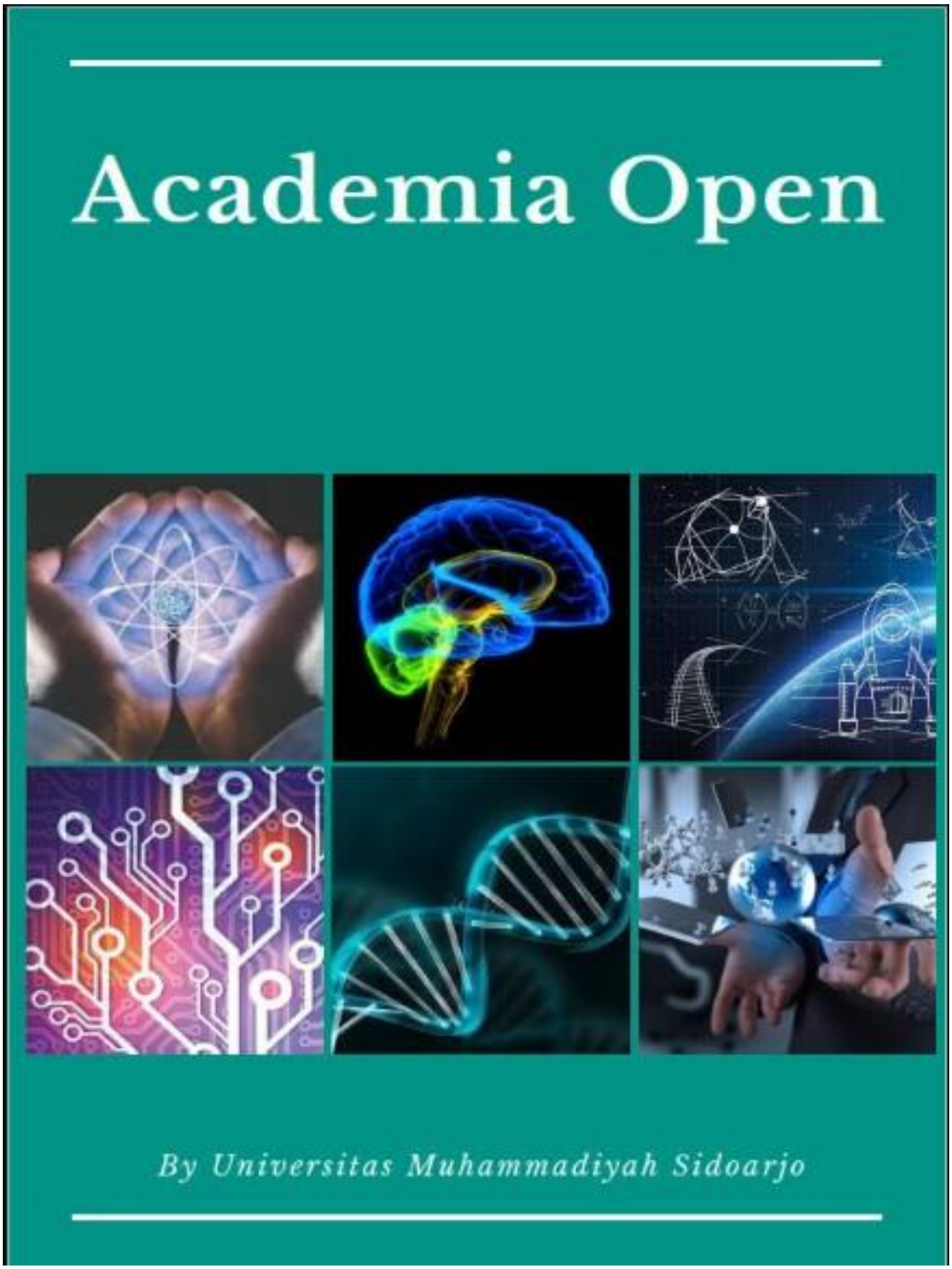
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Integrated Assessment Model for Quality and Safety Resources at A Textile Enterprise

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Abstract

General Background Consistently maintaining product conformity and safety within fabric manufacturing requires the systematic, coordinated governance of personnel, raw materials, equipment, and tracking systems. **Specific Background** Although ISO 9001 frameworks and defect-control programs are widely utilized, manufacturing facilities traditionally monitor human, material, technological, and informational inputs through disparate and disconnected metrics rather than evaluating their combined systemic status. **Knowledge Gap** Current literature extensively covers quality governance frameworks and blockchain-based tracking; however, the integrated evaluation of these four interconnected operational dimensions into a single operationalized dynamic index remains unaddressed for fabric enterprises. **Aims** This study develops and applies a transparent dynamic framework integrating 27 condition proxies across 36 months of operational data to monitor enterprise health and prioritize administrative interventions. **Results** Utilizing expert-assigned weights for normalization and aggregation, the total overall score demonstrated a marked increase from 0.09 in the first month to 0.97 by month 36. This upward trend indicates measurable improvements across the targeted dimensions—human capital, materialinputs, technicalstability, and information tracking—providing clear operational, tactical, and strategic decision thresholds for administrators. **Novelty** This framework introduces a structured, single-metric monitoring scheme combining previously isolated categories, enabling rapid identification of specific operational weaknesses in fabric manufacturing. **Implications** Plant supervisors can utilize this dynamic index to swiftly detect input deficiencies and target specific interventions, though the metric serves as a systemic health proxy rather than a direct measure of actual product safety outcomes.

Highlights:

- Integrating 27 initial operational metrics generates a unified dynamic index to monitor enterprise health and supply allocation.
- Over a 36-month observation period, the aggregated overall score rose from 0.09 to 0.97, reflecting broad systemic improvements.
- The integrated framework successfully pinpoints departmental weaknesses, enabling targeted operational, tactical, and strategic administrative responses.

Keywords: Composite Indicator, Textile Enterprise, Resource Management, Traceability, Quality Management

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I. Introduction

Ensuring product quality and safety in textile manufacturing requires the coordinated management of personnel, input materials, equipment, and information. Recent studies describe quality management practices in textile production [1], review their links to operational performance [2], identify critical manufacturing quality factors [3], and demonstrate improvements from structured defect-control programmes [4]. ISO 9001:2015 establishes a systematic framework for managing processes and product conformity [5]. However, these resource groups are commonly monitored using separate indicators.

Traceability links production batches with raw materials and processing records, enabling better identification of nonconformities [6]. Research has considered blockchain-based traceability and authentication [7], assessed its implications for sustainable fashion supply chains [8], and investigated practical implementation barriers in apparel procurement [9]. These studies motivate the inclusion of information and traceability within an integrated monitoring approach.

Risk-based thinking encourages the integrated evaluation of operational weaknesses [10], while Quality 4.0 emphasizes relationships among people, processes, and technology [11]. Composite-indicator research also shows that normalization, weighting, and aggregation affect the interpretation of performance [12], [13], [14]. However, the combined monitoring of personnel, raw materials, equipment, and traceability at the level of a textile enterprise remains insufficiently operationalized in the cited literature.

The aim of this study is to apply a transparent dynamic resource-assessment model to 36 months of textile-enterprise operational data. The model integrates 27 initial indicators into four resource groups and calculates a total weighted index. The results are intended to support identification of weaker groups and prioritization of management measures. The model evaluates resource-condition proxies; it does not directly measure product-safety incidents or establish a causal effect of the proposed management actions.

The study contributes a single monitoring scheme combining human, raw-material and chemical, technical-technological, and information-traceability resources, with corresponding period-by-period estimates and decision thresholds.

II. Method

The study utilized 36 months of production data from the textile enterprise. The data were divided into four main groups representing human resources, raw material and chemical resources, technical and technological resources, and information and observation resources. Based on the initial indicators X_1-X_27, relative indicators were formed, which were normalized according to positive and negative directions, and weighting coefficients were established based on expert assessments. At the first stage of calculations, a 36-month initial database characterizing the enterprise's activities is formed. These data are divided into four main resource groups: Q1 – human resources, Q2 – raw material and chemical resources, Q3 – technical and technological resources, and Q4 – information and observation resources. Data for each group is placed in separate columns, and their logical interconnection is maintained.

Recent applications of industrial textile inspection show the importance of systematic monitoring and defect analysis [15], [16]. The proposed index is intended as an interpretable monitoring summary rather than a substitute for product-level inspection.

Table 1. Initial resource indicators (selected months, X1–X27).

Month	Q1 - Human resources							
M	**X1**	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**
1	943	218	3,5	10	74	0,84	18200	22
2	945	218	3,5	10	73	0,83	18750	20
3	941	218	3,4	10	75	0,85	19100	20
4	944	218	3,5	10	74	0,84	18600	18
5	947	218	3,5	10	76	0,86	19350	20
6	946	218	3,5	10	75	0,85	19000	20
7	948	228	3,6	12	76	0,86	19600	19
8	944	228	3,5	12	74	0,83	18850	20
….	—	—	—	—	—	—	—	—
9	950	228	3,6	12	77	0,87	20100	22
33	963	305	4	22	82	0,97	23450	11
34	964	305	4	22	83	0,97	23800	10
35	965	305	4	22	83	0,97	24100	9
36	965	305	4	22	85	0,97	24300	10

Month	Q2 - Raw materials and chemicals							
M	**X9**	**X10**	**X11**	**X12**	**X13**	**X14**	**X15**	**X16**
1	10	7	30	28	8	5	3	600
2	10	7	28	27	8	5	3	600
3	11	8	32	31	8	5	2	600
4	11	8	32	30	9	6	3	600
5	11	8	30	30	9	6	3	600
6	12	9	32	31	9	6	3	600

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Month	Q2 - Raw materials and chemicals							
M	X9	X10	X11	X12	X13	X14	X15	X16
7	12	9	30	30	9	6	3	600
8	12	9	31	28	10	7	4	600
….	—	—	—	—	—	—	—	—
9	13	10	32	31	10	7	3	600
33	18	17	43	42	15	14	1	700
34	18	17	42	42	15	14	1	700
35	18	17	42	41	15	14	1	700
36	18	18	40	40	15	15	1	700

Month	Q3 - Technical and technological resources							
M	X17	X18	X19	X20	X21	X22	X23	X24
1	555	28	22	555	500	16800	68	22
2	558	30	23	558	556	16600	70	28
3	560	29	23	560	558	17000	65	25
4	560	31	24	560	558	16900	67	25
5	575	30	24	575	572	17200	58	25
6	575	32	25	575	572	17000	55	27
7	575	31	25	575	573	17300	54	27
8	580	30	23	580	578	16700	55	28
….	—	—	—	—	—	—	—	—
9	580	32	26	580	577	17500	54	29
33	698	39	38	698	697	19000	40	38
34	698	39	39	698	697	19200	42	39
35	698	39	39	698	698	19300	40	39
36	698	40	40	698	697	19400	37	38

Month	Q4 - Information and traceability		
M	X25	X26	X27
1	20	18	15
2	27	16	16
3	24	14	16
4	23	15	17
5	24	16	18
6	25	15	17
7	26	16	18
8	25	16	18
….	—	—	—
9	27	18	20
33	35	35	34
34	37	36	36
35	39	36	37
36	37	36	36

Table 1 presents the available selected monthly values for the 27 original indicators, grouped as Q1 (human), Q2 (raw-material and chemical), Q3 (technical and technological), and Q4 (information and traceability). The source manuscript does not show values for months 10–32 in this table; consequently, omitted rows are not reconstructed here.

The original dataset comprises 36 observation periods, while the manuscript displays only representative rows of the primary indicator table. Publication of the full dataset and definitions, units, and the beneficial or adverse direction of each X indicator would improve reproducibility.

III. Results and Discussion

A. Results

The proposed integrated assessment model was applied based on 36 months of production data from the textile enterprise. Initially, relative indicators characterizing human, raw material-chemical, technical-technological, and information-observation resources were formed from 27 initial indicators. Indicators were normalized according to their positive and negative directions, and integral indices were calculated for four resource groups - Q_1, Q_2, Q_3 and Q_4 - using weighting coefficients determined based on expert assessments.

The relative indicators were normalized according to whether higher values indicate a favorable or unfavorable state. The exact normalization expressions, boundary choices, and treatment of constant indicators should be documented explicitly to enable replication [12]–[14].

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Within-group weights were obtained from expert ratings; the original calculations and individual expert scores should be made available as supplementary material. Table 2 reports the weights available in the source manuscript.

Table 2. Expert-assigned internal factor weights for the four resource groups.

Resource group	Internal factor	Weight
Q1	g1	0,178
Q1	g2	0,173
Q1	g3	0,162
Q1	g4	0,146
Q1	g5	0,168
Q1	g6	0,173
Q2	g7	0,254
Q2	g8	0,297
Q2	g9	0,246
Q2	g10	0,203
Q3	g11	0,242
Q3	g12	0,250
Q3	g13	0,258
Q3	g14	0,250
Q4	g15	0,242
Q4	g16	0,267
Q4	g17	0,233
Q4	g18	0,258

Integral index of human resources:

$$Q_{1,t} = 0.17838z_{1,t} + 0.17297z_{2,t} + 0.16216z_{3,t} + 0.14595z_{4,t} + 0.16757z_{5,t} + 0.17297z_{6,t} \quad (1)$$

Table 3. Monthly values of the human-resource index (Q1).

Month	Q1	Month	Q1
1	0,06	19	0,53
2	0,06	20	0,52
3	0,09	21	0,53
4	0,10	22	0,58
5	0,14	23	0,59
6	0,11	24	0,53
7	0,22	25	0,66
8	0,11	26	0,75
9	0,21	27	0,73
10	0,18	28	0,75
11	0,18	29	0,82
12	0,24	30	0,81
13	0,25	31	0,89
14	0,34	32	0,93
15	0,37	33	0,94
16	0,39	34	0,96
17	0,42	35	1,00
18	0,40	36	0,99

Raw materials and chemical resources index

$$Q_{2,t} = 0.25424z_{7,t} + 0.29661z_{8,t} + 0.24576z_{9,t} + 0.20339z_{10,t} \quad (2)$$

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Technical and technological resources index

$$Q_{3,t} = 0.24219z_{11,t} + 0.25000z_{12,t} + 0.25781z_{13,t} + 0.25000z_{14,t} \quad (3)$$

Information and Traceability Index

$$Q_{4,t} = 0.24167z_{15,t} + 0.26667z_{16,t} + 0.23333z_{17,t} + 0.25833z_{18,t} \quad (4)$$

The value of each integral index is in the range from 0 to 1. An index approaching 1 indicates that this resource group is in a high position, and an index approaching 0 indicates that there are resource problems.

Expert weights of resource groups

According to experimental data, the following weights were obtained based on expert assessments for groups Q1, Q2, Q3, and Q4.

Table 4. Expert ratings and group weights in the integrated model.

Expert / parameter	Q1 Human	Q2 Materials	Q3 Technology	Q4 Information
Quality management	4	5	4	3
Production head	4	4	4	3
Technologist	5	5	4	4
Laboratory	4	4	4	3
Warehouse	5	5	4	4
Digitalization / IT	4	5	4	3
Human resources	4	4	5	4
Average expert score	4,29	4,57	4,14	3,43
Group weight	0,261	0,278	0,252	0,209

As shown in Table 4, the resulting group weights were 0.261 for human resources (Q1), 0.278 for raw-material and chemical resources (Q2), 0.252 for technical and technological resources (Q3), and 0.209 for information and traceability (Q4). The four weights sum to 1.000.

For each month, the Q1-Q4 integral indices are multiplied by the group weights, and the total resource index is calculated:

$$Q_{\text{umum},t} = \begin{array}{l} 0.26087Q_{1,t} + 0.27826Q_{2,t} \\ +0.25217Q_{3,t} + 0.20870Q_{4,t} \end{array} \quad (5)$$

This formula reflects the priority influence of human resources and raw materials and chemical resources on product quality and safety. Q3 represents technical and technological stability, and Q4 represents information flows and product traceability.

As a result of 36-month calculations, the value of Q_"umum" increased from 0.09 in the initial period to 0.97 in the final period. This means that resource management indicators at the enterprise, including qualification, certification, maintenance, and traceability indicators, have improved over time.

Table 5. Reported values of the overall resource index.

Month	Q_{umum}	Month	Q_{umum}
1	0,09	19	0,66
2	0,28	20	0,72
……			
17	0,57	35	0,92
18	0,56	36	0,97

Figure 1. Dynamics of the resource indices and overall composite index over 36 months.

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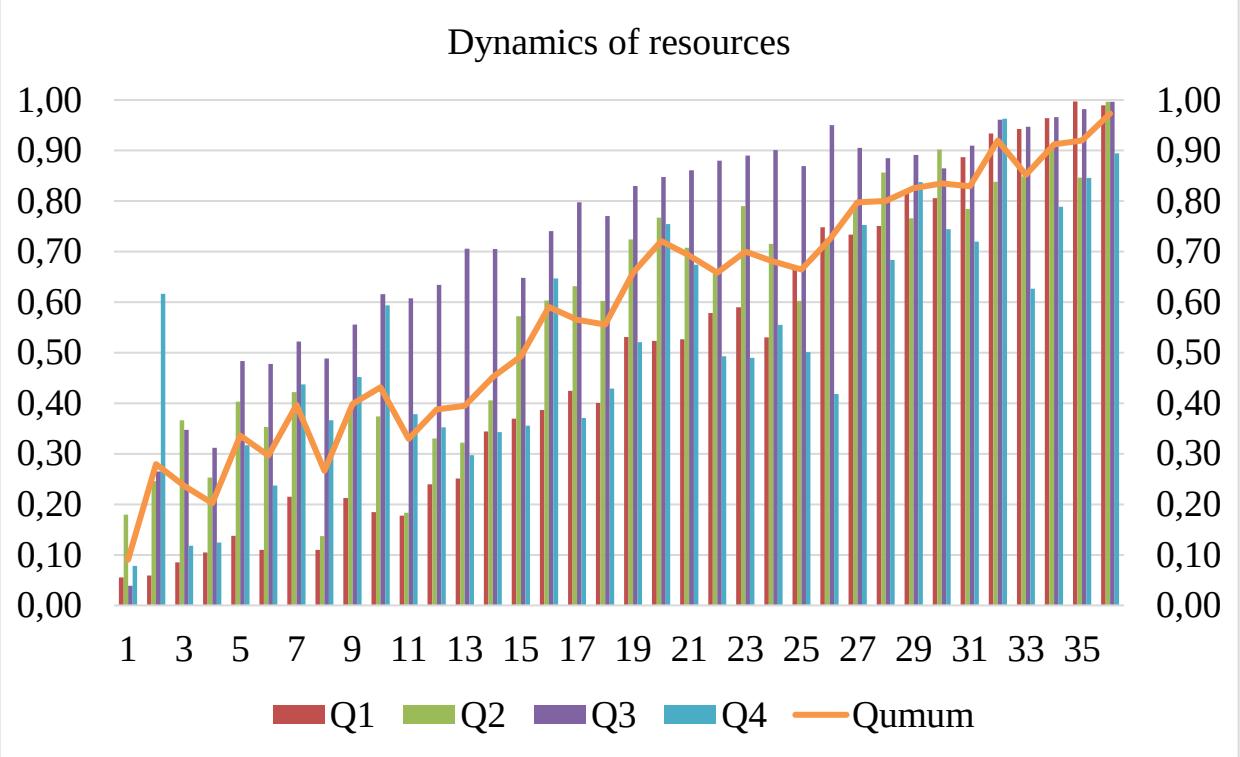


Figure 1 displays the changes in the four group indices and the composite index across the observation period. The overall score rises from approximately 0.09 at month 1 to 0.97 at month 36, although intermediate fluctuations are visible. The trend describes an association in the selected indicators and does not by itself establish the effectiveness of specific management interventions.

B. Discussion

The results obtained show that the integral resource index is of practical importance for managing product quality and safety at a textile enterprise. The increase in the total resource index from 0.09 to 0.97 during the 36-month observation period indicates positive changes in human resources, raw material and chemical supply, technical and technological stability, and information monitoring systems. This result indicates that monitoring resources not individually, but based on a single integral criterion, helps in the timely identification of problematic links in the enterprise.

The index may support decisions at multiple management levels. The following provisional bands are proposed for internal monitoring: 0.80–1.00 (maintain controls), 0.60–0.79 (targeted prevention), 0.40–0.59 (enhanced monitoring and corrective planning), and below 0.40 (urgent resource review). These cutoffs are operational proposals and have not been statistically calibrated against independent product-quality or safety outcomes.

At each level, the response should be based not only on the composite index but also on the weakest resource group and its underlying indicators. Any future deployment should validate the cutoffs against defect, downtime, or incident outcomes.

Priority actions by resource group can include the following:

When Q1 is low, review personnel training, competency assessment, and process discipline.

When Q2 is low, strengthen incoming-material inspection, certification, and nonconforming-batch controls.

When Q3 is low, review maintenance scheduling, equipment adjustment, and unscheduled downtime.

When Q4 is low, improve batch coding, documentation, and end-to-end traceability.

Equipment interventions can be prioritized using maintenance evidence from textile production, including prescriptive maintenance approaches [17] and total productive maintenance assessments in dyeing operations [18].

It is advisable to divide management decisions into three levels:

Operational decisions - measures to be implemented within a period of up to 1 month; for example, restoring access control discipline, terminating problematic batches, and providing immediate instructions to reduce operator errors.

Tactical decisions - medium-term measures implemented within 3-6 months; for example, personnel retraining, revision of the maintenance plan, standardization of the documentation system.

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Strategic decisions - systemic measures designed for a period of 1 year or more; for example, digitalization, modernization of equipment, improvement of the quality management system, transfer of traceability to a fully electronic system.

The main advantage of this approach is that a management decision does not remain a mere general recommendation but rather becomes a system of comprehensive measures linked to a specific resource group, specific indicators, and specific deadlines. As a result, the integrated assessment algorithm serves not just as a simple analytical tool for enterprise management, but as a practical management mechanism for ensuring quality and safety.

IV. Conclusion

The study utilized an integral index model for a comprehensive assessment of human, raw material-chemical, technical-technological, and information-observation resources affecting product quality and safety at a textile enterprise. Based on 36-month data, indicators X_1-X_27were normalized, and resource indices Q_1-Q_4and the total Q_"umum" index were determined using expert weights.

Calculations showed an increase in the total resource index from 0.09 to 0.97. The proposed model allows for the identification of weak links in resources, the monitoring of factors affecting quality and safety, and the justification of operational, tactical, and strategic management decisions.

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