A Measure of the Internal Consistency of Enterprise Digital Twin Data by Control Bsi Method

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Abstract: The research describes internal consistency of data (Cronbach's alpha) so control a digital twin of an enterprise. The British Standards Institution (BSi) method is used for control. It was created in 1901 to set steel standards for British industrialists. The BSi method is evolving to cover information security standards at different levels of availability. The BSi method has not been widely studied as a separate object. This makes it difficult to estimate its impact on the activities of the enterprise. Cronbach's alpha coefficient is used to estimate the consistency of the data in research. It is a widely accepted measure of the internal consistency of the enterprise's data. The research results show the level of internal consistency of the data. The estimation is carried out before the implementation of BSi and after its implementation

1 INTRODUCTION

Cronbach's alpha is a measure of the internal consistency (reliability) of a test or questionnaire. It is used to estimate how internally consistent responses are to various questions or test items. This measure ranges from 0 to 1, with a value closer to 1 indicating higher internal consistency.

The British Standards Institution (BSi) method dates back to 1901, when a committee of engineers set the first steel standards for British industrialists. Since then, this method has developed and expanded, covering standards that ensure the security of information at all levels of access to it.

In the field of control, it is important to study various approaches to analyzing the activities of economic entities, such as inter-industry balances, various modeling and the agent approach. However, the BSi method is not considered as a separate object for research, which creates certain difficulties in estimating its impact on the activities of the enterprise (Vinnichenko, Istomina, 2023; Taranenko, Banzer, 2021).

Various scientists dealt with the issues of control complex systems: V.V. Leontiev, L.V. Kantorovich, A.G. Granberg, A.G. Aganbegyan, V.F. Krotov, M.G. Dorrer, G.A. Dorrer, S.N. Masayev and others (Dorrer, 2023; Dorrer, 2022; Masaev, 2020; Granberg, 2006; Granberg, 2004; Kantorovich, 2011; Krotov, 1990).

Purpose of the work: to measure the internal consistency of the enterprise digital twin data in normal operation and with the implementation of BSi control.

2 METHOD

Cronbach's alpha is calculated using the following formula:

$$\alpha = \frac{N}{N-1}\left(\frac{\sigma_X^2 - \sum_{i=1}^{N}\sigma_{Y_i}^2}{\sigma_X^2}\right), \text{ где } X = \sum_{i-1}^{N} Y_i \qquad (1)$$

where N is the number of sample components, σ_X^2— standard deviation of all considered sets, $\sigma_{Y_i}^2$ standard deviation of an individual component.

Table 1: Cronbach's alpha values.

α	Values
> 0.9	very good

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> 0.8	good
> 0.7	sufficient
> 0.6	doubtful
> 0.5	bad
≤ 0.5	Insufficient

2.1 Initial data

The digital twin of an enterprise is characterized by 34 values over 60 periods (t). For this period, the x_4, x_9, x_{10}, x_{11}, x_{15}, x_{20}, x_{21}, x_{22}, x_{24}, x_{25}, x_{26}, x_{29}, x_{33}, x_{34} values in the appendix have zero values, since the table is given partially. In the rest of the table, the values of x_4, x_9, x_{10}, x_{11}, x_{15}, x_{20}, x_{21}, x_{22}, x_{24}, x_{25}, x_{26}, x_{29}, x_{33}, x_{34} in other periods are different from zero. A detailed description of the enterprise digital twin under study can be read in the monograph (Masaev, 2021).

2.2 Computations

Let's calculate Cronbach's alpha for data without using the BSi method:

$$\begin{gathered} N = 60 \\ \sigma_X^2 = 981\,045\,998\,494.74 \\ \sum_{i=1}^{66} \sigma_{Y_i}^2 = 32\,752\,955\,528.32 \end{gathered} \quad (2)$$

Let's substitute the values from formula 2 into formula 1:

$$\frac{60}{60-1}\left(1 - \frac{981045998494.74}{32752955528}\right) = 0.982997543 \quad (3)$$

Based on the values in Table 1 and what happened in the computations, we can conclude that the data are in very good agreement.

Let's calculate this coefficient for data using the BSi method:

$$\begin{gathered} N = 77 \\ \sigma_X^2 = 1\,227\,645\,808\,383.88 \\ \sum_{i=1}^{77} \sigma_{Y_i}^2 = 36\,063\,010\,941.87 \end{gathered} \quad (4)$$

Let's substitute the values from formula 4 into formula 1:

$$\frac{77}{77-1}\left(1 - \frac{1227645808383.88}{36063010942}\right) = 0.983395626 \quad (5)$$

The data from the obtained result are also in very good agreement.

When using the BSi method, the Cronbach's alpha coefficient was higher, which suggests that the data using the BSi method fit better than those without.

3 CONCLUSIONS

Cronbach's alpha coefficient values were obtained. For data without using the BSi method, 0.982997543 and for data using the BSi method, the value is 0.983395626. Both coefficient values exceed 0.9, indicating very good internal consistency of the data in both samples. The coefficient value for data using the BSi method is slightly higher. It's a higher degree of internal data consistency across the enterprise.

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APPENDIX

Table 1: Data on the digital twin of an enterprise without the BSi method.

	t								
values x_n	1	2	3	4	5	6	7	8	9
x_1	0.00	0.00	9682.44	9682.44	7546.65	16843.74	16843.74	16843.74	16843.74
x_2	0.00	0.00	0.00	120.94	603.89	7263.85	4349.36	1127.44	5167.66
x_3	0.00	0.00	43939.12	43939.12	13384.41	66167.10	66167.10	66167.10	66167.10
x_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_5	0.00	0.00	0.00	0.00	7761.26	7774.52	7787.78	7801.04	7814.30
x_6	23574.51	23754.74	23754.74	23754.74	21204.40	44015.85	44015.85	44015.85	44015.85
x_7	3064.69	3088.12	3088.12	3088.12	2756.57	5722.06	5722.06	5722.06	5722.06
x_8	8015.33	8076.61	8076.61	8076.61	7209.49	14965.39	14965.39	14965.39	14965.39
x_9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{10}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{11}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{12}	0.00	0.00	7251.17	7251.17	9386.96	89.88	89.88	89.88	89.88
x_{13}	0.00	0.00	0.00	1072.22	4772.72	3031.11	3422.58	0.00	1780.84
x_{14}	0.00	0.00	22331.71	22331.71	68326.34	15543.65	15543.65	15543.65	15543.65
x_{15}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{16}	0.00	0.00	8852.85	8871.14	1128.18	1133.21	1138.25	1143.28	1148.32
x_{17}	34705.99	35214.50	35214.50	35214.50	37764.84	14953.39	14953.39	14953.39	14953.39
x_{18}	4511.78	4577.88	4577.88	4577.88	4909.43	1943.94	1943.94	1943.94	1943.94
x_{19}	11800.04	11972.93	11972.93	11972.93	12840.05	5084.15	5084.15	5084.15	5084.15
x_{20}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{21}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{22}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{23}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	819.01
x_{24}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{25}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{26}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{27}	0.00	0.00	2136.24	0.00	0.00	6278.01	0.00	0.00	6081.94
x_{28}	0.00	0.00	0.00	0.00	0.00	533.69	0.00	0.00	533.69
x_{29}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{30}	0.00	0.00	415.82	571.18	571.18	571.18	571.18	571.18	571.18
x_{31}	0.00	0.00	0.00	901.86	455.11	896.95	1521.26	540.96	1043.11
x_{32}	0.00	0.00	1582.16	2086.16	2086.16	2086.16	2086.16	2086.16	2086.16
x_{33}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{34}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2: Data on the digital twin of an enterprise using the BSi method.

	t								
value x_n	1	2	3	4	5	6	7	8	9
x_1	0.00	0.00	9607.54	9607.54	7471.75	16768.84	16768.84	16768.84	16768.84
x_2	0.00	0.00	0.00	120.94	603.89	7263.85	4349.36	1127.44	5167.66
x_3	0.00	0.00	41929.57	41929.57	11374.87	64157.55	64157.55	64157.55	64157.55
x_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_5	0.00	0.00	0.00	0.00	7761.26	7774.52	7787.78	7801.04	7814.30
x_6	23574.51	23754.74	23754.74	23754.74	21204.40	44015.85	44015.85	44015.85	44015.85
x_7	3064.69	3088.12	3088.12	3088.12	2756.57	5722.06	5722.06	5722.06	5722.06
x_8	8015.33	8076.61	8076.61	8076.61	7209.49	14965.39	14965.39	14965.39	14965.39
x_9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{10}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

x_{11}	0.00	0.00	0.00	0.00	200.00	0.00	0.00	0.00	0.00
x_{12}	0.00	0.00	7251.17	7251.17	9386.96	89.88	89.88	89.88	89.88
x_{13}	0.00	0.00	0.00	1072.22	4772.72	3031.11	3422.58	0.00	1780.84
x_{14}	0.00	0.00	22331.71	22331.71	68326.34	15543.65	15543.65	15543.65	15543.65
x_{15}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{16}	0.00	0.00	8852.85	8871.14	1128.18	1133.21	1138.25	1143.28	1148.32
x_{17}	34705.99	35214.50	35214.50	35214.50	37764.84	14953.39	14953.39	14953.39	14953.39
x_{18}	4511.78	4577.88	4577.88	4577.88	4909.43	1943.94	1943.94	1943.94	1943.94
x_{19}	11800.04	11972.93	11972.93	11972.93	12840.05	5084.15	5084.15	5084.15	5084.15
x_{20}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{21}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{22}	0.00	0.00	0.00	0.00	600.00	0.00	0.00	0.00	0.00
x_{23}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	819.01
x_{24}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{25}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{26}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{27}	0.00	0.00	2136.24	0.00	0.00	6278.01	0.00	0.00	6081.94
x_{28}	0.00	0.00	0.00	0.00	0.00	533.16	0.00	0.00	533.16
x_{29}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{30}	0.00	0.00	415.82	571.18	571.18	571.18	571.18	571.18	571.18
x_{31}	0.00	0.00	0.00	901.86	455.11	896.95	1521.26	540.96	1043.11
x_{32}	0.00	0.00	1582.16	2086.16	2086.16	2086.16	2086.16	2086.16	2086.16
x_{33}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x_{34}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00