APPLICATION OF AN UPGRADED RISK-CONTROLLING MECHANISM FOR ENSURING ECONOMIC STABILITY OF MANUFACTURING ENTERPRISES

Svilen V. Simeonov
Technical University of Varna, Bulgaria

ABSTRACT— The proposed article presents an upgraded risk-controlling mechanism performing a consultative function to the management when taking managerial decisions. The performance of this function is expressed in risk assessment provision and alternative solutions for risk impact elaboration. The described actions refer to any risk jeopardizing the sustainable economic growth of a manufacturing enterprise. To perform this function, the risk-controlling mechanism relies on tools measuring the impact of external and internal factors; application of control cards for risk admissibility assessment; a model of identification and elaboration of alternative solutions on the effect on risk by the Monte Carlo method. The risk-controlling mechanism based on the application of the mentioned basic tools is approbated in a manufacturing enterprise in the processing industry: manufacture of metal structures. The results of the carried-out approbation are presented here.

Keywords: control card, decision making, ensuring sustainability of economic development, management effectiveness, risk-controlling, risk-management

1. INTRODUCTUON

Sustainability, as a term, is related to ensuring the necessary resistance and stability against indicated influence. In that direction, the characterization of the category of economic sustainability may be sought. This is an economic category that is related basically to the maintenance of economic viability and the ensuring of a long-term economic development of the business regardless of any influence on it. The achievement of the development and its sustainability is formed in the interaction between the external and internal environment of the enterprise (Охладский, 2000; Острейковский, 2005; Асаул, 2008). The enterprise management should ensure economic sustainability in the said interaction, i.e. achieve dynamic stability and balance of economic indicators notwithstanding any unwanted impact (Камаев, 2008; Орлов and Шарлов, 2014; Омельченко 2007, Гусев 2010; Харчевников 2011; Брянцева, 2003). In this context the strategic management of an enterprise should be considered as a managing subject responsible for ensuring sustainable economic development of a manufacturing enterprise. The so defined management responsibility requires to take proactive and effective managerial decisions. It is important to note that the process of taking the mentioned decisions is predetermined by the unspecified nature of the environment (external and internal) where the enterprise should develop. Taking the above decisions in the mentioned environment is a process which should inevitably take account of the risk. That focuses on risk management and the category of risk which ensures sustainability by the management.

The ISO 31000:2018 standard defines risk as influence of indetermination on the achievement objectives, and risk management as coordinated actions for the management of an organization with taking account of the risk. The given definitions direct the problematics regarding the
ensuring of sustainable economic development towards the achievement of the objectives characterizing that development. Risk is an objective reality and its impact may not be reduced to zero and, therefore, the full achievement of the objectives characterizing economic growth may not be guaranteed by the management. That raises the issue of admissible deviation of the objectives set: the admissible risk (Wheeler and Chambers, 2009). The basic stages of the risk management process reflect its assessment (including risk identification, analysis and assessment) of admissibility and the impact on inadmissible risk until it is reduced to admissible levels. The performance of this process leads to loading the management with actions requiring the application of the specific risk management instruments which entice them from their obligations in relation to the overall management of the enterprise and influences its efficiency. It is reasonable to search for a solution to this issue in the application of a management instrument to provide a consultative function to the management. The performance of the mentioned above function should ensure information-analytical and methodical security to the management regarding the risk (Карминский, 2014) in the case related to ensuring sustainable economic development of an enterprise. This function is based on the management concept of risk controlling and it is possible to build a risk-controlling mechanism (Simeonov, 2016) on its basis. The mentioned mechanism provides a methodical basis for the performance of the described consultative function regarding the risk jeopardizing the provision of sustainability. A risk-controlling mechanism (RCM) is currently implemented enabling the design of probability deviations from values of an indicator measuring the return on invested capital ROI (ROA), considering it in a deductive and inductive aspect (Simeonov, 2017). The mentioned mechanism does not take into account the influence of external factors, it does not assess the risk admissibility, and the admissibility of any elaborated alternative solutions for impact on it either, but it enables neither the assessment of admissibility of such deviations, nor the influence of any external factors. The shortcomings limit the management efficiency of this mechanism. To overcome such limitation, the mechanism should be upgraded with additional tools to ensure consideration of the external factors’ impact on the internal ones; extension of the scope of monitored internal factors; enabling the identification, analysis and assessment of the risk of a broader spectrum of internal factors, enabling the generation of probability alternative solutions for impact on the risk and assessment of their admissibility. The resolution of upgrade of the risk-controlling mechanism and the results of its approval are presented in the statement of this article.

2. MATERIALS AND METHODS

A free interview, where the risk-controlling mechanism is applied, with the management of each enterprise is stipulated in order to determine the spectrum of external factors affecting the sustainability of economic growth. The said interview should be held every three months and it should have a defined objective: Determination of any external factors influencing the economic development of the manufacturing enterprise. Any external factors specified in result of the interview will be assessed as dynamics (a change in the factors having occurred in the last three-month period) and provision of opportunities or threats to the enterprise development. The assessment of the factor dynamics is presented in a table model (table 1). The assessments obtained from a model form a variation percentage which is applied in the model of risk identification and elaboration of alternatives for impact on it.

The upgraded risk-controlling mechanism includes and has enclosed the deductive factor models of profitability indicators presented in formulae 1, 2 and 3. The shown models reveal on one hand the profitability indicators as results of the economic development of the enterprise and, on the other hand, the factors determining that development.
Table 1: Table model for assessment of the influence of external factors

<table>
<thead>
<tr>
<th>External factors:</th>
<th>Dynamic criteria:</th>
<th>Dynamic assessment:</th>
<th>Is the change good? Yes/No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Currency risk:</td>
<td>Changing in BNB law.</td>
<td>0</td>
<td>Yes</td>
</tr>
<tr>
<td>2. Price risk:</td>
<td>Loss of contracts with value over 1400000 BGN per quarter.</td>
<td>0</td>
<td>Yes</td>
</tr>
<tr>
<td>3. Price risk - materials:</td>
<td>Change in price or delivered metals over than 3%.</td>
<td>0</td>
<td>Yes</td>
</tr>
<tr>
<td>4. Inflation risk:</td>
<td>Reporting inflation in the national economy higher than 3% on a quarterly basis;</td>
<td>0</td>
<td>Yes</td>
</tr>
<tr>
<td>5. Deflation risk:</td>
<td>Reporting deflation in the national economy higher than 3% on a quarterly basis.</td>
<td>0</td>
<td>Yes</td>
</tr>
<tr>
<td>6. Change in VAT law:</td>
<td>Changes have occurred in the last three months.</td>
<td>1</td>
<td>Yes</td>
</tr>
<tr>
<td>7. Changes in environmental standards and law:</td>
<td>The changes affect business development.</td>
<td>0</td>
<td>Yes</td>
</tr>
<tr>
<td>Total factors with reported dynamics:</td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Assessment of the dynamic in external factors (as a percentage from the total number of observed factors): 14%

The determinated factor models are integrated in a model of risk identification and elaboration of probability alternative solutions of impact on risk. The model is based on the Monte Carlo method.

\[
ROA = ATO \times ROS = \left( \frac{SR}{TA} \right) \times \left( \frac{NI}{SR} \right) \tag{1}
\]

ROA – Return on assets
ATO – Asset turnover
ROS – Return on sales
SR – Sales Revenue
TA – Total Assets
NI – Net Income

\[
ROE = ATO \times ROS \times LR = \left( \frac{SR}{TA} \right) \times \left( \frac{NI}{SR} \right) \times \left( \frac{TA}{E} \right) \tag{2}
\]

ROE – Return on Equity
ATO – Asset turnover
ROS – Return on sales
LR – Leverage ratio
SR – Sales Revenue
TA – Total Assets
NI – Net Income
E – Equity

\[
ROS = \frac{NI}{SR} \tag{3}
\]

NI – Net Income
SR – Sales Revenue

The model by the Monte Carlo method has been developed in the Anaconda 3 open platform.
for Python programming language (Figure 1). It provides the option to input report data from MS Excel tables. The given data covers the period of the last eight reporting quarters of the enterprise activity and refers to TA, E, SR and NI indicators required for performing empirical normal allocation included in the determinate factor models. Prior to the data import in the developed model, the assessment of external factors impact should be included in the data; the assessment obtained from their chart assessment model forms a minimum interval and a maximum interval which the data subject to import may be altered in.

![Image](image_url)

**Figure 1: Developed Monte Carlo model in Anaconda 3 on the Python programming language**

The model of risk identification and elaboration of probability alternative solutions of impact on risk is based on the Monte Carlo method. The model stipulates reporting data import and forming normal allocation of empirical data by means of a random number generator. The formation of the allocation is in result of the application of the Box-Muller transformation.

```python
def BoxMuller(param, num, minV, maxV):
    ...
    U1 = rnd.random()
    U2 = rnd.random()
    value = (-2 * math.log(U1)) ** 0.5 * math.cos(2 * pi * U2) * Sigma + mu
    result[i] = value
```

The formed empirical normal allocation allows determination of the argument value, assessment of the argument probability, a standard error for each argument. The obtained probability values allow risk identification, analysis and assessment. It is performed by the following three criteria:

- A risk is considered to be any probability variation of the profitability indicators ROA, ROE and ROS from their target values determined by the central line of the control cards;

- An admissible risk would be any variation from the target values of the indicators falling
within the admissible limits set by the X and R control cards;

- An inadmissible risk would be any variation from the target values of the indicators exceeding the admissible limits set by the X and R control cards.

The application of the mentioned criteria requires the enclosure of statistical control cards of individual significance to the identified risks by the model working by the Monte Carlo method. The control cards of individual significance are two types referring to the average value of X and its dispersing R, the so-called X and R cards. The enclosed X cards have three elements represented in formulae 4, 5, and 6.

\[
UNPL_X = \bar{X} + 2.660 \times mR \tag{4}
\]

\[
UNPL_X = \text{Upper Natural Process Limit of X} \tag{4}
\]

\[
\bar{X} - \text{Average arithmetic value of X} \tag{4}
\]

\[
mR - \text{Average sliding range} \tag{4}
\]

\[
CL_X = \bar{X} \tag{5}
\]

\[
CL_X = \text{Central (target) line of X} \tag{5}
\]

\[
\bar{X} - \text{Average arithmetic value of X} \tag{5}
\]

\[
mR - \text{Average sliding range} \tag{5}
\]

\[
LNPL_X = \bar{X} - 2.660 \times mR \tag{6}
\]

\[
LNPL_X = \text{Lower Natural Process Limit of X} \tag{6}
\]

\[
\bar{X} - \text{Average arithmetic value of X} \tag{6}
\]

\[
mR - \text{Average sliding range} \tag{6}
\]

\[
C_p = \frac{U_{CL} - L_{CL}}{6\sigma} \tag{7}
\]

\[
C_p - \text{coefficient of reproducibility and} \tag{7}
\]

\[
C_p > 1.33 \text{ indicate availability of statistical} \tag{7}
\]

\[
C_p = 1.33 = 8SD \text{ min for reproducibility of the process} \tag{7}
\]

\[
C_p = 1.00 = 6SD \text{ min for admissibility of the calculation} \tag{7}
\]

\[
U_{CL} - \text{Upper limit of CL} \tag{7}
\]

\[
L_{CL} - \text{Lower Limit of CL} \tag{7}
\]

\[
\sigma - \text{Standard Deviation (SD)} \tag{7}
\]

The cards include an additional element - being the formation of warning limits around the central card line. These warning limits form a green, yellow and red warning zone. The range of the stated zones is measured in standard X variations. The green zone encompasses an interval outlying to the size of a standard variation from the card target line. The yellow zone encompasses an interval of one to two standard variations from the target line, and the red zone covers the interval above the yellow one to the formed limits of the control card. The warning zones formed that way give additional information of the assessment of risk and any elaborated alternative solutions of impact on it.

The applied control cards with individual meaning for dispersing (R) are formed of two elements presented in formulae 8 and 9, and the very dispersing in the cards is considered as average crawling amplitude. A peculiarity of these individual cards is that they do not form a lower limit and thus the value 0 is assumed as such (Wheeler and Chambers, 2009).
The performance of the risk management process requires the execution of actions on the inadmissible risk (ISO 31000:2018). The described risk-controlling mechanism facilitates the process of taking managerial decisions and elaborates and proposes alternative solutions for impact on the inadmissible risk.

The presented solutions are elaborated through the application of the model, developed by the Monte Carlo method, where any values imported during the risk identification, but with adjusted values of the external factors assessment, are imported in it. The above adjustment reflects the direction of the desired impact on risk and the influence of external factors, which the enterprise should overcome for achieving its economic development. The results obtained from this simulation analysis are transformed as target values which the enterprise should achieve in the following quarter.

\[
UCL_R = 3.268 \cdot \overline{mR}
\]

\[
UCL_R - \text{Upper limit or range}
\]

\[
\overline{mR} - \text{Average sliding range}
\]

\[
CL_R = \overline{mR}
\]

\[
CL_R - \text{Central (target) line of range}
\]

\[
\overline{mR} - \text{Average sliding range}
\]
Decision for final introduction of RCM

1. Regulating the introduction of RCM
   - Procedures

2. Defining the goals characterizing the economic development of the enterprise:
   - Analyzing industry reporting information;
   - Analyzing reporting information from the enterprise;
   - Construction of statistical control charts.

3. Determining the influence of external factors:
   - Application of a spreadsheet evaluation model

4. Collection information for the state of internal factors;

5. Defining of risk criteria and the risk tolerance

Providing effective application of RCM

Figure 3: Methodology for application of the risk-controlling mechanism

The performance of the so-implemented risk-controlling mechanism is regulated by the application of its methods of introduction, application and assessment (Figures 2, 3, 4)

Reported values from the period without RCM
Reported values from the period with RCM
Calculation of indicators Cp and SD
Comparative analysis and results

Figure 4: Methodology for evaluating the risk-controlling mechanism

3. RESULTS AND DISCUSSION

The results presented for the approbation period of the risk-controlling mechanism aim at revealing its role as an effective management mechanism performing a consultative function to the management responsible for ensuring the sustainable economic growth of the manufacturing enterprise. In such case effectiveness is considered in its management aspect, i.e. as achieving the objectives set by the management of the enterprise. Such effectiveness is covered by the definitions of risk and risk management already presented.

Two consecutive reporting periods are reviewed for revealing the shown effectiveness. Each of these periods covers three quarters. The achieved management effectiveness is reported in the first three quarters without application of the risk-controlling mechanism, and the achieved management effectiveness with application of the risk-controlling mechanism is reported in the next three quarters.
The results achieved by the enterprise in the period, where the elaborated mechanism was not applied, are presented in Figures 5, 6, 7, 8, 9, 10. The figures 5, 6 and 7 show results from the constructed control cards with individual meaning of average value (X) – period without applying RCM.

Figure 5: Control card for average value (ROS) for period without applying of RCM

Figure 6: Control card for average value (ROA) for period without applying of RCM

Figure 7: Control card for average value (ROE) for period without applying of RCM
The figures 8, 9 and 10 show results from the constructed control cards with individual meaning for average value of the sliding range – period without applying RCM.

Figure 8: Control card for average sliding range (ROS,\textsubscript{x}) for period without applying of RCM

Figure 9: Control card for average sliding range (ROA,\textsubscript{x}) for period without applying of RCM

Figure 10: Control card for sliding range (ROE,\textsubscript{x}) for period without applying of RCM
Figure 10: Control card for average sliding range (ROEₜ) for period without applying of RCM

The results achieved by the applied risk-controlling mechanism are presented in Figures 11, 12, 13, 14, 15, 16. The figures 11, 12 and 13 show results from the constructed control cards with individual meaning of average value (X) – period with applied RCM.

Figure 11: Control card for average value (ROSₜ) for the period with applied RCM

Figure 12: Control card for average value (ROAₜ) for the period with applied RCM

Figure 13: Control card for average value (ROEₜ) for the period with applied RCM
The figures 14, 15 and 16 show results from the constructed control cards with individual meaning for average value of the sliding range – period with applied RCM.

Figure 14: Control card for average sliding range (ROS) for the period with applied RCM

Figure 15: Control card for average sliding range (ROA) for the period with applied RCM

Figure 16: Control card for average sliding range (ROE) for the period with applied RCM
The results with the formed profitability are presented in Tables 2 and 3. These results are the basis for the calculation in Tables 4, 5, and 6.

Table 2: Achieved profitability in the period without applying RCM

<table>
<thead>
<tr>
<th>Quarters, 2018:</th>
<th>TA</th>
<th>E</th>
<th>SR</th>
<th>NI</th>
<th>ATO</th>
<th>LR</th>
<th>ROS</th>
<th>ROA</th>
<th>ROE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q2</td>
<td>11246.00</td>
<td>8253.00</td>
<td>17023.00</td>
<td>1750.00</td>
<td>1.51</td>
<td>1.36</td>
<td>10.28</td>
<td>15.56</td>
<td>21.20</td>
</tr>
<tr>
<td>Q3</td>
<td>11072.00</td>
<td>8322.00</td>
<td>18311.00</td>
<td>1823.00</td>
<td>1.65</td>
<td>1.33</td>
<td>9.96</td>
<td>16.46</td>
<td>21.91</td>
</tr>
<tr>
<td>Q4</td>
<td>14538.00</td>
<td>9521.00</td>
<td>15531.00</td>
<td>1790.00</td>
<td>1.07</td>
<td>1.527</td>
<td>11.53</td>
<td>12.31</td>
<td>18.80</td>
</tr>
</tbody>
</table>

Table 3: Achieved profitability in the period with applied RCM

<table>
<thead>
<tr>
<th>Quarters, 2019:</th>
<th>TA</th>
<th>E</th>
<th>SR</th>
<th>NI</th>
<th>ATO</th>
<th>LR</th>
<th>ROS</th>
<th>ROA</th>
<th>ROE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>12525.00</td>
<td>7223.00</td>
<td>11947.00</td>
<td>1822.00</td>
<td>0.95</td>
<td>1.73</td>
<td>15.25</td>
<td>14.55</td>
<td>25.22</td>
</tr>
<tr>
<td>Q2</td>
<td>14712.00</td>
<td>7413.00</td>
<td>12725.00</td>
<td>1842.00</td>
<td>0.86</td>
<td>1.98</td>
<td>14.48</td>
<td>12.52</td>
<td>24.85</td>
</tr>
<tr>
<td>Q3</td>
<td>13455.00</td>
<td>7275.00</td>
<td>11932.00</td>
<td>1828.00</td>
<td>0.89</td>
<td>1.85</td>
<td>15.32</td>
<td>13.59</td>
<td>25.13</td>
</tr>
</tbody>
</table>

The calculated values of the coefficient of reproducibility (formula 7) and standard deviation (SD) for the two periods are included in Tables 4, 5, 6. The following two tables show the achieved results during the two observed periods. Table 4 demonstrate results from the period without applied RCM. The results presented in table 5 are from the period with application of RCM.

Table 4: The values of the indicators in the period without application of RCM

<table>
<thead>
<tr>
<th>Indicator ROS (X):</th>
<th>Indicator ROA (X):</th>
<th>Indicator ROE (X):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standart deviation (SD):</td>
<td>0.83</td>
<td>2.18</td>
</tr>
<tr>
<td>6SD:</td>
<td>4.97</td>
<td>6SD:</td>
</tr>
<tr>
<td>Coefficient of reproducibility (Cp):</td>
<td>1.01</td>
<td>Coefficient of reproducibility (Cp):</td>
</tr>
</tbody>
</table>

Table 5: The values of the indicators in the period with applied RCM

<table>
<thead>
<tr>
<th>Indicator ROS (X):</th>
<th>Indicator ROA (X):</th>
<th>Indicator ROE (X):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standart deviation (SD):</td>
<td>0.47</td>
<td>1.01</td>
</tr>
<tr>
<td>6SD:</td>
<td>2.81</td>
<td>6SD:</td>
</tr>
<tr>
<td>Coefficient of reproducibility (Cp):</td>
<td>1.53</td>
<td>Coefficient of reproducibility (Cp):</td>
</tr>
</tbody>
</table>

The date in tables 4 and 5 are the basis for comparative analysis. The results of this analysis are presented in table 6.
Table 6: Results from the comparative analysis

<table>
<thead>
<tr>
<th>Indicators:</th>
<th>Base period - without application of risk-controlling mechanism (Q2, Q3, Q4 of 2018):</th>
<th>Period with application of risk-controlling mechanism (Q1, Q2, Q3 of 2019):</th>
<th>Amendment and effect achieved:</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROS (X):</td>
<td>Standart deviation (SD): 0.83</td>
<td>0.47</td>
<td>-43%</td>
</tr>
<tr>
<td></td>
<td>Coefficient of reproducibility (Cp): 1.01</td>
<td>1.53</td>
<td>51%</td>
</tr>
<tr>
<td>ROA (X):</td>
<td>Standart deviation (SD): 2.18</td>
<td>1.01</td>
<td>-54%</td>
</tr>
<tr>
<td></td>
<td>Coefficient of reproducibility (Cp): 1.03</td>
<td>1.35</td>
<td>32%</td>
</tr>
<tr>
<td>ROE (X):</td>
<td>Standart deviation (SD): 1.63</td>
<td>0.20</td>
<td>-88%</td>
</tr>
<tr>
<td></td>
<td>Coefficient of reproducibility (Cp): 1.04</td>
<td>1.49</td>
<td>43%</td>
</tr>
</tbody>
</table>

The results shown in the table represent a reduction of the variation from the objectives defined by the control cards in the periods with applied risk-controlling mechanism. The indicator Cp has value above 1, which is a minimum for validity of the results (Cp=1=6SD). The results from the period with applied RCM show Cp>1,33 which indicated achievement of statistical manageability and reproducibility of the generated profitability (Cp=1,33=8SD).

4. CONCLUSIONS

The current paper presents a detailed description of the developed toolkit for the upgraded RCM – a toolbox that takes into account the influence of the internal and external factors, the application of statistical control cards for risk assessment and a model using the Monte Carlo method for identifying and developing of alternative solutions for risk impact. The obtained results are derived from the development and implementation of methodologies for pilot initiation, application and RCM evaluation methodology of RCM. The result from the RCM approbation are based on comparative analysis of data obtained from two consecutive reporting periods. Each of these periods covers three quarters – the first is defined as base period and does not use RCM as the second one. The results from the comparative analysis reveals a significant reduction of the standard deviation in the profitability indicators and an increase of their reproducibility coefficients, which in the RCM period already exceeded the minimum limit of 1,33. Furthermore these results reveal that the RCM application has provided an effective and proactive management decisions, which leads to a reduction in the risk levels associated with ensuring the sustainability of the enterprise’s economic development. The risk mitigation has provided an increase in the management efficiency, responsible for the economic development of the enterprise.
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5. GLOSSARY

RCM – risk-controlling mechanism
R – control card for dispersing
ISO 31000:2018 Risk management – Guidelines