Section 3.3. Model of Integration of Loyalty Assessment Results into the Threat Management System of the Economic Security of an Industrial Enterprise

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Abstract. *Industrial enterprises operate under growing uncertainty, where human factor risks interact with technological, financial and information vulnerabilities. The paper proposes a sociotechnical model that embeds personnel loyalty into the threat management system of economic security, treating loyalty as a leading indicator that precedes changes in key risk and performance metrics. The objective is to develop and formalize an integrated model that connects loyalty assessment results with process, financial and risk indicators in order to quantify the impact of loyalty dynamics on the integral economic security index of an industrial enterprise and to support anticipatory managerial decisions. The model combines a five layer conceptual framework, an integral loyalty index L with affective, normative, instrumental and behavioral components, and an integral economic security index S constructed from normalized financial, operational, safety, compliance and information security indicators. The mathematical mechanism uses transfer functions, elasticities, regression based estimation on panel data with control variables, robustness checks and scenario calculations that translate changes in L into shifts in S. Implementation follows a staged procedure of diagnosis, design, piloting, scaling and institutionalization with strict ethical and data governance requirements. The model demonstrates that loyalty can be treated as a quantitatively specified risk factor rather than a purely qualitative construct. Formal links between L and S show that increased loyalty is typically associated with lower incident rates, reduced turnover, improved process stability and higher operating margins. The approach yields an aggregated sensitivity parameter β that allows estimation of the expected change in S under given loyalty scenarios, including saturation effects at high security levels. The model is operationalized through dashboards, risk registers, escalation thresholds and targeted interventions at shop floor and corporate levels. The model forms a reproducible management contour that connects validated loyalty measurements with hard performance metrics, closes the loop from monitoring to action and learning, and strengthens the resilience and economic security of industrial enterprises under high uncertainty. Future work should test the model across sectors and countries, refine causal identification strategies, explore nonlinear and machine learning based transfer functions, integrate real time digital traces of behavior, and examine interactions between loyalty, leadership style and organizational culture in shaping economic security trajectories.*

Keywords: *personnel loyalty index; economic security; industrial enterprise; risk management; transfer function; resilience; occupational safety; information security; human factor risk; performance indicators; scenario modelling; loyalty assessment.*

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1. Theoretical premise for the development of the Model. The proposed model of integration of personnel loyalty assessment results into the threat management system of the economic security of an industrial enterprise (hereinafter the Model) is presented as a holistic sociotechnical construct that transforms data on employees' attitudes, their behavioral patterns and interaction practices into manageable managerial impacts.

In the proposed Model, loyalty is interpreted as a multidimensional characteristic of commitment to the organization with affective, normative and instrumental dimensions, which is manifested in compliance with technological discipline, occupational safety, stability of productivity, readiness for training and participation in process improvement. Employee loyalty influences productivity, quality, occupational safety, compliance with procedures, discipline of costs, preservation of competencies and the risk of events caused by the human factor. Therefore, its measurement and managed embedding into the risk management contour is the key to reducing operational losses and increasing resilience.

Economic security in this Model is understood as the state and capacity of the enterprise to detect, prevent and neutralize destabilizing factors in a timely manner without critical loss of value, controllability and operational stability.

The theoretical premise of the Model consists in recognizing loyalty as a leading indicator that precedes changes in key risk indicators, operational coefficients and financial results and therefore can serve as a basis for anticipatory threat management.

Based on the results of the conducted study, the theoretical and methodological foundations for the integration of the human factor into the contour of economic security of an industrial enterprise have been clarified, taking into account the requirements of modern risk management and resilience oriented logic.

The purpose of the developed Model is conceptually and operationally to combine the assessment of personnel loyalty with quantitative and qualitative security indicators in order to reduce the time lag between the emergence of weak signals and managerial intervention. The structure is built around three provisions, each of which has its own scope of application and a set of verifiable indicators.

First, personnel loyalty is proposed to be understood as a multidimensional commitment to the organization with clearly separated but interrelated dimensions: affective, normative and instrumental. The affective dimension reflects the emotional acceptance of values and social identification with the team, which is manifested in voluntary participation

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in improvement initiatives and in the positive tone of internal communications. The normative dimension captures the sense of obligation to follow rules and maintain quality and safety standards, which is specified by the stability of procedural compliance and the readiness to take shifts during peak periods. The instrumental dimension reflects a rational evaluation of the balance of benefits and costs of employment, which is manifested in the willingness to renew the contract, in a decrease in the search for alternative vacancies and in pragmatic support for changes if they improve working conditions. To move from concept to operationalization, these three dimensions are represented by indicators of two types. The first type covers self assessment scales and short survey waves that provide sensitivity to mood shifts. The second type includes observable behavioral indicators, in particular turnover, absenteeism, timeliness of safety briefings, participation in training, frequency of violations of technological regulations and the share of rationalization proposals that have passed validation. The dimensions are combined into a composite through normalization to an interval from zero to one, verification of the internal consistency of indicators and weighting according to criteria of reliability and strategic relevance for a particular technological system. Such a construction minimizes method biases and ensures a balanced reflection of both attitudes and actual behavior.

Second, the economic security of an industrial enterprise is considered as an integrated index of the state and capacity of the system to maintain target parameters in five domains that are important for value creation. The quantitative contour includes cash flows, profitability and liquidity, which record financial stability in the short and medium term horizons. The process contour includes continuity of operations, efficiency of equipment use, inventory turnover and discipline of schedule execution, which reproduce technological controllability and the capacity to counteract disruptions. The production and technological contour includes compliance with quality standards and occupational safety standards, which directly affect the risk of incidents and rework costs. The information contour includes data protection and the register of event related access violations, which determine resilience to cyber threats and social engineering. The managerial and compliance contour includes the status of audit reservations, the presence of credit covenant triggers and the results of control inspections. Indicators in each domain undergo a unified procedure of normalization, validation and weighting, taking into account sectoral specifics, after which they are aggregated into a final indicator with an interpretation scale that reflects changes in the managerial regime when crossing key thresholds. Such an

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integral construction does not reduce security to financial ratios but combines financial, operational and organizational properties of the system, which makes it sensitive to early deviations.

Third, the integration of loyalty into the management of threats to economic security is carried out within the logic of enterprise risk management with a full cycle from context to monitoring. At the context setting stage, strategic goals, process maps and critical roles are defined for which loyalty has the greatest impact on operational results. At the risk identification stage, a list of threats from personnel that are modulated by the level of loyalty is formed, in particular procedural violations, production incidents with a human factor, information leaks and failure to close shifts. At the analysis stage, a causal chain is established from changes in the loyalty index to key risk indicators in the process and financial contours, and local elasticities are determined that reflect the sensitivity of each indicator to behavioral shifts. At the risk assessment stage, the results are integrated into a risk map with thresholds for escalation and a typology of response scenarios. At the response stage, interventions are chosen that have the highest marginal return in view of bottlenecks, in particular the adjustment of shift schedules, retention of critical competencies, strengthening of occupational safety standards and targeted development programs for managers. At the monitoring and communication stage, a rhythm of short measurement waves is introduced, the frequency of dashboard updates is agreed and the rules of “closing the loop” are fixed, which require the transformation of deviation signals into specific actions with defined deadlines and responsible persons. In this architecture, loyalty performs the role of a leading indicator for the subsystems of operational, personnel, technological and compliance risk and thereby reduces the time lag between the appearance of a weak signal and managerial intervention. This approach strengthens the predictive capacity of the security contour and increases the resilience of the enterprise under conditions of high uncertainty.

2. Conceptual framework of the Model. The conceptual framework of the Model has five interconnected layers that form a continuous cycle from data to decisions (Figure 3.1).

The first layer is responsible for the collection and unification of data on loyalty from surveys, short "pulse" waves, interviews, turnover and absenteeism metrics, participation in training, assessment results, internal support tickets and feedback. The data are normalized to a scale from zero to one, the internal consistency of the instruments and the stability of the scales between waves are checked.

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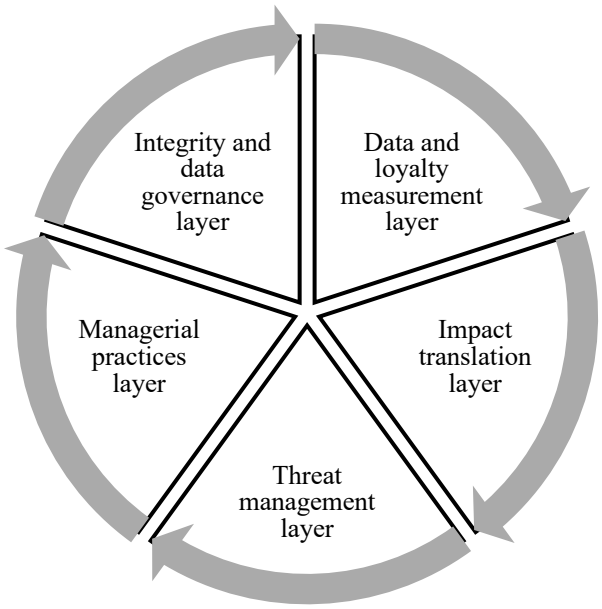


Fig. 3.17. Five interconnected layers of the conceptual framework of the Model for integrating the results of loyalty assessment into the threat management system of the economic security of an industrial enterprise

Source: developed by the author

The second layer defines the mechanism for transferring the impact of loyalty into key performance indicators. For each indicator, elasticity with respect to changes in loyalty is determined, the indicators are transformed into normalized components of the security index with transparent weights, and normalization coefficients are stored for reproducibility.

The third layer implements threat management through a register of personnel related risks, risk maps, key risk indicators and escalation triggers based on threshold values of the integral index.

The fourth layer focuses on managerial practices and includes plans for retaining critical competencies, changes in shift work regimes, safety protocols, communication standards and targeted training programs for managers.

The fifth layer ensures the ethics and quality of data through consent policies, anonymization, role based access, indicator passports, audit logs and quality control.

Loyalty is measured through an integral indicator L, which aggregates three subindices of commitment and a block of behavioral signals. The affective component reflects the emotional acceptance of organizational values and the team, the normative component captures the sense of

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obligation to stay and support standards, the instrumental component represents the rational benefits of cooperation with the employer. Behavioral signals include stability of attendance, the share of participation in training, timeliness of occupational safety briefings, the frequency of submitting rationalization proposals and indicators of disciplinary incidents. For each block, weights are set that are determined on the basis of the reliability of the indicators and their strategic relevance for the specific technological structure of the enterprise. The resulting index is interpreted on a scale from low to high loyalty using control points that are established based on the results of retrospective analysis and mark changes in the managerial regime.

Personnel loyalty index and its relationship with economic security. The personnel loyalty index is considered as a latent multidimensional characteristic that reflects employees' readiness to remain in the organization, support its goals and comply with established norms of behavior under conditions of increased uncertainty. Within the Model it is denoted as L and belongs to the interval from 0 to 1, where values close to 0 correspond to low loyalty and values close to 1 correspond to high, stable loyalty. Conceptually, the index L is formed on the basis of three subindices: affective loyalty, normative loyalty and instrumental loyalty, which makes it possible to link the subjective attitudes of employees with their actual behavior and the subsequent impact on economic security risks.

The basic representation of the loyalty index is specified as a weighted linear composition:

$$L = w_a L_a + w_n L_n + w_i L_i, \qquad (3.13)$$

where L_a is affective loyalty (emotional commitment to the enterprise), L_n is normative loyalty (a sense of obligation and moral duty to remain in the organization), and L_i is instrumental loyalty (a rational assessment of the benefits and losses from continuing to work at the enterprise).

The weight coefficients w_a, w_n, w_i belong to the interval from 0 to 1 and satisfy the condition $w_a + w_n + w_i = 1$. Their values are determined either by experts or by calibration on historical data, proceeding from which components of loyalty are the most significant for a particular type of industrial enterprise.

Each subindex is formed on the basis of a system of primary indicators obtained from several groups of sources. For affective loyalty, the key ones are the results of anonymous employee surveys, in particular the average score on the scale of attitude to the employer, willingness to recommend the enterprise as a place of work, and subjective pride in belonging to the company. For example, the affective subindex can be calculated as:

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$$L_a = \frac{\bar{S}_{af}-1}{5-1}, \qquad (3.14)$$

where $\bar{S}_{af}$ is the average score for a set of affective statements on a five point Likert scale, 1 is the minimum possible value and 5 is the maximum possible value. In this way the affective component is converted to a normalized scale from 0 to 1.

Normative loyalty L_n is based on indicators that characterize the sense of obligation to remain in the organization, in particular agreement with statements such as "I feel a moral obligation to stay in this enterprise", "it would be wrong to leave the company under the current conditions", as well as behavioral markers of length of service in the enterprise. Normalization can take the following form:

$$L_n = \alpha_1 \frac{\bar{S}_{nor}-1}{5-1} + \alpha_2 \frac{T_{stazh}}{T_{max}}, \qquad (3.15)$$

where $\bar{S}_{nor}$ is the average score for normative statements, T_{stazh} is the employee's actual length of service in years, T_{max} is the chosen upper threshold of tenure (for example, 10 years), and α_1 and α_2 are weight coefficients that reconcile the contribution of survey based and tenure based indicators. If the length of service exceeds T_{max}, the value of the fraction is fixed at 1.

Instrumental loyalty L_i reflects the employee's rational assessment of the material and non material benefits of remaining in the organization. It is based on self assessment of satisfaction with wages, the social package, working conditions, opportunities for reservation from mobilization, as well as data on employees' behavior in the labor market. In a simplified form:

$$L_i = \beta_1 \frac{\bar{S}_{comp}-1}{5-1} + \beta_2 \left(1 - \frac{R_{zvil,dobrov}}{R_{etalon}}\right), \qquad (3.16)$$

where $\bar{S}_{comp}$ is the average score of satisfaction with compensation and benefits, $R_{zvil,dobrov}$ is the annual rate of voluntary resignations, and R_{etalon} is the reference (critical) turnover rate for the industry.

If the actual turnover exceeds the reference threshold, the corresponding fraction is limited to a zero value. In this way, employees' subjective assessments are combined with objective statistics on staff retention.

To ensure transparency of calculations, the primary data for forming the index L are structured in the form of a single source table. Table 1 presents an example of a list of typical indicators, their symbols, units of measurement and sources.

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Table 3.5. Main primary indicators for calculating the personnel loyalty index

Loyalty block	Indicator	Designation	Unit of measurement	Data source	Collection frequency
Affective loyalty	Average score of agreement with the statement "I am proud to work for this company"	S_(1,"af")	score on a scale of 1 to 5	Anonymous online employee survey	once a year, more often if necessary
Affective loyalty	Willingness to recommend the company as a place to work (eNPS or similar)	S_(2,"af")	score or index from 0 to 10	Survey, eNPS module in HRM system	once a year
Normative loyalty	Aggregate score for statements about the moral obligation to stay in the organization	S_"nor"	score from 1 to 5	Employee survey	once a year
Normative loyalty	Employee's length of service in the company	T_"stag"	years	Personnel accounting data, HRM system	monthly update
Instrumental loyalty	Average score of satisfaction with salary and social package	S_"comp"	score from 1 to 5	Survey, satisfaction module	once a year
Instrumental loyalty	Level of voluntary layoffs	R_"leave,goods"	percentage of average headcount	HR and accounting reporting	quarterly
Instrumental loyalty	Share of employees who have the opportunity to officially reserve from mobilization	P_"book"	share from 0 to 1	HRM system, legal department	quarterly
Behavioral component	Level of unplanned absences (excluding sick leave and vacations)	A_"unpaid"	days per employee	Timesheet system, HRM	monthly update
Behavioral component	Number of internal complaints and appeals regarding working conditions per 100 employees	C_"skar"	number per 100 people	Feedback channels, HRM	quarterly

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All primary indicators are converted into normalized variables in the range from 0 to 1. For survey scales, linear normalization is used according to the formula:

$$z = \frac{x - x_{\min}}{x_{\max} - x_{\min}}, \qquad (3.17)$$

where x is the actual average score, x_min and x_max are the scale limits (e.g., 1 and 5).

For indicators where more means worse (layoff rate, unplanned absences, number of complaints), the inversion is applied:

$$z = 1 - \frac{x - x_{\min}}{x_{\max} - x_{\min}}, \qquad (3.18)$$

which ensures a single interpretation: the higher the normalized indicator, the higher the expected contribution to loyalty. After normalization, for each block the mean or weighted mean value is calculated, which serves as the corresponding subindex L_a, L_n, L_i.

The relationship between loyalty and economic security in the Model is specified through the integral economic security index S, which is also normalized on the interval from 0 to 1. In general form:

$$S = 0{,}70S_{\text{quant}} + 0{,}30S_{\text{qual}}, \qquad (3.19)$$

where S_{quant} is the aggregated block of financial and process indicators (liquidity, profitability, operating costs, inventory turnover, indicators of production continuity), and S_{qual} is the block of qualitative indicators (presence of audit reservations, number of significant occupational safety incidents, legal disputes, credit covenant triggers, quality of information security).

In this context, the loyalty index L acts as one of the key explanatory variables that affect both individual basic indicators S_{quant} and S_{qual} and the integral value S.

The formalized relationship between personnel loyalty and the integral economic security index is described through several types of indicators. First, the correlation coefficient between L and S is applied, which in the simplest form is calculated as

$$r_{LS} = \frac{\operatorname{cov}(L,S)}{\sigma_L \sigma_S}, \qquad (3.20)$$

where $\operatorname{cov}(L,S)$ is the covariance between the indices and σ_L and σ_S are their standard deviations. Values of r_{LS} close to 1 indicate a strong direct relationship between an increase in loyalty and a rise in the level of economic security, whereas values close to zero indicate a weak or absent linear relationship.

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Second, the elasticity of economic security with respect to loyalty is assessed on the basis of a regression model:

$$S_t = \alpha + \beta L_{t-1} + \gamma' Z_{t-1} + \varepsilon_t, \qquad (3.21)$$

where S_t is the value of the integral economic security index in period t, L_{t-1} is the loyalty index in the previous period, Z_{t-1} is the vector of control variables (external macroeconomic conditions, energy price levels, regulatory shocks, war related events), α is the intercept, β is the coefficient of sensitivity of economic security to changes in loyalty, γ is the vector of coefficients for the control variables, and ε_t is the random error term. In this model, β is interpreted as an approximate estimate of the derivative $\partial S / \partial L$, that is, as the magnitude of the change in the integral security index for a unit change in loyalty under ceteris paribus conditions.

Third, for managerial interpretations, indicators of the "difference in means" type are applied, which reflect differences in the average level of economic security between groups of enterprises with high and low loyalty. Formally, this can be written as:

$$\Delta S = \bar{S}^{\text{вис}L} - \bar{S}^{\text{низ}L}, \qquad (3.22)$$

where $\bar{S}^{\text{high } L}$ is the mean value of the economic security index for the cohort of enterprises with high values of L (for example, $L \geq 0.75$), and $\bar{S}^{\text{low } L}$ is the mean value for enterprises with low loyalty (for example, $L \leq 0.50$). A positive and statistically significant ΔS indicates that higher personnel loyalty is associated with a more favorable state of economic security. A separate group consists of event type indicators that link changes in loyalty with the probability of occurrence of adverse events in the field of security. For example, for the frequency of occupational safety incidents it is possible to estimate the regression coefficient in the model:

$$\lambda_{\text{інц}} = \delta_0 + \delta_1 L + u, \qquad (3.23)$$

where λ_{inc} is the intensity of occupational safety incidents (the number of incidents per 100 employees or per 1 million hours worked), and δ_1 is a parameter that reflects the change in the intensity of incidents when loyalty changes. A negative value of δ_1 indicates that an increase in loyalty is associated with a decrease in the frequency of incidents, that is, with an improvement in one of the key dimensions of economic security.

A summary of the main indicators of the relationship between personnel loyalty and the economic security of an industrial enterprise is presented in Table 2.

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Table 3.6. Indicators of the relationship between the loyalty index and economic security

Indicator type	Formalized definition	What measures	Management interpretation
Correlation between loyalty and security	$r_{LS} = \text{cov}\,(L,S)/(\sigma_L\sigma_S)$	Strength of linear relationship between L and S	Should we expect unidirectional changes in S with changes in L
Elasticity of economic security	β з регресії $S_t = \alpha + \beta L_{t-1} + \gamma' Z_{t-1} + \varepsilon_t$	Marginal sensitivity of S to L	To what extent does increasing loyalty change the integral level of security
Difference in average levels of security	$\Delta S = \bar{S}^{\text{high}L} - \bar{S}^{\text{low}L}$	Structural differences between groups	To what extent are enterprises with high loyalty more resilient in terms of security
Event risk indicators	$\lambda_{\text{inc}} = \delta_0 + \delta_1 L + u$	Effect of L on incident rate	To what extent does increasing loyalty reduce the risk of security-threatening events

Source: developed by the author

Thus, the loyalty index L, constructed on the basis of clearly defined and normalized primary indicators, is embedded into the economic security system not only as a descriptive socio psychological parameter but as a quantitatively specified risk factor. This opens up the possibility for scenario modelling, the construction of forecasts and targeted managerial interventions aimed at the simultaneous increase of personnel loyalty and the strengthening of the integral economic security of an industrial enterprise.

Mathematical mechanism for integrating loyalty assessment results into the economic security index. The mathematical mechanism for integrating the results of personnel loyalty assessment into the economic security management system of an industrial enterprise is intended to formalize the chain "personnel loyalty - key performance indicators - integral economic security index". In other words, it is necessary to describe clearly how a change in the loyalty index L is transformed into a change in specific operational, financial and risk indicators and, through them, into a shift of the integral economic security index S. This approach provides not only descriptive analysis but also makes it possible to carry out scenario modelling and to quantify the effect of managerial interventions aimed at increasing loyalty.

System of indicators, normalization and construction of the security index. The starting element is the system of key performance and risk indicators $\{KPI_i\}$, which reflect the main dimensions of the enterprise's economic security. This system may include, in particular, the level of

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voluntary staff turnover, the frequency of production incidents, the share of defective output, liquidity ratios, operating margin, frequency of compliance violations, fulfilment of credit covenants, share of unplanned downtime and the intensity of unplanned employee absences. For further integration all indicators are converted to a dimensionless scale $[0; 1]$ in the form of normalized components Z_i, where 0 corresponds to the most unfavourable state and 1 to the best state.

In general form the integral economic security index of the enterprise is specified as a weighted sum of normalized components:

$$S = \sum_{i=1}^{n} w_i Z_i, \qquad (3.24)$$

where Z_i is the normalized component corresponding to the i-th indicator, w_i is the weight coefficient that reflects the relative importance of this component in the overall structure of economic security, and n is the number of components.

The weights satisfy the condition:

$$\sum_{i=1}^{n} w_i = 1, w_i \geq 0 \qquad (3.25)$$

As a rule, the indicators are grouped into blocks: financial, operational, personnel, information security, and legal compliance. For each block, an intermediate subindex can be calculated, after which the integral index S is formed in accordance with the adopted model.

Normalization of each indicator KPI_i is carried out using a selected transformation function $f_i(\cdot)$, which reflects the nature and direction of its impact. In the simplest case, linear normalization of the type is used:

$$Z_i = f_i(KPI_i) = \begin{cases} \frac{KPI_i - KPI_i^{\min}}{KPI_i^{\max} - KPI_i^{\min}}, & if\ "the\ more\ the\ better", \\ 1 - \frac{KPI_i - KPI_i^{\min}}{KPI_i^{\max} - KPI_i^{\min}}, & if\ "the\ less\ the\ better" \end{cases} \qquad (3.26)$$

Here $KPI_i^{\min}$ and $KPI_i^{\max}$ are the lower and upper reference bounds of the indicator, which can be set on the basis of industry standards, historical data or target benchmarks. In this way, a positive dynamic of the indicator in the "correct" direction is always reflected by an increase in the corresponding Z_i.

For further calculations, an important element is the normalization coefficient g_i, which is defined as the derivative of the normalization function:

$$g_i = \frac{\partial Z_i}{\partial KPI_i} \qquad (3.27)$$

In the case of linear normalization, g_i is a constant value and equals:

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$$g_i = \frac{1}{KPI_i^{\max} - KPI_i^{\min}} \qquad (3.28)$$

for an indicator of the "the more the better" type, or

$$g_i = -\frac{1}{KPI_i^{\max} - KPI_i^{\min}} \qquad (3.29)$$

for an indicator of the "the less the better" type. It is precisely the sign and magnitude of g_i that subsequently determine how a change in the basic indicator affects the normalized component and the index S.

For illustrative purposes, Table 3 presents examples of basic indicators that can be included in the Model, the corresponding normalized components and the expected direction of the impact of an increase in personnel loyalty L on these indicators.

Table 3.7. Examples of key indicators, normalization and expected relationship with loyalty

Risk block	Baseline KPI_i	Rationing type	Normalized component Z_i	Expected impact of L growth on KPI_i	Expected sign g_i
Human Resources	Voluntary staff turnover rate, %	"less is better"	Z_"flow" =1-(KPI-KPI^min)/(KPI^max-KPI^min)	Reduced turnover	negative
Human Resources	Average time to close vacancies in critical roles, days	"less is better"	analogous normalization	Reduced closing time	negative
Operational	Share of defects in total production, %	"less is better"	analogous normalization	Reduced defect rate	negative
Operational	Share of unplanned downtime, %	"less is better"	analogous normalization	Reduced downtime	negative
Occupational Safety	Frequency of incidents with violation of safety regulations	"less is better"	analogous normalization	Reduced incident rate	negative
Financial	Operating margin, %	"more is better"	Z_"margin" =(KPI-KPI^min)/(KPI^max-KPI^min)	Increased margins due to reduced losses	positive
Information Security	Number of incidents due to the "human factor"	"less is better"	analogous normalization	Reduced incidents	negative

Source: developed by the author

Thus, the economic security index S is a deterministic function of a set of normalized components {Z_i}, which, in turn, depend on the basic

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indicators {KPI_i}. The next step is to formalize how the loyalty index L affects these indicators.

The transfer function "loyalty - indicators - security index". To build a mathematical relationship between staff loyalty and the economic security index, the concept of a "transfer function" is used. It describes how a small change in the loyalty index ΔL is transmitted through the system of indicators {KPI_i} to a change in the integral security index ΔS.

In the first step, the elasticity of each basic indicator with respect to loyalty is given:

$$\alpha_i = \frac{\partial KPI_i}{\partial L} \qquad (3.30)$$

This parameter reflects how many units the KPI_i indicator changes when loyalty changes by one conditional unit on a normalized scale. For example, α_"flow" =-4 may mean that an increase in the loyalty index by 0.1 points is associated with a decrease in voluntary staff turnover by 0.4 percentage points, all other things being equal.

In the second step, the normalization KPI_i→Z_i is taken into account. For this, the previously defined coefficient is used:

$$g_i = \frac{\partial Z_i}{\partial KPI_i} \qquad (3.31)$$

If the normalization is linear, g_i is a constant, and its sign and magnitude reflect how sensitive the normalized scale is to changes in the underlying indicator. In the case of nonlinear normalization, g_i may depend on the current value of KPI_i, but in practical applications, for small changes, a local linear approximation is often used.

The third step uses the structure of the index S itself. Since:

$$S = \sum_{i=1}^{n} w_i Z_i, \qquad (3.32)$$

its derivative with respect to the normalized components equals:

$$\frac{\partial S}{\partial Z_i} = w_i \qquad (3.33)$$

By combining these three relationships (the impact of L on KPI_i, the impact of KPI_i on Z_i, and the impact of Z_i on S), we obtain, by the chain rule of differentiation:

$$\frac{\partial S}{\partial L} = \sum_{i=1}^{n} \frac{\partial S}{\partial Z_i} \cdot \frac{\partial Z_i}{\partial KPI_i} \cdot \frac{\partial KPI_i}{\partial L} = \sum_{i=1}^{n} w_i \cdot g_i \cdot \alpha_i \qquad (3.34)$$

Let us denote:

$$\beta \equiv \frac{\partial S}{\partial L} = \sum_{i=1}^{n} w_i g_i \alpha_i \qquad (3.35)$$

The parameter β acts as an aggregated sensitivity of the economic security index to changes in loyalty. It integrates three important aspects: managerial priorities (through the weights w_i), the technique of

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normalization and scaling (through g_i), and the empirical impact of loyalty on specific indicators (through α_i).

In practice, the parameters α_i are estimated on the basis of historical data using regression analysis. For each indicator, a model of the following form is constructed:

$$KPI_{i,t} = a_i + b_i L_{t-1} + c_i' X_{t-1} + \varepsilon_{i,t}, \qquad (3.36)$$

where $KPI_{i,t}$ is the value of the indicator in period t, L_{t-1} is the loyalty index in the previous period, X_{t-1} is the vector of control variables (external conditions, price shocks, regulatory changes), and $\varepsilon_{i,t}$ is the stochastic error term. The estimated coefficient b_i is interpreted as an empirical approximation of α_i. These estimates are then scaled in accordance with the chosen scale of L and the range of KPI_i and are used in the calculation of β.

To ensure transparency of the relationships between loyalty and economic security, it is advisable to summarize information on the contribution of individual indicators in tabular form. Table 4 conditionally shows illustrative examples of such a summary.

Table 3.8. Summary of the transmission mechanism "loyalty - indicators - security index"

Indicators KPI_i	Weight w_i in the index S	Normalization coefficient g_i	Estimated elasticity α_i	Partial contribution to β: $w_i g_i \alpha_i$	Interpretation of the impact of an increase in L
Voluntary staff turnover	w_{turn}	$g_{\text{turn}} < 0$	$\alpha_{\text{turn}} < 0$	positive	An increase in loyalty reduces turnover, which improves security
Frequency of occupational health and safety incidents	w_{OHS}	$g_{\text{OHS}} < 0$	$\alpha_{\text{OHS}} < 0$	positive	Loyal employees violate safety rules less frequently
Defect rate	w_{def}	$g_{\text{def}} < 0$	$\alpha_{\text{def}} < 0$	positive	An increase in loyalty reduces defects, increasing resilience
Operating margin	w_{marg}	$g_{\text{marg}} > 0$	$\alpha_{\text{marg}} > 0$	positive	Higher loyalty contributes to better financial results
Frequency of information security incidents	w_{IS}	$g_{\text{IS}} < 0$	$\alpha_{\text{IS}} < 0$	positive	Loyalty reduces the risk of the human factor in information security

Source: developed by the author

In the presented table it can be seen that for most "risk" indicators where "less is better", the elasticity α_i has a negative sign and the normalization

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coefficient g_i is also negative. This means that the product $g_i\alpha_i$ is positive, and, given positive weights w_i, the overall contribution to β will be positive. In other words, an increase in loyalty in typical cases is associated with an increase in the integral economic security index.

3. Basic assessment of scenarios of changes in the security index. For the practical application of the Model, it is necessary to move from the differential characteristic $\beta = \partial S / \partial L$ to an approximate estimate of the change in the security index S under a specific scenario of a change in loyalty ΔL. If one considers relatively small changes in loyalty and assumes that β remains constant within the corresponding range of values of L, a linear approximation can be applied:

$$S' = S_0 + \beta \cdot \Delta L, \qquad (3.37)$$

where S_0 is the baseline value of the economic security index in the initial period and S' is the modelled value of the index under a change in loyalty by ΔL.

For example, if for a particular industrial enterprise the baseline value of the security index is $S_0 = 0.72$, and the aggregated sensitivity β according to the calibration results equals 0.55, then a scenario of increasing loyalty by 0.10 points (that is, $\Delta L = +0.10$) gives:

$$S' = 0.72 + 0.55 \cdot 0.10 = 0.775 \qquad (3.38)$$

In terms of the interpretation scale, this may mean a transition from the "satisfactory" zone to the upper boundary of the "satisfactory" zone or an approach to a "high" level of security, depending on the specified thresholds. If the changes in loyalty are larger or if the enterprise is already in the upper segment of the S scale, it is advisable to take saturation effects into account. In this case, a modified formula can be used:

$$S' = S_0 + \beta \cdot \Delta L \cdot (1 - \gamma S_0), \qquad (3.39)$$

where $\gamma \in [0; 1]$ is a parameter that dampens the increment as S_0 approaches the maximum value of 1.

At high values of S_0, the factor $(1 - \gamma S_0)$ reduces the effective increase, reflecting the fact that further improvements in security become progressively more costly and less perceptible. Similarly, different values of β can be specified for different zones of the scale (critical, vulnerable, satisfactory, high), which reflects different marginal returns from increasing loyalty: in crisis situations, even a small increase in loyalty can produce a significant effect, whereas in stable systems this effect is more moderate.

Thus, the mathematical mechanism for integrating loyalty assessment results into the economic security index provides a formal, reproducible and transparent link between the "soft" socio psychological characteristics of

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personnel and the “hard” financial, operational and risk metrics. Through the use of the transfer function, the aggregated sensitivity β and scenario calculations of S', the management system obtains the ability to plan and quantitatively assess the expected effect of loyalty enhancement programs on the integral level of economic security of an industrial enterprise.

Calibration of sensitivity is carried out on panel data for several years with control of external factors, in particular energy prices, logistics constraints and event related shocks. To avoid bias, robust estimators are applied, the stability of parameters in subsamples and years is checked, and cross validation is performed on hold out data. The obtained coefficients are adjusted to the normalized index scale so that changes in loyalty are correctly projected into changes in security. If necessary, nonlinearities are introduced, for example saturation of the effect in the upper part of the scale or differentiated sensitivities in vulnerable and satisfactory zones, where the presence of bottlenecks in processes determines a higher marginal return from the growth of loyalty.

The procedure for implementing the model envisages the stages of diagnosis, design, piloting, scaling and institutionalization. At the diagnosis stage, the readiness of data and processes is assessed, an audit of sources is carried out, gaps in quality and completeness are eliminated, indicator passports and unified reference directories are created. The design stage fixes the content of questionnaires, scales, weights, measurement frequencies and the normalization regulation, which ensures the compatibility of waves over time. Piloting is carried out on a critical site or cluster of units with the formation of baseline index values and verification of the controllability of the transmission mechanism for a specific technology and personnel structure. Scaling includes the deployment of dashboards, the integration of results into regular managerial reporting, and the setting of thresholds and escalation routes. Institutionalization consolidates roles and responsibilities, determines the periodicity of pulse measurements, the intervals for reviewing weights, and introduces mandatory action plans for each risk category.

A component of the model is a register of threats to economic security from personnel with a distinction between internal and external factors. Internal factors include a decline in safety discipline, violations of technological procedures, errors on critical equipment, premature departure of key competence holders, leaks of confidential information and conflicts that undermine the coordination of shifts. External factors include attempts at social engineering and phishing campaigns, legal pressure on individual employees, psychological consequences of war, regulatory turbulence and

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supply chain risks that indirectly change personnel behavior. For each threat, key risk indicators are established, threshold values are determined, response routes and deadlines are linked, and responsible persons with access rights to relevant dashboards are designated.

Ethical requirements and data quality are a critical precondition for trust in the model. The procedures provide for informed consent of employees, anonymization of personal records, differentiated role based access, logging of all data operations and transparent communication regarding the purposes of using the results. Punitive use of loyalty indicators is prohibited. The results must be directed toward prevention, development and support, not punishment. The quality of measurements is verified through the reliability of scales, consistency between instruments, the sensitivity of the model to changes in weights and normalization, and the predictive value with respect to adverse events over a quarterly or annual horizon.

The controllability and practical applicability of the model are manifested in the rapid transformation of signals into actions with measurable results. If the security index approaches a threshold or crosses it, recovery programs are activated, occupational safety protocols are strengthened, shift schedules are revised and measures for retaining competencies are deployed. If local declines are recorded in specific workshops or shifts, targeted interventions are coordinated at the level of foremen and unit managers, including training, mentoring and process adjustments. If the index moves into a higher zone, the effect is consolidated, successful practices are standardized and the intensity of monitoring is gradually reduced without losing sensitivity to early signals.

The limitations of the model concern potential endogeneity between loyalty and performance outcomes, as well as sensitivity to sectoral differences and the frequency of data collection. To strengthen the evidence for a causal relationship, it is recommended to apply quasi experimental approaches, instrumental variables, difference in differences, the logic of pilots at comparable sites and analysis of time lags. Sectoral calibration of weights and elasticities reduces transfer errors and makes it possible to adapt the model to infrastructural, energy or metallurgical profiles. The frequency of short measurements and operational logs determines the speed of the managerial cycle, therefore it is important to ensure sufficient regularity of pulse measurements and integration with corporate systems.

4. Integration of personnel loyalty assessment results into the threat management system of the economic security of an industrial enterprise. The expected effects of integrating personnel loyalty assessment results into the threat management system of the economic security of an industrial

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enterprise should be viewed as a test of the practical viability of the model. If the previous blocks of the model describe how loyalty is measured, linked to process and financial indicators and embedded in the decision making contour, then the expected effects show whether these analytical actions are transformed into tangible changes in the level of economic security. This concerns not only the formal increase in the integral economic security index but also the real reduction in the frequency of incidents, the stabilization of production, the increase in margins and the reduction of the enterprise's vulnerability to internal and external shocks.

The first block of expected effects is related to the reduction of staff turnover and the shortening of the time required for employees to reach the target level of productivity in critical shifts. In industrial companies, it is turnover in key occupations (machinists, technological line operators, power engineers, maintenance personnel, shift specialists) that creates the greatest risk for economic security, since each separation generates costs for search, selection and adaptation and temporarily reduces the stability of output. An increase in loyalty due to properly designed support programs, transparent communication and a fair reward system reduces the probability of voluntary resignations, especially among experienced employees. At the same time, the willingness of personnel to engage in mentoring and internal training increases, which shortens the average time needed for new employees to reach the normative level of productivity. At the level of economic security, this means fewer forced downtimes due to staff shortages, lower costs for overtime work and outsourcing, and a smoother dynamics of production indicators throughout the year. As a result, the quantitative component of the integral economic security index is stabilized, in particular the subcomponents related to operational efficiency and personnel costs.

The second block of effects concerns the reduction of the share of defects, the number of reworks and the duration of downtime, which indirectly improves the operating margin and cash flows. Loyal personnel are, as a rule, more inclined to comply with technological regulations, safety procedures and quality standards, and also to signal deviations and hidden defects in a timely manner. This reduces the likelihood of errors caused by careless attitudes to work, decreases the volume of non productive expenditures on rework, write offs of raw materials and finished products, and increases the stability of production plan fulfilment. In addition, increased loyalty and engagement support a culture of early warning, in which employees do not conceal problems but initiate their discussion before they grow into serious incidents or prolonged downtimes. At the financial level, this is manifested in a higher operating margin, better dynamics of

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operating cash flow and lower volatility of profitability indicators. In the integral economic security index, the block related to the profitability of core activities, the reliability of the production process and the efficiency of resource use is strengthened.

The third block of expected effects is associated with a reduction in the frequency of occupational safety incidents, industrial injuries and violations of compliance requirements. In an industrial environment, especially under conditions of war and resource shortages, the human factor often becomes the cause of critical events. Loyal personnel are more likely to comply with rules, are less inclined to consciously bypass procedures, and treat the use of personal protective equipment, electrical safety and fire safety regulations more responsibly. In addition, this group of employees, as a rule, reports violations more quickly, which makes it possible to prevent risk escalation. From the point of view of compliance, increased loyalty reduces the motivation for self interested or opportunistic actions, decreases the risk of participation in corruption schemes and unauthorised operations with assets, and reduces violations of the code of ethics. This directly affects economic security through the reduction of fines, compensations, litigation costs and expenses for eliminating the consequences of accidents, as well as through lower reputational risks that may lead to the loss of contracts, access to financing or deterioration of borrowing conditions.

The fourth block concerns the dynamics of the integral economic security index of the enterprise and the risk that its values will cross critical threshold limits. The proposed model envisages the identification of at least three threshold zones: a critical zone where the value of the economic security index is below 0.50, a vulnerable zone where the index is in the range from 0.50 to 0.64, and a zone of satisfactory or high economic security where the value of the index exceeds 0.65. An increase in personnel loyalty through the above mentioned channels of influence (staffing, operational, safety, compliance) reduces the probability of sharp declines in the index associated with the realization of internal threats. Under conditions of a turbulent external environment, this means that even in the presence of external shocks (damage to infrastructure, changes in regulatory requirements, price fluctuations) the enterprise has a human margin of safety that mitigates the negative scenario. As a consequence, the economic security index less frequently falls below the thresholds of 0.65 and 0.50 and, if this does occur, it is for a shorter time and with less depth of decline. This increases the predictability of operations, improves the perception of the enterprise by creditors, investors and regulators, and expands the space for strategic decisions instead of reactive fire fighting.

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For the systematization of the expected effects, it is advisable to present a summary scheme that links the main directions of the impact of personnel loyalty with key indicators of economic security.

Table 3.9. Expected effects of increasing personnel loyalty for the economic security of an industrial enterprise

Direction of loyalty impact	Transmission channels of the effect	Key economic security indicators	Expected result for economic security
Stabilization of the personnel structure	Reduction of turnover, shortening of adaptation time, strengthening of mentoring	Share of separations in critical roles, average time to reach productivity, costs of recruitment and adaptation	More stable output, lower personnel risks, lower costs of staff replacement
Reduction of defects and downtime	Better adherence to technological regulations, timely signals about deviations	Share of defects, number of reworks, duration of downtime, operating margin, operating cash flow	Increase in production efficiency and profitability, reduction of non productive expenditures
Reduction of occupational safety and compliance incidents	Compliance with safety rules, reduction of opportunistic behavior, timely reporting of violations	Frequency of industrial injuries, number of compliance violations, amount of fines and compensations, number of significant incidents	Reduction of direct losses and litigation costs, lower reputational risks, more stable operating conditions
Stabilization of the integral economic security index	Attenuation of the impact of internal threats, increase in the human margin of safety	Value and dynamics of the integral economic security index, frequency of crossing the 0.65 and 0.50 thresholds	Lower probability of falling into the critical zone, higher level of stakeholder trust, expansion of strategic opportunities

Source: developed by the author

The expected effects show that the integration of personnel loyalty assessment results into the threat management system of economic security is not a purely analytical procedure. It is directly aimed at changing the behaviour, processes and performance outcomes of the enterprise and makes it possible to translate abstract loyalty indicators into specific improvements in production, financial and safety dynamics. This strengthens the role of the human factor as a resource of economic security and creates a more sustainable foundation for the long term development of an industrial enterprise under conditions of high uncertainty.

In summary, the model forms a reproducible management contour in which validated measurement of loyalty is combined with a formalized transmission mechanism into process and financial indicators, threshold interpretation of the security index and regulated managerial actions. The architecture tightly links monitoring, analysis, decisions and learning, which ensures a reduction in the frequency of incidents, stabilization of output and an increase in the resilience of an industrial enterprise under conditions of

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high uncertainty. In practice, a small but steady increase in loyalty recorded by the system of regular measurements can shift the economic security index by a sufficient amount to move to a higher risk category. This opens up opportunities for better financing conditions, reduced regulatory pressure and increased stakeholder trust, which together create a long term effect of strengthening the resilience and value of the business.

Conclusions. The proposed model provides a controlled embedding of loyalty assessment results into the threat management system of the economic security of an industrial enterprise. It combines validated instruments for measuring loyalty, a formalized transmission mechanism to process and financial indicators, an integrated economic security index, and clear managerial triggers. The process architecture of the model closes the cycle from monitoring to action and learning, which makes it possible to reduce the frequency of incidents, stabilize output and increase the resilience of the enterprise. Institutionalization of the model through policies, roles, data and regulations creates a long term basis for strengthening economic security under conditions of high uncertainty.

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