assessed separately. Training is reported in terms of hours or the number of employees trained, whereas production performance is measured by output, downtime and defect rates, and the link between the two remains invisible to managers. Against this background, the article proposes an integrated framework for assessing workforce competency development and production efficiency in textile manufacturing.

2. Methods

The study is based on a methodological research design that combines a structured literature review, analysis of statistical and policy data, and methods of composite index construction.

First, a structured review of scholarly literature was carried out on human capital, competency modelling, the returns to training, production efficiency measurement and Industry 4.0 in the textile and apparel sector. Searches were conducted in Scopus, Web of Science and Google Scholar using combinations of the terms "workforce competency", "competency model", "training", "productivity", "textile", "garment" and "overall equipment effectiveness". The screening of sources followed the principles of the PRISMA 2020 statement regarding transparency of inclusion criteria [19]. Priority was given to randomised field experiments, firm-level panel studies and systematic reviews, complemented by foundational works on human capital and competencies.

Second, data from the World Bank, official sources of the Republic of Uzbekistan, the International Labour Organization and the World Economic Forum were used to characterise the development of the textile industry and the demand for workforce skills [8]. Third, methods of composite index construction were applied: normalisation of indicators, weighting by the analytic hierarchy process standard industrial engineering formulas for equipment and line efficiency and methods of training evaluation [9]. Logical, comparative and structural-functional analysis were used to integrate these elements into a single framework.

The study has limitations. The framework is methodological and has not yet been tested on a sample of enterprises; the weights of competency domains are expert-based and may vary by sub-sector (spinning, weaving, knitting, finishing or garment production). Its validation using enterprise data is a task for further empirical research.

3. Results and Discussion

3.1. Structure of workforce competencies in textile manufacturing. The analysis made it possible to distinguish five domains of competencies that determine the performance of textile production personnel: technical and operational, quality and process, digital, behavioural, and safety, compliance and sustainability competencies. Each domain is assessed on a five-level proficiency scale: (1) novice, working under constant supervision; (2) advanced beginner, performing standard operations with occasional help; (3) competent, working independently at the standard rate; (4) proficient, handling deviations and performing several operations; and (5) expert, able to train others and improve the process. Table 1 presents the structure of the proposed framework and shows how each competency domain is connected with production efficiency.[10]

Table 1. Integrated framework for assessing workforce competencies and production efficiency in textile manufacturing

Block	Content	Assessment methods and indicators	Link to production efficiency
Technical and operational competencies	Operation and setting of spinning, weaving, knitting, finishing and sewing equipment; knowledge of process parameters	Practical skills test; multi-skill matrix; proficiency level 1–5	Availability (less downtime and set-up time); performance rate
Quality and process competencies	Product standards; recognition of defects; lean tools (5S, quick changeover, standard work)	Defect recognition test; audit of standard work	Quality rate; first-pass yield; rework
Digital competencies	Work with ERP and production data, CAD/CAM and programmable equipment	Task-based digital assessment	Use of automated equipment; data accuracy; lead time
Behavioural competencies	Teamwork, communication, problem solving, adaptability	360-degree assessment; supervisor rating	Line balance; output on joint operations; absenteeism
Safety, compliance and sustainability	Occupational safety rules; social compliance; resource-saving practices	Audit results; incident records	Lost-time incidents; energy and material use; access to export markets
Production efficiency (outcome block)	Use of equipment, lines and labour	OEE; line efficiency; labour productivity; first-pass yield	Production Efficiency Index (PEI)

The level of competencies of a team, line or workshop is summarised by the Integrated Competency Index (ICI):

$$ICI = \sum w_k \cdot C_k / C_{\max}, \quad \sum w_k = 1, \quad (1)$$

where C_k is the average assessed proficiency level of employees in competency domain k ; $C_{\max} = 5$ is the maximum level; w_k is the weight of domain k , determined by expert pairwise comparison using the analytic hierarchy process [11]; $k = 1, \dots, 5$. The index takes values from 0.2 to 1.0; values of 0.8 and above are proposed to be interpreted as high, from 0.6 to 0.8 as medium and below 0.6 as low.

3.2. Indicators of production efficiency. Production efficiency is assessed using indicators that are already familiar to textile enterprises but are rarely combined. Equipment efficiency is measured by OEE [12]:

$$OEE = A \times P \times Q, \quad (2)$$

where A is availability (operating time divided by planned production time), P is the performance rate (actual output relative to the output possible at the ideal cycle time) and Q is the quality rate (good output divided by total output). In sewing and other labour-intensive

operations, the efficiency of a production line is calculated on the basis of standard allowed minutes established by work study [13]:

$$E_{\text{line}} = (N_g \times SAM) / (n \times T) \times 100\%, \quad (3)$$

where N_g is the number of good units produced, SAM is the standard allowed minutes per unit, n is the number of operators and T is the working time of one operator in minutes. These indicators, together with labour productivity (output per employee or per hour worked) and first-pass yield (the share of products that pass quality control without rework), are combined into the Production Efficiency Index (PEI):

$$PEI = \sum v_j \cdot e_j, \quad e_j = \min(x_j / x_{j,\text{target}}, 1), \quad (4)$$

where x_j is the actual value of efficiency indicator j , $x_{j,\text{target}}$ is its target or benchmark value, e_j is the normalised indicator and v_j is its weight ($\sum v_j = 1$). Normalisation to target values makes the index comparable across workshops and sub-sectors with different technologies.

3.3. Linking competencies and efficiency. The two indices are brought together in a diagnostic matrix with four quadrants. A combination of high ICI and high PEI indicates sustainable efficiency, which should be maintained through mentoring and the retention of key personnel. High ICI combined with low PEI shows that efficiency is limited by technical or organisational factors — outdated equipment, poor line balancing, material shortages or planning failures — so that further training will have little effect and investment should be directed elsewhere. Low ICI combined with high PEI signals vulnerable efficiency that depends on a small number of skilled workers and is exposed to staff turnover. Finally, low values of both indices define a priority zone for targeted training programmes. The matrix thus prevents a common managerial error: treating every efficiency problem as a training problem, or vice versa.

Where enterprise or line-level panel data are available, the strength of the relationship can be estimated with an augmented production function, following the approach used in studies of training and productivity [14]:

$$\ln LP_{it} = \alpha + \beta \cdot ICI_{it} + \gamma \cdot \ln(K/L)_{it} + \delta \cdot Z_{it} + \varepsilon_{it}, \quad (5)$$

where LP_{it} is the labour productivity of enterprise or line i in period t , K/L is capital per worker, Z_{it} is a vector of control variables (product mix, order size, equipment age) and β shows by how much productivity changes when the competency index increases. The economic return on a specific training programme is assessed as follows [15]:

$$ROI = (B - C) / C \times 100\%, \quad (6)$$

where B is the monetary value of the efficiency gains attributable to training (reduced downtime, defects and rework, increased output) and C is the full cost of training, including the working time of trainees. In terms of Kirkpatrick's model [16], the change in ICI reflects the learning level, observation of work methods on the line reflects the behaviour level, the change in PEI reflects the results level, and formula (6) adds the fifth level of return on investment. The evidence reviewed suggests that the expected effects are economically significant: productivity gains of 13.5–23% and a net return of 256% have been documented for well-designed programmes [17].

3.4. The textile industry of Uzbekistan as a context for applying the framework. The need for systematic competency management in Uzbekistan follows from the scale and speed of the industry's growth. Employment in the textile industry more than tripled between 2018 and 2025, reaching 623,000 people, and production output amounted to UZS 134 trillion in 2025 [18] (Fig. 1).

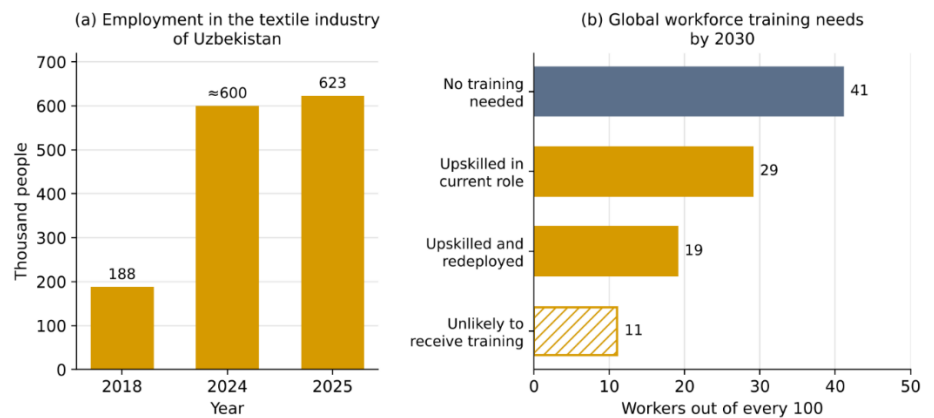


Fig. 1. Employment in the textile industry of Uzbekistan and global workforce training needs to 2030

On average, this corresponds to about UZS 215 million of output per employee (calculated by the author from [20]). Textile exports reached US\$2.6 billion in 2025, delivered by 1,409 exporting enterprises to 75 countries, and exports of finished textile products increased by 18.5% compared with 2024; the target for 2026 is US\$4.0 billion [19]. Achieving such growth with a largely new workforce is possible only if labour productivity and quality rise together with employment. The programme for the industry envisages implementing Better Work, BCI, FWF and Organic EU standards at 60 enterprises and introducing ERP systems and artificial intelligence technologies at 40 enterprises [20], which increases the demand for compliance and digital competencies reflected in Table 1. Global trends point in the same direction: the majority of workers will need training by 2030, and a significant share of them risk not receiving it [21].

3.5. Barriers and directions for development. The analysis identified four groups of barriers to integrating competency development with production efficiency at textile enterprises. The first is informational: data on personnel and data on production are kept in separate systems and are not linked at the level of lines and workshops. The second is related to the workforce itself: rapid expansion has brought many employees with little industrial experience, and staff turnover reduces the return on training. The third concerns the training system: a shortage of qualified instructors and technologists and insufficient alignment between vocational and higher education curricula and the needs of enterprises. The fourth is managerial: training is often treated as a cost rather than an investment, because its results are not measured [22].

Based on the results, the following directions are proposed. (1) Enterprises should introduce competency matrices for each line and workshop and calculate the ICI at least twice a year. (2) Personnel data should be integrated with production data in ERP or manufacturing execution systems so that the ICI and PEI can be monitored together. (3) Training should combine on-the-job instruction, mentoring by expert-level workers and soft skills programmes, whose effectiveness in garment production has been demonstrated experimentally [23]. (4) Every significant training programme should be evaluated up to the level of results and return on investment. (5) Cooperation between enterprises, technical universities and vocational colleges should be strengthened through dual training and joint development of curricula based on competency models. (6) Remuneration and career progression should be linked to confirmed competency levels, which increases the motivation to learn and reduces turnover.[24]

Overall, the discussion shows that workforce competencies and production efficiency in textile manufacturing should be managed as one system. Integrated assessment makes it possible to direct resources to where they produce the greatest effect – to training where efficiency is limited by competencies, and to equipment and organisation where it is limited by other factors.[25].

4. Conclusion

The study shows that the efficiency of textile manufacturing depends not only on equipment and technology but also on the competencies of the people who use them, and that the link between the two can be measured. The proposed integrated assessment framework includes five competency domains with a five-level proficiency scale, the Integrated Competency Index, the Production Efficiency Index based on OEE, line efficiency, labour productivity and first-pass yield, a diagnostic matrix linking the two indices, and tools for evaluating the economic return on training.

For Uzbekistan, where employment in the textile industry has more than tripled since 2018 and the industry aims to increase exports of finished products substantially, the systematic development of workforce competencies is a precondition for raising productivity and meeting the requirements of international markets. Application of the framework would allow enterprises to distinguish competency deficits from technical and organisational constraints, to target training investment and to demonstrate its economic results.

Future research should test the framework at textile enterprises of different sub-sectors, determine empirically the weights of competency domains and estimate the relationship between the Integrated Competency Index and production efficiency using enterprise-level panel data.

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