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Scientific and theoretical foundations of resource management in ensuring product quality and safety at light industry (sewing and knitting) enterprises

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Abstract: This article analyzes the scientific and theoretical foundations of the resource management system in ensuring product quality and safety in light industry enterprises, particularly garment and knitwear. The aim of the study is to systematically analyze the conceptual content of the resource management concept, its historical evolution, its interconnection with international quality and safety standards (ISO 9001:2015, ISO 14001, OEKO-TEX Standard 100), as well as the experience of leading foreign enterprises (Zara, Toyota, Nike, H&M). The study employed methods of comparative analysis, systematization of scientific literature, and content analysis of regulatory legal acts.

Keywords: resource management, quality management, product safety, ISO 9001:2015, OEKO-TEX Standard 100, garment and knitwear industry, resource efficiency, circular economy, Industry 4.0.

1. Introduction

Light industry, including the textile, garment-knitting, leather-footwear, and fur industries, is considered one of the most labor-intensive and export-oriented sectors of the global economy. According to the latest statistics, the total value of the global textile and clothing market is more than 1.2 trillion US dollars, with the finished clothing and fashion industry accounting for 72.7%; more than 90 million people are employed in the industry worldwide, most of whom are located in the Asia-Pacific region [1-3].

Being competitive in international trade requires light industry enterprises to guarantee not only the volume of products but also their quality and safety in accordance with the requirements of international certificates such as ISO 9001, OEKO-TEX Standard 100, GOTS, Sedex (SMETA), and Amfori BSCI. Such certificates allow enterprises to export to major markets such as the USA and the European Union, but their achievement is ensured not only through final product inspection but also through the systematic management of the enterprise's material, technical, human, financial, and information resources [2].

The classics of quality management theory-W. Deming, J. Juran, F. Crosby, K. Ishikawa, and A. Feigenbaum-defined product quality as a set of characteristics of compliance with consumer requirements, justifying that quality control must begin at the initial stage of production. In the field of security management, the concept of risk prevention developed by W. Henry and F. Bird, as well as the HACCP system, serve as an important theoretical foundation. Among the studies specific to light industry, the "Quality Control-CE" model by L. Mitreva and N. Taskov, the Lean Six Sigma methodology by J. Anthony, the life cycle analysis (LCA) by L. Farrant and Daniel, and the artificial intelligence-based quality control systems by Fang and Getuli are of particular importance [4-5].

2. Research methodology

The study was conducted based on a theoretical-descriptive approach to the topic, using the following scientific research methods:

The method of systematizing and summarizing scientific literature was applied - journal articles, monographs (W. Schuhart, E. Deming, J. Juran, K. Ishikawa, A. Feigenbaum) indexed in the Scopus and Web of Science databases, as well as works by domestic scholars (G. Khojiahmedov, G.Sh. Khankeldiyeva, Yu.S. Shakirova, M.T. Khojiev, S.S. Gulomov, and others).

A content analysis of regulatory legal acts was conducted - the texts of ISO 9001:2015, ISO 14001, ISO 2859-1 (AQL), OEKO-TEX Standard 100, and the European Union's REACH regulation were studied, and their requirements for resource management were compared.

The comparative analysis method was applied - the resource management system was compared with production operational management, financial management, and international quality management systems based on the criteria of management object, purpose, scope, and impact on product safety[5-8]

Based on the case study method, the experience of resource management of international corporations such as Zara (Inditex), Toyota, Nike, and H&M was studied, and their potential for adaptation to the practices of garment and knitwear enterprises was evaluated.

3. Results and discussion

To reveal the specific strategic significance of the resource management system at a garment and knitwear enterprise, a comparative analysis was conducted with other structural management systems of the enterprise (Table 1). The analysis showed that the resource management system is the most comprehensive in terms of scope, covering the entire life cycle from the design stage to product disposal,

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and directly influences product safety through OEKO-TEX 100 and REACH requirements.

Table 1

Comparative analysis of resource management and other management systems

Comparison criteria	Resource management system	Production operations management	Financial management system	International quality management
Object of management	Integration of all resources (material, human, technical, time, information)	Only technological processes and sewing-line flow in the shops	Cash flows, profit, costs, investments	Compliance of processes with international standard requirements
Main goal	Guaranteeing quality stability and safety with minimal resource use	Meeting the planned production output within the set deadline	Maximizing financial stability and net profit	Ensuring consumer satisfaction and eliminating defects
Scope of coverage	Widest: covers the whole chain from design to disposal	Local: from fabric cutting to the finished product	Local: only financial transactions	Broad: organizational processes and quality policy
Impact on product safety	Direct: controlled through OEKO-TEX 100 and REACH filters	Indirect: only addresses mechanical (size, seam) quality	No impact, only finances the safety-related costs	Indirect: requires safety-control processes

Comparative analysis shows that resource management acts as a "provider" for all other management systems: if material and human resources are not managed systematically, operational production management cannot fulfill its plans, resulting in increased waiting times and the number of defects, while the financial system faces a crisis due to frozen capital.

Statistical data on the coverage of the main international certificates used by light and textile industry enterprises to increase export potential and the number of certified enterprises have been systematized (Table 2).

Tabel 2

Geographical coverage of international management system certificates and number of certified organizations

Comparison criteria	Resource management system	Production operations management	Financial management system
Object of management	Integration of all resources (material, human, technical, time, information)	Only technological processes and sewing-line flow in the shops	Cash flows, profit, costs, investments
Main goal	Guaranteeing quality stability and safety with minimal resource use	Meeting the planned production output within the set deadline	Maximizing financial stability and net profit
Scope of coverage	Widest: covers the whole chain from design to disposal	Local: from fabric cutting to the finished product	Local: only financial transactions
Impact on product safety	Direct: controlled through OEKO-TEX 100 and REACH filters	Indirect: only addresses mechanical (size, seam) quality	No impact, only finances the safety-related costs

Source analysis shows that the concept of resource management has passed through four main historical stages. In the 1910s–1940s, F. Taylor, G. Gantt, and L. Gilbreth ushered in the era of "scientific management and standardization"- during this period, resource management was primarily interpreted as the optimization of working time and human actions (Gantt diagram). In the 1950s–1970s, W. Schuhart, E. Deming, and J. Juran developed systems for statistical quality control (SPC) and material requirements planning (MRP). In the 1980s–2000s, with the development of T. Ono (Toyota's system) and the ERP concept, a lean manufacturing philosophy was formed, where the main goal was to eliminate any waste rather than simply managing resources. Today, the resource chain is managed in real-time through cloud ERP and PLM systems, Computer Vision, and IoT sensors (Table 3) [9-10]

Table 3

Comparative analysis of the historical and modern state of resource management

Comparison criterion	Traditional resource management (late 20th century)	Modern resource management (current state)
Management method	Local, separate for each shop or department (isolated)	Integrated, across the entire supply chain
Data exchange	Periodic, in the form of paper or archived reports	Rapid, in real time, digital
Optimization factor	Only reducing volume and financial costs	Cost reduction plus chemical-ecological safety guarantee
Technological foundation	Mechanized equipment and human labor	Industry 4.0, artificial intelligence, IoT, cloud systems

The modern resource management system relies on a combination of three scientific approaches: a systems approach (where all resources are managed as a holistic system covering all stages of the product lifecycle), a process approach (the "input → process → output" chain in accordance with ISO 9001:2015 requirements), and a risk-based approach (Risk-based Thinking - anticipating risks such as supply disruptions or the influx of low-quality raw materials). Based on these approaches, three core principles are formed: eco-efficiency and safety sustainability (priority of OEKO-TEX 100 and REACH requirements), systematic waste reduction (efficient production methods), and continuous development and the Kaizen philosophy [11].

Enterprise resources are traditionally divided into five groups: material resources (raw materials, yarn, fabric, fittings, chemical dyes - controlled by ISO 9001 and OEKO-TEX standards), technological and technical resources (production equipment, sewing machines, buildings), human resources (staff, technologists, qualification of quality controllers - regulated by clause 7.1.2 of ISO 9001), financial resources (cash, investments, working capital), and information-digital resources (management programs, technical documentation, standards base) [12].

When developing a resource management system for garment and knitwear enterprises based on international standards, ISO 9001 (for process and management quality) and OEKO-TEX Standard 100 (for raw material and product safety) are complementary but conceptually different standards. Paragraph 7.1 of ISO 9001 requires the systematic distribution of material, human, and technical resources at the enterprise, while OEKO-TEX Standard 100 monitors the absence of more than 1,000 chemicals harmful to human health (formaldehyde, heavy metals, prohibited azo dyes) in these resources (Table 4).

Table 4

Comparative analysis of SO 9001:2015 and OEKO-TEX Standard 100 standards

Comparison criteria	ISO 9001:2015 Standard	OEKO-TEX Standard 100 System
Main object of resource management	Processes and management system: how resources are planned and allocated	Product composition: limits the amount of over 1,000 chemical substances and harmful elements
Approach to material resources	Focuses on the raw material's technical characteristics, dimensions, and quality stability	Examines the raw material's effect on human health and its ecological purity
Technical-technological resources	Requires managing the overall productivity of equipment	Controls residues of chemical agents (oils, dyes) used in equipment from transferring onto the fabric
Resource audit method	Document analysis, internal audits, observation of organizational processes	Rigorous laboratory analyses (pH level, heavy metals, formaldehyde content)

An analysis of the experience of leading international corporations in resource management revealed four main directions. The Zara (Inditex) experience - using cloud ERP and PLM systems, reduced the period from design to store shelf from 6 months to 2-3 weeks, reducing overproduction volume to almost 0%. Toyota's experience - through Just-in-Time and 5S systems, each worker is empowered to identify resource waste; when a defect is detected on the line, the process is halted and the problem is eliminated at its root. Nike and H&M's experience - 100% aligning the supply chain with OEKO-TEX Standard 100 and REACH requirements, recycling used fabric waste into the life cycle as a secondary resource (fibre-to-fibre) based on the principle of a circular economy.

As a result of applying this integrated approach, the following changes are observed in the enterprise's key quality indicators (Table 5).

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Table 5

Comparative effectiveness of implementing the integrated resource management system

Controlled resource / quality criterion	In the traditional management system	In the ISO/Lean integrated system	Result achieved
First Pass Yield (FPY)	85–87%	95–97%	Rework costs and time losses are minimized
Material Utilization Rate (MUR)	78–82%	88–92%	Raw material is saved, unit cost decreases by 2.5–3%
Overall Equipment Effectiveness (OEE)	60–65%	80–85%	Equipment downtime is reduced by 40%
Export safety guarantee (REACH/OEKO-TEX)	Uncontrolled, high risk	100% guaranteed	Direct export contracts secured with international brands

Discussion

The results obtained show that the resource management system serves as the foundation for all other management systems of a garment and knitwear enterprise (operational production management, financial management, quality management), but in practice, these systems often operate in isolation from one another. In particular, the traditional production system seeks to ensure quality and safety at the final control stage, which leads to human error ranging from 30 to 40%. Conversely, integrating Schuhart control cards, IQ statistical sampling, and Computer Vision technologies into the process can reduce the number of defects caused by the human factor by up to 95%.

Analysis of international experience (Zara, Toyota, Nike, H&M) has confirmed that the highest efficiency of resource management is manifested in integrating not just one standard or methodology, but several approaches - rapid information exchange (Zara model), lean manufacturing (Toyota model), and environmental and chemical compliance (Nike/H&M model) - into a single system. For Uzbek garment and knitwear enterprises, adapting this experience is an important strategic opportunity, especially given the geographical proximity to the European market (near-shoring advantage) and the presence of a national raw material base for cotton and yarn [13]

At the same time, the analysis showed that there are a number of scientific, practical, technical and methodological gaps in the field. From a scientific perspective, a localized model combining the ISO 9001, ISO 14001, and OEKO-TEX Standard 100 systems within a unified resource management concept, as well as multi-factor statistical models for predicting defects, has not been sufficiently developed. In practical terms, many local enterprises are issuing ISO certificates only formally to meet export requirements rather than as a real optimization tool, which reduces the level of traceability in the supply chain. From a technical perspective, the problem of the level of utilization of real-time monitoring systems based on artificial intelligence and IoT, as well as the weakness of the laboratory base, remains. Methodologically, the standards for fabric consumption and working time are outdated and do not fully account for the characteristics of modern stretchable knitwear, while modern methods for assessing employee competence have not been implemented in practice [14]

Global trends - the intensification of near-shoring processes due to digitalization and artificial intelligence (Industry 4.0), the Digital Product Passport (DPP), environmental bans (complete prohibition of PFAS/PFHxA substances), and logistical risks - are further strengthening the need for integrated scientific models aimed at addressing these gaps.

4. Conclusion

As a result of the analysis, the following conclusions were drawn. Firstly, the resource management system is the most comprehensive management system for a garment and knitwear enterprise, covering all stages of the product life cycle and directly affecting product safety. Second, the concept of resource management has historically undergone a four-stage evolution, from work time standardization to digital management at the level of today's Industry 4.0. Thirdly, modern resource management relies on a combination of systemic, process, and risk-based approaches and is implemented based on a four-phase functional model consisting of planning, mobilization, monitoring, and optimization. Fourth, ISO 9001:2015 and OEKO-TEX Standard 100 standards play a complementary role in resource management - one ensures process quality, while the other guarantees the chemical safety of the product. Fifth, implementing the experience of international corporations as an integrated system will increase the FPY indicator to 95–97%, the MUR indicator to 88–92%, and reduce equipment downtime to 40%.

At the same time, the development of a localized resource management model in harmony with ISO/OEKO-TEX standards and digital algorithms (AI/SPC) for garment and knitwear enterprises in Uzbekistan, increasing the transparency of the supply chain, updating the modern regulatory and methodological framework, and implementing a scientifically grounded methodology for assessing employee competence have been identified as promising areas of research.

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CONTEXT / MUNDARIJA

T. Alimov, J. Shukurov, Y. Ergashev, N. Abdujabarov
*An integrated framework for multidisciplinary design optimization of unmanned aerial vehicles……..**61***

E. Khujamkulov
*Digital national microprocessor-based semi-automatic interlocking system for improving the throughput capacity of Uzbekistan Railways……..**67***

O. Mukhitdinov, S. Khudaykulov, D. Kaniev
*Energy equations of a channel suspension-carrying flow with full account for the work of interphase interaction forces……..**71***

Mu Zhendi
*Network diagnosis and governance-coupled optimization in seaport–dry port multimodal transport corridors under the maritime Silk Road……**78***

N. Sotivoldieva
*Scientific and theoretical foundations of resource management in ensuring product quality and safety at light industry (sewing and knitting) enterprises……**87***