Impact of Free and Open-source Software Paradigm for Environmental Sustainability - Case Study in Higher Education Sector

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Abstract *- Sustainability means achieving people's needs without compromising the ability of future generations to meet their needs, considering three domains including economic, social and environmental sustainability. Pulp and paper industry makes an enormous negative impact on environmental sustainability, and software development and usage also significantly effect on environmental sustainability. This research was carried out to determine environmental sustainability impact of open-source software reuse in development of Educational Management Information System and usage of open-source e-learning platform called Moodle during a year of time in the University of Moratuwa, Sri Lanka. Case study research methodology was used to analyse the data quantitatively and qualitatively. Research outcomes show that some components of environmental stainability concepts called three R's - Reduce, Reuse and Recycle can be achieved by using free and open-source software solutions. The case study showed that available open-source solution could reduce millions of papers used per year in a higher education institute. Medium-scale Management Information System development can reuse free and open-source software components and save hundreds of Gigawatt Hours of energy and dozens of e-waste computers produced by software development. Accordingly, this research concludes that there is a significant impact of free and open-source software paradigm for environmental sustainability in the higher education sector by reducing and reusing resources, especially in limited financial allocations in Information and Communications Technology development.*

Keywords *- Environmental Sustainability, Paper Industry, Free and Open-source Software (FOSS), Education Management Information System (EMIS), E-learning, Higher Education Sector.*

I. INTRODUCTION

Ecological, social and economic dimensions have been altogether considered as sustainable development parameters by the United Nations - World Commission on Environment and Development in 1987 [1]. Ecological or environmental stainability is one of the key aspects of sustainable development, which is significantly affected throughout the world. The Worldwatch Institute published that pulp and paper mills are among the worst polluters to air, water and land [2], [3], [4]. Academic institutes such as universities, colleges and schools are some of the highest paper consumers. For example, paper consumption is hundreds to thousands of tons per year in medium size institutes [5]. Furthermore, software development process applied even in the higher education sector consumes the gigantic amount of electrical energy and makes lots of e-waste as a by-product of used computers [6], [7], [8].

The paper begins by briefly discussing sustainability, pulp and paper industry, free and open-source software, e-learning and EMIS. It then introduces the research context and the case study methodology. The paper then discusses the case study and analyses the data gathered through the selected case study. Based on the data analysis, research has tried to

understand how and what level of impact from free and open-source software paradigm influence environmental suitability through resources reuse and reduce concepts.

II. ENVIRONMENTAL SUSTAINABILITY

Sustainability means achieving people's needs without compromising the ability of future generations to meet their needs. In addition to natural resources, it requires social and economic resources. Sustainability is not just environmentalism. Furthermore, it gives meaning to concerns for social equity and economic development [9], [1], [10]. Even though sustainability is not a new concept, but thousands of years old one for some communities, for some parts of the world it is a relatively new idea. Sustainability movement collectively has roots in social justice, conservationism, internationalism and other past movements with rich histories. By the end of the last century, many of these different ideas had come together in the call for 'sustainable development' [1], [11]. It identified that economic development at the cost of ecological health and social equity did not lead to long-lasting success. It is clearly required to find a way to harmonise ecology with prosperity.

'Brundtland Commission' which established Under the United Nations - World Commission on Environment and Development published their report in 1987 and defined sustainability as a holistic approach that considers ecological, social and economic dimensions, recognising that all must be considered together to find lasting prosperity. It has identified Environment, Economy and Society as three pillars of sustainability [1].

A. Economic Sustainability

All human communities in any part of the world are able to maintain their independence and have access to the resources that they require, financial and other, to meet their needs. Economic systems are intact, and activities are available to everyone, such as secure sources of livelihood. It is very important to have a better economic policy - including questions of income distribution, impact in terms of the inclusiveness of growth and employment, regional economic integration, structural and industrial policy and strategies for economic development in resource-rich countries. Furthermore, it is necessary to integrate all the relevant parties into economic policy decision-making and strategy development especially as public, private sectors.

B. Social Sustainability

Universal human rights and basic necessities are attainable by all people in any part of the world, and they have access to enough resources in order to keep their families and communities healthy and secure. Healthy communities have just leaders who ensure personal, labour and cultural rights are respected, and all people are protected from discrimination. [1]

The UN Guiding Principles on Business and Human Rights state that countries have the obligation to "respect, protect, and fulfil human rights and fundamental freedoms" and required to comply with all applicable laws and respect human rights. The concept of Social Sustainability approach should incorporate social equity, social responsibility, social justice, liveability, health equity, community development, social capital, social support, human rights, labour rights, placemaking, cultural competence, community resilience and human adaptation. [1], [10], [12]

C. Environmental Sustainability

Even though sustainability has a border meaning, environmental sustainability is the key pillar which gave initial identity to sustainability. Ecological integrity is maintained, all of the earth's environmental systems are kept in balance while natural resources within them are consumed by humans at a proper rate where it is able to replenish themselves. [1]

III. THE THREE R's

The three R's - Reduce, Reuse and Recycle are the three essential components of environmentally-responsible consumer behaviour to cut down the amount of waste throw away to the environment. The environment is everything around us including the air, water, land, plants, and human-made things. The waste we create has to be carefully controlled to be sure that it does not harm the environment. [13], [14], [15]

The first 'R' is Reduce - the concept of reducing what is produced and what is consumed is essential to the waste hierarchy. The logic behind it is simple to understand - if there is less waste, then there is less to recycle or reuse. The process of reducing begins with an examination of what you are using, and what it is used for. [13], [14], [15]

The second 'R' is Reuse - the concept is appearing with defining a re-purpose or new way of using an anything currently not in using or using for another purpose. Reuse helps to reduce waste generating and reduce new production insignificant level. [13], [14], [15]

The third 'R' is Recycling - the last stage of the waste hierarchy is to recycle and to recycle something means that it will be transformed again into a raw material that can be shaped into a new item. There are very few materials on the earth that cannot be recycled. [13], [14], [15]

IV. PULP AND PAPER INDUSTRY

Paper is a major product of the forestry industry and is used widely in our society. Paper products are used not only in their obvious applications in the publishing industry and for writing on, but also in a variety of speciality papers, cardboards, brown papers etc. In addition, various chemicals are produced as a by-product of the pulp and paper industry. Paper is made by pulping wood, bleaching this pulp and then spreading it out into sheets to make it into the paper. At various stages of the process, chemicals are used to give the paper particular properties, such as the bleaching chemicals that make paper white.

Facts about Paper and Paper Waste; [2], [3], [4]

- The pulp and paper industry is the third largest energy consumer in USA industrial sector
- The pulp and paper industry is the third largest industrial buyer of elemental chlorine.
- Third largest user of fossil fuels worldwide
- Paper manufacturing is the largest industrial user of water per kilogram of finished product
- 324 litres of water is used to make 1 kilogram of paper
- 10 litres of water is needed to make one piece of A4 paper
- Making one ton of paper emits more than 1.5 tons of CO2e (carbon dioxide equivalent)
- Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2) and Carbon Dioxide (CO_2) are all emitted during paper manufacturing.
- The pulp and paper industry is also associated with important emissions of heavy metals. In Canada, for example, this industry is the third source of lead (Pb) emissions to water
- 93% of paper comes from trees
- 50% of the waste of businesses is composed of paper
- 70% of office waste is paper
- Paper accounts for up to 71.6 million tons of waste per year in the USA

The U.S. Toxic Release Inventory report states that pulp and paper mills are among the worst polluters to air, water and land of any industry in the country published by the U.S. Environmental Protection Agency (EPA) and the Worldwatch Institute published similar statistics for the rest of the world. [2], [3], [4]

The United Nations (UN) definition for sustainable development is *"The use of goods and services that respond to*

basic needs and bring a better quality of life, while minimising the use of natural resources, toxic materials and emissions of waste and pollutants over the life cycle, so as not to jeopardise the needs of future generations.". However, pulp and paper industry violates entire aspects of UN sustainable development parameters. Basically, if it is possible to reduce usage of pulp and paper products even by a single paper, it supports to ensure the global sustainable development.

V. HIGHER EDUCATION SECTOR

Higher education profoundly affects the economy, society, and culture of a country. Whether viewed as engines of economic growth, keepers of the keys to culture, or tools of credentials, universities are powerful, important, and pervasive forces, a fact attested to by the attention that scholars have paid to them over the years. Although the main responsibility of higher education historically has not been to prepare students for specific jobs, the economy of a country depends on the knowledge output of the higher education sector of a country. [16]

Higher education today is caught up in conflicting political pressures that are increasingly relying on it to solve economic and social problems. Universities are called on to expand their already broad missions and make higher education available not only to all recent high school graduates but also to older adults trying to adjust to changing labour markets. [17]

Low investment can have several negative consequences for a higher education system over the long term. Sri Lanka is considered one of the lowest investors in higher education even among the South Asian nations. Under-investment in the capital education budget means that the ability of the country to develop a stock of modern education assets and spaces, such as lecture theatres adapted to the use of technology, science laboratories, computer libraries, science equipment, IT equipment, and teaching-learning material, is severely constrained. Further low investments in IT systems and automation will get the institutions stuck in traditional operational methodologies and techniques. Paper-based, low efficient operational procedures are preferred by many higher educational institutes in Sri Lanka due to the lack of capital investments to turn the organisations into digital institutions. This, in turn, can have a negative effect on both the quality of teaching and learning and on research. [18] Under-investment in the recurrent budget also affect most of the operation level quality enhancement tasks including purchasing services, software licenses, maintain their plant and equipment, etc. In addition, it weakens the ability of higher education institutions to operate and maintain their plant and equipment and upgrade their technology. [18]

Academic institutes such as universities, colleges and schools are one of the highest paper consumers and if it operates in more traditional course delivery and operational mechanisms condition will be gigantic. Most of the common paper usage activities are course materials, assignment and project submissions, quizzes and exams, evaluation and other forms, and clerical operations. Generally, paper consumption is hundreds to thousands of tons per year in medium size institutes. [5]

VI. LMS, ERP AND EMIS

Information and Communications Technology (ICT) plays an essential role in today's organisation environment. Information Systems (ISs) hold an enormous control in organisational functions with all the information is entirely controlled by it. Enterprise Systems (ESs) such as Enterprise Resource Planning (ERP), Management Information System (MIS), Customer Relationship Management (CRM), Supply Chain Management (SCM), Advance Planning and Scheduling (APS) systems are the most cutting-edge IS in present corporate world covering all the business sectors [19].

Most of the education institutes' primary interest in Education Management Information Systems (EMIS) and E-Learning systems or Learning Management System (LMS) as their Enterprise Systems. However, last decade some institutes tried to move from highly customised or in-house developed EMIS solutions to ERP solutions. Unfortunately, most of the cases are not received expected success. Most of the university ERP implementation projects have taken far longer than expected and cost five times more than what the projected price [20]. In addition to those domain-specific systems, institutes frequently used other common systems such as Web Servers, Document Management System (DMS), Library Management System, E-Mail service, Proxy service, Centralised Authentications, Domain Name System (DNS), Helpdesk Management System, Firewalls, IP based Private Branch Exchange (PBX), etc.

A. E-Learning and Learning Management System

E-learning (also called Educational Technology) is a modern learning environment which utilises information and communication technologies (ICT's) as a platform for teaching, learning, collaborating activities. A learning management system (LMS) is a software application for the administration, documentation, tracking, reporting and delivery of E-learning courses or training programs. Advancements in computers and electronic communications have narrowed spatial and temporal barriers. Today, knowledge can be obtained and delivered as and when desired. There are very different ideas about what e-learning is and how e-learning can be/should be used. [21], [22], [23].

LMS and Computer-based training (CBT) are two different concepts and E-learning should and can be about something much more. E-Leaning is not just learning content. E-Learning system or LMS is the framework that handles all aspects of the learning process. LMS delivers content but also handles registering for courses, course administration, skills gap analysis, tracking, and reporting. More productivity coming with high collaboration facility for facilitator-learner and learner-learner through various tools such as forums, wiki, chat, VOIP, task management, comments, feedback and many more options. [24], [23], [25].

There was an enormous growth in E-learning and Mobile based Learning usage in last decade with enhancement of ICT sector including internet connectivity, Web 2.0 technologies and high-level mobile usage [24]. Global E-Learning Market to Reach $107 Billion by 2015, According to New Report by Global Industry Analysts, Inc. an annual compound growth rate is 9.2% based on last five years. As a country India and as a region Asia becomes fastest growth rate of self-paced eLearning. Learning Management System (LMS) market is expected to worth approximately $4 billion in 2015 and over $7 billion in 2018 [26].

Leading Learning Management Systems;

i. Blackboard *(Proprietary)*
   Market-share 34.22% (in 2015)
ii. Moodle *(Open-source)*
   Market-share 22.98% (in 2015)
iii. Desire2Learn *(Proprietary)*
iv. Canvas *(Open-source)*

B. Enterprise Resource Planning system

ERP system connects the organisation's different operations organised into a single large integrated system with proper controls so that interconnectivity creates an extra opportunity for growth and increased productivity [27]. Commonly ERP system contains Human Resource, Inventory, Sales & Marketing, Purchase, Finance & Accounting, Customer Relationship, Production, Asset, Project, Supply Chain, etc. management modules. Organizations spend millions of dollars to implement a suitable ERP system with enormous effort consuming hundreds of man months of an implantation team to harvest these benefits. [27], [28].

Still, mainly ERP domain is managed by proprietary ERP systems such as SAP ERP, Oracle E-Business Suite, Microsoft Dynamics, Epicor, Infor ERP [1]. Sage ERP, ERPProcessPro, ERP and IFS ERP also hold large market share with leading vendors in ERP domain today [27], [12], [19]. However, within the last decade open-source ERP applications are noticeably growing and acquiring the ERP market, especially small and medium scale organisations have more significant preferences for it. Presently hundreds of open-source ERPs are available, and some of the leading systems are Openbravo, ERP5, xTuple, OpenERP, webERP, Dolibarr, Opentaps, Adempiere, iDempiere, LedgerSMB, Tryton, Adaxa Suite, Odoo, GNU Enterprise and Compiere [27], [29], [30].

C. Education Management Information Systems

An Educational Management Information System (EMIS) is a comprehensive software system integrated across the various operation units in the institutes, and it is producing, managing, and disseminate educational data and information, usually within the institute and sometimes with national Ministry or Department of Education. An EMIS is a repository for data collection, processing, analysing and reporting of educational information including students, teachers, staff and any other information related to the institutions. Usually, most of the institutes have spreadsheet-based data collection mechanism, and simple meaning of EMIS is a change from computer-based to internet-based integrate system. Sometime EMIS refer to a national level information system which makes integrate and collect information from different institutes in the country. In that scope it is used by Ministries of Education, NGOs, researchers, donors and other education stakeholders for monitoring, evaluation, planning, policy and decision making tasks [31], [32], [33].

There are only a few open-source and commercial EMIS solutions in the market today. EduSec, openSIS, OpenEMIS, eSIMS, FreeSMS, Fedena, Ascend SMS, Gibbon are popular open-source EMIS solutions and Spire, Academia ERP, EDUMAAT, IFW EduTech, CampSteer, GoSchool, ARPMS EMIS, Prodigy, UMS ERP, IUMS and EUMS are some commercial EMIS solutions [32], [34], [35], [36].

Most of the EMIS implementations are not like the institution expectations. EMIS is never a technology issue, but it is an information management challenge. Most of the university system implementations projects have taken far longer than expected and budget overruns. Most of the higher education institutes have high autonomous with department and staff. And related academic rules are very dynamics. And rules changes are happening very frequently compared with other domains. Most of the rules are unique for program, faculty or department and sometimes just for a subject or its offering and sometimes just for one intake, etc. So, it makes business processors more and more complicated. With these challenges, most of the institutes achieve successes with highly customised or in-house developed system rather than ERP solutions [20], [33].

VII. FREE AND OPEN-SOURCE SOFTWARE

Free and open-source software (FOSS) term become one of the most popular words in IT field in last one and half decades. The Free Software Foundation (FSF) was founded around thirty years back in 1985 to support the free software movement, which promotes the universal freedom to study, distribute, create, and modify computer software, being distributed under copyleft terms. FOSS is computer software that can be categorised as both free software and open-source software. Open-source software gives freedom for anyone to freely licensed to use, copy, study, and change the software in any way. With that source code is openly shared so that people are encouraged to voluntarily improve the software [29], [30], [37]. FOSS is in contrast to proprietary software commonly appears as non-free software with under restrictive copyright and the source code is usually hidden from the users [37].

Open-source Initiative provides broader definitions than access to the source code. The distribution terms of open-source software must comply with the following criteria:

- Free Redistribution and the license shall not require a royalty or other fee for such sale
- The program must include source code and must allow distribution in source code as well as compiled form
- The program must include source code and must allow distribution in source code as well as compiled form
- Integrity of The Author's Source Code
- No Discrimination Against Persons or Groups
- No Discrimination Against Fields of Endeavor
- The rights attached to the program must apply to all to whom the program is redistributed without the need for execution of an additional license by those parties
- License Must Not Be Specific to a Product
- License Must Not Restrict Other Software
- License Must Be Technology-Neutral [38]

Figure I shows that different type of software categories commonly available in the market today. Proprietary software and free and open-source software are most common two types of software presently. In addition, there are other two categories called Freeware and commercial open-source software.

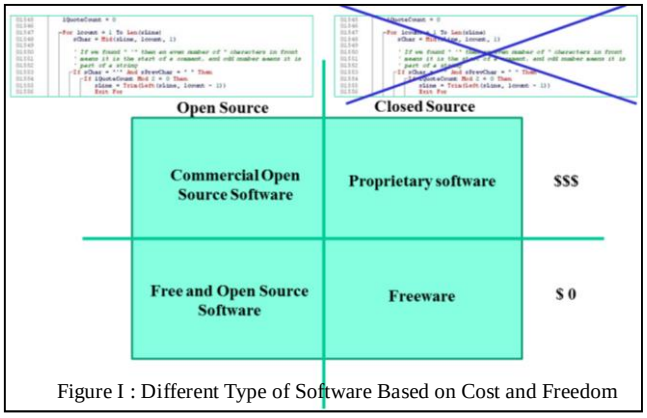

Figure I : Different Type of Software Based on Cost and Freedom

An open-source license is a type of license for that allows the source code, design to be used, modified and/or shared under defined terms and conditions. The open-source licensed software is mostly available free of charge, though this does not necessarily have to be the case. One popular set of open-source software licenses are those approved by the open-source Initiative (OSI) based on their open-source Definition (OSD). There are more than eighty licenses, and the following OSI-approved licenses are popular, widely used, or have strong communities:

- Apache License 2.0
- BSD 3-Clause "New" or "Revised" license
- BSD 2-Clause "Simplified" or "FreeBSD" license
- GNU General Public License (GPL)
- GNU Library or "Lesser" General Public License (LGPL)
- MIT license
- Mozilla Public License 2.0
- Common Development and Distribution License
- Eclipse Public License

Presently, almost all necessary software solutions provided by Free and open-source software and some products are more popular and high standing than proprietary software solutions [39]. Free and open-source operating systems such as Linux and BSD widely operate today, powering millions of servers, desktops and Android operating system powers billions of Smartphone and tablets [40], [41]. Free and open-source Apache and NGINX provide a better platform for more than 70% of web-servers [42].

Linux, MySQL, Apache, JBoss, Mozilla Firefox, Gnome, KDE, GIMP, Apache OpenOffice, Docker, FileZilla, MinGW, PortableApps.com, Weka, Scrollout F1, SquirrelMail, Sendmail, Open LDAP, Squid proxy, BIND DNS, OpenSSL, Pidgin, Gimp, VLC media player, Sahana and WordPress are few of thousands popular open-source software [43], [44], [45], [46]. More than 99% the 500 fastest supercomputers in the world, most powerful and most accurate rifle gun in the world

named TrackingPoint, a most powerful warship in the world called Zumwalt Destroyer and much more world most advance solution are utilised open-source software [47], [48], [49].

Same as most of other domains, open-source makes a significant contribution to education and higher education sectors. E-Learning Systems and Education Management Information Systems (EMIS) perform significant role compare with general software solutions commonly used in other domain.

VIII. SOFTWARE DEVELOPMENT

Software development is a complicated process. It requires careful planning and execution to meet the goals. Sometimes a developer must react quickly and aggressively to meet ever-changing market demands. Maintaining software quality hinders fast-paced software development, as many testing cycles are necessary to ensure quality products.

A commercial software product is usually derived from market demands. Sales and marketing people have first-hand knowledge of their customers' requirements. Based upon these market requirements, senior software development experts create an architecture for the products along with functional and design specifications. Then the development process starts. After the initial development phase, software testing begins, and many times it is done in parallel with the development process. Documentation is also part of the development process because a product cannot be brought to market without manuals. Once development and testing are done, the software is released, and the support cycle begins. This phase may include bug fixes and new releases. [50]

For several decades, power consumption has been a secondary concern in software engineering. Most software has been developed for desktop computers, which have a continuous power supply. While industries like satellite sciences and healthcare have been traditionally more power-aware, the general software engineering community did not have the need to research power consumption. This is about to change or to depend on the viewpoint has changed now. With mobile phones and tablets gaining wide usage in everyday life, new challenges are brought to software development. There are many stakeholders that now care about power: end-users realize that certain applications can reduce battery life dramatically and consider energy consumption as an important quality attribute. [51]

As an example, if 25 software developers work eight hours in 250 days per year by using Desktop computers and common five small servers to developments and office space has an air-conditioning facility, a simple calculation gives average consumption is more than 3000 MWh per software developer per year. This is a significantly large power consumption rate, and usually, such an environment use more than this amount. However, if developers use Laptop computers and Cloud or Virtual Private Servers (VPS) facilities, this number can be reduced. [6], [7], [8].

IX. RESEARCH APPROACH AND METHODOLOGY

This reach was conducted by using case study research methodology. Reasons behind the selecting the case study methodology it facilitates to add strength to what is already known through previously. Case studies highlight detailed contextual analysis of a limited number of events or conditions and their relationships. Case study research is flexible, but when changes are made, it should be documented systematically. Identifying correct operational measures for the concepts being studies makes the validity of outcomes. For increasing validity can be used multiple sources of evidence such as interview, refer reports, some data and facts is a most common method. In this study mainly based on case study of open-source software reuse in development of Educational Management Information System (EMIS) and usage of open-source e-learning platform

called Moodle and its sustainability impact during a year of time in University of Moratuwa, Sri Lanka.

IX. CASE STUDY

The University of Moratuwa is most sought after technological university in Sri Lanka conducting undergraduate and postgraduate courses through six faculties such as Architecture, Business, Engineering, Information Technology, Information Technology and Graduate Studies and one Institute for Technology studies. University is a medium scale state institute, and it has around 8000 undergraduates and approximately 500 postgraduate students and nearly 500 academic staff.

The University of Moratuwa has a rich Educational Management Information System (EMIS) project started in 2007 and when estimated by using the standard estimating methods (COCOMO II - Constructive Cost Model) project value is more than 1.5 million USD. University of Moratuwa EMIS and e-Learning project has two key attributes such as all the tools and techniques based on free and open-source technologies, and all the development was entirely handled by an in-house team. The last couple of years university has achieved great success in EMIS and e-Leaning system implementation including high secure online transcripts, etc. and following are the key module of the system;

- Asset Management Module
- Course Registration Module
- Document Management System
- Establishment Module
- Examination Module
- Examination Rosters Module
- Faculty of Graduate Studies Module
- Field Selection Module
- Graduation Survey Module
- Hostel Management Module
- Inventory & Supplies Management
- Letter Tracking Module
- Learning Management System: e-Learning Platform (Moodle)
- Security and Discipline Information Module
- Space and Resource Management Module
- Staff Development Module
- Staff ID/Email/Library Access Module
- Staff Medical Insurance Module
- Student Clearance Module
- Student ID/Record Book Module
- Student Registration Module
- Student Welfare Module
- Students' Medical Information Module
- Supplication Management Module
- Vehicle Reservation Management Module

Case study contains two main part. First part - the University of Moratuwa uses customised version free and open-source e-learning platform called Moodle during a year of time in 2016. Even, e-learning usage is still limited in the University of Moratuwa; first part demonstrates how it impacted to environmental sustainability through reducing paper usage.

Second part - with a limited budget and available expertise the University of Moratuwa has achieved the success of their in-house EMIS development and implementation with the high-level utilisation of open-sources technology. The second part demonstrates how recuse impacted to environmental sustainability through software developments by using free and open-source components.

X. ANALYSIS

E-Learning usage is still limited in the University of Moratuwa, and as an example since 2013, more than 1900 non-student user accounts were created. However, only 31.6% (602) have login to Moodle - Learning Management System at least

once till date. A simple calculation shows in Table I that usage around 6% to 7% during 2016. However, the impact is significant even it is less than 10%.

TABLE I. LMS Usage Statistic of the University of Moratuwa in 2016

Item	Stat	Average Percentage	Comment
Number of courses	2,394		
Number of resources	2,479	**7%**	*14 weeks per semester and at least one resource per week per course (33,516)*
Number of assignments	583	**6%**	*At-least four assignments per course per semester (9,576)*
Number of submissions	30,790	**7%**	*More than 14 courses per year per student and at-least four assignments per course and 7500 students (420,000)*
Number of quizzes	75		
Number of answers	8,245		

Number of paper saved per year from undergraduate course;

- Number of resources - 2,479 * 50 (average number of students) * 8 (average number of double-sided printed papers)
- Assignment submissions - 30,790 * 10 (average number of single side printed papers)
- Quiz answers - 8,245 / 6 (average number of questions per double-sided paper)

Total number of paper saving during last year only from e-Leaning system with resources sharing, online assignment submission and quizzes = **1,300,874**

Paper saving during last year only from e-Leaning system = 1,300,874 * 0.0045 = **5,854 kg**

TABLE II. Environment Positive Impact from LMS

Item	Quantity	Unit
Trees	100	numbers
Fossil fuels	8,430	litters
Water	1,899	m3
Air pollution	9	tons
Energy	24	GWh
Landfill space	14	m3
All chemicals	7	tons

TABLE II shows who LMS impact to environmental sustainability with reducing paper usage and reducing harmful impact. Presently the University of Moratuwa implementing e-Senate concept through Document Management System (DMS) and during a year of time university used **810,375** papers as Senate document. In addition to that paper saving from e-Learning platform, there is a significant level of paper saving from EMIS with various forms and other automated paper works.

EMIS usage is really high level in the University of Moratuwa from students' registration to online transcript level and with most of the administrative and academic functions. With a limited budget and available expertise, the University of Moratuwa has achieved the success of their in-house EMIS development, and implementation with the high-level utilisation of the open-sources technologies.

- Required development effort - more than 2000 man-months (According to estimation carried using standard methods - COCOMO II)

- Actual used development effort - less than 400 man-months

Software reuse due to open-source technologies reduce the development effort - 133 man-years

- **Saving energy** = 133 * 3000 MWh= **400 GWh**
- **Reduce E-Waste** = 133 / 5 = **27 e-waste computers**

The University of Moratuwa has customised a free and open-source Enterprise Resource Planning (ERP) system, Library Management system, Document Management system and many other open-source solutions with minim effort customisation. In addition to above calculation, mentioned free and open-source software made a huge impact to environmental sustainability through reuse.

Moodle is the global leading free and open-source e-learning platform, and it has more than 20% market share. Main reasons to become a such a popularity is the its way of offers system to users as free and open source philosophy, and it is 100% free to use for anybody. Following table III shows that usage statistics of Moodle e-learning platform globally. [52]

TABLE III. Moodle Statistics

Registered sites	89,297
Countries	233
Courses	14,061,361
Users	118,715,422
Enrolments	475,696,669
Forum posts	244,007,699
Resources	126,401,828
Quiz questions	694,115,014

Number of total paper saving by Moodle free and open source platform (Assumption - above stated activities are not do repeatedly by using papers)

- Average number of users per course - 475,696,669/14,061,361 = 34.8
- Number of resources - 126,401,828 * 34.8 (average number of students) * 8 (average number of double-sided printed papers)
- Quiz answers - 694,115,014 * 34.8 (average number of students) / 6 (average number of questions per double-sided paper)

Total number of paper saving by Moodle e-Leaning system = **42,036,767,396**

Paper saving during last year only from e-Leaning system = 42,036,767,396 * 0.0045 = **189,165,453 kg**

TABLE IV. Environment Positive Impact from Moodle

Item	Quantity	Unit
Trees	3,215,813	numbers
Fossil fuels	272,106,143	litters
Water	612,896,067	m3
Air pollution	283,748	tons
Energy	771,228	GWh
Landfill space	442,560	m3
All chemicals	226,999	tons

XI. CONCLUSION

Higher education institutes consume significant level of energy and resources to better serve their students and relevant stakeholders. The level of energy (electricity) and paper usage are enormous in the institutes, and its negative impact to environmental sustainability is significant. E-Learning platforms or Learning Management Systems (LMSs) support to reduce paper usage in significant level. In addition to that, properly implemented Document Management Systems (DMSs) and Education Management Information Systems (EMISs) help to reduce the substantial level of paper usage in

institutes. However, medium-size higher education institutes in developing counties face difficulties to invest commercial LMS, EMIS, DMS or ERP systems with their limited ICT budget. In the last decade, enormous growth of free and open-source software (FOSS) advancements solved aforementioned financial barriers offering same-level or superior solution as commercial solutions. In other words, open-source software paradigm positively influences environmental sustainability with reduced millions of papers usage annually in the higher education institutes.

The ICT sector consumes a significant level of energy and produces tonnes of e-waste both in the software development phase and in the usage phase. During the software development phase, all developers use computers for developments and necessary infrastructure also consume a significant level of energy. Usually every five development years, the amount of e-waste generated us equal to one computer. Furthermore, most of the modern commercial enterprise systems require new high-calibre infrastructure to run the system. Development of open-source software paradigm enabled a high degree of reuse of the resources such as software modules, libraries, themes, add-ons, etc. The University of Moratuwa EMIS developments case study shows the significance of software reuse by implementing the open-source philosophy. Additionally, open-source software has inherited light-weight concept which enables the utilisation of available infrastructure without investing in additional ICT resources to run the system. All these benefits positively influence environmental sustainability in the higher education sector.

Accordingly, this research concludes that there is an impact of free and open-source software paradigm for environmental sustainability by reducing and reusing resources in the higher education sector.

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