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ACCREDITED PROJECT EFFICIENCY OF STATE UNIVERSITIES IN TURKEY

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ABSTRACT

One of the most important functions of universities is to produce knowledge by making scientific projects and to ensure the transfer of the knowledge produced to different sectors. Universities in developed countries have a very high level of social contribution in this area. Within the scope of this study, the project numbers and budgets of the state universities in Turkey, supported by the Scientific and Technological Research Council of Turkey and the General Directorate of Science and Technology of the Ministry of Science, Industry and technology were evaluated. In short, these are described as “TUBITAK project” and “San-TEZ project”, respectively. The numbers and budgets of these projects in 2010, 2011, 2012 and 2013 were examined on the basis of University categories. The study has shown that averagely forty percent of the accredited projects produced by universities in Turkey belongs to nine universities (İstanbul, İstanbul Teknik, Ankara, Ege, Karadeniz Teknik, Orta Dogu Teknik, Ataturk, Hacettepe and Bogazici), which are in the A-category according to the year of establishment. This proportion increases further in favor of A-Category universities, when considered the efficiency of projects.

Keywords: Project efficiency, higher education, state university, university category

Introduction

Currently, information is one of the most important and essential needs that affect social life in the developed countries. Knowledge-based technology can be produced in the environment in which universities are located. The process of transferring is the last step of multi-stage operation. When this innovative spirit and entrepreneurial enterprise are combined, the information is revealed and transferred to meet the needs of different sectors. This process can be carried out in the most accurate way on the basis of project support. It is possible to execute this operation by universities in the area where project support is the most efficient. In other words, universities should be an higher education institution to be integrated with the industry and producing information rather than the institutions that carry out classical education and training services, In developed countries mostly transform their researches to the society. Universities in relevant countries are supported by the governments in order to transform and accelerate transformation, which is considered as a strategic change.

It should be noted that state support for North American universities is largely towards to research and development projects. It has been stated that should be followed in detail how the results are reflected in society. Winston (1998) stated that the transformation in universities must be ensured and that higher education institutions must not be managed like a company and underlined that certain balances within the institution must be absolutely protected. For this reason, author thinks that studies have been carried out and methods have been proposed which include specific evaluation criteria in order to make the universities more effective and productive (Tosun, 2004, 2006, 2011, 2015, 2016, 2019a and 2019b). In the developed countries, there are various thoughts about project support to the universities (Brown, 1997; Harazama, 1998; Noll, 1998 and Williams, 2000).

As of the end of 2019, there are 130 state universities across the country, and the number of qualified projects supported per year for working period of this study is 1204. For the universities taken into account within the scope of this study, the average number of qualified projects per year is 11.7. But this ratio differs from university to university. Therefore, the project effectiveness of universities in this study was determined according to the university categories classified by the author. In this study, the project efficiency of state universities are discussed and the university categories proposed by the author are evaluated on the basis of accredited projects. At the end of the study, it is recommended that a certain part of Central government budget should be based on the project efficiency on the view of performance assessment process.

Materials and Methods

In this study, projects supported by two institutions with serious evaluation criteria were taken into account. The number and budgets of projects supported by the Turkish Scientific and Technological Research Institution (TUBITAK) and the General Directorate of Science and Technology of the Ministry of Science, Industry and technology were evaluated. In this context, the related projects were defined as” TUBITAK project “and” San-TEZ project”, respectively. TUBITAK is a public organization established by Law No. 278, which entered into force in 1963, in order to support and encourage research and development activities carried out by University, public and private sector institutions and organizations. This organization tries to spread the culture of science, to help for forming a society at peace with science and technology and to encourage the institutions for the projects submitted under the different programs by providing financial support. It also provides financial support to industry

and cooperated international projects. In addition to TUBITAK, the Ministry of Science, Industry and Technology supports joint projects with industry. The relevant institution supports projects to be carried out in order to enable core and small industrial organizations, which make up an important part of the industry, to gain a culture of research and development and innovation and to solve their problems by using the knowledge generated in universities with the Industrial theses program, which is briefly defined as SAN-TEZ. The projects which are supported by these two organizations are defined as well-accredited projects in Turkey. Therefore, only these projects have been considered for this study.

In developed countries, project support provided by the state is carried out according to the category in which the university is located and continued according to the performance of the universities. But such a situation does not exist in Turkey. In this study, all state universities in the country were classified into six separate categories, taking into account the years of establishment of the university. The main reason for creating categories according to the year of establishment is that universities are funded largely from the state budget, they invest with the government support they receive, and these investments constitute a significant accumulation depending on the years. Table 1 introduces the categories of state universities, established between 1933 and 2011 in Turkey. In Turkey. The hundred-three state universities were established between 1933 and 2011 during the republic period. In this study, the financial resources of state universities were discussed on the basis of the categories defined in Table 1.

Table 1. The categories of State Universities on the basis of collage age.

Category	Number of Universities	Range for establishment year	The Covered Universities
A	9	1933-1971	İstanbul, İstanbul Teknik, Ankara, Ege, Karadeniz Teknik, Orta Doğu Teknik, Atatürk, Hacettepe and Boğaziçi.
B	10	1973-1978	Anadolu, Çukurova, Dicle, Cumhuriyet, Fırat, İnönü, Ondokuz Mayıs, Selçuk, Uludağ and Erciyes.
C	9	1982-1987	Akdeniz, Dokuz Eylül, Gazi, Marmara, Mimar Sinan Güzel Sanatlar, Trakya, Yıldız Teknik, Yüzüncü Yıl and Gaziantep.
D	25	1992-1994	Abant İzzet Baysal, Adnan Menderes, Afyon Kocatepe, Balıkesir, Bülent Ecevit, Celal Bayar, Çanakkale Onsekiz Mart, Dumlupınar, Gaziosmanpaşa, Gebze Yüksek Teknoloji, Harran, İzmir Yüksek Teknoloji, Kafkas, Kahramanmaraş Sütçü İmam, Kırıkkale, Kocaeli, Mersin, Muğla, Mustafa Kemal, Niğde, Pamukkale, Sakarya, Süleyman Demirel, Eskişehir Osmangazi and Galatasaray.
E	41	2006-2008	Adıyaman, Ahi Evran, Aksaray, Amasya, Bozok, Düzce, Erzincan, Giresun, Hitit, Kastamonu, Mehmet Akif Ersoy, Namık Kemal, Ordu, Recep Tayyip Erdoğan, Uşak, Ağrı İbrahim Çeçen, Artvin Çoruh, Batman, Bilecik Şeyh Edebali, Bingöl, Bitlis Eren, Çankırı Karatekin, Karabük, Karamanoğlu Mehmetbey, Kırklareli, Kilis 7 Aralık, Mardin Artuklu, Muş Alparslan, Nevşehir, Osmaniye Korkut Ata, Siirt, Sinop, Ardahan, Bartın, Bayburt, Gümüşhane, Hakkâri, Iğdır, Şırnak, Tunceli and Yalova.
F	9	2010-2011	Abdullah Gül, Bursa Teknik, Erzurum Teknik, İstanbul Medeniyet, İzmir Kâtip Çelebi, Necmettin Erbakan, Türk-Alman, Yıldırım Beyazıt, Adana Bilim ve Teknoloji.

Results and Discussion

As part of this study, the numbers and amounts of projects belonging to state universities in Turkey, supported by the Turkish Scientific and Technological Research Institution and the Ministry of Science, Industry and Technology, were evaluated. Data on the project numbers and project amounts in 2010, 2011, 2012 and 2013 for these projects, which are briefly called "TUBITAK project" and "SAN-TEZ project", are presented in detail in Tosun (2015).

In 2010 and 2011, TUBITAK supported 1 021 and 995 projects, respectively, and a total amount of these projects were 168 825 400 and 158 191 500 TL for two years. In 2012 and 2013, 890 and 1361 projects were supported by the same institution, respectively, and total amount of 141 759 200 TL and 206 079 359 TL were contributed to these projects in the relevant years. During four-years period, the largest number of projects

generally belong to Middle East Technical, Aegean, Hacettepe, Istanbul Technical, Ankara and Boğaziçi universities. The change in the number and amount of projects supported by TUBITAK for the defined categories is presented in Table 2. A graphical representation of the relevant data is shown in Figure 1. The most productive universities in terms of number of projects are in Category A. These universities have 39.0 percent of the projects supported by TUBITAK. In terms of project cost, the rate for the same category are too higher than that of number of projects (45.2 percent). The rates for Category D are 25.3 and 22.6 percent on average in terms of the number and the amount of the projects. The rates of universities in the category E, established between 2006-2008, are quite low (7.1 and 5.0 percent), although their rates have increased relatively in recent years.

Table 2. Number of the TUBITAK projects and total project amount on the basis of university categories

University Categories	2010		2011		2012		2013	
	Number of Project (Project amount in TL)	Rate (%)	Number of Project (Project amount in TL)	Rate (%)	Number of Project (Project amount in TL)	Rate (%)	Number of Project (Project amount in TL)	Rate (%)
A-Category (9 universities)	423 (83.105.900)	41,4 (49,2)	392 (72.237.800)	39,4 (45,7)	339 (61.471.100)	38,1 (43,4)	502 (87.694.604,34)	36,9 (42,6)
B-Category (10 universities)	164 (23.271.800)	16,1 (13,8)	133 (20.978.900)	13,4 (13,3)	115 (17.863.700)	12,9 (12,6)	186 (27.545.481)	13,6 (13,3)
C-Category (9 universities)	129 (20.139.900)	12,6 (11,9)	145 (22.130.900)	14,6 (14,0)	127 (20.287.200)	14,3 (14,3)	193 (27.555.775,97)	14,2 (13,4)
D-Category (25 universities)	239 (36.790.600)	23,4 (21,8)	263 (35.548.400)	26,4 (22,4)	236 (34.365.100)	26,5 (24,2)	336 (44.984.232,68)	24,7 (21,8)
E-Category (41 universities)	66 (5.517.200)	6,5 (3,3)	60 (7.019.500)	6 (4,4)	68 (6.880.600)	7,6 (4,9)	114 (14.809.765,80)	8,4 (7,2)
F-Category (9 universities)	0 (0)	0,0 (0,0)	2 (276.000)	0,2 (0,2)	5 (891.500)	0,6 (0,6)	30 (3.489.499,40)	2,2 (1,7)
Total	1021 (168.825.400)	100 (100)	995 (158.191.500)	100 (100)	890 (141.759.200)	100 (100)	1361 (206.079.359)	100 (100)

In short, the Industrial Thesis Program, defined as SAN-TEZ, provides support to industry-university joint projects in order to ensure the development with science and technology. The number of supported projects and their amounts are presented in Tosun (2015). In 2010 and 2011, 94 and 154 projects of universities were supported within the scope of SAN-TEZ, respectively, and a total of 43 797 568 TL and 78 250 200 TL were contributed to these projects in these years. In 2012 and 2013, 118 and 183 projects were supported, respectively, and these projects were supported by 34 474 853 TL and 51 401 096 TL during these years. The largest number of projects for the working years belong to Middle East Technical, Gazi, Istanbul Technical, Hacettepe, Ege and Dokuzeylül universities.

The numbers of amounts of projects, supported within the scope of SAN-TEZ Program, are presented in Table 3. The change of the relevant data by year is given in Figure 2.

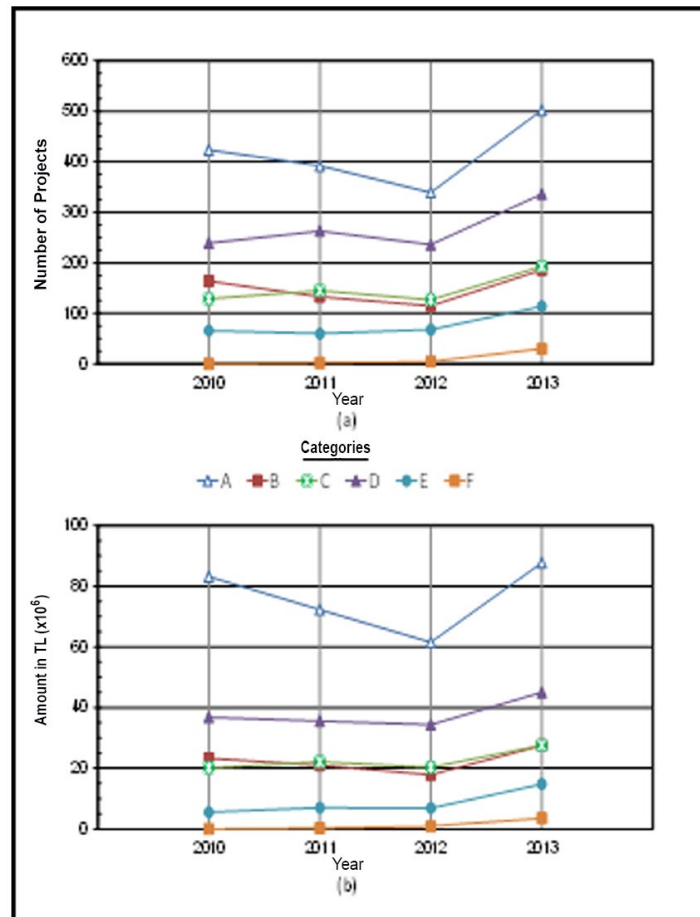


Figure 1. Number of and amount of total TUBITAK projects on the basis of university categories: (a) number of the projects and (b) amount of projects.

Table 3. Number of the SANTEZ projects and total project amount on the basis of university categories

University Categories	2010		2011		2012		2013	
	Number of Project (Project amount in TL)	Rate (%)	Number of Project (Project amount in TL)	Rate (%)	Number of Project (Project amount in TL)	Rate (%)	Number of Project (Project amount in TL)	Rate (%)
A-Category (9 universities)	39 (24.530.776)	41,5 (56,0)	68 (33.478.642)	44,2 (42,8)	45 (15.407.109)	38,1 (44,7)	65 (18.768.712)	35,5 (36,5)
B-Category (10 universities)	17 (8.206.398)	18,1 (18,7)	22 (9.662.341)	14,2 (12,3)	17 (3.749.229)	14,4 (10,9)	25 (6.124.519)	13,7 (11,9)
C-Category (9 universities)	18 (6.940.747)	19,1 (15,9)	28 (18.969.052)	18,2 (24,2)	27 (8.714.495)	22,9 (25,3)	43 (11.661.364)	23,5 (22,6)
D-Category (25 universities)	16 (3.337.873)	17,0 (7,6)	28 (10.592.356)	18,2 (13,5)	20 (5.122.275)	17,0 (14,6)	43 (12.324.553)	23,5 (24,1)
E-Category (41 universities)	4 (781.774)	4,3 (1,8)	8 (5.547.809)	5,2 (7,1)	7 (1.183.035)	5,9 (3,4)	2 (1.439.249)	1,1 (2,8)
F-Category (9 universities)	0 (0)	0 (0)	0 (0)	0 (0)	2 (298.710)	1,7 (0,9)	5 (1.082.699)	2,7 (2,1)
Total	94 (43.797.568)	100 (100)	154 (78.250.200)	100 (100)	118 (34.474.853)	100 (100)	183 (51.401.096)	100 (100)

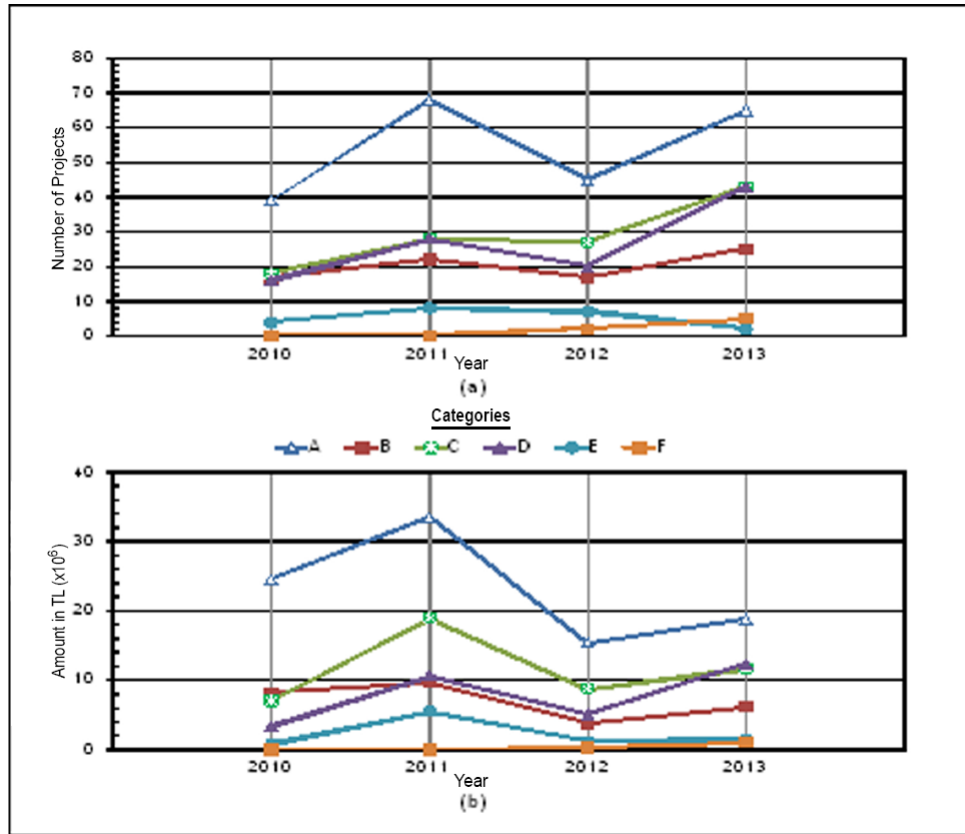


Figure 2. Number of and amount of total SANTEZ projects on the basis of university categories: (a) number of the projects and (b) amount of projects.

As with TUBITAK Projects, the universities belonging to the category A have the highest realization rates in this context. The nine universities in this category have 39.8 percent of all projects supported during the working years in terms of the number of projects and 45.0 percent in terms of the amount of the project. For Category D, which includes 25 universities, the rates related to the number and amount of the projects were 19.0 and 15.0 percent, respectively. In Category E, which includes 41 universities established between 2006-2008, the number of amount of the projects are quite low (4.1 and 3.8 percent). Figure 3 presents the proportional size of the number of TUBITAK and SAN-TEZ projects according to university categories.

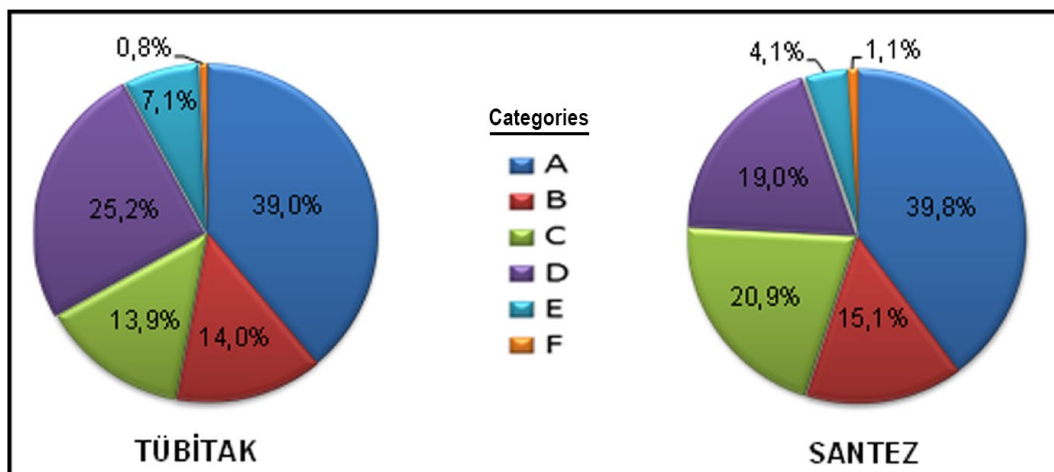


Figure 3. Percentages of the numbers of TUBITAK and SANTEZ projects on the basis of university categories.

Conclusion

The amount of project-based support for the higher education system in Turkey is very small compared to developed countries. Project support for All Country Universities is less than support for a small research

university in the United States. Currently, project support to universities is a waste of resources in Turkey, even if not a huge amount. Universities often present their projects to create scientific infrastructure facilities. It does not seem possible to provide information production that can compete with the international system. For this purpose, universities or university associations or university-public sector joint venture or university-private sector joint venture etc., must compete for projects accredited by the newly established National Accreditation Agency. In addition, the National Accreditation Institute should call upon projects that it will accredit in subsequent years and establish a project framework that can be supported on a national and international scales. As can be seen from this study, the category-A universities (9 universities) in Turkey should be fully equipped with master's and doctoral programs. Research facilities should be provided for these universities on the specified topics by means of project supports. Government agencies and organizations such as the Ministry of Agriculture and forestry, the Ministry of Science, Industry and Technology and the Ministry of Energy need to finish project support as soon as possible.

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CONTRIBUTION OF KKHSOU TO HUMAN RESOURCE DEVELOPMENT: A SWOT ANALYSIS

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ABSTRACT

Access to higher education is still a dream for millions of people residing in India. In the context of higher education, the average Gross Enrolment Ratio (GER) in Asia is more than 30% where the country like China has more than 48% GER in tertiary education; India has 26.3% and Bangladesh 17%. Besides the issues of GER and provision of quality education, the need for adequate higher education avenues or institutional set up against the demand of the population, achievement of global learning by the people in rural and urban areas, providing equal access to learning, justice to cost benefit analysis, research and innovations, use of educational technology, quality and adequate funds for expansion of higher education are some of the other issues challenging the creation of the much required knowledge enabled population in a country like India. In fact, it is the right time to see whether Open and Distance Learning (ODL) is able to mitigate this situation and bring the educational opportunities to all so that they can realise their potentialities and can maintain a decent standard of living. Thus, the basic objective of the paper is to find out the challenges of the prevailing higher education in general and ODL in India in particular. In order to meet this objective, emphasis has been laid on how Krishna Kanta Handiqui State Open University—the only State Open University of North East India, has rendered a significant impact on the educational landscape of a state like Assam in its ten years of existence, in providing quality education to the people of this region. Finally, through this paper, an attempt has been made to make a SWOT analysis on the activities of the university that have already rendered a great service to human resource development in the North Eastern part of India.

Keywords: Higher Education, Access, Equity, Human resource development, Empowerment, ODL.

INTRODUCTION

Enlightenment in human beings can be realized only when they are educated, and their capabilities are strengthened in order to bring up the knowledge population of a country. However, providing opportunities of education also means that a country is able to protect the people from any discrimination, provide the required opportunities to all concerned, and make them empowered in every aspects of life. Therefore, after the economic liberalization of mostly in 1990s in India, various laws, policies and actions under the means of social as well as human security have been implemented from time to time for ensuring welfare of the people residing in this country. Again, India having the world's largest population as well as the world's largest education system, where the basic motto is to bring democratization of education to all, has enabled a knowledge population. In the 21st century, people have started to broadly discuss education which should be skill-oriented and which shall develop and strengthen the capabilities of the people so that they become productive citizens in future. In fact, the need of the 21st century is to provide quality education, which also implies providing equality of opportunity to all so that each individual can achieve equity, social justice and empowerment. In the 7th Century BC, Kuan Chung, the Taiwanese reformer, rightly stated that "If your plan is for one year, plant rice. If your plan is for ten years, plant trees. If your plan is for one hundred years, educate children." So, sustainable education is the only way that produces human capital and empowers the people to contribute to the nation building process. Sustainable education is also the way to sensitise the people regarding maintaining ecological, social and political balance against economic growth in the society. For example, Vienna named world's top city for quality of life, because Vienna became top due to social and economic conditions, health, education, housing and the environment. What can the whole world learn from this is yet another important question.

It should be mentioned here that on 25th September 2015, the Heads of States, Governments and High Representatives, in their meeting at United Nations Headquarters in New York, adopted the document titled *Transforming Our World: the 2030 Agenda for Sustainable Development*. The idea was to adopt a new set of global Sustainable Development Goals which will transform the world in the next 15 years. There are a total of 17 goals to be achieved by 2030 for sustainable development. With regard to education, there is a specific goal (Goal 4), where there is a target to achieve the inclusive and equitable quality education and to promote life-long learning opportunities for all. One of the objectives of the goal is to focus on the acquisition of foundational and higher order skills, greater and more equitable access to technical and vocational education, training and higher education, training throughout life; and the acquisition of the knowledge, skills and values needed to be functional so that it would contribute to society. Thus, the basic focus of SDG4 is 'lifelong learning opportunities for all'

which comprises all learning activities undertaken throughout life with the aim of improving knowledge, skills and competencies, within personal, civic, social and employment-related perspectives.

Apart from this, there is an urgent need of the hour to develop the human resources, because India has a rich demographic dividend as 54% of population is below the age of 25 and 66% people under the age of 35 (Census 2011). It means that this young population of India is considered an asset for the entire country. If proper skill-based education could be given to this population, it could contribute significantly to enhancing the positive social transformation through social and economic mobility, and creating the knowledge-enabled population of the country. Therefore, higher educational institutions which are the think tanks of socio-economic development progress of a nation can play an important role by enabling the people to judge critically what is right and wrong, by helping them realize their duties and responsibilities, by making them participate in the decision making process, and by involving them in productive activities which in turn may help in the formation of an empowered and developed nation. Therefore, it is the need of the hour to see how the higher educational institutions could play their role for mobilising the capacity of the people in order to bring the growth and development of a society or a nation.

OBJECTIVES OF THE PAPER

The main objectives of the study are:

- To study how education is related to human resource development,
- To highlight the various challenges faced by the higher education system of India, and
- To throw light on the role played by an open university like KKHSOU for human resource development and in mobilizing the system of higher education in the state of Assam.

METHODOLOGY

This paper is based on both primary and secondary data. Analysis was done by using simple statistical tools like percentage. After getting the feedback on the questionnaire, a SWOT analysis was conducted for depicting the clear picture on the role of KKHSOU for making generating knowledge-enabled population as a whole. While preparing this paper, descriptive research methodology has been used.

Primary Sources:

- For primary data collection, 10 study centres from Kamrup (Metro) district, were randomly selected for the study as the highest numbers of study centres are located in the district (total=55).
- 20 learners were randomly selected (10 Male + 10 Female=20) in each study centre.
- A total of 200 learners at the under graduate level were selected for the study, because the undergraduate programmes were conducted through these centres.
- A questionnaire was used covering the learner's perspectives on the education offered by KKHSOU and their feedback on the courses.

Secondary Sources:

- Various reports and data available in the web resources of various Open Universities in Asia as well as of Commonwealth of Learning (COL) have been used.
- A detailed case study was done on KKHSOU. The data of the general enrolment trend at undergraduate and post-graduate level, sex-wise enrolment, various online activities of the university, the official records of KKHSOU were used.
- Apart from the above mentioned secondary sources, analysis was done based on the data extracted from the secondary sources of information. The sources like World Development Report 2017, 2018; Global Monitoring Report 2017; India Human Development Report 2011; Human Development Report 1990, 2018,2019; Economic Survey 2016; NFHS-I, II and III; Report of 11th Five Years Plan, 12th FYP; Census of India 2011; SDGs Report 2016 etc. are also used during the course of this paper.

EDUCATION AND HUMAN RESOURCE DEVELOPMENT

Human Development is defined as the process of enlarging people's freedom and opportunities, improving their well-being, and helping them to lead a meaningful life which can help a society to develop economically, educationally, socially, culturally and so on. Besides, it also indicates toward making the people productive as human resource and human capital. Subsequently, the ideas of Human Resource Development have come to signify enlargement of people's choices, enhancement of their skills, capacities, attitudes etc. However, for this, the people must be well acquainted with the need-based skills, be aware of their basic rights and duties, possess

the power of critical thinking, have the capacity to judge what is right and what is wrong in the surroundings, and so on. In this context, it is well defined by HDR, 1990 that Human Development is a process of enlarging people's choices, leading a long and healthy life and becoming educated and enjoying a decent standard of living. Following such an idea of development, it can be observed that there is a close link between the human resource development and all-round socio-economic and cultural development of a nation. But in reality, in a country like India the higher educational institutions are not up-to-the mark in achieving rare kind of world class education system compared to many developing countries like China, Malaysia, Korea, Japan, Singapore, Hong Kong etc. Therefore, until and unless India is not able to achieve the world class quality education, then it is not possible to retain the high rate of economic growth and enriched educational standards and recognition as well as becoming the manufacturing hub.

Quality education also implies providing equality of opportunity to all so that each and every individual can achieve quality of life, equity, social justice and empowerment. But, in reality, if we see the rank of the country like India, it stands in the 129th rank among 189 countries in terms of Human Development Index (HDI), 122nd out of 189 countries in terms of Gender Inequality Index (GII) for the year 2019, which put the country in the Medium Human Development category as compared to Sri Lanka (71), Thailand (77) and China (85) (HDR 2019) which are "high human development" countries. Again, in terms of unemployment rate, Bangladesh is in 90th position whereas India's rank is 46th among the developing countries in the world (Human Development Report 2016, UNDP).

Human Development in the true sense can be ascertained which would also lead to an equitable living in a developmental perspective. However, human development can be achieved through providing access to education to all in equal manner, adopting the mechanism of equity and justice, expansion of educational avenues, quality and sustainable education and so on. Open and distance learning plays the crucial role for promoting the human resources to a great extent compared to conventional system, because of remarkable use of information and communication technologies. Open education widens the scope of learning opportunities in terms of access and choice facilitated by the emerging theme of "bring your own device". The modern interventions like Open Educational Resources (OERs) and MOOCs have provided the platform for opening up the minds of the people hungry of knowledge. Again, being well-equipped with digital skills is the pre-requisite for getting jobs and livelihood in the digital economy. The utilization of on-line learning in general as well as distance and open learning in particular has made learning truly global. Along with this, the whole pedagogy of education is to make people functionally literate or digitally skilled. This kind of education system, thus, helps the learners to possess the relevant digital skills that help to promote inclusive and equitable education and lifelong learning opportunity for all.

Manjulika S & V Venugopal Reddy, (1996) in their book stated that education has been changing rapidly as in today's changing world. The development of the human capital is the main factor in the overall development of countries. Distance education has proved to be the right alternative to the conventional system as it is cost-effective and has the potential to reach to large segments of the population. Now it has become an important component of higher and adult education. Besides, in this book, the emerging new technologies related to Distance education systems, the emergent collaborative network in today's context, the areas and issues relating to the openness, delivery systems and funding of distance education system have been critically examined. To eliminate the existing biases and to improve the quality of distance education, the authors have suggested the incorporation of the market philosophy and orientation.

Kanwar, Asha & Daniel, John (2020) stated in the paper 'From Response to Resilience' Learning for sustainable development, as COVID-19 and similar crises in future may be the cause for further vulnerable situation, therefore, it is imperative to provide the scope of ODL learning opportunity to all. In this context, the curricular variety and reach of open universities and open schools have been greatly enhanced by the generating freely available own educational resources that is one of the strongest ways for harnessing the education system for social justice. In terms of HDR by providing the opportunity to access, equity, quality and effectiveness of the ODL system to all, it seems that ODL can accommodate large numbers of learners at low unit cost. Open schools and open universities reach millions of learners without the constraints of place and time. In open institutions costs per student can vary from one third to one half of those of classroom instruction – with comparable results. In fact, there is no significant difference of learning outcomes between ODL and traditional classroom instructions. Persons with disabilities often prefer ODL because it is flexible, affordable, and offers the anonymity of studying at home.

Regarding the emergence of remote learning for providing education in any situation, it is the distance education only through which the basic need based education can be transmitted to the people irrespective of any social situation. The World Bank (2020) further points out that:

“Education systems must confront issues of inequity front and centre. They must also prepare multi-modal responses, capitalizing on existing infrastructure and utilizing a combination of different learning mediums to ensure students are engaged and learning. [Emergency remote education] can ensure that students continue learning through a variety of avenues. While digital technologies can offer a wide set of capabilities for remote learning, most education systems in low- and middle-income countries, including schools, children and/or teachers, lack access to high-speed broadband or digital devices needed to fully deploy online learning options. As such, education systems need to consider alternative ways for students to continue learning when they are not in school, like in the current Covid-19 crisis” (p. 1). In this regard, it can be argued that, during the Covid-19 pandemic, with similarities and differences (Bozkurt, & Sharma, 2020; Hodges et al., 2020; Huang et al., 2020; Tzifopoulos, 2020), it was emergency remote education that was applied and it can be further argued that emergency remote education is a branch of distance education as in the case of online learning, e-learning, m-learning, or homeschooling. (AJDE, 2020)

In fact, for ensuring quality human resources into productive form, it is the online or blended learning system that could make justice prevail in the long run. Mittal, Pankaj (2020) in the research paper rightly pointed out that the future of learning is undoubtedly in blended pedagogy comprising face-to-face, distance, continuing, digital and online modes of delivery. One must not forget that quality online education not only needs technology but a robust curriculum and pedagogy to facilitate independent learning. However, online education need not be used as an easy tool merely to increase the GER. Such steps may be detrimental, unless the quality, relevance, skills, and employability issues are sufficiently addressed. We should make efforts to improve the quality of school education as well as access and relevance to higher education to contribute towards national development and improve international competitiveness. We may need to deglamourise general education degrees and give social recognition/prestige to skill and vocational training. A renewed strategy of bridging blue- and white-collared education may help enhance the employment opportunities in India and abroad. This will probably be a great tribute to the vision of a rapidly emerging young and aspiring new India.

HIGHER EDUCATION IN INDIA AND ITS CHALLENGES

After Independence, the growth of higher educational institutions is taking place at a fastest rate in India as there are 993 Universities, 39931 Colleges and 10725 Stand Alone Institutions across India. Out of the total number of universities, only 14 are State Open Universities, 1 Central Open University. Regarding the total enrolment in higher education, only 54% are male and 46% female and the GER is still not reaching 30% (AISHE, 2019). In fact, access to higher education to every citizen of the country in the true sense is yet to be harnessed due to the following challenges.

- The average GER in Asia is more than 30% but there are also some variations within the Asian countries. For example, the country like China has more than 48% GER in tertiary education; India has 26.3% and Bangladesh 17%. (HDR 2018). For the Scheduled Castes in India, it is 23%, and for Scheduled Tribes, it is 17.2% which is very poor as compared to the national average. Assam and Nagaland have the lowest GER (18.7%) among the North Eastern States of India. (AISHE, 2019) Besides, it has been observed that the female GER is less than that of the male in India and other states of the North East except Arunachal Pradesh, Sikkim and Manipur. This reveals that the overall inclusion of girls and women in higher education is poor compared to boys and men.
- Besides GER, the need of required higher education avenues or institutional set up against the demand of the population, achievement of global learning by the people in rural and urban areas, providing equal access to learning, justice to cost benefit analysis, research and innovations, use of educational technology, quality and adequate funds for expansion of higher education, modern up to date education to the internal migrants are some of the challenges that create an obstacle in the process of making a knowledge enabled population in the country mostly in India.
- Apart from this, there are some other ground realities prevailing in India, that most of the women are deprived to get their required livelihood mostly in the Government as well as the private enterprises or establishments due to lack of their required skills and competencies. Again, it also reflects that a major percentage of women is general degree holders rather than professional and vocational skill based holders or takers compared to men. This has led to an increase in the educated unemployment among the women, which also indicates the poor level of Workforce Participation Rate (WPR) in various parts of India. If we see the percentage of Labour Force Participation Rate in the age of 15 and older it has found that women consist of 23.6%, and the

percentage of men is 78.6%. Apart from this in terms of Inequality in education, the position of India is far below in compare to many developing countries even in the South East Asia. For instance, the percentage of Inequality in education is 37.8% whereas the percentage is not more than 11% in the countries like Sri Lanka and China. (HDR 2019).

- Again, if education is related to human resource development, it seems that higher education could not supply the adequate need based skilled workforce for which India is far lagging behind in term of ensuring a better position in quality living. It seems that compared to many developing countries, India's vulnerable employment is 76.7% whereas the same in countries like China, Sri Lanka ranges are from 30-40%. (HDR 2019). However it is expected that due to COVID-19 situations, the percentage will become much worse in the history of the Indian economy.
- Again, if we throw light on the percentage of the population with at least some secondary education above the age of 25 and older, it seems that there are also huge disparities between the sexes in India. The percentage of male population with secondary education is 63.5 and female 39 with the gap of 24.5 percent. (HDR, 2019) Thus, it proves that there are gender inequalities in terms of accessing educational opportunities in the country.
- In fact, in India, there is a major crisis of withdrawing the financial help or assistance from the public sector that makes higher education a costly affair for the common learners with aspirations and requirements for education. In India, the cost of expenditure on education was 3.8% only of the GDP in 2018; (HDR 2018) which is very poor compared to many developing countries such as Thailand 4.1%, Malaysia 6.1% in the context of South East Asia. Apart from the allocation of public expenditure on education as a whole, the expenditure for higher education is very few compared to elementary and secondary educational segments in India. For instance, out of the total expenditure on education, the cost of expenditure was 1.12% only of the GDP in 2015 for higher education. (*Economic Survey 2015-16*).
- If higher education is talking about skill education, the fact is that only 5% of the population of 19-24 age groups has acquired some skills through vocational education, when the corresponding figure for a country like Korea is as high as 96%. (Twelfth 5 Year Plan, 2012-17 on Social Sectors, Vol. 3). This has posed a serious challenge in front of the government whereas the basic agenda of the present government of India is to 'build skill India'
- Besides the abovementioned challenges, one of the basic factors of higher education particularly in open and distance learning system is that there is a huge rate of drop outs from the academic programme in each year which directly lead the wastage human and material resources.
- The digital division between the haves and have nots also creates the problems in establishing or ensuring the equity in education system to all. The used of ICTs for accessing knowledge and information in MOOCs and OERs platform or any other online platform by the learners is also varied. The learners from urban areas may get the advantageous position to access information from the online platform than the learners in rural and remote areas. This may lead an obstacle to create an inclusion of knowledge based society in the country.
- In the 21st Century, ICTs with the help of internet provides the plenty of opportunities to everyone to access national and internationalised digital contents. However, it seems that during the COVID 19 pandemic, teachers as well as learners of the educational institutions irrespective of the mode of learning are using technological tools for providing the course contents to the learners across the states so that learners can access them without any disruptions. However, it is also a fact that India being the second largest internet market in the world, the percentage of internet users for academic purpose is very low compared to many countries even within South East Asia. Besides, there is an apprehension on the part of the teachers and the learners particularly from the conventional ones that the use of online learning could damage the quality of the academic transition in the teaching environment. Apart from these, it has also been observed that although the teachers are using online tools for transacting the teaching contents, however they are not much aware of the basic pedagogical issues and the knowhow of the techniques in terms of using the techno-pedagogy in the teaching learning systems.
- In a country like India, the issue of availability of the adequate infrastructure and resources for using online technology in teaching learning transactions is another big challenge for the nation as the variations create the digital division between haves and have nots in terms of accessing the online contents into a great extent.

Thus, for mitigating the situations, there is a need to conduct a thorough study on the education system on the part of the researchers, policy makers and as thinkers. Nobody can deny the fact that there is variation between the places and aspiration of the people of the regions. The planning and management of the places or regions will be sustained if the policy for the developmental programmes and plans are made on the basis of locally required needs and demand. Therefore, every educational institution in each area should focus the need of human development in specific localities, exploring a proper educational mechanism, which is affordable and accessible to all, so that eventually the resilient could be able to serve the mission of the nation. Considering the wide scope of the ODL system to provide flexible access to higher education—general, professional and vocational, the governments, both at the centre and the states, since 1980s, are giving due emphasis, on the expansion of quality

higher education through the ODL mode which accounts for about 12% of the total enrolment in the segment of higher education. It has also contributed substantially towards the rise of the GER of India, which is about 26%. The most significant contribution of ODL in the field of higher education is that it provides the wider opportunity to the female learners for educating themselves and having a dignified life in the society. For instance, the enrolment of women in higher education through distance mode is 46.03% whereas in regular mode, their share is 45% only. (AISHE, 2015-16). In India, along with IGNOU, the other state open universities play the prominent role in spreading the knowledge in order to make people empowered for living a decent standard of life. Therefore, a case study was done on K Handiqui State Open University to check whether this university could able to play its role for human resource development in the state or not.

THE ROLE OF KKHSOU FOR HUMAN RESOURCE DEVELOPMENT IN ASSAM

With the motto of providing access, equity, and quality education to a vast majority of people, KKHSOU—the lone state open University in the North Eastern part of India, has rendered a significant impact on the educational landscape of Assam in its 13 years of existence. KKHSOU has been preparing its diverse academic programmes to suit the learning needs of the potential learners through about more than 300 access points (Study Centres) in Assam, most of which are located in rural and remote areas. As an open university, KKHSOU is not only trying to identify the needs of various stakeholders, but is also trying to ensure sustainable living by taking so many initiatives besides offering many need-based programmes through a variety of collaborative activities like producing audio-visual contents on areas like tea-production, small scale industries, mobile phone repairing and so on. The university has also been producing important OERs in local languages to meet local requirements. A number of educational audio-visual programmes are uploaded in YouTube.

KKHSOU has also undertaken some important social responsibilities one of which being the removal of barriers of education for the inmates of the Central Jails located in different parts of Assam and providing them the facilities of free education. Besides that, keeping the welfare of the society in mind, the University has undertaken “Mother Teresa Social Welfare Mission” and have adopted two relatively very backward tribal villages of Assam where free health camp was also organized. During the Covid 19 pandemic, KKHSOU has provided helping hands to the needy poor in terms of supplying the food items and other necessary academic supports to the learners as well as the stockholders. Along with a modest digital presence, KKHSOU has rendered a significant service in the state of Assam even during the present pandemic following which the learners of the University are accessing the academic and administrative services of the University even in the Lockdown situation. Live classes through official Face book page, uploading the academic contents in the University’s YouTube Channel are the basic support services to the learners during the lockdown situations.

The data related to the various aspects of the university has been discussed in the following:

Enrolment Trend of KKHSOU at Graduate Level:

In terms of providing educational opportunity to the masses of the entire state of Assam, KKHSOU is able to motivate the aspiring people to fulfil their dreams to become educated by enrolling themselves in various courses offered by the university, which is very much up-to-date, relevant and contextual in nature.

Table 1: Sex Wise Enrolment of learners in Bachelor’s Degree Programmes of KKHSOU during the Sessions 2008-09 to 2016-17

Category	Sex	2008-2009	2009-2010	2010-2011	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	Cumulative total	Programme-wise female learners per 100 males
BA	Male	2,785	4,556	7,933	11177	11623	11326	9037	11660	70097	69
	Female	1,465	3,524	5,738	8354	7957	8065	6073	7426	48602	
	Total	4,250	8,080	13,671	19531	19580	19391	15110	19086	118699	
BMC	Male	193	196	167	83	70	60	55	45	869	61
	Female	112	121	96	47	43	43	38	26	526	
	Total	305	317	263	130	113	103	93	71	1395	

B.Com	Male	194	334	441	368	419	421	382	415	2974	14
	Female	16	47	56	60	58	64	64	64	429	
	Total	210	381	497	428	477	485	446	479	3403	
BBA	Male	232	214	157	69	58	52	54	37	873	20
	Female	49	38	32	14	15	10	12	03	173	
	Total	281	252	189	83	73	62	66	40	1046	
BCA	Male	383	377	352	187	165	87	105	114	1770	29
	Female	87	88	89	48	73	60	26	38	509	
	Total	470	465	441	235	238	147	131	152	2279	
All degree programmes	Male	3,787	5,677	9,050	11884	12335	11946	9633	12271	76583	66
	Female	1,729	3,818	6,011	8523	8146	8242	6213	7557	50239	
	Total	5,516	9,495	15,061	20,407	20,481	20,188	15,846	19,828	12,6822	
Year-wise female learners per 100 males		46	67	67	72	66	69	64	62	66	

(Source: KKHSOU Database)

N.B.: The data of the Year of 2011-12 in terms of Male and Female enrolment is not found.

From the **Table 1** it is seen that from 5,516 learners enrolled in 2008, the total number of learners enrolled in Bachelor's Degree programmes in 2014-2015 has increased up to 20188. However, in the years 2015-16 and 2016-17, the number slightly declined to 15,846 and 19828 respectively. Again, it is seen that the trend of enrolment in the Bachelor of Arts is higher than in other professional and vocational programmes at the undergraduate level. Besides, it seems that there is a wide range of disparity between the two sexes in all courses or programmes in both general and professional programmes. From 2008-2009 to 2016-17 in all the programmes at the undergraduate level, the number of female learners in professional courses is less than the number in general courses. The number of female learners is 69 against per 100 male learners in BA programmes. The highest gender disparity is found in B.Com Programmes (only 14 female per 100 male), followed by programmes like BBA (20 female per 100 male), BCA (29 female per 100 male), BMC (61 female per 100 male) and BA (69 female per 100 male). Besides, it is also found that the gender disparity in terms of enrolment in all the undergraduate programmes has gradually vanished since 2008-09 to 2016-17.

From 2018 onwards, the trend of enrolment has decreased as there were a total of 10,318 enrolments in 2018-19 and in 2019-2020; it was 15833 enrolments only as a whole for both the undergraduate and post graduates level programmes. The basic reason for the decreasing enrolment in the programmes is that the University Grant Commission has withdrawn the permission for running some programmes e.g. MA in Education, Social Work, Mass Communication, Master of Computer Application (MCA) etc. in 2018. Although in the year 2018 and 2019, the trend of enrolment has been decreasing, from the starting period i.e. 2012 to 2017 the trend was quite positive in Post Graduate Level Programmes at KKHSOU. Let us see the trend of enrolment at the post graduate level in the sub-section 6.2.

Enrolment Trend in Post Graduate Programmes:

The following Table 2 shows the enrolment trend of postgraduate level from last five years from 2012-13 to 2016-17. The trend of enrolment at the Postgraduate level reveals that except in the general programmes i.e. Master of Arts, the numbers of female learners against the male learners is less in other programmes at the Post Graduate level.

Table 2: Sex wise Enrolment of Learners in Postgraduate Programmes of KKHSOU during the Sessions since 2012-13 to 2016-17

Category	Sex	2012-13	2013-14	2014-15	2015-16	2016-17	Cumulative Total	Programme-wise female learners per 100 males
MA	Male	832	838	1485	1474	1964	6593	118
	Female	1077	1121	1642	1649	2317	7806	
	Total	1909	1959	3127	3123	4279	14,399	
MSW	Male	126	155	194	140	208	823	77
	Female	74	121	150	112	180	637	
	Total	00	276	344	252	388	1460	
MBA	Male	38	78	69	63	138	386	26
	Female	08	15	27	20	30	100	
	Total	46	93	96	83	168	486	
MCA	Male	23	46	30	26	55	180	47
	Female	09	19	14	14	29	85	
	Total	32	65	44	40	84	265	
MMC	Male	28	26	20	17	17	108	44
	Female	07	13	18	05	05	48	
	Total	35	39	38	22	22	156	
MSc.IT	Male		18	21	28	20	87	25
	Female		02	05	08	07	22	
	Total		20	26	36	27	109	
All Postgraduate programmes	Male	1047	1161	1819	1748	2400	8175	127
	Female	1175	1291	3535	1808	2568	10377	
	Total	2222	2452	5354	3556	4968	18,552	
Year-wise female learners per 100 males		112	111	194	103	107	127	

Source: KKHSOU Database

In the above mentioned Table 2, it has been found that in general post graduate courses (Master of Arts) the number of female learners is more than that of male (118 female per 100 male). However, in professional and vocational courses that number is less compared to that of male. For example, in MBA course, there are only 26 female learners against 100 male in the last five years.

However, it seems that in all the Postgraduate programmes, the number of female learners is more than that of male; it is 127 female per 100 male in the last five years. Again, it has also been found that there is a gradual increase in the female enrolment as compared to male year wise from 2012-13 to 2016-17 (112 female per 100 male to 127 female per 100 male) in all Post- graduate programmes as a whole. Thus, from this Table 2, it is proved that in compared to regular mode of education; ODL is able to motivate more female learners than the male at higher stage of education. In fact, KKHSOU has played a significant role in terms of reducing gender disparities and also in providing the access to learning particularly to female learners who were deprived of higher education due to various constraints in their lives.

Enrolment in Certificate, Diploma and PG Diploma:

KKHSOU offers certificate courses in Computer Application, Scientific Tea Cultivation and Counselling Skills; Diploma programmes in Library and Information Science, Journalism and Mass Communication etc. and PG Diploma programmes in Business Management, Computer Application, Mass Communication, Yoga and Naturopathy for the learners. Interestingly, there is more male enrolment in the certificate and diploma level courses except PGDY (Post Graduate Diploma in Yoga)

Result of the Examination in Bachelor Degree Programmes

The result or the outcome of the academic programmes reveals the progress and achievement on the part of the learners. But, it has been found that the pass percentage of the academic programmes offered by KKHSOU has

been declining year wise. This also indicates the trend of drop outs of the learners due to various reasons. For instance, if we see the gender wise pass percentage of in Bachelor’s degree programmes, then it is found that the pass percentage has massively declined in the year 2017 compared to the previous years. The following **Table 3** shows the picture.

Table 3: Gender Wise Pass Percentage in Bachelor Degree Examinations in 2014, 2015, 2016, 2017

Year	Male	Female	Total
2014	87.46%	88.96%	88.14%
2015	90.74%	90.16%	90.47%
2016	82.58%	84.05%	83.43%
2017	67.12%	71.63%	69.21%

Thus, from this Table 3 it has been found that at the undergraduate level for all the Bachelor’s programmes, the total female pass percentage in the last four years is better than the male learners although there is a declining trend of pass percentage as a whole. Again in the year 2018, the pass percentage increased to 72% where the female percentage was more than the male.

Besides the secondary data, a detailed case study was done by selecting some learners for realising the role of KKHSOU as only single and state alone open university in the region. The following is the result of the case study.

DETAILED CASE STUDY ON KKHSOU BASED ON PRIMARY DATA

For realising the services of KKHSOU, a study was conducted in the capital city of the Kamrup (Metro) district of the state of Assam where the highest numbers of study centres of KKHSOU are located. For collecting primary data, a questionnaire was used and feedback was collected from 200 learners (100 male and 100 female) of the randomly selected study centres (10 centres). The following are the some findings of the study:

Sex Wise Enrollment

Out of 200 learners, 85 enrolled in the programme of Bachelor of Arts (BA), 20 enrolled in Bachelor of Computer Science (BCA), 42 enrolled in Bachelor of Commerce (B.Com), 38 enrolled in Bachelor of Business Administration and 15 enrolled in Bachelor of Mass Communication (B.MC). Majority of female learners (about 70.58%) are found in the BA Programmes. The following **Table 4** has shown the enrolment of the selected learners in different programmes at the undergraduate level.

Table 4: Sex Wise Enrolment of the selected learners in different academic programmes :(F=100, M=100)

Programmes	Female	Male	Total
BA	60 (70.58%)	25 (29.4)	85
BCA	05 (25%)	15 (75%)	20
B.Com	12 (28.57%)	30 (71.42%)	42
BBA	15 (39.47%)	23 (60.52%)	38
BMC	08 (53.33%)	07 (46.07%)	15

(In brackets the percentage has been shown)

From this **Table4**, it has found that the trend of enrolment is just like the general enrolment trend of KKHSOU which was discussed in the earlier **Table 1**. Except in BA and MMC programmes, the female enrolment is comparatively lower than the male in the professional and vocational programmes mostly in BCA, B.Com and BBA programmes.

Caste Wise Enrolment

The following **Table 5** has shown the caste-wise enrolment of the learners as below:

Table 5: Caste wise enrolled learners in the selected study centres (F=100, M=100)

Caste	No. Female Learners	No. Male Learners
General	40	35
MOBC	5	7
OBC	15	18
SC	22	20
STH	08	09
STP	10	11

From the Table 5, it has been found that there are more numbers of learners from the general communities or categories for both the sexes. KKHSOU is also able to motivate the learners from other communities although the number is few compared to the general category.

Sex Wise Marital Status of the selected Learners:

Table 6: Marital status of the selected learners (M=100, F=100)

Categories	No. of Male Learners	No. of Female Learners
Single	63	35
Married	20	50
Widow/Widower	07	08
Not answer	10	07

From this Table 6, it has been found that KKHSOU is able to provide educational opportunities to all who desire for pursuing higher education at their own space. Generally, in India or other states of the country, most of the people, particularly women, have to withdraw their education without completing the level of education due to various socio-economic constraints. But, this mode of education is able to help them immensely for fulfilling their dreams by giving the required degree and diploma irrespective of age, sex, geographical location of the learners etc. By acknowledging this fact, from the **Table 6**, it has been found that out of total 100 female learners, more than 50% married women are enrolled in varied programmes offered by KKHSOU at undergraduate level.

Sex-wise Working Status of the selected Learners:

Table 7: Working Status of Selected Learners in the selected Study Centres (M=100, F=100)

Categories	No. of Male Learners	No. of Female Learners
Employed	48	20
Unemployed	30	60
Under employed	20	15
Not answer	2	5

From the Table 7, it has been found that out of the total of 100 male learners, a major percentage of male learners is employed in different government and private sectors. The basic reason behind the enrolment is that after getting the degree from the university, they will get promotion and also that it would help them to enhance their career prospects in life. In case of female learners, a major percentage is found in the category of unemployed sector. Their aims in enrolling in the programmes are to fulfil their dream of getting degree only, because most of the female learners have to leave their education due to their early marriage and poor economic conditions in their families.

Sex Wise Responses on the Expectations of the Learners on Some Basic Parameters:

Table 8: Expectations of the Learners on some basic parameters (Male 100 + Female 100=200) (in percentage)

Parameters	% of the Expectation of the Female Learners (total 100)	% of the Expectation of the Male Learners (total 100)
To get skill and knowledge	80%	90%
To get further Education	86%	89%
To get employment	40%	50%
To develop better managerial competence	55%	60%
To enhance Social Status	88%	50%
To involve in decision making process	65%	78%
To teach their own children	45%	12%
To improve teaching abilities	55%	55%
To develop the capacity for economic independency	30%	50%
To develop career prospects	40%	60%

From the Table 8, it has been found that the expected outcome between the sexes is varied. Generally, most of the male members are already involved in the decision making process inside and outside the household, as well as they are less interested in increasing their values in social market in comparison to the female. Instead, it has been found that the male learners are very much concerned to acquire knowledge and skills, develop their economic independence and career prospects respectively. On the contrary, the female learners are very much fond of developing their social status in society. They would also want to involve in the decision making process while also developing their knowledge for teaching their own children.

Feedback of the Selected Learners on Course Content:

Table 9: Feedback of the Selected Learners on Course Content (N=200)

Course Materials (SLMs)	Feedback of the Learners (in %)
a) Up-to-date course materials	
i. Agree	60%
ii. Disagree	25%
iii. To some extent Agree	15%
b) Language used in SLMs	
i. easy to understand	70%
ii. difficult to understand	20%
iii. take help from others to understand	10%
c) Using interactive dialogue method in the materials	
i. Agree	50%
ii. Disagree	40%
iii. To some extent Agree	10%
d) The SLMs are free from gender bias	
i. Agree	65%
ii. Disagree	5%
iii. To some extent Agree	30%

e) Encourage the learners to apply new knowledge and skills	
i. Agree	30%
ii. Disagree	45%
iii. To some extent Agree	25%

Self Learning Materials are one of the major components of the learners support services, and they help to stimulate independent study or learning behaviour of the learners. From the above Table 9, it has been found that the SLMs of KKHSOU, out of total 200 learners, 60% agree that the SLMs are up-to-date, 70% agree on using simple language, 50% agree on using interactive dialogue method in SLMs, 65% agree that SLMs are free from the gender bias. Apart from this, it is also a serious concern that only 30% learners agree that they are capable of using new and innovative thoughts after going through the SLMs. This figure proves that although the SLMs are up to date and interactive, there is the scope of making the SLMs more creative and practical based. Besides, during the COVID 19 pandemic situation through face book live sessions and using other social media like YouTube channel of the university, the necessary academic supports have been disseminated to the learners so that learners may feel care and cohesion during the lockdown time and continue their learning without having many difficulties.

FINDINGS OF THE STUDY

After carrying out the detailed case study on KKHSOU, it has been found that the university is able to play a prominent role in terms of providing educational opportunities to the learners in every nook and corner of the society. For improving the quality of the courses, KKHSOU has engaged active, young and energetic practitioners who have been doing their work or developing the contents in both print and on-line form rigorously. In terms of Learner Support Services, the university may not be able to do the needful justice equally for all the learners in the enrolled study centres, because of poor participation of the staff of the study centres, absence of adequate counselling sessions, inadequate infrastructure for implementing online courses on the part of the learners etc. But, as a social institution, KKHSOU is able to render its services in a remarkable way. Therefore, it is an urgent need to make a SWOT analysis after doing the case study on the university in order to realise the actual growth and development of the university as a whole.

SWOT Analysis on KKHSOU	
Strength	<ol style="list-style-type: none"> 1. Providing access to the higher educational opportunities to all irrespective of age, class, caste and sex. 2. Motivating most of the female learners (House wives or house makers, married women etc.) at post graduate courses as a whole. In fact, this university plays a dominant role in reducing the gender disparity in terms of accessing higher education. 3. Developing the self-confidence on the part of the learners. 4. Good quality SLMs and up-to-date syllabus. 5. The compulsory courses like Computer Application, Spoken English/Office Management offered by KKHSOU at undergraduate level immensely help the learners to get employment in the government as well as private offices. 6. The best practices like adopting model village, health campaigning, mentoring and care through live classes during the lock down time, etc. have brought the university into the national focus. 7. Various educational programmes uploaded in KKHSOU YouTube (www.youtube.com/user/kkhsou.) are becoming so popular that the University is able to motivate the listeners both from within the country and other parts of the world. The planning for developing e-contents consisting of four quadrants of learning opportunities through e-vidya Learning Management System is one of the biggest Learner Support Services of the university and it will place the university into a new direction in the upcoming days in the field of online learning.
Weakness	<ol style="list-style-type: none"> 1. Poor level of counselling classes in the study centres. 2. Lack of adequate infrastructure and internet connectivity for online learning 3. Little scope to apply new knowledge and skills during the course on the part of the learners. 4. Lack of action oriented activities in the general courses. 5. Library facilities are not up to the mark in the study centres. 6. Lack of Learner's exchange programmes.

	<ol style="list-style-type: none"> 7. Lack of internship policy for the professional and vocational courses offered by KKHSOU in Bachelor's Programmes. 8. No policy has been adopted by the University for providing recruitments to the learners mostly in the BBA/BCA programmes.
Opportunities	<ol style="list-style-type: none"> 1. By using asynchronous technologies, this university can offer some need- based courses as MOOCs in the SWAYAM platform. 2. For developing the required skills on the part of the learners and for giving livelihood opportunities, KKHSOU can offer some skilled-based courses at certificate level. 3. The <i>Recognition of Prior Learning</i> facilitated by National Skill Development Agency can be offered through KKHSOU for giving the formal recognition of the people's traditional skills into a productive form in the region in order to motivate the people for better livelihood. 4. With the help of various educational programmes such as TV Programmes, All India Radio Programmes, Programmes uploaded in the University's YouTube under creative commons licence, Community Radio programmes etc. can lead to the knowledge movement to a great extent. 5. Collaborative work within the departments of the university, between the open universities in Asia or South Asia context, may encourage the faculty members for doing research based activities on some important academic and pedagogic issues.
Threats	<ol style="list-style-type: none"> 1. In Assam as well as in India as a whole, the basic challenge is the use of ICT for academic purpose by the learners. There are some places where electricity and internet connectivity is still a far cry for which people are unable to access the information and knowledge available in the online platforms. 2. Declining rate of pass out results at the undergraduate and post-graduate programmes of the university which may lead the drop outs of the learners from the institution. 3. Crisis for public expenditure on the part of the government for the state open university like KKHSOU.

CONCLUSION

After conducting the SWOT analysis, it has been found that KKHSOU is able to render its service in imparting education to the unreached and ensuring pedagogy of the oppressed in the true sense. In fact, the University has been able to develop human resources by mobilising the capacity and skills of the learners. Besides, KKHSOU has played a significant role in establishing equity, ensuring quality and expanding higher education from regional to international level with the help of both print media, online and e-based programmes. However, it has a long way to go to achieve its fulfilment in terms of research and social activities in order to meet the needs of the stakeholders of the state. In this context, we could also assume that the result of the case study also reflects similar situations in other Indian open universities. In order to ensure quality education for human resource development, there is no alternative other than to introduce some compulsory vocational and professional skill-based programmes in the higher educational institutions. The four pillars of education will be achieved only by developing knowledge and critical thinking skills (learning to know), practical skills (learning to do), personal skills (learning to be) and social skills (learning to live together) on the part of the learners. Real achievements in terms of these four objectives will lead to human development and finally bring the transformation in the society in the true sense.

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SPECTRAL PROPERTIES OF NON-SELF-ADJOINT ELLIPTIC DIFFERENTIAL OPERATORS

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ABSTRACT

The study of non-self-adjoint differential operators is a historical issue. Before and until now, most studies of operator theory have been about self-adjoint operators. But non-self-adjoint operators have recently found many applications in other sciences. These operators have received much attention in thermodynamics and quantum mechanics. Because there is no general spectral theory for these operators, it is more difficult to study these operators than the self-adjoint type. The spectrum of these operators is usually unstable and their resolvent is unpredictable. In this paper, a second-order non-self-attached differential operator is considered and its spectral properties and solvent estimation are studied. This operator is much more common than second-tier operators such as Storm-Liouville and Schrodinger.

Keywords: spectrum, eigenvalues, non-self-adjoint elliptic differential operators, resolvent
AMS 2000 Subject Classifications. 35JXX, 35PXX

1. Introduction

Let $\Omega \subset \mathbb{R}^n$ be a bounded domain with smooth boundary i.e. $\partial\Omega \in C^\infty$. Let $Au(x) = -\sum_{i,j=1}^n (\omega(x)q(x)u'_{x_i}(x))'_{x_j}$ defined in the space $H_\ell = L_2(\Omega)^\ell$.

Here $q(x) \in C^2([0, 1], \text{End } \mathbf{C}^\ell)$ and $\omega \in C^1([0, 1])$ is a non negative function. Then

A is a non-self-adjoint differential operator. Let the weighted Sobolev space $H_\ell = W_{2,\omega}^2(\Omega)^\ell$ as the space of vector functions $u(x) = (u_1(x), u_2(x), \dots, u_\ell(x))$ defined on Ω with finite norm

$$\|u\|_s = \left(\sum_{i=1}^n \int_{\Omega} \omega(x) |u'_{x_i}(x)|_{C^\ell}^2 dx + \int_{\Omega} |u(x)|^2 dx \right)^{\frac{1}{2}}$$

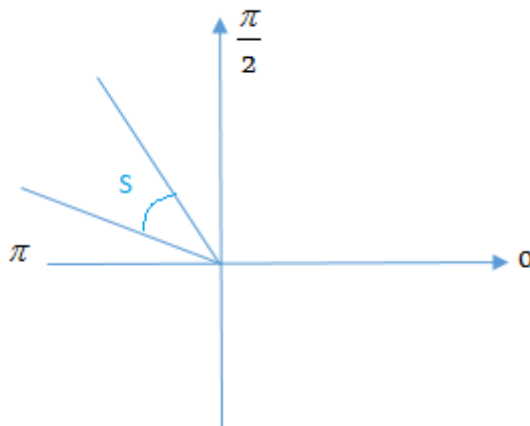
To find the spectral properties of this operator, assume that

$$D(A) = \left\{ u \in \mathring{H}_\ell \cap W_{2,loc}^2(\Omega)^\ell : \sum_{i,j=1}^n (\omega(x)q(x)u'_{x_i}(x))'_{x_j} \in H_\ell \right\}$$

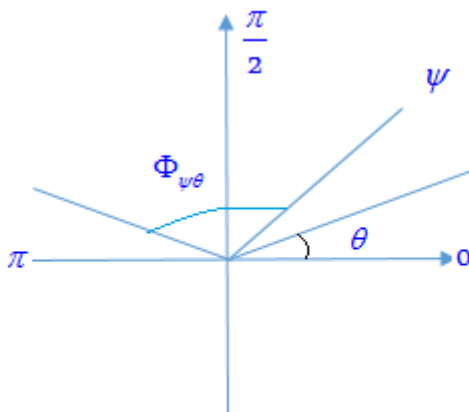
Let for all $x \in \Omega$, $q(x)$ is diagonal matrix, that is assume that $q(x)$ has ℓ simple eigenvalues $\mu_1(x), \mu_2(x), \dots, \mu_\ell(x)$ in the complex plane in the following way:

$$\mu_1(x), \mu_2(x), \dots, \mu_r(x) \in \mathbb{R}^+ \text{ (Then } \arg \mu_j(x) = 0 \text{ for } j = 1, 2, \dots, r) \text{ and}$$

$$\mu_j(x) \in S, j = r+1, r+2, \dots, \ell \text{ where } S = \left\{ z \in \mathbb{C} : \frac{\pi}{2} < |\arg z| < \pi \right\}$$



Let the angle $\Phi_{\psi\theta} = \{z \in \mathbb{C} : |\arg z| > \psi\}$, $\theta < \frac{\pi}{2}, \psi \in \left(\theta, \frac{\pi}{2}\right)$



One of the things that has been done in this article is to resolvent estimate of this operator. That is, it is proved that for sufficiently large in modulus $\lambda \in \Phi_{\psi\theta}$ the inverse operator $(A - \lambda I)^{-1}$ exist and is continuous.

Lemma 1.1.

There is a matrix function $a(x) \in C^2([0, 1], \text{End } \mathbf{C}^\ell)$ such that $a^{-1}(x) \in C^2([0, 1], \text{End } \mathbf{C}^\ell)$ and

$q(x) = a(x) \Lambda(x) a^{-1}(x)$. Here $\Lambda(x)$ is a diagonal matrix, i.e.

$$\Lambda(x) = \text{diag} \{ \mu_1(x), \mu_2(x), \dots, \mu_\ell(x) \}, \mu_j(x) \in C^2(\Omega), j = 1, 2, \dots, \ell$$

2. On the resolvent of A

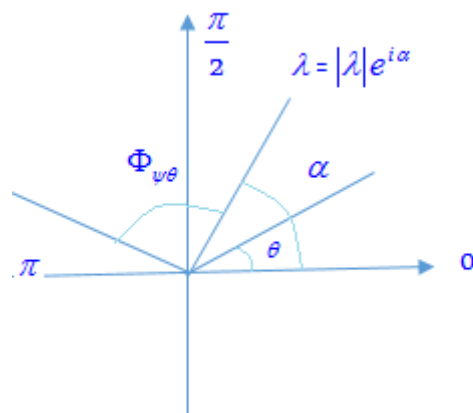
Lemma 2.1.

For $\lambda \in \Phi_{\psi\theta}$ there exist $\gamma \in (-\pi, \pi]$ such that for some positive number c we have:

$$c|\lambda| \leq -\text{Re}\{e^{i\gamma}\lambda\}$$

Proof:

Let $\lambda \in \Phi_{\psi\theta}$ and $\lambda = |\lambda|e^{i\alpha}, \alpha > \theta, \alpha < \frac{\pi}{2}$



Let γ such that $\frac{\pi}{2} < \gamma + \alpha < \pi$ therefore there exist $\varepsilon > 0$ such that $\gamma = \frac{\pi}{2} - \alpha + \varepsilon$

$$\cos(\gamma + \alpha) = \cos\left(\frac{\pi}{2} + \varepsilon\right) \text{ and } \cos\left(\frac{\pi}{2} + \varepsilon\right) < 0. \text{ But } \operatorname{Re}\{e^{i\gamma}\lambda\} = \operatorname{Re}\{|\lambda|e^{i(\gamma+\alpha)}\} = |\lambda|\cos\left(\frac{\pi}{2} + \varepsilon\right)$$

Then $\operatorname{Re}(e^{i\gamma}\lambda) < 0$

$$\operatorname{Re}(e^{i\gamma}\lambda) < 0 \Rightarrow \exists c > 0 : c < -\operatorname{Re}(e^{i\gamma}\lambda) \Rightarrow$$

$$c|\lambda| \leq -\operatorname{Re}(e^{i\gamma}|\lambda|e^{i\alpha})$$

$$\Rightarrow c|\lambda| \leq -\operatorname{Re}(e^{i\gamma}\lambda)$$

Theorem 2.2.

Let A be the operator that defined in above. For sufficiently large in modulus $\lambda \in \Phi_{\psi\theta}$ the inverse operator $(A - \lambda I)^{-1}$ exist and is continuous. In the other word for sufficiently large in modulus $\lambda \in \Phi_{\psi\theta}$ there exist $M_{\psi\theta}, C_{\psi\theta} > 0$, such that the following estimate is valid, that is the resolvent of A exist,

$$\|(A - \lambda I)^{-1}\| \leq M_{\psi\theta} |\lambda|^{-1}, |\lambda| \geq C_{\psi\theta}$$

Proof. Let the operator $Au(x) = -\sum_{i,j=1}^n (\omega(x)q(x)u'_{x_i}(x))'_{x_j}$ where

$u(x) = (u_1(x), u_2(x), \dots, u_\ell(x)), x \in \Omega \subset \mathbf{R}^n$ And let the weighted Sobolev space

$H_\ell = W_{2\alpha}^2(\Omega)^\ell \subset H_\ell$ with finite norm

$$\|u\|_s = \left(\sum_{i=1}^n \int_{\Omega} \omega(x) |u'_{x_i}(x)|^2_{C^\ell} dx + \int_{\Omega} |u(x)|^2 dx \right)^{\frac{1}{2}}$$

By this norm, we defined $\mathring{H}_\ell \subset H_\ell$ such that $\mathring{H}_\ell = \text{closure of } C_0^\infty(\Omega)^\ell \text{ in } H_\ell$.

And then the domain of A as follow

$$D(A) = \left\{ u \in \mathring{H}_\ell \cap W_{2,loc}^2(\Omega)^\ell : \sum_{i,j=1}^n (\omega(x) q(x) u'_{x_i}(x))'_{x_j} \in H_\ell \right\}$$

Let $q(x)$ to be the matrix function with ℓ distinct simple eigenvalues

$\mu_1(x), \mu_2(x), \dots, \mu_\ell(x) \in C^2(\Omega)$ and this eigenvalues arranged in the complex plane in the following way:

$\exists r \in \{1, 2, \dots, \ell\}$ Such that for this r: $\mu_j(x) \in \mathbf{R}^+$ that is $\arg \mu_j(x) = 0$ for $(j=1, 2, \dots, r)$

And for $j = r + 1, r + 2, \dots, \ell$ we have: $\mu_j(x) \in \Phi_{\psi\theta}$ where

$\Phi_{\psi\theta} = \{z \in \mathbf{C} : |\arg z| > \psi\}, \theta < \frac{\pi}{2}, \psi \in \left(\theta, \frac{\pi}{2}\right)$. Now we defined the operators

$$A_j u(x) = - \sum_{i,j=1}^n (\omega(x) \mu_j(x) u'_{x_i}(x))'_{x_j}, j = r + 1, r + 2, \dots, n,$$

and

$$D(A_j) = \left\{ u \in \mathring{H}_\ell \cap W_{2,loc}^2(\Omega)^\ell : \sum_{i,j=1}^n (\omega(x) \mu_j(x) u'_{x_i}(x))'_{x_j} \in H_\ell = H \right\}.$$

Now let $I(u) = \sum_{i=1}^n \int_{\Omega} \omega(x) |u'_{x_i}(x)|^2 dx$. For every $S = (s_1, \dots, s_n) \in \mathbf{C}^n$ we have uniformly elliptic

condition $|S|^2 \leq c \operatorname{Re} \sum_{i,j=1}^n s_i \bar{s}_j$ if $s_i = u'_{x_i}, s_j = u'_{x_j}$ then

$$|S|^2 = \sum_{i=1}^n |s_i|^2 \leq c \operatorname{Re} \sum_{i,j=1}^n s_i \bar{s}_j \leq c \operatorname{Re} \sum_{i,j=1}^n u'_{x_i} \bar{u}'_{x_j},$$

and so

$$\begin{aligned} I(u) &= \sum_{i=1}^n \int_{\Omega} \omega(x) |u'_{x_i}(x)|^2 dx \leq c \operatorname{Re} \left\{ e^{i\gamma} \sum_{i,j=1}^n \omega(x) \mu_k(x) u'_{x_i} \bar{u}'_{x_j} \right\} \\ \Rightarrow I(u) &\leq c \operatorname{Re} e^{i\gamma} \left\langle - \sum_{i,j=1}^n (\omega(x) \mu_k(x) u'_{x_i}(x))'_{x_j}, u(x) \right\rangle \end{aligned}$$

But we have $c|\lambda| \leq -\operatorname{Re}(e^{i\gamma} \lambda)$ then

$$I(u) + |\lambda| \|u\|^2 \leq c \operatorname{Re} \langle e^{i\gamma} (A_k - \lambda I)u, u \rangle$$

So we have:

$$I(u) + |\lambda| \|u\|^2 \leq c \operatorname{Re} \|u\| \|(A_k - \lambda I)(u)\|$$

And so

$$|\lambda| \|u\|^2 \leq c \|u\| \|(A_k - \lambda I)(u)\| \Rightarrow |\lambda| \|u\| \leq c \|(A_k - \lambda I)(u)\|.$$

By this relation we conclude that $A_k - \lambda I$ is a one to one operator and $\|(A_k - \lambda I)^{-1}\| \leq \frac{1}{c} |\lambda|^{-1} = M |\lambda|^{-1}$, similar inequalities apply to operators $A_k, k = 1, 2, \dots, r$. Because these operators are self-adjoint. So this estimate hold for linear operator A. see [1,2,4]

3. On the spectrum of A

Theorem 3.1.

The operator A has a discrete spectrum for any $\theta < \frac{\pi}{2}, \psi \in \left(\theta, \frac{\pi}{2}\right)$

Proof.

If $\lambda \in \rho(A)$ then $(A - \lambda I)^{-1}$ is compact, by Relish's theorem. Therefore, the Riesz-Schaud theory of compact operators implies that the spectrum of $(A - \lambda I)^{-1}$ consists only of eigenvalues of finite multiplicity, whose only possible limit point is the number 0, which is also in the spectrum of $(A - \lambda I)^{-1}$. This implies that the spectrum of A is itself discrete, (see [3]) so every complex number in the spectrum is an eigenvalue. And the eigenvalues of A have finite multiplicity.

Theorem 3.2.

Denote by $\lambda_1, \lambda_2, \lambda_3, \dots$ the eigenvalues of A then: $\arg \lambda_j \rightarrow 0 \quad (j \rightarrow +\infty)$

Proof.

Because $\{\arg \lambda_j : j = 1, 2, 3, \dots\}$ is a bounded set so it has a limit point. Zero is the only limit point in this set.

If it has a nonzero limit point $\{\arg \lambda_{j_k}\}$ sequence -, then there is a convergent sub $[-\phi, \phi]$ in the interval ϕ_1 in this set that converges to ϕ_1 . Suppose S is a closed sector with zero vertices containing radius

$\Upsilon = \{z \in \mathbf{C} : \arg z = \phi_1\}$ in the complex plane. now let N_1 be natural number such that for every there is a natural numberso $\lambda_j \rightarrow \infty$.but $k \geq N_1; \lambda_{j_k} \in S$

N_2 Such that $|\lambda_{j_k}| > C_{\phi_1}$ for $k \geq N_2$. if $k > \max\{N_1, N_2\}$ then $\lambda_{j_k} \in S, |\lambda_{j_k}| > C_{\phi_1}$ so theorem3.6 implies that λ_{j_k} is not eigenvalues that is a contradiction. Then we have: $\arg \lambda_j \rightarrow 0 \quad (j \rightarrow +\infty)$

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THE THERMODYNAMIC INVESTIGATION OF THE USAGE OF PYRENE AS A CARBON SUPPORT WITH PLATINUM CATALYST IN DIRECT METHANOL FUEL CELLS

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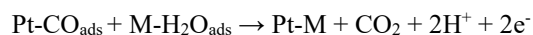
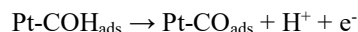
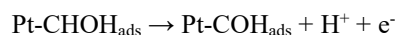
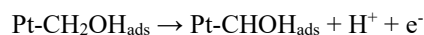
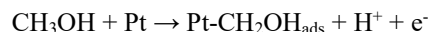
ABSTRACT

The anode of the direct methanol fuel cell (DMFC) includes methanol oxidation reaction which produces 6 moles of electrons per methanol molecule (the overall oxidation reaction: $\text{CH}_3\text{OH} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + 6\text{H}^+ + 6\text{e}^-$). This reaction is thought to occur in four steps with Pt catalyst producing Pt-CO_{ads} species at the last step which plays an important role in poisoning of the carbon support ($\text{CH}_3\text{OH} + \text{Pt} \rightarrow \text{Pt-CO}_{\text{ads}} + 4\text{H}^+ + 4\text{e}^-$). Generally, a second transition metal catalyst is used to overcome the surface poisoning problem. The second metal catalyst reacts with the main Pt catalyst to produce 2 more moles of electrons and converts CO_{ads} to free CO₂ ($\text{Pt-CO}_{\text{ads}} + \text{M-H}_2\text{O}_{\text{ads}} \rightarrow \text{Pt-M} + \text{CO}_2 + 2\text{H}^+ + 2\text{e}^-$). Therefore, the Pt-CO_{ads} species and the carbon support that holds it are the two key points. Pyrene, with its four fused benzene rings, was not used as a carbon support in the literature to the best of the knowledge. It has a D_{2h} symmetry point group which means that two of its benzene rings can act as binding surfaces for Pt-CO. (Note that CO is the reaction intermediate in CH₃OH oxidation.) Therefore, the present study included the calculation of the interaction Gibbs free energies ($\Delta G^{\circ}_{\text{int}}$) of the two possible complexes, Pyrene-PtCO Complex-1 and Pyrene-PtCO Complex-2 from their components of Pyrene-Pt_{ads} and CO. (In the reaction mechanism, first Pt is adsorbed on the carbon surface and then CH₃OH is bound to Pt. After that, CH₃OH is converted into CO by oxidation reaction.) DFT M06L/LANL2DZ theoretical level was used for the calculations. The results showed that $\Delta G^{\circ}_{\text{int}}$ of the two complexes had negative signs which denoted that both formations were spontaneous. $\Delta G^{\circ}_{\text{int}}$ of Complex-2 was -230.8 kJ/mole and was found to be about 25 kJ/mole more negative than that of Complex-1 (-206.1 kJ/mole). One of the reasons of this result might be explained like that: The calculated NICS(1) aromaticity value of the benzene ring to which Pt(CO)_{ads} was bound in Complex-2 was found to be higher compared to Complex-1. As a result, binding to the more aromatic ring produced the more stable complex. The other reason was thought to be the electrostatic charge distribution on the optimized pyrene ring which was obtained from the CHELPG analyses at the same level of theory. Complex-2 had a greater negative electrostatic charge on the benzene ring to which Pt(CO)_{ads} was bound compared to Complex-1. It was also concluded that the more stable complex, Complex-2, would need more energy for Pt-CO bond breakage and to combine with the second metal catalyst with respect to Complex-1 in a DMFC assembly.

Keywords: Pyrene, Carbon Support, Methanol Oxidation, DFT, M06L

Introduction

Direct methanol fuel cells (DMFC) convert the chemical energy of the methanol molecule to the electrical energy in their anodic half cells, directly. The overall oxidation reaction is known as $\text{CH}_3\text{OH} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + 6\text{H}^+ + 6\text{e}^-$. The advantage of this reaction is that 1 mole of methanol molecule produces 6 moles of electrons. Mainly, platinum catalysts are used for this conversion on a carbon support (Samad et al., 2018) in which the possible reaction mechanism can be shown as below (Hamnett, 1997):



The Pt-CO_{ads} species produced at the 4th step plays an important role in a reaction mechanism hence it may stay as a surface poison on a carbon support if a proper second metal catalyst is not used in a proceeding reaction. Generally, the transition metal catalysts (mainly the Ru catalyst) are used to overcome the surface poisoning problem and convert the methanol completely to CO₂ (Park et al., 2014). Consequently, the surface poisoning (the Pt-CO_{ads} species) and the type of carbon support used are the two important points in this area.

Pyrene, with a chemical formula of C₁₆H₁₀, is a yellow solid and is the smallest peri-fused (where the rings are fused through more than one face) polycyclic aromatic hydrocarbon. It is generally produced by the incomplete

combustion of organic compounds. It has a planar molecular structure with D_{2h} symmetry point group. Figure 1 shows the chemical structure and ring numberings of pyrene molecule.

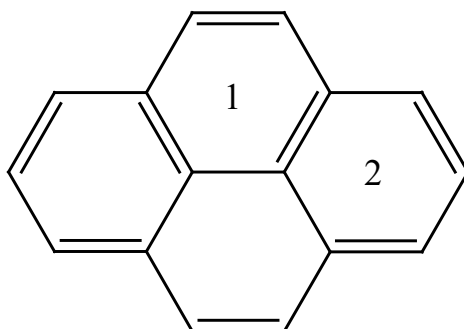


Figure 1. The molecular structure and ring numberings of pyrene molecule having D_{2h} point group.

It was not used as a carbon support in DMFC studies previously to the best of the knowledge. The D_{2h} symmetry in pyrene provides it to have two different kinds of benzene rings which means that two of these rings can bind to Pt-CO_{ads} species, separately. Therefore, the present study focused mainly on the calculation of interaction Gibbs free energies (ΔG°_{int}) of these two possible complexes.

Methods

All the calculations were performed in the gas phase using Gaussian 09 program software (Frisch et al., 2009). The structure optimizations were performed at DFT M06L/LANL2DZ level of theory. The interaction energies of both complexes were calculated using the same level of theory and corrected with basis set superposition error (BSSE) contributions (Ebrahimi et al., 2014). BSSE corrections use the Boys and Bernardi counterpoise technique (Ebrahimi et al., 2014) which are due to overlap of the wave functions of the moieties (Mottishaw and Sun, 2013). The calculations of the considered complexes contained zero point energy corrections and had no imaginary frequencies which indicated that they stood for no transition states or saddle points on the potential energy surfaces. The diamagnetic and paramagnetic effects of ring currents related to aromaticity and anti-aromaticity can be gauged by Nucleus Independent Chemical Shift (NICS) criterion (Schleyer et al., 1996). The NMR calculations were performed at the same level of theory using Gauge Independent Atomic Orbital (GIAO) method (Ebrahimi et al., 2014). Since NICS at 1 Å above the center of the ring, NICS(1), was recommended as a better aromaticity diagnostic than the NICS(0) (NICS at the center of the ring) (Ebrahimi et al., 2014), NICS(1) calculations were performed for the considered complexes.

The CHELPG (CHarges from ELectrostatic Potentials using a Grid based method) analyses were also performed at the same level of theory to evaluate the electrostatic charges distributed over pyrene molecule.

Results and Discussion

Structure Optimizations

The optimized structures of both the complexes titled as Pyrene-PtCO Complex-1 and Pyrene-PtCO Complex-2 were demonstrated in Figure 2. According to the structures, it was possible to mention that the platinum catalyst interacted with the edges of both Ring 1 and Ring 2 of pyrene, respectively (Figures 1 and 2). This statement was discussed in detail in the further section.

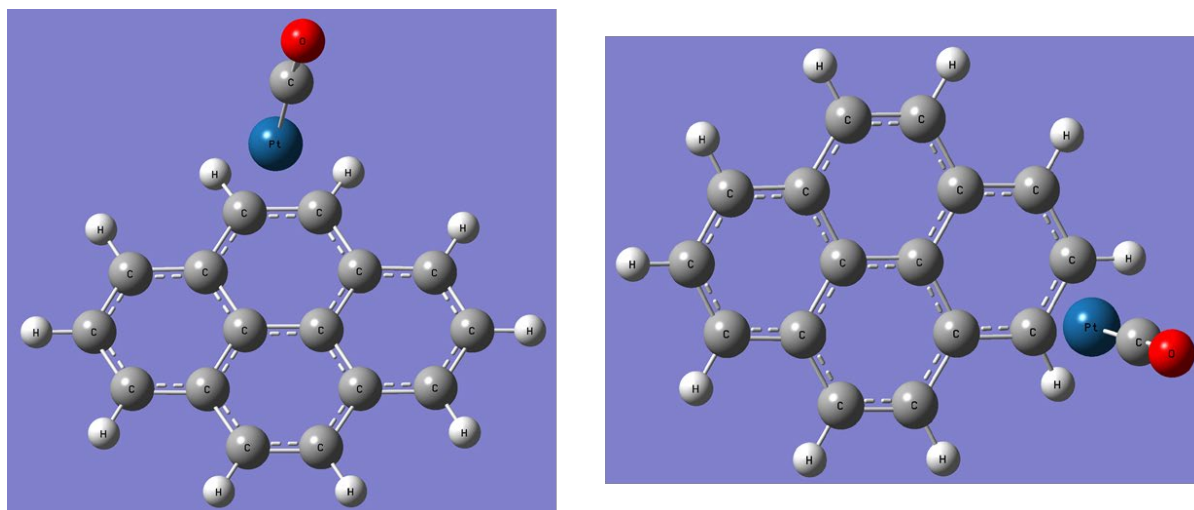


Figure 2. The optimized structures of Pyrene-PtCO Complex-1 (left) and Pyrene-PtCO Complex-2 (right) at the theoretical level of DFT M06L/LANL2DZ.

The Calculated Interaction Gibbs Free Energies of the Complexes

Before discussing this section, it is necessary to note that Pt is adsorbed on the carbon surface first and then CH₃OH binds to Pt. After that, CH₃OH is converted into CO by 4 steps oxidation reaction in the reaction mechanism which was presented previously. That was why Pyrene-Pt_{ads} and CO species were thought to be two different components of the interaction in the present study (Table 1). The interaction Gibbs free energies of the complexes were calculated according to the equation below in which ΔG°_{int} : standard interaction Gibbs free energy of the reaction, $G^{\circ}(\text{Complex})$: standard Gibbs free energy of the complex, $G^{\circ}(\text{Pyrene-Pt}_{ads})$: standard Gibbs free energy of the Pyrene-Pt_{ads} component, $G^{\circ}(\text{CO})$: standard Gibbs free energy of the CO component, BSSE: Basis Set Superposition Error.

$$\Delta G^{\circ}_{int} = G^{\circ}(\text{Complex}) - [G^{\circ}(\text{Pyrene-Pt}_{ads}) + G^{\circ}(\text{CO})] + \text{BSSE}$$

The values in Table 1 denoted that the formation of both complexes from their components were exothermic (spontaneous). However, the interaction Gibbs free energy of Pyrene-PtCO Complex-2 was found to be 24.7 kJ/mol more negative (more stable) than Pyrene-PtCO Complex-1.

Table 1. The calculated interaction Gibbs free energies of the complexes at the theoretical level of DFT M06L/LANL2DZ (1 au = 2625.5 kJ/mol).

	$G^{\circ}(\text{Complex})$ (au)	$G^{\circ}(\text{Pyrene-Pt}_{ads})$ (au)	$G^{\circ}(\text{CO})$ (au)	BSSE (au)	ΔG°_{int} (au)	ΔG°_{int} (kJ/mol)
Pyrene-PtCO Complex-1	-847.94730	-734.58217	-113.28072	0.00591	-0.07849	-206.1
Pyrene-PtCO Complex-2	-847.94476	-734.57029	-113.28072	0.00586	-0.08789	-230.8

The Calculated NICS(1) Aromaticity Values of the Rings of Pyrene

NICS(1) aromaticity analyses of Ring 1 and Ring 2 of pyrene were performed in order to explain the energy difference of interactions between the two complexes (Table 2). Both the considered rings of pyrene were aromatic but Ring 2 NICS(1) value was more negative than that of Ring 1. It indicated that Ring 2 was more aromatic than Ring 1 since the more negative NICS values implied the more aromaticity (Schleyer et al., 1996). This observation denoted that Pt and CO moieties bound stronger to Ring 2 compared to Ring 1 and as a result a more negative interaction energy was obtained in Pyrene-PtCO Complex-2.

Table 2. The calculated NICS(1) aromaticity values of the considered rings of pyrene at DFT M06L/LANL2DZ theoretical level.

NICS(1) (ppm)	
Ring 1	-6.53
Ring 2	-12.12

CHELPG Analyses of Pyrene Surface

CHELPG analyses of pyrene surface was performed at the same theoretical level and demonstrated in Figure 3. According to the charge distribution, the ESP charge of -0.279 located on two of the identical carbons of Ring 2. The two of the carbons of Ring 1 were also identical with the ESP charge of -0.216. (The complexes that bound to one of these identical carbons were investigated in the present study.) Consequently, the more negative charge located on Ring 2 made it possible to form a more stable complex, Pyrene-PtCO Complex-2.

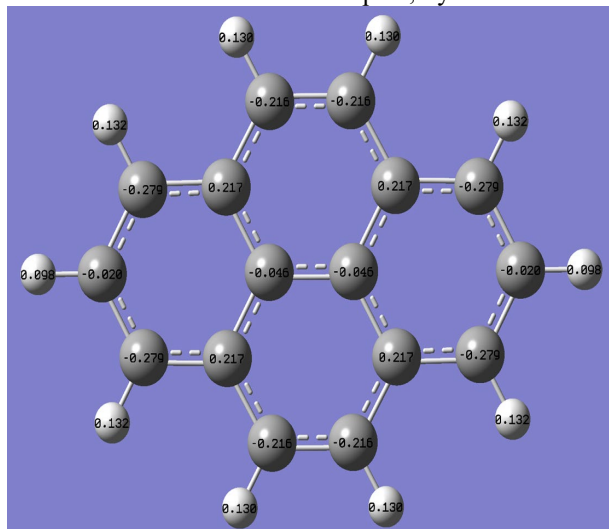


Figure 3. CHELPG analyses of the optimized pyrene at DFT M06L/LANL2DZ theoretical level.

Conclusion

The conclusion of this study were listed with two major outcomes:

1. Planar pyrene molecule might serve as a good surface for Pt catalyst in a direct methanol fuel cell since it had a potential of forming stable Pyrene-PtCO_{ads} complexes.
2. The more stable complex, Pyrene-PtCO Complex-2, would need more energy to break Pt-CO bond and combine with the second metal catalyst with respect to Pyrene-PtCO Complex-1 in a direct methanol fuel cell assembly.

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