

Selection and Optimization Model of Key Performance Indicators

Nyamsuren Purevsuren*, Zolzaya Dashdorj **, Tamir Khujuu ***, Erdenekhuu Norinpel ****

**Department of Communications Engineering, Mongolian University of Science and Technology, Ulaanbaatar, Mongolia*

***Department of Computer Science, Mongolian University of Science and Technology, Ulaanbaatar, Mongolia*

****Department of Educational Studies, Mongolian National University of Education, Ulaanbaatar, Mongolia*

***** Department of Communications Engineering, Mongolian University of Science and Technology, Ulaanbaatar, Mongolia*

nyamsuren@must.edu.mn, zolzaya@must.edu.mn, tamir@mnue.edu.mn, erdenekhuu@must.edu.mn

Abstract— Big data innovations and development brings opportunities to leverage the impacts of performance metrics on a strategic plan.

The purpose of this research work is to study the selection of the performance metrics based on the preferences, and find out what metrics are prioritized in a current strategic plan and how to translate big data insights into meaningful managerial actions.

The authors prioritized group commitments and commitment of KPIs in the case study of universities in Mongolia, using the AHP approach for multi-criteria decision makings. Hardcopy questionnaire and interview sessions were used for collecting data to analyse the prioritization results.

Based on the prioritization results of strategies, we find that decision-makers strongly prefer strategies with the goals and this preference causes the imbalance of metrics on the dashboard.

The prioritization of metrics is highly influenced by the data availability of management reporting. Prioritization of performance metrics are data-driven and bring bottom-up impacts on the dynamics of the strategic plan. The conflicted interests of stakeholders, internal policy, and the excessive amount of metrics make strategic decision makings difficult.

The application of AHP in the case study contributes to improving the speed of decision-making processes, providing scientific results on KPIs prioritization and selection, and providing an approach to assess the differences between what strategic planners think and what they execute and prioritize on a practical level.

The prioritization of performance metrics is the sustainable approach that can be extended to other strategic decision makings as well, for example prioritizing business model elements or business processes.

This research work proves that the multi-criteria decision-making approach AHP can be used to prioritize and identify strategic focus based on selections of the performance metrics.

The research also demonstrates the importance of combining bottom-up data-driven analytics with top-down strategy-making processes in big data developments.

Keywords— KPIs, performance, metrics, strategy, decision making

I. INTRODUCTION

Information is multiplying at an exponential rate and institutions intensively planning to take advantage of fast moving and complex data to achieve improvements in the performance. Traditional information systems used by

organizations in the decision-making process have primarily focused on historical events rather than real-time changes (Bhimani, 2015). How to unleash possibilities in the strategy-making process and create strategic value via big data innovations has become a top concern for a growing number of organizations [1], [2].

Nowadays, big data innovations enable organizations to measure all kinds of performances [3]. However, limitless information is being analyzed with limited imagination and limited processing power (Priestley, 2015).

Several existing studies have focused on assessing the relationship between strategy decision making and the performance measurement, such as evaluate performance of alternative strategic choices (Bitici et al, 2001), prioritization organizational KPIs with SMART criteria and goal settings (Shahin and Mahbod, 2006), the selection of KPIs based on analytic network process approach (Carlucci, 2010), assess a KPI monitor system by using Technology Acceptance Model (Muniandy, 2011), the development of performance metrics repository for business model innovations and implementations (Bouwman et al, 2013).

The current research aims to use the Analytical Hierarchy Process (AHP) (Saaty, 1980) as a research approach to identifying the most preferred performance metrics based on preferences [4]. Because rationality and behaviour issues play significant roles in the strategy-making process, both qualitative and quantitative criteria are included in the multi-actor, multi-criteria decision-making process [5], [6]. The AHP approach is applicable to fulfill the needs of decomposition, comparative judgment, and synthesis of priorities (Shahin & Mahbod, 2006).

This study work contributes to research by assessing the effectiveness of the performance metrics while aligning objectives of the strategy, models, and processes supported with the empirical evidence.

The application of AHP in the case study contributes to 1) improving the speed of processes, 2) providing scientific results on KPIs prioritization and creating insights to translate the performance results into convincing argumentative terms, 3) providing an approach to assess the differences between

what decision-makers think and what they executed and prioritized in the operations [7], [8], [9].

The present paper is structured as follows. Relevant literature is reviewed and discussed in Section 2. Section 3 explains the research methodology in details and section 4 introduces case descriptions for the application of the AHP approach. The results and research findings are presented in section 5. Section 6 concludes the limitations and suggestions for further research.

II. LITERATURE REVIEW

Henry Mintzberg defined the strategy with five Ps: plan, ploy, pattern, position and perspective, strategy in his words are more like a stream of actions and decisions rather than planning. In 2011, Max McKeown argued, "Strategy is about shaping the future" with human attempts to achieve "desired ends with available means." Kaplan and Norton (1996) perceive strategies as "the unique and sustainable ways which organizations create value".

Design failures usually happen in two situations. Firstly, design failure occurs when companies use too few or too many measures [10], [11], [12]. Too few KPIs lead to an imbalance between the outcomes they want to achieve and the performance measures that drive the outcomes, and too many KPIs indicate that the critical few are never going to be identified [13], [14]. Secondly, the design failure occurs "when business units within the company are not aligned with an overall strategy" and each unit develops its Balanced Scorecard due to their interests [15]. In this situation, no common language is used across the organizations, and the balanced scorecard turns to "Scorecard Babel" (Kaplan and Norton, 2001).

A business model is positioned as a conceptual and architectural implementation of the business strategy (Osterwalder, 2002). Followed by the application of the AHP approach, Carlucci (2010) evaluates and selects KPIs based on the analytic network process (ANP) based model. His study work identifies a set of the criteria for multi-criteria decision making and enhances the quality of KPIs selection by using exact weights [16], [17], [18], [19]. However, the AHP approach is only applied and tested with only seven KPIs and the selection criteria lack sufficient theoretical bases.

Generally speaking, both qualitative and quantitative models have been used to make contributions to overcoming the gaps in the design and implementation of performance measurement systems [20]. Conceptual models are more often being used to assess the alignment between strategic goals and performance metrics, and being validated by interviews, surveys or case studies [21]. Quantitative models are more likely being used to assess the effectiveness of performance measurement systems and metrics, for example, the AHP approach or other mathematical iterative models [22], [23], [24].

III. RESEARCH METHODOLOGY

Analytical Hierarchy Process (AHP) is the structured approach developed in the 1970s by Saaty. In past decades,

the AHP approach and the PC-based software Expert Choice have been widely used by both the public and private sectors, in more than 30 diverse decision-making areas including strategic planning, resource allocation and policy-making procedures (Shahin and Mahbod, 2006). Recent studies verified that the AHP method can provide a systematic procedure to represent the elements of any problems in multiple decision-making situations, such as choice, ranking, prioritization, benchmarking, etc. (Saaty, 1983; Gass, 2011). By applying the AHP approach, both quantifiable and intangible criteria are well utilized in problem-solving frameworks (Vargas, 1990). On the one hand, the performance measurements are required to present real facts with reliable data [25]. On the other hand, the practitioners are eager to know which measures or metrics are actually "Key" for them to measure and improve the performance of the systems [26]. The multi-actor, multi-sector, networked-enterprise environment decides prioritization or the selection of key performance indicators a complex problem [27], [28]. The application of the AHP method can provide solid mathematical and psychological bases for decision-making with a particular focus on prioritizations, which greatly contributes to avoiding the selection and design of KPIs that are solely based on "gut feelings" [29], [30], [31]. Meanwhile, recent studies have shown the feasibility to select or prioritize KPIs with the AHP method and confirmed the selection can deliver meaningful guidance and managerial implications (Shahin and Mahbod, 2006; Carlucci, 2010).

To organize the decision-making procedures and to generate the priorities, Saaty (2008) proposes four steps to decompose the decisions: "1) Define the problem and determine the kind of knowledge sought; 2) Structure of the decision hierarchy from top to down [32]. Starting from the top - the goal of the decision, then the objectives from a broad perspective, followed by the intermediate level criteria on which subsequent elements depend, to the lowest level, a set of alternatives; 3) Construct a set of pairwise comparison matrices; and 4) Use the priorities obtained from the step 3 to weigh the priorities until the final priorities of the alternatives in the bottom level are obtained.

The KPI selection model should be seen as an indispensable tool, which can help for providing support in the identification of the critical spots/weaknesses and resolve them in the future perspective by measuring and analysing the selected metrics. The great number of growing metrics that are influenced by the management. As a result, unnecessary quantities of unprocessed data are being collected. For using this data, it's required to make the analysis.

Also, the Analysis Model is a part of the KPI selection model and it can be divided into the next main phases. Steps of research method in this study:

- Data collection (getting answers on the questions);
- Data analysing;
- Weight calculation (based on answers);
- Ranking of the answers;
- KPIs selection;
- KPIs implementation;

- Data collection;
- Data analysis - An AHP analysis tools.

The whole process, shown in Figure 1 should be repeated continuously, as the situation is changed rapidly and it requires the monitoring of the whole processes in the universities.

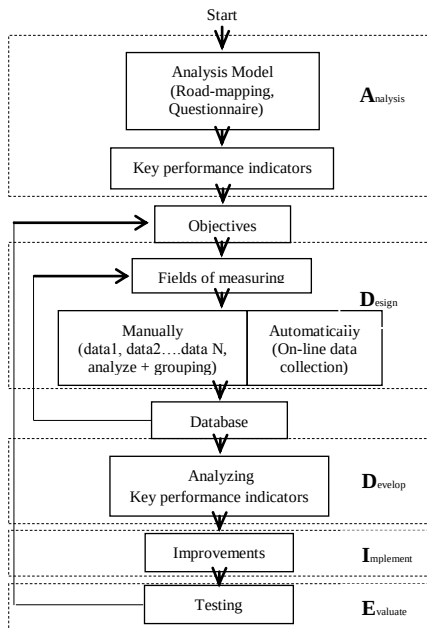


Figure 1. KPI selection model and Optimization procedure

The optimization problem considered can be formulated as:

$$\begin{aligned}
 & \text{Min } R_i \\
 & \text{subjected to} \\
 & KPI \leq KPI^* \\
 & \text{questions} \leq \text{questions}^*, \\
 & PI > PI^*
 \end{aligned} \quad (1)$$

R_i -stands for resources (total time for analysis, working hours for completing the questionnaire, etc.), KPI^* - and questions^* are estimated upper limits for the number of KPIs and questions, respectively. To keep the model adequate, the information related to performance PI should be retained upper critical limit PI^* .

The basic steps of the KPI selection/optimization procedure can be outlined as follows:

- Step1. Forming the initial questionnaire, KPIs
- Step1.1. Composing initial questionnaire based on literature, experts, KPIs
- Step1.2. Identifying links between constructs and questions, KPIs
- Step1.5. Classification of KPIs (direct, indirect, suggested)
- Step2. Applying an expert group for reducing questions, KPIs
- Step2.1. Ranking questions
- Step3. Applying outlier's method for reducing questions, KPIs
- Step3.1. Employing the standard deviation method

Step3.2. Selection of outliers based on the results of applying outlier's methods

Step4. Estimating the final set of KPIs and questions.

The KPI selection model with the data flow and necessary steps/optimization procedure illustrates in the above figure.

IV. DATA COLLECTION

This study work focuses on the research domain of prioritization and selection of performance metrics of top universities in Mongolia. The high variety of operational performance indicators and performance management systems makes it difficult to devise an actionable strategic plan [33], [34], [35]. Visions, missions, and commitments illustrate that which kind of key performance indicators required to be selected.

A. The questionnaire

After decomposing the problem into a hierarchy tree, the elements (factors, attributes, and alternatives) on each level have to be compared by the pair-wise method [36], [37]. Elements of pair-wise method will be compared based on its relative importance to the parent level [38], [39]. The scale which is showed below (Table 1), it is used to express the level of relative importance in pair-wise comparisons. This scale is designed based on past AHP studies and the setup of questionnaires.

TABLE 1. SCALE FOR PAIR-WISE COMPARISON
(ADAPTED FROM NIKOU, 2012)

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities considered equally important
3	Moderate importance of one over another	One activity is marginally favoured over another
5	Essential or strong importance	One activity is strongly favoured over another
7	Very strong importance	One activity is very strongly favoured and its dominance is demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order
2,4,6,8		Intermediate values between two adjacent judgments

The questionnaire was used for this research work to collect the data from pair-wise comparisons. It was designed based on the study of Nikou (2011). The draft questionnaire was designed firstly. After that required to make the test by expert and some potential participants [40], [41]. All questionnaires are revised based on the feedback and comments [42], [43], [44].

It is always required that participants obtained a certain level of knowledge about the studied topics (Nikou, 2011).

In reality, it is a small group of managers who knows and works on institutional strategy by using KPIs. Most of the participants are managers or directors, who are owners of

commitment KPIs from different groups or functions in the institutional. Table 2 lists the information of participants who completed the questionnaires.

Questionnaires are distributed and collected via face-to-face meetings. The value of the position coefficient characterizes the impact of the manager's team position on the answer. The higher coefficient shows more trustworthy information. It is influenced by the final answer.

For evaluation of the coefficient values, the judgment of the expert group of members must be with more than 5-year work experience in the field of process optimization in the main research/activity area. It was taking into account the coefficients values and the results are introduced in table 2.

TABLE 2. INFORMATION OF PARTICIPANTS

Participants	Coefficient
Governing board	1
President	0.9
Vice-president	0.8
Directors of institutions	0.7
Managers	0.6

B. Data analysis

A total of 84 people participated and 67 respondents returned to the completed questionnaires. 17 respondents uncompleted questionnaires. To simplify the analysis of the received data, the answers were grouped by the number of respondents from whom they were received. Reliability analysis was performed to check the consistency of the survey data. Cronbach's Alpha was calculated. According to the theory, the data is reliable, if Cronbach's coefficient alpha is above 0.700 and the acceptable minimum must be 0.600.

V. EXPERIMENT RESULTS

In this section, the results of applying the AHP approach in KPIs prioritization are discussed and elaborated.

The alpha coefficients for each group of answers are given in table 3.

TABLE 3. THE ALPHA COEFFICIENTS FOR EACH GROUP OF ANSWERS

Group №	Amount Questions	of number respondents	of Cronbach Alpha
Group 1	42	43	0.756
Group 2	32	43	0.963
Group 3	36	40	0.444
Group 4	36	41	0.689
Group 5	38	34	0.623
Group 6	32	35	1
Group 7	34	35	0.785
Group 8	32	50	0.149

From table 3 we can see that the results of the groups 3, 8 are not consistent. The questions could be the reason for the low consistency, as the data set was evaluated from 1 to 9 score. The answers on duplicated questions, which have differed from each other more than 1 point, were not taken into account and were eliminated from the analysis. Figure 2 shows the question distribution functions.

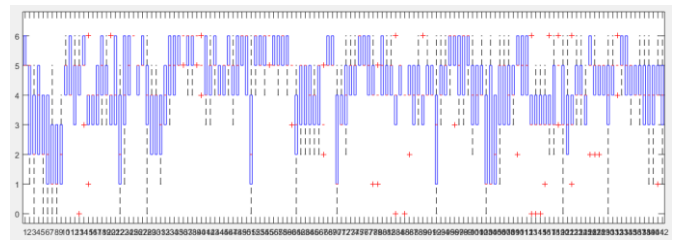


Figure 2. The question distribution function

In statistics, the standard deviation is a measure of the amount of variation or dispersion of a set of values.

$$s = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (x_i - \bar{x})^2} \quad (2)$$

Where $\{x_1, x_2, \dots, x_N\}$ are the observed values of the sample items, $\bar{x}$ is the mean value of these observations, and N is the number of observations in the sample.

A low standard deviation indicates that the values tend to be close to the mean of the set, while a high standard deviation indicates that the values are spread out over a wider range.

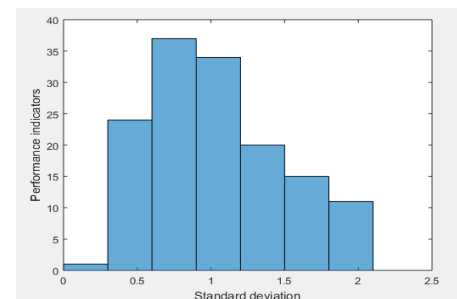


Figure 3. Performance indicators standard deviation

The value of the standard deviation is fixed from 0 to 2. The main standard deviation is found below than 1 and it's the performance indicators set as from 141 to 50. The main idea of the duplicated questions based on the compared checking procedure.

Questions	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	Total amount	PV		
1	P1	1.00	3.00	3.00	5.00	7.00	5.00	7.00	8.00	7.00	5.00	3.00	9.00	3.00	1.00	3.00	7.00	5.00	3.00	1.00	0.33	0.11	12.00	0.14		
2	P2	0.33	1.00	0.33	1.00	0.33	0.20	0.33	0.11	0.14	0.20	0.33	0.11	0.33	1.00	0.33	0.14	0.20	0.33	1.00	0.33	0.11	8.42	0.01		
3	P3	0.33	3.00	1.00	3.00	5.00	7.00	5.00	7.00	7.00	5.00	3.00	9.00	1.00	1.00	3.00	7.00	5.00	1.00	3.00	3.00	9.00	93.33	0.90		
4	P4	0.20	1.00	0.33	1.00	1.00	0.33	1.00	0.14	0.14	0.14	0.20	0.33	0.11	1.00	1.00	0.14	0.20	1.00	0.20	1.00	0.33	0.11	17.92	0.03	
5	P5	0.14	3.00	0.20	1.00	1.00	1.00	7.00	7.00	5.00	5.00	9.00	3.00	3.00	5.00	5.00	7.00	5.00	3.00	1.00	5.00	7.00	41.34	0.97		
6	P6	0.11	5.00	0.14	3.00	1.00	1.00	1.00	0.14	0.17	0.20	0.33	0.11	0.33	1.00	0.33	0.14	0.20	0.33	0.20	1.00	0.33	0.14	16.20	0.02	
7	P7	0.14	3.00	0.20	1.00	1.00	1.00	1.00	7.00	7.00	5.00	3.00	9.00	3.00	1.00	3.00	7.00	5.00	3.00	1.00	3.00	7.00	76.34	0.06		
8	P8	0.33	9.00	0.14	7.00	0.14	7.00	0.14	1.00	1.00	0.33	0.20	0.33	0.14	0.14	0.20	1.00	0.33	0.14	0.33	0.11	0.20	1.00	39.23	0.03	
9	P9	0.14	7.00	0.14	7.00	0.14	7.00	0.14	1.00	1.00	3.00	3.00	5.00	7.00	7.00	5.00	1.00	3.00	7.00	3.00	9.00	5.00	1.00	62.57	0.07	
10	P10	0.20	5.00	0.20	5.00	0.20	5.00	0.20	2.00	0.33	1.00	0.33	0.20	0.20	0.14	0.33	1.00	0.20	1.00	0.14	0.33	0.33	25.35	0.02		
11	P11	0.33	3.00	0.33	3.00	0.20	3.00	0.20	0.20	0.20	1.00	7.00	3.00	3.00	1.00	1.00	1.00	1.00	5.00	1.00	5.00	5.00	48.52	0.04		
12	P12	0.11	9.00	0.11	9.00	0.11	9.00	0.11	3.00	0.20	5.00	0.14	1.00	0.20	0.20	0.20	1.00	0.33	0.20	0.33	0.14	0.20	1.00	49.68	0.03	
13	P13	0.33	3.00	1.00	0.33	3.00	0.33	7.00	0.14	5.00	1.00	5.00	1.00	1.00	1.00	3.00	1.00	1.00	1.00	1.00	1.00	1.00	41.14	0.04		
14	P14	1.00	1.00	1.00	1.00	0.33	1.00	1.00	7.00	0.33	5.00	1.00	1.00	1.00	1.00	0.20	0.33	1.00	0.33	1.00	0.14	0.20	1.00	32.81	0.05	
15	P15	0.33	3.00	0.33	3.00	0.20	3.00	0.33	0.20	3.00	1.00	5.00	1.00	1.00	1.00	3.00	1.00	1.00	1.00	5.00	1.00	5.00	44.40	0.03		
16	P16	0.14	7.00	0.14	7.00	0.14	7.00	0.14	1.00	1.00	1.00	0.33	1.00	0.33	0.33	1.00	1.00	0.33	1.00	0.20	1.00	1.00	27.69	0.04		
17	P17	0.20	5.00	0.20	5.00	0.20	5.00	0.20	3.00	0.33	1.00	1.00	3.00	3.00	1.00	1.00	1.00	1.00	5.00	1.00	5.00	3.00	44.42	0.03		
18	P18	0.33	3.00	1.00	1.00	0.33	3.00	0.33	7.00	0.14	5.00	1.00	5.00	1.00	3.00	0.33	1.00	0.33	0.33	1.00	0.14	0.20	1.00	35.27	0.04	
19	P19	0.20	5.00	0.20	5.00	0.20	5.00	0.20	3.00	0.33	1.00	1.00	3.00	3.00	1.00	1.00	1.00	1.00	5.00	1.00	5.00	3.00	44.42	0.03		
20	P20	0.20	1.00	0.33	1.00	1.00	1.00	1.00	8.00	0.11	7.00	0.20	7.00	0.33	1.00	0.20	5.00	0.20	1.00	1.00	1.00	0.14	0.20	1.00	48.91	0.04
21	P21	0.33	3.00	0.33	3.00	0.20	3.00	0.33	0.20	3.00	1.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	34.40	0.03		
22	P22	0.11	9.00	0.11	9.00	0.14	7.00	0.14	1.00	1.00	2.00	0.20	1.00	1.00	7.00	0.20	0.20	1.00	0.33	7.00	0.33	7.00	57.57	0.04		
Total amount		6.57	92.80	10.79	82.88	29.22	88.53	21.28	91.39	34.93	75.73	26.74	89.87	28.87	43.43	29.46	54.83	33.46	41.54	33.46	55.93	31.73	56.12	948.72	0.997	

Figure 4. Calculation of expert evaluation by AHP approach

The average value of weight was calculated and the rank was applied for each question. The investigated situation which is described by the question was recognized as acceptable.

Arguments with an average weight between 2 and 4 were placed into a second group. The situation was considered, the average weight fixed less than 3 were placed in a group. In table 4 shows the importance of the problems which have

been characterized by the values of the rank and average weight of the questions.

TABLE 4. QUESTIONS RANKING

Questions	Average	Comment	Rank
the total number of research and teaching staff.	3.281	Higher->better	15
number of articles indexed in the Web of Science and Scopus databases	2.339	Higher->better	4
number of full-time international students	1	Higher->better	1
total number of full-time students	2.771	Higher->better	10
number of main educational programs delivered in English	2.701	Higher->better	6
the average number of university research and teaching staff.	3.027	Higher->better	12
number of researchers qualified through a competitive selection process and working under postdoctoral programs	2.613	Higher->better	7
the number of user's electronic educational products.	3.206	Higher->better	14
reputation score among employers	2.2	Higher->better	2
the number of Ph.D. and DSc theses defended.	2.623	Higher->better	8
number of full-time graduate students	2.277	Higher->better	3
number of full-time postgraduate students	2.748	Higher->better	9
English language proficiency	2.479	Higher->better	5
number of the official documents that have duplicates in English	3.133	Higher->better	13
income from all the income-generating activities	2.893	Higher->better	11

According to the main concept of the analysis model, each argument/question was connected to KPIs at the beginning of the survey and the main KPIs group with their ranking rating was selected (see table 5) in the previous studies. Based on this knowledge, the metrics for universities should follow in the future to change the situation were selected.

Based on the KPIs ranking and the ranking of the issues, the final table with rankings is introduced in table 6. According to the results, TOP3 critical issues at the tested universities were:

- Percentage of research and teaching staff with publications indexed in the Web of Science and Scopus databases (number of articles, number of research and teaching staff.);
- Percentage of International students (number of International students, number of total students);
- Reputation among employers (Percentage of educational programs delivered in English, New unique and cutting-edge educational programs, Number of electronic educational products users, Specific area of social infrastructure facilities, Courses delivered in English).

TABLE 5. RANKING OF THE MAIN KPIs

KPI No	KPI Name	Rank
KPI 1	Percentage of income from non-budgetary sources in the revenue structure of the university	9
KPI 2	Percentage of graduate, postgraduate students and doctoral candidates in the total number of full-time students	10
KPI 3	Percentage of educational programs delivered in English	8
KPI 4	Percentage of research and teaching staff with publications indexed in the Web of Science and Scopus databases	1
KPI 5	Number of postdoc researchers	7
KPI 6	Reputation among employers	3
KPI 7	defence of Ph.D. and DSc theses	4
KPI 8	International students enrolled in joint educational programs	5
KPI 9	Percentage of International faculty	6
KPI 10	Percentage of International students	2

The quality issues according to the analysis also needed to be introduced to the management.

The proposed KPIs analysis should be performed not only one time but it needed to be iteratively evaluated.

Now we are introducing the package of recommended metrics for universities to make performance evaluation, to increase the competitiveness and use it for decision making strategy and planning.

TABLE 6. THE PACKAGE OF RECOMMENDED METRICS IN UNIVERSITY EXAMINED

KPIs	Rank	Importance
Percentage of research and teaching staff with publications indexed in the Web of Science and Scopus databases	1	↑ ↓ high Low
Percentage of International students	2	
Reputation among employers	3	
Defence of Ph.D. and DSc theses	4	
International students enrolled in joint educational programmes	5	
Percentage of International faculty	6	
Number of postdoc researchers	7	
Percentage of educational programmes delivered in English	8	
Percentage of income from non-budgetary sources in the revenue structure of the university	9	
Percentage of graduate, postgraduate students and doctoral candidates in the total number of full-time students	10	

The proposed AHP-based model has limitations on assessing alignments of analysis models and the process via performance metrics.

VI. CONCLUSIONS

The KPIs ranking accelerates the development of universities and supports government policy.

Further development of the research work should be related to improving the model by particularly focus on analysis model design aspects and the selection of related metrics while addressing the barriers of a large number of metrics. Finally, the model is open and replicable for future

development. In conclusion, this paper proposed a KPIs prioritization framework with the application of an AHP approach. This KPIs prioritization can help with the selection of performance metrics and assess the alignments of strategy, models, and processes.

This study work contributes to providing exploratory evaluations of a quantitative approach to the developments in the managerial decision-making process and performance management.

ACKNOWLEDGMENT

This research work was supported by the Ministry of Education, Culture, Science, and Sports and by the Mongolian University of Science and Technology, Mongolian National University of Education.

REFERENCES

- [1] Amit, R., & Zott, C. (2001). Value creation in business. *Strategic management journal*, 22(6/7), 493-520.
- [2] Muhammad Hanif, Choonhwa Lee. (2017). Capacity-aware Key Partitioning Scheme for Heterogeneous Big Data Analytics Engines. *ICACTION Transactions on Advanced Communications Technology (TACT) Vol. 6*
- [3] Bhimani, A. (2015). Exploring Big Data's Strategic Consequences. *Journal of Information Technology*, 30(1), 66-69.
- [4] Banker, R. D., Chang, H., Janakiraman, S. N., & Konstans, C. (2004). A balanced scorecard analysis of performance metrics. *European Journal of Operational Research*, 154(2), 423-436.
- [5] Barrows, E., & Neely, A. (2011). *Managing performance in turbulent times: analytics and insight*. John Wiley & Sons.
- [6] Bellman, R., Clark, C. E., Malcolm, D. G., Craft, C. J., & Ricciardi, F. M. (1957). On the construction of a multi-stage, multi-person business game. *Operations Research*, 5(4), 469-503.
- [7] Bouwman, H., De Vos, H., & Haaker, T. (2008). Mobile service innovation and business models (Vol. 2010). Berlin: Springer.
- [8] Bouwman et al. (2013). Business Models and Metrics. *International Journal of Operations and Production Management*
- [9] Bouwman, H., De Reuver, M., Solaimani, S. Daas, D., Haaker, T., Janssen, W., Iske, P. and Walenkamp B. (2012). *Business Models, Tooling and Research Agenda*. Paper presented at the first 25 years of the Bled Conference.
- [10] Brignall, S., Silvestro, R., & Voss, C. (1991). Performance measurement in service businesses. London: Chartered Institute of Management Accountants.
- [11] Cavalieri, S., Gaiardelli, P., & Ierace, S. (2007). Aligning strategic profiles with operational metrics in after-sales service. *International Journal of Productivity and Performance Management*, 56(5/6), 436-455.
- [12] Chesbrough, H., & Rosenbloom, R. S. (2002). The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin" off companies. *Industrial and corporate change*, 11(3), 529-555.
- [13] Chesbrough, H. (2010). Business model innovation: opportunities and barriers. *Long-range planning*, 43(2), 354-363.
- [14] Cross, K., & Lynch, R. (1989). Accounting for competitive performance. *Journal of Cost Management*, 3(1), 20-28.
- [15] Gordijn, J., & Akkermans, H. (2001). Designing and evaluating e-business models. *IEEE Intelligent Systems*, 16(4), 11-17
- [16] Hart, S. L. (1992). An integrative framework for strategy-making processes. *Academy of management review*, 17(2), 327-351.
- [17] Hartmann, P. M., Zaki, M., Feldmann, N., & Neely, A. (2014). Big Data for Big Business. *A Taxonomy of Data-Driven Business Models Used by Start-up Firms*. University of Cambridge, Cambridge Service Alliance.
- [18] Hartwich, F. (1999). The weighting of Agricultural Research Results: Strength and Limitations of the Analytic Hierarchy Process (AHP). Universität Hohenheim.
- [19] Heikkilä, J., Heikkilä, M., & Tinnilä, M. (2005). The Role of Business Models in Developing Business Networks. In Saarinen T., Tinnilä M. and Tseng A. (Eds.), *Managing Business*
- [20] Heikkilä, J., Tyrväinen, P. and Heikkilä, M. (2010), "Designing for performance - a technique for business model estimation", In Seppä, M., Helander, N., Ilvonen, I., (eds.). *Proceedings of EBRF Research Forum to Understand Business in Knowledge Society*. Ishizaka, A., & Labib, A. (2009). Analytic hierarchy process and expert choice: Benefits and limitations. *OR Insight*, 22(4), 201-220.
- [21] Kaplan, R. S., & Norton, D. P. (1996). Using the balanced scorecard as a strategic management system. *Harvard business review*, 74(1), 75-85.
- [22] Kaplan, R. S., & Norton, D. P. (2001). *The strategy-focused organization: How balanced scorecard companies thrive in the new business environment*. Harvard Business Press.
- [23] Larcker, D. F. (2014). Organizational Strategy, Business Models, and Risk Management, Center for Leadership Development and Research, *Stanford Business Graduate of School*.
- [24] Lukac, E. G., & Frazier, D. (2012). Linking strategy to value. *Journal of Business Strategy*, 33(4), 49-57.
- [25] Feyissa Woyano, Soyeon Lee, Sangjoon Park. (2016). Evaluation and Comparison of Performance Analysis of Indoor Inertial Navigation System Based on Foot Mounted IMU. *ICACTION2016*, 796-802
- [26] McAdam, R., & Bailie, B. (2002). Business performance measures and alignment impact on strategy: The role of business improvement models. *International Journal of Operations & Production Management*, 22(9), 972-996.
- [27] Martikainen, O., & Halonen, R. (2011, August). Model for the Benefits Analysis of ICT. In AMCIS.
- [28] Millet, I., & Saaty, T. L. (2000). On the relativity of relative measures—accommodating both rank preservation and rank reversals in the AHP. *European Journal of Operational Research*, 121(1), 205-212.
- [29] Mitra, T. Business-driven development. IBM developer Works article, IBM (2005).
- [30] Neely, A., Gregory, M., & Platts, K. (1995). Performance measurement system design: a literature review and research agenda. *International journal of operations & production management*, 15(4), 80-116.
- [31] Neely, A. D., Adams, C., & Kennerley, M. (2002). *The performance prism: The scorecard for measuring and managing business success*. London: Prentice-Hall Financial Times.
- [32] Neely, A., Yaghi, B., & Youell, N. (2008). Enterprise performance management: The global state of the art. *Oracle and Cranfield School of Management*, 9, 3-4.
- [33] Nikou, S., Mezei, J., & Bouwman, H. (2011, June). Analytic Hierarchy Process (AHP) Approach for Selecting Mobile Service Category (Consumers' Preferences). In Mobile Business (ICMB), 2011 Tenth International Conference on (pp. 119-128). IEEE.
- [34] Niven, P. R. (2011). *Balanced scorecard: Step-by-step for government and nonprofit agencies*. John Wiley & Sons.
- [35] Osterwalder, A., Pigneur, Y., & Tucci, C. L. (2005). Clarifying business models: Origins, present, and future of the concept. *Communications of the Association for Information Systems*, 16(1)(1).
- [36] Osterwalder, A. (2004). The business model ontology: A proposition in a design science approach. Institut d'Informatique et Organisation. Lausanne, Switzerland, University of Lausanne, Ecole des Hautes Etudes Commerciales HEC, 173.
- [37] Osterwalder, A., & Pigneur, Y. (2010). Business Model Generation: A Handbook for Visionaries, Game Changers, And Challengers Author: Alexander Osterwalder, Yves.
- [38] Platt J., Souza, R., Checa, E., Chabaladas, R. (2014). Seven Ways to Profit from Big Data as a Business. The Boston Consulting Group Publications.
- [39] Pohle, G., Korsten, P., & Ramamurthy, S. (2005). Component business models: making specialization real. *IBM Institute for Business Value*. August, 19.
- [40] Priestley T. (2015). Chasing Big Data and The Data Scientist Unicorn. The Forbes. July 2015. Rohm, H., & Malinoski, M. (2010). Strategy-Based Balanced Scorecards for Technology. *Balanced Scorecard Institute*.
- [41] Solaimani, S., Bouwman, H. (2012). "A framework for the alignment of the business model and business processes: A generic model for trans-sector innovation", *Business Process Management Journal*, Vol. 18 Iss: 4, pp.655 - 679

- [42] Stede, W. A. V. D., Chow, C. W., & Lin, T. W. (2006). Strategy, choice of performance measures, and performance. *Behavioral Research in Accounting*, 18(1), 185-205.
- [43] Teece, D. J. (2010). Business models, business strategy and innovation. *Long-range planning*, 43(2), 172-194.
- [44] Timmers, P. (1998). Business models for electronic markets. *Electronic markets*, 8(2), 3-8.



Nyamsuren Purevsuren is a lecturer of the Department of Communication Engineering Technology, School of Information and Communication Technology of MUST. She is a member of the Management Board of Technology Innovation Mongolian Young Scientist Association, Mongolian Association for Higher Education Research. Her current research focuses on Big Data, learning technologies.



Zolzaya Dashdorj received a Ph.D. degree in ICT from the University of Trento, Italy in 2015. She is currently the senior lecturer in the Department of Computer Science at the Mongolian University of Science and Technology in Mongolia. Her research interests include artificial intelligence, big data, data mining, knowledge management, semantics, geography computation, text mining, bioinformatics, and machine learning.



Tamir Khujuu is head of the Department of Educational Studies, received his B.S. and M.S. degrees in Civil Engineering from School Civil Engineering and Architecture, Mongolian University of Science and Technology (MUST) in 1995 and 1997. He received his Ph.D. degree from Mongolian National University of Education. His research interests are Educational Studies, modern higher education technology, pedagogy.



Erdenekhuu Norinpel is head of the department of communication engineering and received his Ph.D. degree from Mongolian University of Science and Technology, Mongolia, in 2007. His research interests focus on satellite communication technology, Green ICT technology, and modern higher education technology. Currently, he works as a team leader of the CDIO implementation project in telecommunications engineering technology programs of MUST since 2014.