The balanced scorecard as an adaptive control system

**Streszczenie.** W artykule przedstawiono jeden z instrumentów zarządzania strategicznego którym jest zrównoważona karta wyników w postaci adaptacyjnego systemu sterowania na przykładzie mapy strategii dla elektrociepłowni. Przedstawiony system adaptacyjny w zadowalającej sposób opisuje wewnętrzne środowisko przedsiębiorstwa w trybie ciągłego dostosowywania się do warunków zewnętrznych.

**Abstract.** The paper describes a balanced scorecard as an adaptive control system built on the basis of a strategic map of a heat-supply plant. The proposed adaptive system in the form of a tracking system adequately describes the processes of transformation of the enterprise internal environment in the mode of constant adaptation to the changes in the external environment. (Zrównoważona karta wyników jako adaptacyjny system sterowania).

**Słowa kluczowe:** zrównoważona karta wyników, zarządzanie adaptacyjne, system organizacyjny, elektrociepłownia.

**Keywords:** balanced scorecard, adaptive management, organizational system, thermal-electric power station.

**Introduction**

An important criterion for any production pattern is proper management of the company as well as human resources. The choice of managerial decisions should be mainly aimed at reducing the overall cost of production, improving its observability and controllability, qualitative and quantitative characteristics, as well as reliability. Under market economy, enterprises interested in the development and economic growth must constantly review their actions in order to achieve the best results in comparison with their competitors.

The carried out analysis of the published data shows that the traditional systems of strategy construction in most cases were based solely on financial indicators of enterprises; as a result enterprises could not identify and integrate all the factors that were crucial for improving the enterprise performance [1-6].

**BSC as a tool for achievement of the main goals of the company**

At present the Balanced Scorecard (BSC) established by David Norton and Robert Kaplan became widespread among the generated approaches towards building strategies [7].

On the basis of generalization of numerous studies, the Balanced Scorecard developers offered to operate using four major perspectives: “Finance”, “Customers”, “Internal Business Processes” and “Learning and Growth.”

A BSC is used by a company as a tool of management according to the hierarchical levels including all the resources, as well as staff, through a system of incentives closely engaged with the key performance indicators which are aimed at a common purpose.

Balanced consideration of the mentioned perspectives in developing strategies of a company (enterprise) allows developing a balanced system of objectives (Figure 1 and Figure 2).

**Fig.1. The Balanced Scorecard**

After determining the main objectives, it is necessary to concentrate the efforts of the team on them. Therefore, the following problem arises: bringing the targets to subordinate units, as well as developing a system of incentives to encourage the achievement of these objectives and direct the efforts of numerous sub-divisions in order to achieve the major goal of the company [8].

In order to make it easier to achieve the goals, it is necessary to assign all the objectives, indicators, targets and measures to specific employees and departments, that is to decompose the card according to the units [9].
One of the advantages of multi-dimensional organizational structures that best meet the requirements of adaptability is that this type of organization eliminates the need for ongoing restructuring, which is replaced by resources redistribution. Replacing restructuring with the procedure of rational allocation of resources can significantly improve the speed of the adaptation process.

The properties that characterize the principles of modeling adaptive organizational structures should be supplemented by the principle of stochastic (probabilistic) modeling. The optimality criterion presents the minimum of some functional which characterizes the degree of discrepancy between the organization parameters and the requirements of the external environment in the steady state [14].

Substantively this criterion means striving for such management adaptation which will provide the minimum of the systematic and random components of the discrepancy.

The process of adapting an organization to the changing conditions of the external environment can be represented by the following generalized scheme:

\[
\begin{align*}
\Delta_{1} & \rightarrow \text{Observation} \rightarrow \Delta_{2} \rightarrow \text{Analysis} \rightarrow \Delta_{3} \rightarrow \text{Decision} \rightarrow \Delta_{4} \rightarrow \text{Transformation} \rightarrow \Delta_{5} \\
\end{align*}
\]

The diagram uses the following notations:
- \( \Delta - \) the variables of the external environment the change of which requires immediate company response;
- \( Z_{1} - \) observation of \( \Delta \) variables taking into account possible information uncertainty;
- \( Z_{2} - \) the results of analysis of the company deviation from the requirements dictated by the changes in the external environment;
- \( Z_{3} - \) the results of adaptive transformations of the company internal environment;
- \( Z_{4} - \) the results of analysis of the company deviation from the requirements dictated by the changes in the external environment;
- \( U - \) the managerial decision which requires implementation of adequate transformations in the company internal environment.

The proposed model of organization in the form of a tracking system adequately describes the processes of change in the internal environment of a company in the mode of constant adaptation to the changes in the external environment.

The implementation of the adaptive model for the strategic map based BSC of a thermal supply complex (Figure 5) is as follows.

1. The strategic map is a four-level system (finance, customers, internal business processes, learning and development), which describes the objectives and indicators. The lower-level goals are indicators of the higher-level objectives.
2. The highest level of a strategic plan is finances. That is the targets of this level are priority-oriented. At this level there are three goals: increase in profits, tariff consumption and reducing consumer debt. The main goal is to increase profits.
3. The BSC analysis showed the need for building an adaptive system and the transformation of the strategic map presented in the classic version (shown in Figure 5) in the following manner, which is a more convenient form of construction of adaptive systems (Figure 6).
The adaptive model is built in the multidimensional case, where $m$ and $n$ denotes number of inputs and outputs, respectively. Such an adaptation model was proposed by P.A. Mikhnenko [17]. The scheme is based according to the strategic map of a thermal power station, whose output is the ultimate goal of increasing profits (Figure 8).

Having constructed an adaptive model aimed at the increase of profits we derive the conclusion on the need for using feedback, that would take into account the output value of the upper level in the lower stages of the
The hierarchical structure of the strategic map. The feedback in the proposed scheme characterizes the discrepancy of the current value from the planned one, which is denoted by $\epsilon$. The lower level of the adaptation system is presented in Figure 9.

**Fig. 7. Stochastic multidimensional adaptive control system**

$X_0$, $X_1$... - Information about the current state and plans for the system's states.
$Y_0$, $Y_1$... - Information about the state of the system due to external factors.
$Z_0$, $Z_1$... - Information about the state of the system due to internal factors.
$R_0$, $R_1$... - Information about the desired state of the system.

**Fig. 8. The adaptive system of control of the increase in profits**

$X_0$, $X_1$... - Information about the current state and plans for the system's states.
$Y_0$, $Y_1$... - Information about the state of the system due to external factors.
$Z_0$, $Z_1$... - Information about the state of the system due to internal factors.
$R_0$, $R_1$... - Information about the desired state of the system.

**Fig. 9. An adaptive system of controlling tariff consumption with the account of profit increase indicators**

$X_0$, $X_1$... - Information about the current state and plans for the system's states.
$Y_0$, $Y_1$... - Information about the state of the system due to external factors.
$Z_0$, $Z_1$... - Information about the state of the system due to internal factors.
$R_0$, $R_1$... - Information about the desired state of the system.

Conclusions

$W$ matrix in Figure 7 denotes compatibility matrix which prescribes the adaptation target system by establishing relationship and the required quantitative level of transformation. $K$ is a matrix of resources allocated for the implementation of transformations of each factor of the internal organization environment whereas $S$ matrix describes the organization structure applied to organizational interaction of the structural units of an organization. In the future a detailed description of these matrices and provide their stochastic model in the form of a tracking system that would adequately describe the processes of transformation in the internal environment of a company in the mode of constant adaptation to changes in the external environment. It would make possible to developing an adaptive control algorithm over the management strategy of a thermal-electric power station.

**REFERENCES**