Technical Effeciency of Faculties in Sana'a University Using Data Envirnment Analysis (DEA)

Akram Sufian M. Budair*

Abstract—The effectiveness of seventeen faculties at Sana'a University (FSU) is investigated in this article. The aim of this paper is to estimate and evaluate efficiency in (FSU) for the 2018/2019 academic year. The total number of graduated students is calculated as output and using the total number of the indicators as inputs; enrolled students and academic teaching staff. To calculate the efficiency score, the researcher used an output orientated model with variable return to scale (VRS). The results revealed that (7) FsSU, or 41.18 percent were effective in terms of variable return to scale VRS efficiency, with an average of 0.79. In terms of Constant return to scale CRS efficiency, FSU obtained an average scale efficiency of 0.91 and only five FSU achieved the optimum size, with four FSU being effective with an average of 0.72.

Index Terms— Technical Efficiency, variable return to scale, Data Envelopment Analysis.

1 Introduction

Sana'a University_ as the first university in Republic of Yemen_ established in 1970 with two faculties, Faculty of Education and Faculty of Sharia'a and Law, and (260) male and female students. Due to the remarkable growth of social demand for the academic education, was opened many faculties of education in many governorates and a significant expansion of faculties and their members staff of teaching and students. The number of registered students at (FSU) 83,357 male and female students during 2018/2019 and the number of academic staff members reached 1815.

The objective of this paper is to use the data envelopment analysis method to estimate and evaluate the efficiency of (17) faculties at Sana'a University FSU for the academic year 2018/2019.

The success of maximizing output from a given set of inputs is known as "efficiency" (or vice versa) (Bornmann & et al., 2019:3). Farrell (1957), who is known for his studies on calculating effective production, recognized the value of determining the degree to which outputs can be increased without utilizing additional resources (inputs) by increasing efficiency (Avkiran, 2001). So the efficiency is the ability of the institution for the optimal using of the available possibilities and resources (inputs) to attain the best amount of (outputs) in an optimum returns and fewer cost, effort and time.

While numerous studies in developed economics have calculated the efficiency of universities in various countries around the world using various parametric and non-parametric approaches (Alshayea & Battal, 2013:177). DEA has been applied in analyzing efficiency of universities like Germany (Bornmann & et al., 2019), Colombia (Cadavid & et al., 2017, Canal & et al., 2015), Romania (Olariu & Brad, 2017), Czech (Mikusova, 2017), Turkey (Gul & et al., 2017, Topcu & Kabak, 2017, Erkog, 2016, Selim & Bursalioglu, 2013), Malaysia (Adamu & et al., 2016), Italy (Agasisti & et al., 2015), Spain (Martínez & et al., 2018), India (Bhagavath, 2005), Australia (Abbott & Doucouliagos, 2003), Argentina (Martinez & et al., 2018) and Canada (Mcmillan & Datta, 1998). There are another group of scientific papers have evaluated the efficiency of academic departments like (Goksen & et al., 2015, Sirbu, 2016, Duguleana, 2015). But there are a few Studies in Arabs countries, special in Republic of Yemen.

Literature Review

It is important to examine the various definitions of efficiency and some types of efficiency in order to address DEA in greater depth.

EFFICIENCY

Efficiency measurement is not only giving information about the accomplishments of a unit, but it also identifies the projections for improvement for future development (Kao, 2017: 680). Operational efficiency is a critical metric for assessing an organization's ability to convert resources or inputs into outputs at the highest possible level (Kashim & et al., 2018:

• *Assistant Professor of Educational Administration & Planning, Ministry of Education, Republic of Yemen, Tel. No. +967 775781749.*
E-mail: budair2015@gmail.com
E-mail: budair2000@gmail.com

570).So the efficiency represents the economic relationship between available resources and achieved results through maximizing the outputs under the same inputs.

1.1. WAYS OF IMPROVING EFFICIENCY:

There are many approaches to develop the efficiency of the institution can help the decision makers to choose any accordingly the personification of those elements that the responsible on the faults, in addition to those outer constraints, these approaches are:

1. Outputs' Steadiness with Inputs Decreasing: Disposability of the extra and not exploited inputs elements, whereby do not effect on the achieved outputs.
2. Increasing of Outputs with Steadiness of Inputs: Using all the managerial methods, which moves the resources ahead, and preventing the lost values to be in the institution.
3. Increasing of Outputs and Increasing of Inputs: This occurs conditionally the percentage on the outputs upper. This approach depends on the expansion and expenditure, e.g. the motivations and the productivity.
4. Decreasing of outputs and Decreasing of Inputs: Inputs decreasing should be more than the previous situation, e.g. decreasing the size of overflowing activities, which did not achieve any competitive characteristic for the institution.
5. Increasing of Outputs with Decreasing of Inputs: This approach is the best, there is more inputs with fewer outputs.

1.2. INDICATORS OF MEASURING THE EFFICIENCY IN UNIVERSITIES:

- Classification of academic teaching staff with different scientific degrees and the average of students per teacher/ doctor.
- Ratio of the developing curriculum and achieved scientific researches and periodicals, and the library references.
- Ratio of the laboratories and physical equipment.
- Followed managerial model and the type of available information in the higher education institutions.
- Enrolling methods in the educational institutions and evaluating methods.
- Determining the finance of higher education in the future, therefore attainability actual development by the resources distribution. (Budair, 2020:43)

In this paper, the indicators will be (enrolled students number, academic teaching staff, and graduated students number).

1.3. MEASUREMENT AND EVALUATION OF EFFICIENCY CONDITIONS:

1. Effectiveness is often a subjective term. Efficiency as a concrete value has information value only when compared to the efficiency of other alternatives; there is no acceptable information value without this contrast.

2. In order to express efficiency in quantities, we must have quantifiable (numerical) input and output values. (Rosenmayer, 2014: 36).

The Data Envelopment Analysis is a method intended for evaluation of production efficiency using technical efficiency.

2 ANALYSIS OF DATA ENVELOPMENT (DEA)

Data Envelopment Analysis (DEA) is a non-parametric modern Quantitative Methods approach for evaluating and measuring the productivity of a group of related entities in order to make the best decision.

2.1 THE DEA AND DIFFERENT CONCEPTS OF EFFICIENCY

DEA tests the efficiency of an entity within a group in comparison to observed best pursuit within that group, typically using linear programming.

The methodology used in this paper is based on a calculation of faculties' technical efficiency at Sana'a University. The word "technical efficiency" in this context refers to the maximization of output or supply of goods, but not necessarily in relation to demand (Rosenmayer, 2014: 36). Technical efficiency is defined as the maximum reduction in all inputs while allowing the production of a given output to continue (Silva, & et al. 2004: 39). The term "technical productivity" refers to maximizing output given a set of inputs. Efficiency is calculated in terms of costs per unit or as a ratio of outputs to inputs.

Technical efficiency is the most common efficiency concept: the conversion of physical inputs (such as enrolled students and academic teaching staff) into outputs (graduated students) in comparison to best practice.

Relative efficiency is the ability of any institution to use the available resources (inputs and outputs) in its faculties, colleges and centers as the optimal using to achieve the relative characteristic through they are on the Efficiency Frontier and the relative efficiency degree equal (1) or (100%). This efficiency contains the Technical Efficiency (TE) and Scale Efficiency (SC).

If the organization is being studied already completely technically efficient, allocating efficiency refers to whether inputs are chosen to reduce the cost of production for a given amount

of output and set of input prices. The word "al-locative efficincy" refers to a collection of production processes for estimating market supply and demand. It can also be expressed as a percentage score, with a score of 100 percent indicating that the institution is using its inputs in the most cost-effective manner.

The term "cost efficiency" refers to the combination of technical and allocative efficiencies. Only if an enterprise is both technically and allocatively efficient, it can be cost efficiency. Cost efficiency is measured as the product of technical and allocative efficiency scores (expressed as a percentage), so an institution can only achieve a 100 percent cost efficiency score if both technical and allocative efficiency are 100 percent.

Scale efficiency (SC) measures the gap between the efficiency score of a DMU under Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS).

Data Envelopment Analysis (DEA) is ascientific technique for determining the technical efficiency of DMUs with multiple inputs and outputs (Charnes et al. 1994; Banker et al., 1984). The method used here is a straightforward application of data envelopment analysis (DEA), which was developed by Charnes, Cooper, and Rhodes (1978) to assess the performance of similar public-sector organizations. So Data Envelopment Analysis (DEA) is a linear programming technique that determines the efficiency of decision-making units by combining multiple inputs and outputs (DMUs).

Productivity is largely determined by production technology, performance, and the production environment. The second, or production efficiency, for each production unit of a group of decision-making units (DMUs) — in this case, faculties at universities — is the subject of Data Envelopment Analysis (DEA). Comparability refers to a group of producers that have similar goals and generate similar outputs with similar inputs and technologies (Rosenmayer, 2014:41).

DEA compares the efficiency of the decision-making units (DMUs) to the best performer in the study to determine the efficiency of the DMUs (Alshayea & Battal, 2013:178). The number of homogeneous entities relative to each other is used by the DEA as a subjective indicator of operational performance. Through a number of samples unit that form together a performance frontier curve envelopes all observations:

$$\Theta = \max \theta$$
$$s.t.\ \theta x_{io} \le \sum^{n}_{j=1\,j} x_{ij} \qquad j = 1.., m$$
$$y_{ro} \ge \sum^{n}_{j=1\ j} y_{rj} \qquad r = 1, \ldots, s$$
$$\sum^{n}_{j=1} \qquad \lambda_j = 1$$
$$\lambda_j \ge 0 \quad \forall_j$$

Where xij and yrj denote the levels of the jth university's ith input and rth output, respectively, and j = 1,2,3,... n. The first two constraints demand that a university's performance in terms of inputs xio and outputs yro falls within a production possibility set specified by the envelopment of all data points. The final two constraints, where λ is a N*1 vector, allow variable returns to scale by imposing a convexity constraint that results in a convex hull of intersecting planes as a frontier.

This application examines DEA's technical efficiency in Sana'a University's faculties FSU using different approaches. The output maximization in Faculties of Sana'a University FSU was determined using the variable returns to scale (VRS) model (output orientated). The next move was to figure out how much scale productivity was worth (SE). The aspect of technical efficiency that can be attributed to the size of operations is called scale efficiency (SE). In scale inefficiency, variations from the most efficient scale size are represented. The software Data Envelopment Analysis Program (DEAP) version 2.1 was used in this study.

2.2. DEA MODELS

The DEA models used for efficiency calculation may have constant returns to scale (CRS) or variable returns to scale (VRS), with the goal of minimizing inputs or maximizing outputs. The most basic forms of DEA are CCR (Charnes, Cooper and Rhodes) and BCC (Banker, Charnes and Cooper). These can be analyzed as input and output orientated. If decision makers can control inputs; input orientated analysis should be done. Otherwise, output orientated analysis should be done (Goksen & et al., 2015:229).

2.2.1 *CRS MODEL OR CCR MODEL:*

Charnes, Cooper, and Rhodes put the CCR model which bases on Constant Returns to Scale (CRS), where this model is considered the base of the following models. It is worth mentioning that data envelopment analysis depends on that the change in inputs quantity which is used by inefficient unit, affects constantly in service quantity (outputs) when moving to the frontier line of the efficiency, this model is called Constant Returns to Scale (CRS) on the production and it is only

appropriate when all compared units work at the optimum size.

2.2.2. VRS MODEL OR BCC MODEL:

In DEA, Banker, Charnes, and Cooper proposed a model for estimating technical and scale efficiency. The BCC or VRS model replaced the CCR or CRS model's constant return to scale assumption, allowing researchers to investigate whether each DMU's performance was conducted in the region of increasing, constant, or decreasing returns to scale in multiple outputs and multiple inputs situations.

TABLE 1
TECHNICAL EFFICIENCY SCORES AT FSU.

No	Faculties	CRS TE	VRS TE	Scale Efficiency	Return Scale
1	Education/ Sana'a.	0.602	0.603	0.998	irs.
2	Sharia'a & Law.	0.324	0.524	0.618	drs.
3	Arts & Human Sciences.	0.750	0.967	0.776	drs.
4	Science.	0.715	0.725	0.986	drs.
5	Medicine & Healthy Sciences.	0.985	1.000	0.985	drs.
6	Commerce & Economics.	1.000	1.000	1.000	—
7	Engineering.	0.609	0.656	0.928	drs.
8	Agriculture.	1.000	1.000	1.000	—
9	Pharmacy.	0.528	0.565	0.935	irs.
10	Information.	1.000	1.000	1.000	—
11	Education/ Almahweet.	0.908	0.943	0.962	irs.
12	Education/ Arhab.	0.965	1.000	0.965	drs.
13	Languages.	0.504	0.584	0.862	drs.
14	Education, Sciences & Arts/Khawlan.	0.205	0.207	0.987	drs.
15	Dentistry.	0.586	0.586	1.000	—
16	Computer & IT.	1.000	1.000	1.000	—
17	Sport.	0.540	1.000	0.540	irs.
Mean.		0.719	0.786	0.914	

Source: Outputs of DEA program ver. 2.1

3 DATA AND RESULTS

The data of this paper have been taken from public administration of Sana'a University. The variables were the total numbers of enrolled students and the academic staff as inputs, and the total number of graduated Bachelor students as output (Appendix no. 1). Data Envelopment Analysis Program (DEAP) has been involving for analyzing those data in the variables (inputs and output). Table no. 1. shows the efficiency score (constant return to scale technical efficiency CRS TE, variable return to scale technical efficiency VRS TE and Scale efficiency SC) of seventeen Faculties of Sana'a University FSU.

The results illustrate that five faculties, Commerce and Economics, Agriculture, Information, Dentistry and Computer and IT have achieved the full efficiency (scale efficiency) in both models; CRS TE and VRS TE, this means those faculties used their available resources from inputs optimally to achieve output. So there is no need to expansion in their inputs.

The results show that the mean of CRS TE and VRS TE are 0.72, 0.79 respectively, so four faculties have full efficiency, Commerce & Economics, Agriculture, Information and Computer and IT in the model CRS TE at the output orientated, and there are seven faculties, Medicine and Healthy Sciences, Commerce and Economics, Agriculture, Information, Education Arhab, Computer and IT and Sport have achieved the full efficiency in the model VRS at the same orientated, which means that 41.18% are efficient. The mean of Scale Efficiency is 0.91, that means five faculties work in optimal size, four work in increasing re-turn to scale and eight work in decreasing return to scale.

Fig. 1 shows the results of the technical efficiency and acale efficiency for faculties of Sana'a University (FSU) through the variable return to scale model (VRS) with the output orientated of the academic year 2018/2019.

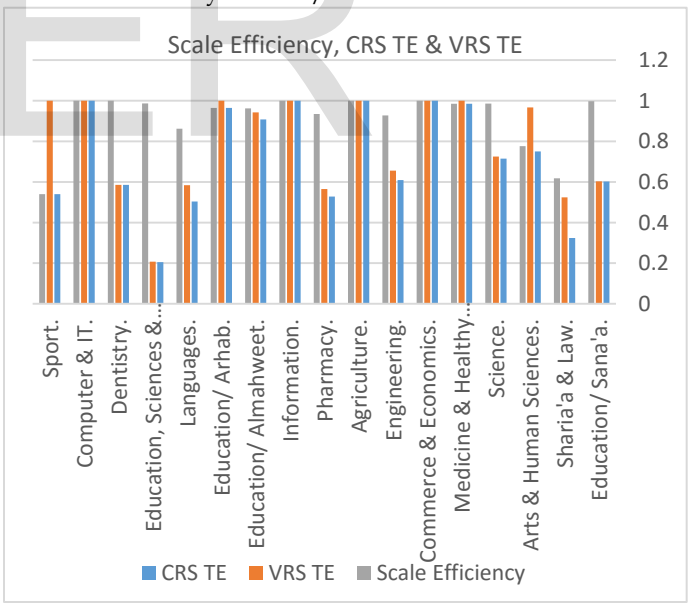

Fig. 1: The results of the technical efficiency and Scale Efficiency for FSU.

The results show that five out of seventeen faculties are efficient in the Scale Efficiency (SE) and achieved (1.00), seven faculties are efficient in the variable return to scale technical efficiency (VRS TE) and four have the full efficiency in the constant return to scale technical efficiency (CRS TE).

4 CONCLUSIONS

This paper investigates the efficiency of seventeen Faculties at Sana'a University (FSU) in the academic year 2018/2019. The results showed that only (5) faculties have full efficiency (1.00), whch means about (29%) are efficient and work in optimal size, where (4) faculties have full efficiency in CRS TE that represents (24%) and (7) faculties have full efficiency in VRS TE that represents (41%). The mean of scale efficiency is (0.914), which means Faculties of Sana'a University (FSU) need (0.086) to achieve full efficiency. There are (4) faculties work in increasing return to scale and (8) faculties work in decreasing return to scale.

This paper, variable return to scale model has been preferred because faculties could not work at the optimal size and could not be controlled by decision makers in university.

The researcher analyzed the data of different faculties of Sana'a University FSU and used the data of the academic year 2018/2019. However, those faculties didn't achieved the full efficiency, can improve their internal operations through increasing or decreasing the inputs or outputs. It is clear that improvement, which will be made in outputs, will affects positively the value of the number of graduated bachelor students which are important for all units of the university.

In conclusion, Technical efficiency analysis of faculties of Sana'a University that is a non-profit organization has been done by using data envelopment analysis in this paper. This offered model to get efficiency scores of university units can be useful for the universities. By using this model, decision makers could take optimal decisions for the best performance.

ACKNOWLEDGMENT

The author wish to thank all persons who support him, his family, Dr. Abdulraqeeb Al Samawi and Dr. Khaleel Alkhateeb.

REFERENCES

[1] Abbott, M. & Doucouliagos, C. (2003): "*The Efficiency of Australian Universities: a data envelopment analysis*", Economics of Education Review, (22), Pergamon, 89_97.

[2] Adamu, Mohammed & et al. (2016): "*An Empirical Analysis of the Factors Affecting Efficiency of Nigeria's Public Universities*", International Journal of Advanced Research, 4(12), 2263-2271.

[3] Agasisti, Tommaso & et al. (2015): "*Evaluating the Efficiency of Italian Public Universities 2008_2011 in Presence of Unobserved Heterogienity*", Società italiana di economia pubblica, dipartimento di scienze politiche e sociali – Università di Pavia, 1_23.

[4] Alshayea, Ali & Battal, Ahmed (2013): "*Evaluating the Efficiency of Faculties in Qassim University using Data Envelopment Analysis*", A Scientific Paper produced to the 11th International Conference of DEA, Titled "Data Envelopment Analysis and Performance Measurement", Samsun, Turkey, p.p 177 – 181.

[5] Avkiran, N. K. (2001): "*Investigating Technical and Scale Efficiencies of Australian Universities through Data Envelopment Analysis*", Socio-Economic Planning Sciences, vol. 35.57-80.

[6] Banker, R.D., Charnes, A., Cooper, W.W. (1984). "*Some models for the estimation of technical and scale inefficiencies in Data Envelopment Analysis*". Management Science, 30, 1078–1092.

[7] Bhagavath, Venkatesh (2005): "*Technical Efficiency Measurement by Data Envelopment Analysis: An Application in Transportation*", Alliance Journal of Business Research.

[8] Bornmann, Lutz & et al. (2019): "*The graduation shift of German universities of applied science*", Plos one, https://doi.org/10.1371/journal.pone.0210160.

[9] Budair, Akram Sufian M. (2020): "*Relative Efficiency in Taiz University using Data Envelopment Analysis DEA*", A PhD thesis of Educational Administration, Educational Foundations & Administration Dept., Faculty of Eduacation, Taiz University.

[10] Cadavid, Delimiro Visbal & et al (2017): "*Assessing the Efficiency of Public Universities through DEA. A Case Study*", Sustainability Journal, Vol. 09, Issue 1416, pp. 01_19.

[11] Canal, Gabriel Yáñez & et al., (2015): "*Research Efficiency Assessment of Colombian Public Universities 2003-2012: Data Envelopment Analysis*", Inge CuC, vol. 11 no. 2, pp 97-108, July – December.

[12] Charnes, A., Cooper, W.W., Lewin, A.Y. and Seiford, L.M. (1994): "Data Envelopment Analysis: Theory, Methodology and Applications", Boston: Kluwer Academic Publishers.

[13] Duguleana, Liliana and Duguleana, Constantin (2015): "*Data Envelopment Analysis for the efficiency of Academic Departments*", Bulletin of the Transilvania University of Braşov, Series V: Economic Sciences • Vol. 8 (57) No. 2, pp. 453-468.

[14] Erkog, Taptuk Emre (2016): "*Measuring Efficiencies of Turkish Public Universities with Non-Parametric Efficiency Estimation Method*", Hacettepe University Journal of Education, DOI:10.16986/HUJE.2016017221, 1-16.

[15] Goksen, Yilmaz; & et al. (2015): "*A Data Envelopment Analysis Application for Measuring Efficiency of University Departments*", The Economic of Balkan and Eastern Europe Countries in the changed world EBEEC 2014, Nis Serbia, Procedia Economics and Finance, Vol. 19, pp. 226 – 237.

[16] Gul, Muhammet & et al, (2017): "*An Efficiency Evaluation Model for Academic Faculties of a Leading University by Data Envelopment Analysis*", Journal of Business Research Turk, 9(3), pp 60_71.

[17] Kao, C. (2017): "*Efficiency measurement and frontier projection identification for general two-stage systems in data envelopment analysis*", European Journal of Operational Research, 261 (2), 679-689.

[18] Kashim, Rosmaini & et al. (2018): "Measuring Efficiency of University Faculty Using a Hierarchical Network Data Envelopment Analysis Model", Journal of Information and Communication Technology, 17(4), 569-585.

[19] Macmillan, Melville & Datta Debasish (1998): "*The Relative Efficiencies of Canadian Universities: A DEA Perspective*", Canadian Public Policy, Analyse De Politiques, vol, XXIV, No. 4.

[20] Martinez, Facundo Quoroga & et al. (2018): " *Efficiency in public higher education on Argentina 2004–2013: institutional decisions and university-specific effects*", Latin American Economic Review, Springer Open, 1_18.

[21] Mikusova, Pavla (2017): "*Measuring the Efficiency of the Czech Puplic Higher Education Institutions: An Application of DEA*", Journal on Efficiency and Responsibilities in Education and Science, Vol. 10, No. 2, pp. 58-63.

[22] Olariu, Gabriela Vica & Brad, Stelian (2017): "*Efficiency Assessment of Universities with DEA Method Based on Public Data*", 8th Balkan Region Conference on Engineering and Business Education and 10th International Conference on Engineering and Business Education, Sibiu, Romania.

[23] Rosenmayer, Tomas (2014): "*Using Data Envelopment Analysis: a Case of Universities*", Review Of Economic Perspectives, VOL. 14, ISSUE 1, 2014, pp. 34–54, DOI: 10.2478/revecp-2014-0003, 34_54.

[24] Selim, Sibel and Bursalioglu, Sibel Aybarc (2013): "*Analysis of the Determinants of Universities Efficiency in Turkey: Application of the Data Envelopment Analysis and Panel Tobit Model*", 2nd. Cyprus International Conference on Educational Research, (CY-ICER 2013), Procedia - Social and Behavioral Sciences, issue 89, pp. 895 – 900.

[25] Silva, Emiliana & et al., (2004): "An Application of Data Envelopment Analysis (DEA) in Azores Dairy Farms", New Medit N. 3.

[26] Sirbu, Adrian & et al. (2016): "*Use of Data Envelopment Analysis to Measures the Performance Efficiency of Academic Departments*",5th International Conference: Agriculture for Life, Life for Agriculture, Agriculture and Agricultural Science Procedia,10, pp.578 – 585

[27] Topcu, Liker & Kabak, Ozgur (2017): "*Operations Research Lecture Notes*", Istanbul Technical University, Turkey.

APPENDIX 1

INPUTS AND AN OUTPUT AT FACULTIES OF SANA'A UNIVERSITY.

No	Faculties	Inputs		Output
		Enrolled Students	Academic Staff	Graduated Students
1	Education/ Sana'a.	13179	179	501
2	Sharia'a & Law.	14723	98	530
3	Arts & Human Sciences.	5518	197	661
4	Science.	2558	128	294
5	Medicine & Healthy Sciences.	3087	302	499
6	Commerce & Economics.	19143	130	1168
7	Engineering.	4349	112	421
8	Agriculture.	918	138	154
9	Pharmacy.	1225	37	103
10	Information.	1816	37	288
11	Education/ Almahweet.	1166	73	171
12	Education/ Arhab.	4130	110	634
13	Languages.	4171	66	275
14	Education, Sciences & Arts/Khawlan.	2386	90	78
15	Dentistry.	1682	53	157
16	Computer & IT.	2883	36	319
17	Sport.	423	29	37
Sum		83,357	1,815	6,290

Source: Sana'a University, Annual Report: 2019.