

# JEAS



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**IN THE NAME OF ALLAH,  
THE MOST GRACIOUS,  
THE MOST MERCIFUL**

**Kingdom of Saudi Arabia  
Ministry of Education  
Majmaah University**



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## Editorial

Scientific publishing has brought many challenges to authors. With increasing number of scientific journals, varying scopes, reviewing requirements, and cost of publishing to authors, finding the right journal to publish an article is a decision many authors must bitterly confront and resolve. The publication of scientific findings is an integral part of the life of researchers. The process of publishing has evolved to become an efficient system of decimating knowledge and collaboration among scientists. Science journals have institutionalized procedures to manage large volume of article submissions per year. In many cases, journals began to define narrower scopes for a dual purpose: managing submissions and delivering outstanding research.

Based on recent studies, the scientific publishing world consists of more than 25 thousand active journals in various disciplines and fields. Science Direct hosts 3,348 journals (as of February 2014). The Directory of Open Access Journals lists in its search engine more than 9,800 open access online journals.

According to recent estimates, the number of scientific journals grows by 3% per year worldwide. With this large number of journals, journals may find it harder to stay afloat.

In its inauguration, the board of editors is honored to introduce to the scientific community the Journal of Engineering and Applied Sciences - JEAS, another scientific journal from Majmaah University. The board has pledged a commitment to JEAS authors and readers to bring the most dynamic and vibrant journal management with better satisfaction.

**Dr. Mohamed Alshehri**



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# Methane Adsorption on Hybrid and Non Hybrid Activated Carbon Synthesized from Coconut Shells and Poly Ether Ether Ketone

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## Abstract

The shorter driving range is the challenge of compressed natural gas (CNG) as a vehicular fuel. In this study, adsorbents were prepared from coconut shells and Poly Ether Ether Ketone (PEEK) using KOH microwave activation to overcome the challenge of CNG storage system. The CNG storage system has some disadvantages which include high-pressure operation with less safety guard, and heavy storage cylinders. The adsorbents were used as a potential Sorbents for methane (CH<sub>4</sub>) storage at different pressures. The coconut shell and PEEK were carbonized from ambient temperature to 700 ± 20 oC at 10 oC min<sup>-1</sup> heating rate with 1 L min<sup>-1</sup> N<sub>2</sub> flow rate. The carbonization temperature of the precursor was determined using thermo-gravimetric and derivative thermogravimetric (TG/DTG) analysis. The activation was achieved with well modified microwave equipment operated at 500 W and 5 minutes. The adsorbents were characterized by Fourier transform infrared spectroscopy (FTIR), nitrogen adsorption and scanning electron microscopy (SEM). The CH<sub>4</sub> adsorption characteristics were conducted using volumetric adsorption equipment at an ambient temperature and pressures of 5-17 bar. The highest CH<sub>4</sub> uptake achieved from hybrid adsorbent at 5, 7.5, 11 and 17 bar are 2.35, 3.04, 4.80 and 7.15 mmol/g respectively. The experimental data simulated using three common adsorption models: Langmuir, Freundlich and Sips. The Freundlich, had high correlation coefficient up to 0.9989 and lower root mean square deviation (RMSD) which fitted our data better than others. The findings revealed the potential of coconut shell-PEEK as sorbents for CH<sub>4</sub> adsorption applications and isotherm models equations used in adsorption applications.

**Keywords:** Hybrid; Non hybrid; Activated carbon; Adsorption; Isotherm

**Article history:** Received: August 20, 2020; Accepted: December 24, 2020

## 1. Introduction

With the recent concern about the emissions from diesel engines, in addition to the increasing demand for energy coupled with instability of conventional fuel prices, has influenced interest towards sourcing alternative fuel <sup>[1]</sup>. Many countries want to reduce their dependency on the imported fuels (diesel and gasoline) due to the

aforementioned issues. These issues could be solve by initiating a reliable and visible technology that can accommodate the demands in the energy application sectors. Works by <sup>[2]</sup> stated that the available and reliable energy that can secure sustainability in environmental delivery with minimal Green House Gases (GHGs) emission is Natural Gas (NG) <sup>[1]</sup>. NG is used

in industries, for transportation vehicles, and for households. For industries application, where there is no pipelines system, it sometimes has to be transported to the location using transportation systems (vehicles). For it to be transported it has to be stored in heavy tanks with pressure ranges between 200-250 bar at room temperature<sup>[2]</sup>. Compression and liquefaction methods were earlier adopted to increase the fuel density to meet up with several applications. However, they were found to be attributed to high-pressure applications and the high cost of processing respectively. To overcome these deficits, the gas stored by adsorption onto the surface of porous carbon at relatively lower pressure to that of compression and at a lower cost to both<sup>[3]</sup>. The gas stored at ambient temperature and moderate pressure range between 35-40 bar which reduces the processing cost and increases the storage capacity.

Various methods reported for the de-pollution of environments such as neutralization, precipitation, adsorption and filtration<sup>[18]</sup>. Adsorption is reported as the most reliable at the current situation, due to its enormous advantages such as easy handling, low cost and high efficiency<sup>[22]</sup>. In a general perspective, conversion of non-living wastes into activated carbon for mitigation of waste or environmental pollution is a very good option<sup>[19]</sup>. The readily available agro-wastes in Malaysia for the production of activated carbon includes coconut shells<sup>[12]</sup>, palm kernel shells<sup>[10]</sup>, rice husk, Kenaf, nut shells, tobacco stems and sugarcane bagasse<sup>[12]</sup>.

The coconut was selected for this research work due to its availability and impact on environmental pollution in this region. It is estimated that in Malaysia about 142,000 hectares of land for coconut plantation<sup>[12]</sup>. A lot of solid waste (shells) generated annually<sup>[20]</sup>. Therefore, channeling the wastes for adsorption application is compulsory due to the current environmental problem<sup>[21]</sup>. Zeolites and commercial activated carbon are very popular in adsorption applications, but the process is expensive. However, activated carbons can be derived from readily available agricultural solid waste with an easier tailoring its textural and surface properties<sup>[12]</sup>. Thus, there is an increase in demand for readily available adsorbent, less expensive for methane adsorption, particularly if the substrate is derived from waste materials. Conversion of coconut shells into activated carbon (waste-to wealth) which can be used as an adsorbent for

CH<sub>4</sub> could add value to this agricultural waste, help to reduce the cost of its disposal, and provide sustainable, reliable and cheap activated carbon that can serve the same purpose as the expensive commercial porous carbons.

It was reported that Poly Ether Ether Ketone (PEEK) porous carbon has good properties for high compressive strength and gas storage applications<sup>[4]</sup>. This is due to the excellent textural properties of the PEEK porous carbon.

Adsorption isotherm models describe the behavior of adsorbent and adsorbent towards their interaction and understanding

of their adsorption process<sup>[9]</sup>. Langmuir, Freundlich and Sips isotherm models have been used to study the interaction behaviors between adsorbent and adsorbent in this study.

In this study, the hybrid activated carbon prepared from coconut shells and PEEK was used to achieve the adsorption of methane at an ambient temperature and pressure up to 17 bar. The adsorption behavior of methane was detected using adsorption isotherm models. The experimental data were fitted using Freundlich, Langmuir, and Sips which were used to describe the experimental data and effective adsorptivity.

The objective of this research paper is to investigate the effect of PEEK toward the adsorption of methane on the surface of the activated carbon impregnated with potassium hydroxide and also to study the behavior of adsorption isotherm models, and equilibrium capacity. The novelty of this work tailored towards adsorbent preparation and adsorption models evaluation. Most studies on PEEK focus on thermal stability since it is one of the highest temperature (260 °C) resistance among all plastics<sup>[5]</sup>, to the best of my knowledge the use of PEEK for this application has not been exploited.

## 2. Experimental Procedures

### 2.1 Adsorbent Synthesis and adsorption application

Raw coconut shells were washed, sun-dried, and then dehydrated at 105 °C for 24 hours using the oven. It was carbonized using the furnace to obtain char which

were later sieved to 0.85-0.5 mm. the PEEK was also carbonized and sieved to same size particle with coconut shells char. The PEEK char was blended with coconut shells char. The blended chars were chemically treated with KOH at a ratio of 1:1.5, and then activated using the microwave, the activated carbon denoted as a hybrid. The adsorption of CH<sub>4</sub> initiated using the adopted procedure elsewhere<sup>[2]</sup>.

### 2.2 Sample characterization

The two samples were named based on their preparation conditions. Preparation of hybrid activated carbon (M33P15) achieved at 300 Watt, 3 minutes irradiation time and 15% amount of PEEK. Non-hybrid activated carbon (M33P0) prepared at the same condition with (M33P15) but without the addition of PEEK. The samples were characterized by Fourier transform infrared spectroscopy (FTIR), nitrogen adsorption and scanning electron microscopy (SEM).

### 2.3 Adsorption Isotherm

Methane adsorption isotherms show how the interaction between CH<sub>4</sub> and the synthesized adsorbents occur.

### 2.4 Adsorption Isotherm Models

Adsorption isotherms are models used for identification of how adsorbent The CH<sub>4</sub> adsorption isotherm shows how the interaction between CH<sub>4</sub> and the synthesized adsorbents occur. Two parameters isotherm models (Langmuir and Freundlich) together with the three model parameters (Sips) were applied for this study. The detail of the aforementioned models is shown in

Table 1. Freundlich and Langmuir exhibit more satisfactory fit to the experimental data for both samples with R2 greater than 0.988 and lower RSMD (Table 1). The values of adsorption intensity (n) for the three models at all the samples were greater than 1, indicating favorable adsorption [16]. In general, the suitability of the three isotherm models predicting the interaction behavior of CH4 adsorption on the porous carbon synthesized is in order of Sips < Langmuir < Freundlich with the corresponding values as shown in Table 1. This shows that Freundlich gives a more accurate description of the interaction between CH4 and the porous carbon synthesized with high values of KLF indicating high adsorption capacity [17] and adsorbate interact to give a clear understanding of their behavior [9]. Langmuir, Freundlich, and Sips model equation are used for this application. Langmuir isotherm predicts the monolayer at the homogeneous surface, while Freundlich for a heterogeneous surface which describes non-ideal and reversible adsorption [10]. Sips is a model which combines the applications of both Langmuir and Freundlich. The nonlinear adsorption isotherm model equations (Langmuir, Freundlich, and Sips) were also shown in Equations 1, 2 and 3.

$$q = q_m \frac{k_1 p}{1 + k_1 p} \quad (1)$$

$$q_e = k_f p^{\frac{1}{n}} \quad (2)$$

$$q = \frac{q_m k_{lf} p^{\frac{1}{n_{lf}}}}{1 + k_{lf} p^{\frac{1}{n_{lf}}}} \quad (3)$$

### 2.5 Validity of Fitting of Models

Root square mean deviation (RSMD) and regression coefficient (R2) values were used to validate the experimental data, as well as its fitness, the values were obtained using equations 4 and 5.

$$RMSD = \left[ \frac{1}{n} \sum (q_{\text{exp}} - q_p)^2 \right]^{\frac{1}{2}} \quad (4)$$

$$R^2 = 1 - \frac{\sum_{n-1}^1 (q_{\text{exp}} - q_p)^2}{\sum_{n-1}^1 (q_{\text{exp}} - \bar{q}_p)^2} \quad (5)$$

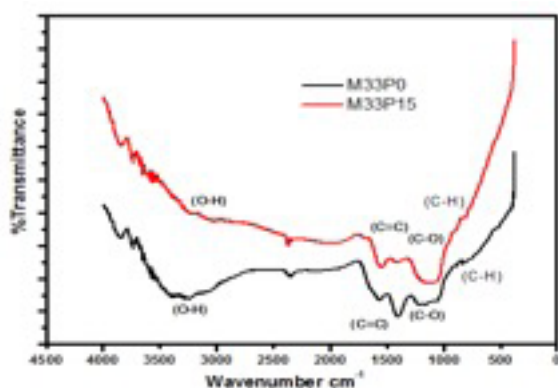
## 3. Results and Discussion

### 3.1 Samples Characterization

Fig.1 shows spectra of the porous carbon from coconut shell (M33P0) presents functional groups that depicted the following bands: (O-H) vibration in the hydroxyl groups were shown in peak 3609 cm-1 indicating the presence of alcohol and phenols [11]. It might be due to the activation with potassium hydroxide (KOH). Previous research conducted by [12] on coconut shell compared with the results obtained from this study showed the functional groups identified are same. The spectra of the coconut-PEEK porous carbon (M33P15) display belonging functional groups, which depicted the following bands. Vibration stretch of the C-H identified at the peak of 2920 cm-1. C=C bond stretching was identified at 1638 cm-1 shown in the benzene ring. Further, the activated carbon

displayed the following bands: 3500-3200, which indicates strong O-H stretch in alcohol and H-bond in moisture. This was obviously enhanced due to the treatment with KOH. Further investigation reveals that there is peak at 1600–1585 indicating the presence of C–C stretch (in-ring) in aromatics; this also assumes that it was enhanced by the treatment of CO<sub>2</sub> during activation [3].

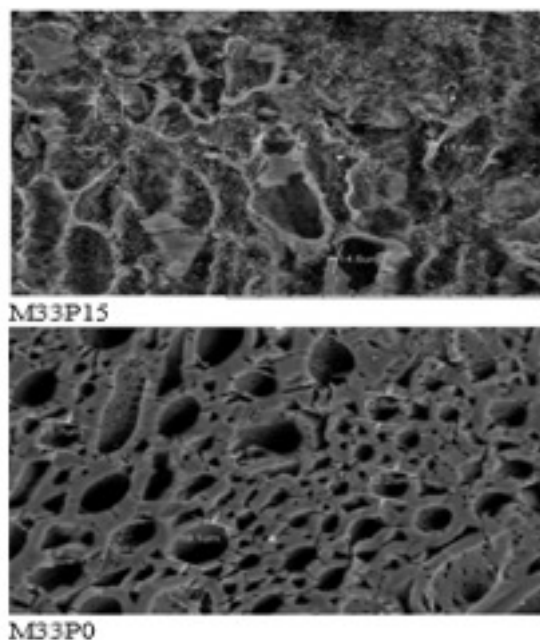
Fig.1: Fourier transforms infrared spectra of samples; M33P15 and M33P0



Scanning electron microscopy images of hybrid (M33P15) and non-hybrid (M33P0) activated carbon were presented in Fig.2. The surface morphology of the images displayed some cavities formation and rudimentary pores. These are created by the evaporation of impregnated KOH derived compounds and volatilization of the lignin, hemicellulose, cellulose and moisture content of the raw CNS after the heat treatment [2]. As seen in these pictures, coconut shell and PEEK (hybrid) form a matrix of porous carbon showing more compacted structures than non-hybrid activated carbon.

Nitrogen adsorption measurement parameters of the synthesized AC from co-

Fig.2: SEM image of (M33P15) hybrid activated carbon and non-hybrid (M33P0) activated carbon



conut shell and hybrid coconut shell and PEEK such as specific surface area, total pore volume ( $V_t$ ), average pore diameter ( $D_{avg}$ ) and average pore width ( $W_{avg}$ ) were shown in Table 1. The surface area of sample M33P15 is higher than sample M33P0. The surface area plays a very good role in activated carbon application, high surface area translates to better adsorptivity. There was an improvement of pores and surface area by adding PEEK to coconut shells; this might be due to a high value of carbon content.

Table 1: Porosity parameters of the synthesized porous carbons obtained from nitrogen adsorption

Sample	Surface area (m <sup>2</sup> /g)	$V_{tot}$ (cm <sup>3</sup> /g)	$V_{micro}$ (cm <sup>3</sup> /g)	$D_{avg}$ (nm)	$W_{Avg}$ (nm)
M33P0	802	0.127	0.091	1.900	3.120
M33P15	1115	0.214	0.165	1.790	2.890

### 3.2 CH<sub>4</sub> Adsorption

Methane adsorption capacity on the surface of hybrid and non-hybrid activated

carbons for the higher pressure were presented in Table 2. The adsorption study was obtained with respect to time at isotherms of ambient temperature and pressures starting from 5 to 17 bar. The methane uptake was fast at the initial stage of the experiment, then, later decrease with increase in contact time. This is due to the increase in the concentration of gas stored in the pore volume of the adsorbent<sup>[10]</sup>. It was observed that the adsorption equilibrium increase with an increase of initial pressure from 5 - 17 bar. Increase in working pressure of the system lead to the increase in the methane adsorption uptake. As stated by<sup>[13]</sup> that increase in working pressure would increase the Van der Waal force of attraction between the adsorbent and adsorbate. The lowest amount of CH<sub>4</sub> uptake at an ambient temperature at pressures 5, 7.5, 11 and 17 bar depicted on non-hybrid sample was 2.06, 3.04, 4.30 and 6.96 mmol/g respectively. While the highest uptake was depicted on hybrid under the same condition with uptake 2.35, 3.04, 4.80 and 7.15 mmol/g respectively. This might be due to the higher surface area display in nitrogen adsorption analysis<sup>[3]</sup>. It was observed more than 60% of the CH<sub>4</sub> adsorbed achieved at the first 60 minutes in all the pressures. According to the functional relationship between the amount of uptake of adsorption and time, it can be seen that when time tends to infinity, the adsorption uptake is prone to a fixed value. This is the actual saturated adsorption uptake<sup>[14]</sup>.

Table 2: Comparison of experimental methane uptake

Sample	Surface area (m <sup>2</sup> /g)	Uptake (mmol/g)
Hybrid (M33P15)	1115	7.15
Non-hybrid (M33P0)	802	6.96

### 3.2 CH<sub>4</sub> Adsorption Isotherm

The CH<sub>4</sub> adsorption isotherm shows how the interaction between CH<sub>4</sub> and the synthesize adsorbents occur. Two parameters isotherm models (Langmuir and Freundlich) together with the three model parameters (Sips) were applied for this study. The detail of the aforementioned models is shown in Table 3. Freundlich and Langmuir exhibit more satisfactory fit to the experimental data for both samples with R<sup>2</sup> greater than 0.988 and lower RSMD (Table 3). The values of adsorption intensity (n) for the three models at all the samples were greater than 1, indicating favorable adsorption<sup>[16]</sup>. In general, the suitability of the three isotherm models predicting the interaction behavior of CH<sub>4</sub> adsorption on the porous carbon synthesized is in order of Sips < Langmuir < Freundlich with the corresponding values as shown in Table 3. This shows that Freundlich gives a more accurate description of the interaction between CH<sub>4</sub> and the porous carbon synthesized with high values of KF indicating high adsorption capacity<sup>[17]</sup>

Table 3. Freundlich, Langmuir and Sips fitting parameters of CH<sub>4</sub> adsorption on M33P15 and M49P0 porous carbon

Sample	Isotherm	n	KF	R <sup>2</sup>	RSMD	
M33P15	Freud.	1.04	0.47	0.99	0.07	
M49P0	Freud.	1.01	0.41	0.99	0.03	
		q <sub>m</sub>	K <sub>L</sub>	R <sup>2</sup>	RSMD	
M33P15	Lang.	136	0.01	0.99	0.07	



M49P0	Lang.	493	0.01	0.99	0.03	
		$q_m$	$n$	$R^2$	RSMD	$K_{LF}$
M33P15	Sips	137	1.04	0.95	0.22	0.1
M49P0	Sips	493	1.01	0.95	0.20	0.1

#### 4. Conclusions

The study investigates both the experimental and modeling of  $CH_4$  adsorption study on KOH microwave treated porous carbon. The  $CH_4$  adsorption study was investigated using static volumetric equipment and method. The

fitness and interaction between the adsorbent and adsorbate were evaluated using the three common kinetics and the common adsorption isotherm models. The amount of  $CH_4$  adsorption uptake increases with increase in pressure.

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# Smart Energy Management System using Wireless Sensing and Actuator Network

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## Abstract

This work presents the use of the Internet of Things (IoT) concept as a tool for developing a wireless network of sensors and actuators to propose a technological update in air conditioning units installed in Saudi educational, industrial, and residential buildings. One way to improve modern buildings' energy efficiency is to apply control and decision mechanisms to decrease power consumption. Data are collected over several months using a Wireless Sensor and Actuator Network (WSAN). Gathered data then applied to an Energy Efficiency Management System (EEMS) to find suitable solutions to have a maximum energy efficiency ratio. The WSAN hardware system is installed in the Engineering Building of Suhag University. The WSAN is linked to the EEMS software for monitoring and recording data received from sensors. The collected data are analyzed, and energy efficiency solutions are applied. Results were promised, and the efficiency ratio reached 23%.

**Keywords:** Real Monitoring; Energy Efficiency Management System; WSAN; Suhag University

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## 1. Introduction

Energy is essential in the world we live in, as many of the tasks we carry out depend on it, and it is there that more and more research is being done for new means and methods to make the energy supply as sustainable as possible. There is an increasing need to rationalize and manage energy consumption efficiently, and it is known that it is essential to monitor consumption to analyze and reduce it to do more with less.

In Saudi Arabia, and mainly in vision 2030, attention is given to reduce the dependence on oil and to implement more efficient energy resources<sup>[12]</sup>.

In terms of energy consumption, residential buildings are responsible for at least 40% of the energy used in most countries<sup>[1]</sup>. Research on this topic is overgrowing in the most developed countries globally, such as the United States or China, where there is rapid growth in intelligent systems so that they can contribute to the regression of climate change and an increase in

energy efficiency.

Efficiency in buildings brings considerable reductions in energy consumption and economic benefits. It is estimated that measures to reduce demand without grid costs can almost halve the expected growth in electricity demand worldwide. However, it is vital to introduce new consumption habits, primarily to mitigate peak situations. For this, it is necessary to have information for consumers<sup>[2]</sup>.

However, the idea of efficiency should not be associated with a lack of comfort since acceptable levels of efficiency can be achieved by taking simple measures, such as purchasing equipment with high energy efficiency, keeping doors and windows closed when the air conditioner is working, taking advantage of the natural light for ambient lighting, among others. These measures intend not to deprive people of comfort but to maintain the same level of comfort with the lowest possible energy expenditure<sup>[3], [4]</sup>.

In Saudi Arabi buildings, it appears that the majority of energy costs are due to the use of air conditioning units. Increasingly accessible, air conditioning units are present both in homes and in work environments, and their use aims to ensure a pleasant room temperature, favoring comfort, productivity, health, and well-being<sup>[5,10]</sup>.

The study stages can be summarized as:

1. Analyze strategies and technologies that allow achieving the Energy Efficient concept, with its difficulties and virtues in its implementation.
2. Assess the impact on the building's con-

sumption, different usage patterns, passive measures and energy efficiency.

3. Technical, financial and environmental comparison of a building with a solution based on current regulations and practices and a building with an energy efficiency solution.

4. Attempt to apply the strategies and technologies mentioned above to a real case study at MU and the respective interpretation and analysis of the results obtained. According to statistics, it is estimated that air conditioners' energy consumption for maintaining thermal comfort represents 40% to 70% of the total consumption of the building<sup>[6,11]</sup>. Preliminary architectural design and non-optimized refrigeration facilities, without automation, often lead to energy waste. An example: in most building environments with window air conditioners, over-cooling occurs, i.e., in the less hot hours of the day, the ambient temperature drops below the comfort temperature. After all, it is not practical to adjust the thermostat for each appliance throughout the day. This energy for cooling beyond the comfort point is a waste of energy.

Wireless Sensor and Actuator Networks (WSAN) is a promising technology used to monitor and control the wireless environment. Based on energy consumption, decisions made using central early programmed software<sup>[7,8,9]</sup>. WSAN can be implemented in different environmental monitoring areas for energy savings and energy controlling<sup>[17]</sup>. Monitoring buildings for energy consumption is one of the primary implementations for WSAN.

The process of Using Sensing Nodes to sense the energy consumption and actor nodes for decision making represents a network for environmental monitoring. Fig. 1 shows a typical WSAAN architecture<sup>[17]</sup>.

The WSAAN main actions are performed using at least one coordinator sensing node and actuator nodes that are communicated wirelessly<sup>[18]</sup>.

The Wireless Sensor Network (WSN) actively shares wireless technology benefits by building a comprehensive network that does not require wires and can be implemented in any desired location such as buildings and houses<sup>[19]</sup>. Moreover, WSN can be applied to WSAANs and Wireless personal area networks (WPAN), which are the most complex applications in modern life [20]. Using smart technologies such as WSAAN is an essential step in achieving a sustainable economy. The intelligent infrastructure for industrial, agricultural, and governmental systems develops different infrastructures, production processes, and services<sup>[21-24]</sup>.

The system provides an opportunity to monitor energy consumption, and users can monitor and inspect the results visually. Moreover, the use of WSAAN eliminates the technical and protocol differences of communicated devices<sup>[22]</sup>.

This paper presents a necessary and essential step in identifying and managing the current state of energy consumption. This paper provides efficient ways of using electricity through theoretical study, design proficiency, hardware implementation, and data collection.

This paper aims to design, implement, and deploy an energy monitoring and control platform using WSAAN to manage the energy consumption in large- and small-scale buildings in an optimum way, i.e., the most efficient way to consume the energy sources in the KSA buildings. WSAAN for remote energy consumption monitoring and energy management is designed to achieve the goal mentioned above; testing and deploy the developed platform into two different rooms: classrooms and faculty offices rooms; Understanding user behavior w.r.t energy usage and optimal design EEMS that stimulate energy saving.

In this paper, the WSAAN method is used to gather data and model all of the building's dynamic disturbance parameters. The optimization problem is solved by benchmarking performance based on a numerical study.

## 2. Problem Formulation and Motivation

In buildings, energy efficiency is directly related to the rational use of energy; that is, energy efficiency and the reduction of costs associated with energy consumption are among the main objectives for our entire society<sup>[26,27,28]</sup>.

Energy efficiency being a significant factor, as this work seeks to find a solution that allows the use of the most efficient equipment and an improvement in the user's daily comfort.

The WSAAN system developed within this paper helps the user to have greater energy efficiency on the use of energy, allowing more savings on electricity bills each month and greater convenience; that is, it

can trigger the system whenever you want, activating which appliances you want to turn on or off, using available solar radiation.

To contribute to solving the problems mentioned above, the EEMS combines software with WSN is implemented to provide a decision-maker with direct and real data from sensor nodes<sup>[13]</sup>. The system is complex regarding the need to synchronize the two systems and provide additional control options. Today, organizations use IEEE802.15.4 and ZigBee to deliver practical solutions for various areas, including consumer electronic device control, energy management, home efficiency, commercial building automation, and industrial plant management<sup>[14]</sup>. Monthly records are provided and analyzed based on the analysis of several monitored buildings<sup>[15]</sup>.

The EEMS for controlling buildings that are presented in this work contain Cyber-Physical System (CPS) architec-

ture-based manufacturing systems, which are integrated and implemented with WSN. This presentation makes the management system more adaptive to different applications<sup>[16]</sup>. Combining the feedback process directly with the CPS using WSN increases energy efficiency significantly, up to several rates.

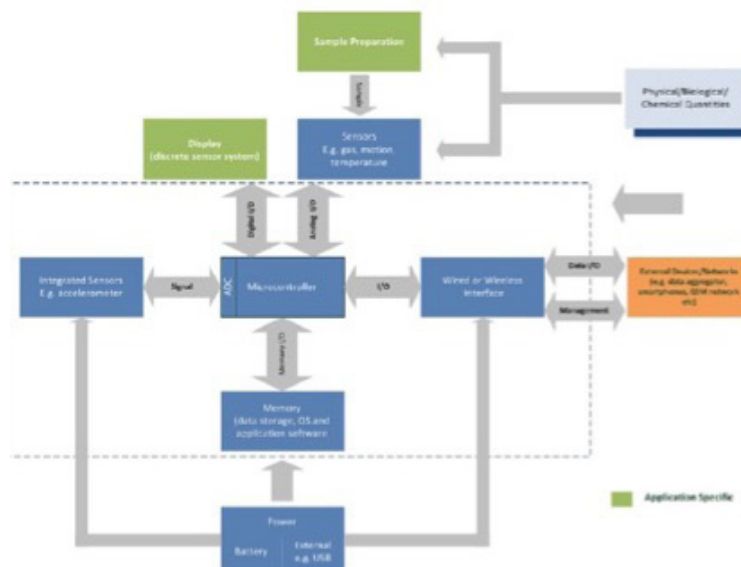
Having data regarding energy consumption collected over a period of time is an efficient way to plan and make future decisions. However, this approach stops high energy consumption rates during times of sensing and monitoring. Thus, real-time monitoring implements smart technologies.

### 3. Energy efficiency systems using WSN.

#### 3.1. WSN software and hardware overview

The main components of any WSN are: Sensors, connected interfaces, microcontrollers (MC), storage device, digital and analog I/O, enclosures, and mountings into an integrated system<sup>[29]</sup>

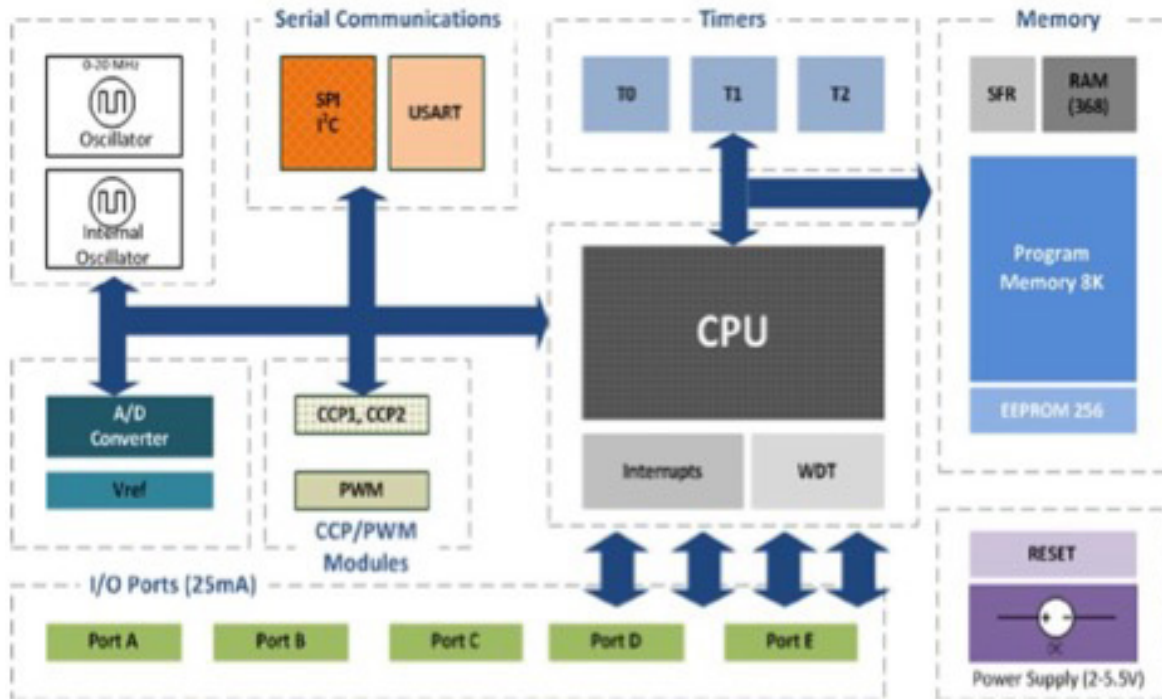
Fig.1. High-level sensor system architecture



Using smart sensing requires MC or microcomputers to compute internal devices. The MC contains Program and data memories, interrupt handling, microprocessors,

and peripherals, including I/O interfaces, as shown in figure 2. This MC is essential for smart sensing [30].

Fig. 2. Block diagram of a microcontroller



The input and output of MC are controlled by the specific tasks performed based on the MC design. In sensing applications, the input usually is data received from sensors. Due to the specific WSN tasks, MC internal devices and software are defined in advance [30].

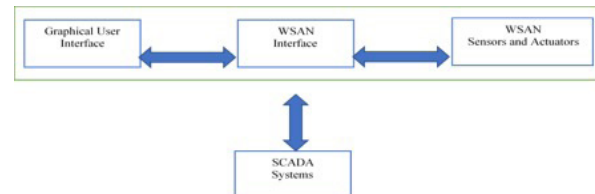
The MC used in the proposed system is The Arduino I/O Board. The Arduino I/O board is mainly programmed using the open-source Arduino programming language. The figure shows the Arduino UNO R3 board. The WSN main actions are performed using at least one coordinator sensing node and actor nodes that are communicated wirelessly. The Wireless Sensor Network (WSN) actively shares

wireless technology benefits by building a comprehensive network that does not require wires and can be implemented in any desired location such as buildings and houses [33].

### 3.2 WSN implementation

The proposed architecture of the Energy Efficiency System is shown in Figure 3

Fig. 3. The architecture of Energy Efficiency System



The measured energy of the sensors is integrated and connected to the actuator module for transmitting the measured val-

ues data wirelessly. The actuator modules are linked with different sensors and interconnected in the form of mesh topology to have reliable data reception at a centralized coordinator. The maximum distance between the adjacent actuator nodes is less than 10 m. The actuator coordinator has been connected through the USB cable of the host computer, which stores the data into a computer system database. The collected sensor data have been sent to an internet gateway for controlling energy consumption.

To sum up, the sensors sense the physical variables of interest, which is the device energy around its sensing range, and report them to the controller, which evaluates collected data by comparing set points. If required, it sends control signals to the actuators. The actuators disconnect the devices which have energy consumption more than the threshold level.

SCADA stands for supervisory control and data acquisition, a term that describes the essential functions of a SCADA system. SCADA is used to control equipment across WSN to collect and record data about measured and sensed signals representing power consumption.

Fig.4 (a) The Z-Wave sensor



Fig.4(b) The gateway.



#### 4. Experimental results

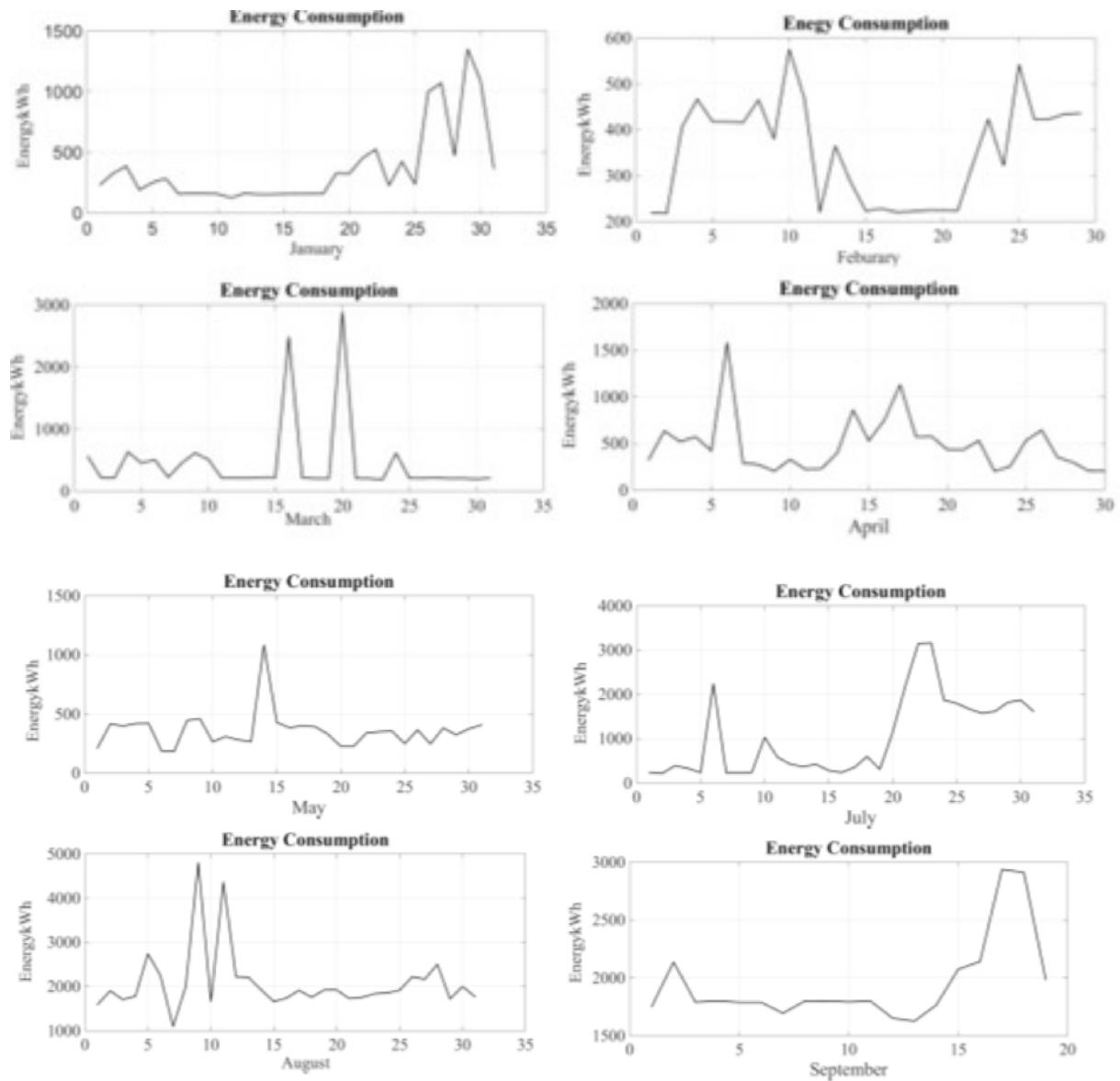
In this section, some preliminary results are shown by monitoring the energy consumption of the Engineering building at Suhag university during one academic year, tracing the changes in the consumption during the different seasons. The primary energy requirement for the entire building for each month corresponds to the overall electricity need. Thus, air conditioning, lighting, printing, ventilation, and auxiliary equipment in an academic building are considered. Figure 5 shows the energy consumption for 9 months, during which the average energy consumption is relatively low during winter and spring days.

Energy consumption at EE is generally characterized by the lighting system and the use of necessary equipment (computers, fans, others) and air conditioning (restricted to administrative areas). The bathrooms have compact fluorescent lamps activated by presence sensors, which minimized the proposal to reduce the building's energy consumption<sup>[23]</sup>.

The monitoring period after the interventions carried out at EE lasted six months,



Fig. 5. The energy consumption of the building in 9 months.



covering September 2018 to Jun 2019. This monitoring was carried out based on the analysis of energy consumption bills issued by the Electricity Company. During this period, it was possible to verify an average reduction of 10% in the consumption of electrical energy in the building, meeting the expectations initially proposed in the study regarding the reduction of 4 to 11% in the building's electrical energy

consumption.

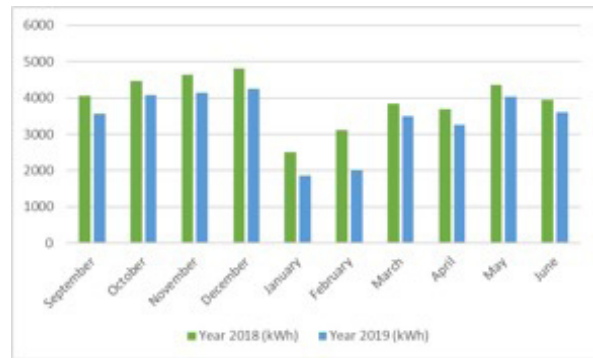
It is noteworthy that, due to budgetary limitations, the interventions covered the building partially. The results indicate two behaviors: in the first moment, again in the reduction of consumption, and in the last two months, a decrease that contradicts the trend obtained initially. Table 1 shows the data that served as a basis for comparing the values obtained with the actions car-

ried out in the building. Figure 6 shows the

Table 1- Reduction in consumption compared to the previous year's reading.

Month	The year 2018 kWh	The year (2019) (kWh)
September	4050	3570
October	4465	4080
November	4630	4140
December	4820	4255
January	2500	1850
February	3100	2000
March	3850	3500
April	3700	3250
May	4370	4030
June	3950	3600

Fig. 6. Reduction in consumption compared to the previous year's reading.



percentage of energy consumption reduction from the year 2018 to 2019 when the WSAN system is used to optimize energy efficiency.

Figure 7 shows the energy reduction in 2019 after the implementation of WSAN.

Fig. 7. Energy reduction in 2019

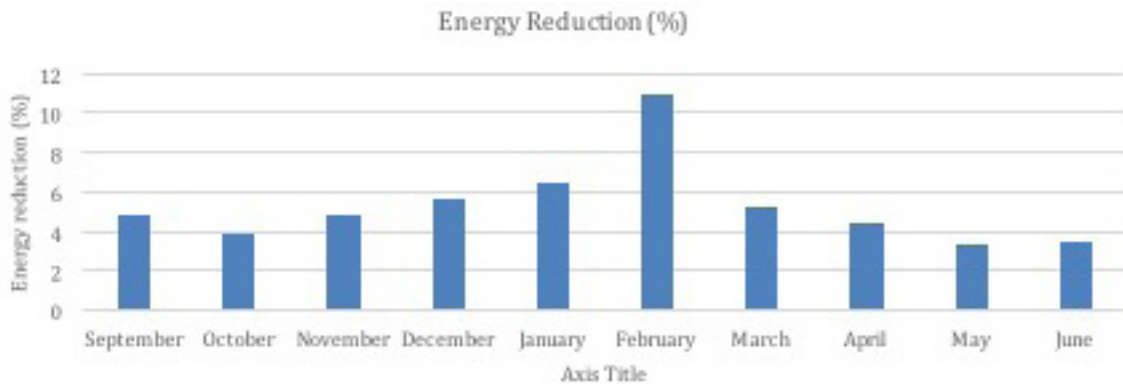


Table 2 Monthly electricity consumption of the EE building in kWh

Month	(kWh) 2015	(kWh) 2016	(kWh) 2017	(kWh) 2018	(kWh) 2019
January	2600	2550	2710	2500	1850
February	2320	2600	2920	3100	2000
March	3550	3620	4010	3850	3500
April	3570	3710	3805	3700	3250
May	3800	3700	4640	4370	4030
June	4050	4400	4211	3950	3600
July	3440	3600	3800	3550	3280
August	3900	4100	3920	3670	3140
September	4020	4150	4310	4050	3570
October	4150	4400	4650	4465	4080
November	4810	4970	4810	4630	4140
December	5100	5300	5170	4820	4255

Fig. 8. Monthly electricity consumption of the EE building in kWh

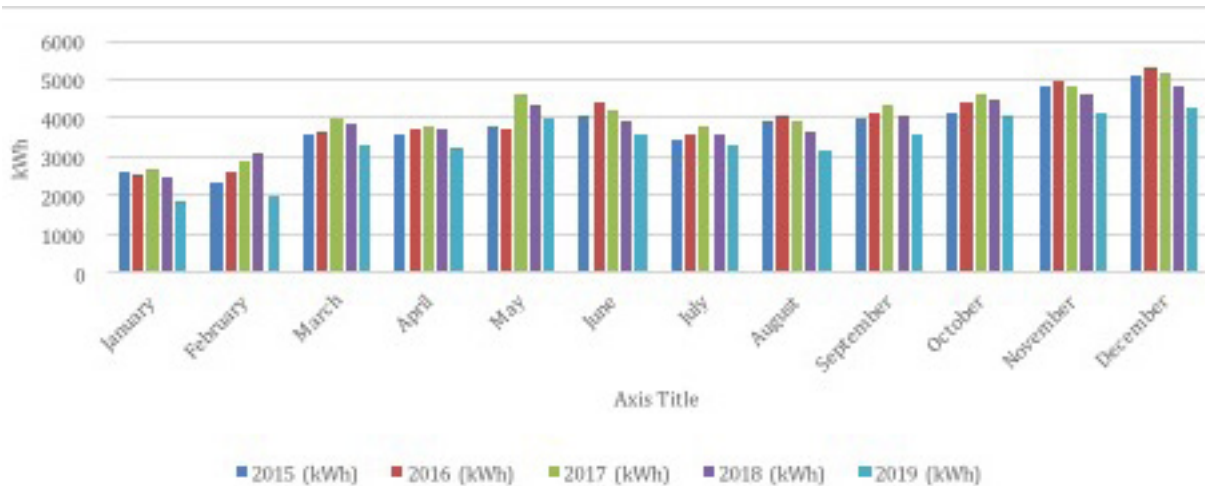


Table 2 and Fig. 8 show the EE building's consumption and electricity monthly from 2015 to 2019. It is important to note that electricity consumption is directly related to the number and hours of use of equipment installed in a given period.

### 5. conclusion

In this work, a decentralized and collaborative decision system for WSN applications for intelligent buildings was proposed. This decision system aims to contribute to environmental sustainability by improving energy efficiency and, consequently, reducing the emission of polluting gases by buildings. This system was implemented to be associated with third-generation intelligent buildings' applications and implemented in RASSF to decentralize the application decision process.

Thus, this study aimed to act with practices in reducing energy consumption in the EE building. In addition, the energy efficiency approach has enabled cost reduction, modernization, and readjustment with the use

of new equipment with more outstanding performance and durability. In the future, the obtained results can be used as a reference to generalize the WSN concept in the college of engineering buildings in Majmaah. Moreover, a thorough analysis of the of the results of first stage and the second stage of the project will be conducted to assess the validity of the WSN for the educational institutes.

### Acknowledgments

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## **E-learning Environment's Effectiveness and Efficiency for Educational Institutions: the case of KAU & QU**

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### **Abstract**

The present research aims to investigate the efficiency and effectiveness of e-learning systems adoption and implementation in context to the Saudi educational sector with specific focus on Saudi universities. It investigates the impact of the system on academic staffs teaching online courses. Adopting quantitative research approach, the IS-Impact Measurement model was used to design the questionnaire to collect the primary data. It was used to find out the effectiveness of the current systems based on the perspectives of academic staff with experience teaching online courses for a year at least. The total outcomes of the whole research ended up proposing a business model to enhance and modify e-learning environments for Saudi universities with specific focus on their quality by assessing and understanding of the impact employees have within their roles.

**Keywords:** e-learning; distance learning; IS impact, Higher Education; Saudi Arabi

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## 1. Introduction

Recently, the Saudi educational sector has grown considerably. Global educational institutes and universities have implemented a range of innovations to offer high-quality courses to their students with the goal of enhancing their learning outcomes and overall quality of education. Within this domain, collaborative e-learning environment has gained considerable attention of many globally recognized universities and has played a pivot role in rising student enrollment. Saudi educational institutes are no exception as they have begun to provide education through eLearning<sup>[1][2]</sup>.

Globally, technology development has been observed to be growing exponentially, and with this, communication and e-learning are also increasing gradually<sup>[2]</sup>. Internet usage has been growing considerably and this is attributed to the influence of the developed services and applications. These include videoconferencing tools, data processing tools, multimedia tools, social media tools, and e-learning systems. It is reported that Saudi Arabia has effectively adopted e-learning systems during the initial stages of its development. Since the last decade, the number of Saudi students' enrollment has increased substantially<sup>[4][40]</sup>. To further keep up with this trend, many educational institutes in Saudi Arabia have adopted e-learning systems to provide high quality education to students from remote locations. Furthermore, these systems ensure that both courses are accessible for both course instructors and students<sup>[1]</sup>.

IS Impact Measurement Framework was used to investigate the efficiency and effectiveness of e-Learning system from user perspective. In this research, the researchers considered four components for e-learning system evaluation<sup>[41]</sup>. These are: organizational impacts, individual impacts, information quality, and system quality. While all these sides except the individual impacts were reported in<sup>[5]</sup>, this research intends to investigate the impact of e-learning systems at individual level with specific focus on Saudi Universities. Two Saudi universities were selected for the application of this study: King Abdulaziz University and Qassim University.

## 2. Related Studies

This whole project assessing the e-learning system is based on the IS-Impact Measurement model<sup>[6][7]</sup>. The IS-Impact Measurement model had been selected because it has four aspects on basis of which, the efficiency and effectively of an educational system is reviewed<sup>[6]</sup>. Furthermore, this evaluation model was chosen because the validation of e-Learning is more reliable than when other financial models are used<sup>[6]</sup>. As an outcome, this research creates a theoretical framework that is relevant to educational organizations in Saudi Arabia. The analysis of existing literature has revealed that the given model can effectively be adopted for educational environment globally. The IS Success/Impact model is known to analyze the whole attributes of the e-learning environment<sup>[8]</sup>.

In addition, the multi-dimensional formative construct was utilized to address the

challenges that can determine the IS Success/Impact[9]. Gable, Sedera and Chan<sup>[10]</sup> stated that it includes the majority of the environments. Based on the research, several models related to e-learning in context to technology and techniques were identified. DeLone and McLean's<sup>[8]</sup> IS-Success model, the Balanced Scorecard<sup>[11]</sup> and Gable, Sedera and Chan's<sup>[10]</sup> The IS-Impact Measurement model was selected for this research as it was found to be appropriate based on the research aim and objectives. The DeLone and McLean IS-Success model has been studied extensively in research<sup>[12]</sup>.

The synthesis of literature demonstrates that the IS Impact Measurement Model is the innovative model pertaining to e-learning environment. It is used for the IS investigation as a model of measurement<sup>[7]</sup><sup>[10]</sup>. It is considered to be efficient for determining whether the given e-learning system is efficient in fulfilling the needs and requirements of the organization. This model has six dimensions with forty-one measures. The dimensions of the model are outlined as follows: Individual Impact, Informational Quality, Organizational Impact, System Quality, User, and User Satisfaction<sup>[6]</sup><sup>[10]</sup>. Gable, Sedera and Chan<sup>[10]</sup> and Rabaa'I and Gable<sup>[13]</sup> have reported that both User and User Satisfaction are the dimensions that have emerged because of before and after of success. Both Information Quality and System Quality have been reported to influence Use and User Satisfaction<sup>[14]</sup>. However, it should be noted that Gable, Sedera & Chan<sup>[10]</sup> have

proposed that the Use dimension is not instrumental in determining the success of IS. Furthermore, they state that "User Satisfaction has been measured indirectly through Information Quality, System Quality and other variables in prior studies"<sup>[10]</sup>. Therefore, this study has adopted four dimensions of the model. The four dimensions have thirty-six measures. These measures will be used to design the questionnaire to collect perception of end users in terms of e-learning systems.

Ramayah & Lee<sup>[15]</sup> studied the IS-Impact model's six dimensions extensively and justified its choice for design and utility in e-Learning systems. These include System use which is considered as successful when e-learners view it as adding value to their learning experiences or improves their performance. User satisfaction, on the other hand, is a measurement to analyze the association of the user with the e-learning system. It evaluates the end users needs and requirements, and it is surmises that frequently utilized systems indicate its successful impact. The dimension of the quality system is evaluated through availability and design of the system in terms of meeting their needs with its success being evaluated by user-friendliness and provision of feedback to the e-learner. Another dimension is the information quality which is examined through the system's output. This dimension is analyzed through different parameters such as precision, efficiency, reliability, and appropriateness in context to e-learning content<sup>[16]</sup>. Additionally, e-learning systems should be user-friendly,

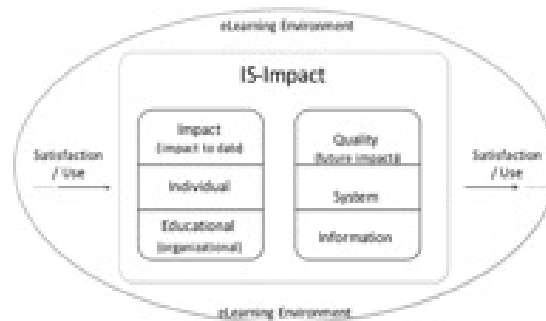


simple, and accessible for the end users<sup>[17]</sup>. It is worth noting that the system utility influences user satisfaction and in turn leads to an improved e-learning system. These dimensions are inter-dependent on each other and form a continuous cyclic process<sup>[18]</sup>. However, these dimensions produce different results depending on whether the system usage is mandatory or voluntarily chosen for e-Learning.

The synthesis of literature pertaining to IS, end-user computing satisfaction, e-learning system, and related areas have identified several variables that can be used to determine the efficiency and effectiveness of the e-learning systems (e.g., Latchman et al.<sup>[19]</sup>; Naidu<sup>[20]</sup>; Hooper<sup>[21]</sup>; Liaw and Huang<sup>[22]</sup>; El Mansour and Mupinga<sup>[23]</sup>; Zembylas and Vrasidas<sup>[24]</sup>; Suthers et al.<sup>[25]</sup>; Okamoto<sup>[26]</sup>; Bonk<sup>[27]</sup>; Reuben<sup>[28]</sup>; Tomsic and Suthers<sup>[29]</sup>; Gable, Sedera and Chan<sup>[7]</sup>; Gable, Sedera and Chan<sup>[10]</sup>; Rabaa'i and Gable<sup>[13]</sup>; Wang, Wang and Shee<sup>[30]</sup>; Wang, Tang and Tang<sup>[31]</sup>; Wang and Tang<sup>[32]</sup>; Wang and Liao<sup>[14]</sup>; Wang<sup>[33]</sup>; Ramayah & Lee<sup>[15]</sup>; Elias<sup>[34]</sup>). Therefore, we ended up with four variables that are most suitable for e-learning system success, see figure 1 below. These variables are organizational impacts, individual impacts, information quality and system quality. All these variables except the variable of individual impacts were reported in Alkhalaf, Drew, AlGhamdi & Alfarraj,<sup>[5]</sup> and Alkhalaf, Drew & Alhussain<sup>[35]</sup>. So, the current paper emphasizes on the individual impacts of staff members of e-learning systems. In terms of individual impact,

this research evaluates how e-learning systems effect individuals. It emphasizes on the evaluation of the e-learning system to determine whether it is beneficial for individuals in context to learning, sharing of information, decision-making, and overall efficiency.

Figure 1: A developed model for staff members using e-Learning systems



### 3. Method

This study was based on the IS-Impact Measurement model. The model has been developed by Gable, Sedera and Chan<sup>[7]</sup>, which is used in surveys. Accordingly, the IS-Impact survey instrument has been used with minor modifications to ensure suitability with our topic, the full instrument items can be found in the appendix. The questionnaire was based on the 4 dimensions of the IS model. The dimensions selected were: individual impact, information quality, organizational impact, and system quality. These dimensions contained 36 items. A five point Likert scale was used for rating these items<sup>[36]</sup>.

The questionnaires were distributed among the faculty members of the Saudi universities, which were selected for this research. These were: Qassim University and King Abdulaziz University. It was presented to 50 faculty members. 11 partici-

pants were the entire members of the Computer Science Department in the College of Sciences and Art, Qassim University, while 39 respondents were the entire from the Computer Sciences Department, King Abdulaziz University, Saudi Arabia. 38 forms were retrieved that were completed. The response rate calculated was found to be 76%. The distribution of respondents by gender was 30 males (78.9%) and eight females (21.1%). Among the sample; 35 members were aged between 20-25 years 92.1 %, two members were aged between 25-30 years 5.2 % and one member was over the age of thirty 2.6%. Thus, it can be said that the sample in this study is representing the whole population.

Analysis of the responses obtained through the questionnaires was achieved using the SPSS software. This software provided an analysis of the questionnaire in terms of the percentage and frequency of each response category for every answer. It also evaluated the statistical level of significance of each response through the chi-square value.

**4. Results and discussion**

Table 1 below shows the Chi-square Goodness of Fit test values for Individual Impact, which is the first dimension of the IS model. 9.49 is the high Chi-square value. Here, the level of significance is 0.05 and 4 degrees of freedom. As shown in Table 1, the expected and actual values for the Individual Impact dimension have significant difference, which statistically is not a coincidence.

From the below table 1 and Figure 2, the

results indicate that Individual Impact is the most essential component of the e-learning system, which helps in their learning and enhancing their productivity. The participants also learnt from using the system, which contributed to their experience. As shown in the table, the mean of the responses was found to be between 3.3 to 3.79. The relative importance varied from 66% to 75.3%. The standard deviation determined for the responses varied from 0.935 to 1.199.

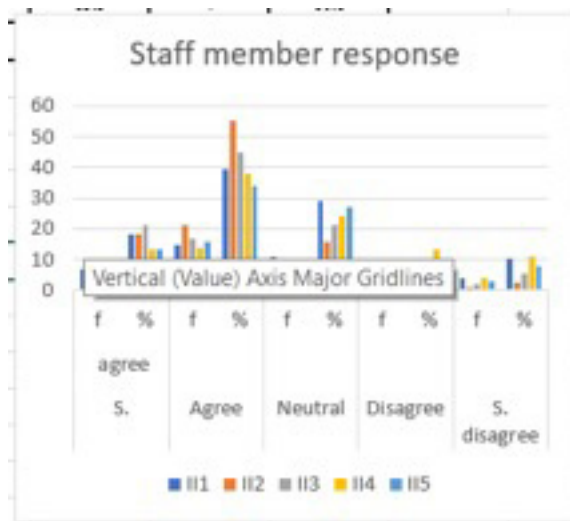
Table 1: Relative numerical distribution and standards deviation and the value of chi-square for related to the dimension (Individual Impact) for the staff members

N	S. agree		Agree		Neutral		Disagree		S. disagree		M	SD	X <sup>2</sup>	Relative weight	#
	f	%	f	%	f	%	f	%	f	%					
II1	7	18.4	17	43.7	11	28.9	3	7.6	4	10.5	3.73	1.158	18.21	75.6	3
II2	7	18.4	20	51.3	6	15.8	3	7.6	3	7.6	3.78	1.405	12.31	71.8	1
II3	8	21.1	17	43.7	8	21.1	3	7.6	2	5.26	3.68	1.068	18.51	73.6	2
II4	3	7.6	14	37.8	9	23.5	5	12.9	4	10.5	3.30	1.199	9.33	66	3
II5	3	7.6	16	41.2	10	27	3	7.6	3	7.6	3.46	1.095	18.92	69.2	4

\*\* Significant at 0.05  
\* Significant at 0.01

Items: II1: I have learnt much through the experience of using the eLearning system (Learning); II2: The e-Learning system enhances my awareness of requirements of educational processes (Awareness/Recall); II3: Using the eLearning system will increase my productivity (Individual productivity); II4: I am satisfied with the experience of using the eLearning system (Experience); II5: Most users have a positive attitude towards or evaluation of the eLearning system functionality (Attitude) The results indicate the following. For Item II1, a rate of 57.9 %, believed there was a positive impact on development from the use of e-Learning, which indicates the effectiveness of e-Learning in the

Figure 2: Staff member response



development of the educational process. An IT manager stated, “The staff members need more time to feel comfortable and learn about the need to use the eLearning system”.

Furthermore, as indicated by Item II2, 73.7% of respondents agreed that the system of eLearning enhances their awareness of the needs of research, and helps them complete their scientific research by utilizing the e-Learning system’s electronic libraries, databases and electronic systems.

Concerning Item II3, 65.8% of respondents confirmed that the use of e-Learning helps increase their production of knowledge. According to a member of Academic Development and a teacher using an e-Learning system, some reasons may hinder the process of production, such as the years of working service. It was found that some of the faculty members with long period of work experiences are reluctant to effectively use the non-traditional teaching style. Also, the type of job or specialty, and the type of college are seen to have impact

on using technology. An IT manager stated, “We have some members of the faculty who have a tough time dealing with technology. They can usually work quickly, but when they use a computer their work is much slower”.

E-learning system offers benefits to faculty members. The most important use of modern electronic systems is to help quicken access to everything they need for obtaining and processing information, educating themselves in the process, and therefore increasing their scientific output. According to a member of Academic Development, “ELearning helped the development of functionality”. Another, faculty member reported that “I learned a lot; I learned about processing lectures from the Internet, I learned more about IT and information security, I learned how to be in communication between myself and the students more closely, I learned that when the students say what they need they use the website (a cooperative Blackboard discussion) or e-mail. Moreover, I learned when e-Learning will be useful to students and when it will not be useful”.

According to all interviewees, e-Learning increases productivity because it saves time and provides more definitive products. The responses from Item II4 found that 51.3% of the participants showed satisfaction in terms of e-learning system based on their usage. This finding may be due to the widespread availability of modern technology recently utilized by the University of Qassim and King Abdulaziz University’s educational systems. 47.7% of the re-

spondents of Item II5 rate the functionality of the e-Learning system as positive.

As a result of the above responses, it has been verified that e-learning systems are beneficial and are practically viable for educational institutes, colleges, and universities, and dramatically increases the capacity of faculty members at Qassim and King Abdulaziz Universities to interpret information accurately, thereby increasing their understanding of the information. It also works to increase faculty members' relevant activities in their scientific departments, as well as helping to provide the basic information used in their studies, which helps in improving both learning and teaching process significantly.

### 5. Implications

This research aimed at analyzing the use of e-learning systems by analyzing the perceptions of the users, which included both learners and faculty members. While this perspective would have been enhanced by interviews with more staff members and managers; this research found that flexibility of the system and positive impact of the IS Model is needed to enhance the e-learning system's capabilities in terms of space, time, speed, and interaction. This research recommends the activation and use of the "Hyper business model of e-Learning", Figure 3, in all divisions and steps, and to monitor its impact on education by using the "IS-Impact Measurement model of e-Learning" at least once every two years. The figure contains five entities: the e-Learning Improvement Project, the Academic Department, the e-Learning System, the Learning Management System, and the System Development/Enhancement Project.

tem, the Learning Management System, and the System Development

Project. This diagram of the business model gives a comprehensive view and descriptions of the life cycle and shows where the items must be taken into account in those five entities' life cycle (both in operation and creation). This mapping is intended to provide a complete view of e-Learning environments (what entities are involved and what their life cycle is), Figure 4, and illustrate where the items (defined by the IS-Impact Measurement model) must be taken into account in the life cycle of these entities (both in operation and creation), e.g., influencing the tasks of academic departments and developmental projects.

Figure 3: Proposed Hyper Business Model of e-Learning

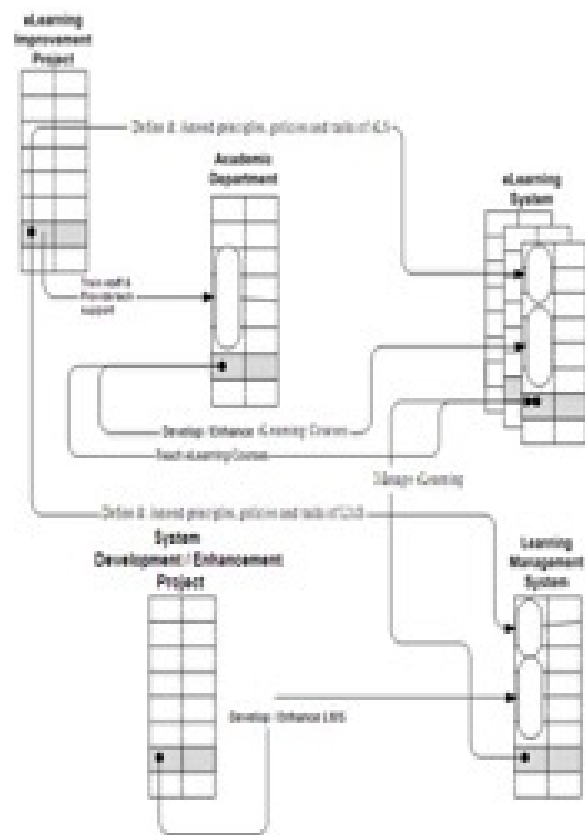
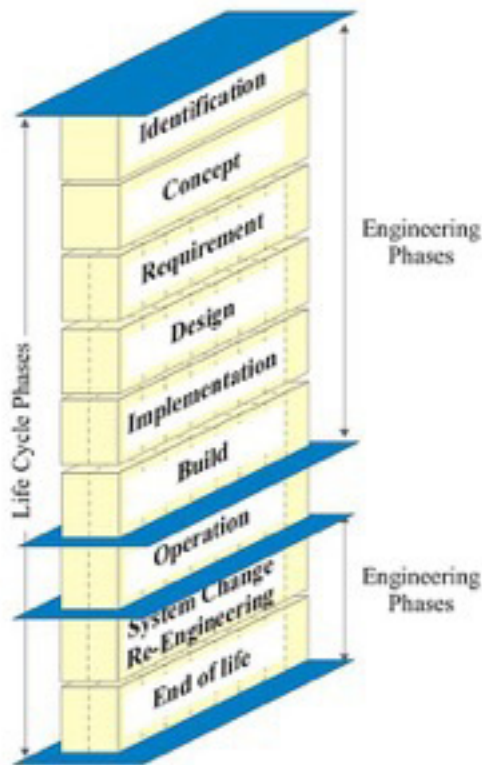


Figure 4: Enterprise architecture life-cycle phases [37]  
[38]



The e-Learning improvement project is intended to improve the e-Learning environments through the analysis and investigation of the content offered by the website along with the analysis of the e-learning tools incorporated. This is in order to improve the quality of e-Learning and to evaluate staff competencies and technical support.

The e-Learning improvement project's responsibility is to identify the e-learning system's concepts and notions, policies, procedures, and responsibilities. Moreover, this entity is responsible for training academic staff and creating technical support within the academic department. The lists of items most satisfied by this entity are:

- Ensuring that the e-Learning components are always available both online and offline, by using a server and providing access to the e-Learning system inside and outside the campus.
- Aiming to design a navigational e-learning system, which is easy to use. It is considered to be simple as compared to LMSs such as Blackboard.
- Creating ease of access while on campus that is as simple as just one click on the Internet.
- Providing all course-related materials on one website, and providing the student with an organized display of assignments and handouts to make it easier to print the relevant materials at his or her convenience. Furthermore, it offers arrangement configurations for documents based on time requirements.

The academic department supports the development of e-Learning courses and provides teachers with e-Learning courses that are delivered through part of the e-Learning system.

The following are considerations must be made to ensure the satisfaction of teachers:

- The adoption of implementing e-learning system is essential for improving teaching methods. Therefore, it is imperative for the academic department to take into account the need for online collaboration and to acknowledge the academic workload associated with such delivery. Therefore, academic staff must be trained so that they are at a capacity to efficiently use collaborative tools.
- Students are active in discussions within

the e-learning environment. However, it is important for the academic department to also actively participate to ensure that students receive adequate feedback to guide them along the correct path.

- e-Learning course materials are always scheduled online on time.

The e-Learning system involves delivering online courses in which the delivery process includes teachers, students, and course materials through support tools (such as collaborative tools). The design of each online course needs to be consistent with the principles and policies defined by the tasks from the e-Learning improvement project. The actual tasks (desired learning outcomes as well as other functional and non-functional requirements) of each course are defined by the academic department. When developing e-Learning courses the academic departments need to take into account the following items of success:

- The teacher should foster student engagement (student interaction).
- Collaborative tools act like a motivational agent that encourages the students to have online interactions with the teacher and with each other.
- The teacher should have an interest in teaching students in an e-Learning setting.
- The teacher always effectively utilizes the e-Learning system.
- Student participation and involvement in discussing topics are always highly active in the e-Learning setting.
- The teacher initiates most of the discussions that make the collaborative tools

more active and effective.

- E-Learning encourages students to ask questions; this enhances their knowledge level when compared to traditional methods.

- Both teachers and students use the e-Learning components more adequately by selecting easier and better approaches for their use.

The Learning Management System is a software, which is responsible for supporting the e-learning system. The software must support collaborative tools to provide a high-quality eLearning environment. The list of items which are most satisfied by this entity include:

- Most of the e-Learning tools used in the collaborative system are easy to use.
- Resources can be browsed and downloaded at a reasonable speed.
- All course-related material is available at the one source, which enables students to easily acquire printouts of assignments and handouts.
- The e-Learning components are always available both online and offline.
- The system development project is involved in context to the e-learning platform. Its duty is to identify the concept and the requirements of the learning management system entity. The item of success most satisfied by this entity is:
  - Students have the right to receive advice/help from the teacher in a collaborative environment.

## 6. Conclusion

In conclusion, this research aimed at investigating the adoption of the e-learning sys-

tems of the Saudi universities perspective to identify its benefits. It focused on the individual influence of the online courses taught by academic staff. The system flexibility and the significant influence of the IS Model are expected to enhance space, time, speed and engagement functionality of the e-learning system. This study suggests that the “Hyper business model of e-learning” should always be enabled and used. Moreover, it recommends that all three stakeholders (teachers, students, and materials) are essential for the success of the model to engage with each other within the context of the structure of the model. The findings of this study also showed a clear understanding of the e-Learning environments. This understanding could create a clear awareness of the employees influence when doing their responsibilities, which could speed up the educational progression and enable students to master concepts more quickly.

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# A Systematic Approach to Develop an Advanced Insider Attacks Detection Module

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## Abstract

Because of its perplexing existence and significant impact on organizations, the insider threat remains one of the most difficult challenges to recognize. Insiders pose a significant danger to organizations due to their knowledge of the organization and its security protocols, their permitted access to the organization's finances, and the difficulty of distinguishing the behavior of an insider threat from that of a regular employee. Thus, the insider-threat field faces the test of creating recognition arrangements that can identify threats without producing an incredible number of bogus positives and can mull over the non-specialized part of the issue. A possibility to concentrate on threat location was led to assess the recognition execution of the proposed arrangement and its ease of use. The field can profit from our proposed systematic approach that is scientific classification and novel arrangement of research that adds to the association and disambiguation of insider threat occurrences and the protection arrangements utilized against them. Insiders, who may know about the vulnerabilities of the systems and business types submitted, have authorized clients with genuine access to delicate and confidential information. Numerous cyber-attacks brought about by malicious insiders are progressively hard to recognize contrasted with those of outside assailants whose impressions are more enthusiastically to cover up. The paper aims to propose a systematic approach to develop an advanced insider attacks detection module. The approach proposed in this paper will help the organization to early detect the insider threat and help them in performing more effectively in cyberspace.

**Keywords:** insider threat; malicious insider; cyber-security; cyber-attacks; vulnerability; threat; fraud; keylogger;

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## 1. Introduction

In this modern era, the most dangerous cyber threats are not from the advance malware or malicious outsiders but from malicious insiders. The insider threat is one of the most moving issues to perceive in light of its befuddling nature and colossal effect on affiliations. Insider threat refers to the risk that an active and retired em-

ployee, consultant, or business associate will exploit their trustworthy connections to damage the institution's staff, clients, properties, credibility, or interests, either unwittingly or maliciously. Due to various their penetration into the organization and its security systems, their reported exposure to the connection's benefits, and the difficulty of seeing the specific of an in-

sider threat from a traditional operator's position, insiders pose an extraordinary risk to organizations. Along these lines, the insider-danger field faces the preliminary of making affirmation game arrangements that can recognize hazards without conveying a stunning number of trick positives and can consider the non-concentrated bit of the issue. A probability to accumulate in hazard region was coordinated to overview the affirmation execution of the proposed game plan and its comfort. An suggested partner smart demand and innovative investigation approach, which contributes to the partnership and disambiguation of insider risk events and the security plans used against their, will benefit the sector. Insiders have aided clients who have genuine access to sensitive/represented information, and they may be aware of the flaws in the submitted systems and market structures. Different assaults acknowledged by compromising insiders are consistently hard to see showed up contrastingly according to those of outside aggressors whose impressions are overall the more enthusiastically to disguise. Many organizations feel unsafe from insiders and are vulnerable to insider attacks. One of the major risk factors for such kind of scenario is giving excessive user access privileges to the insider employees, giving more devices an access to sensitive information, and the complex infrastructure of advanced technologies. One of the most widely used technologies to identify the insider threats include encryption, Data Loss Prevention and solutions for manag-

ing the access and identity in any organization. In order to identify the insider threats, various organizations implement Intrusion Detection and Prevention (IDS), SIEM platforms and logs management.

An insider is a "current or past manager, legitimately restricting worker, or accomplice" with supported access to the rewards of an alliance. An insider incentive tackles an insinuating danger to the association. Insider threats has a fugacity and tremendous impact on affiliations, and it is one of the irritating mechanized defense areas. Its effect is not bound to budgetary accidents yet may jeopardize the security of people and the notoriety of affiliations. The issue of perceiving insider dangers is particularly pursuing for the trouble of recognizing and affirming insider-assaults. The test forms considering the information insiders have on the connection and its security shows, their attested access to the association's advantages, and the trouble of watching the direct of an insider risk from an ordinary expert's lead. The outcomes show the achievement of organizing an answer that builds up the information on security aces during assessment and diminishes the measure of fake positives made by methods for modernized inconsistency affirmation. An ordinary insider-hazard marker<sup>[1]</sup> is an alteration in the regular direct of an insider. Among the rule difficulties looked in insider-risk region is the high pace of trick positives and the hardening of the human and non-concentrated bit of the issue. In view of the chance of the issue, challenges create in seeing varieties from the standard

activated by malicious insiders and those really mirroring an alteration in lead addressing a test in overseeing fake positives and validating assaults. In addition, the issue is remarkable because of the centrality of the movement of the non-concentrated bit of the danger; a point that is endeavoring to take an interest in affirmation courses of action. There has been an expanding case of unintentional insider danger recently. The inspiration for regulating insider chance is high and is likely going to make. An insider danger has been described in the composition from substitute perspectives. It is described as “a current or former master, definitive laborer, or associate who has or had maintained authorization to an affiliation’s structure, scheme, or data and deliberately outmanoeuvred or mismanaged the admission in a manner that adversely impacted the collusion’s knowledge or information systems”. Starting at now, insider risks become a tremendous concern relationship across the globe. Insiders are accepted consumers who have authoritative consent to invest relationship money, according to the regular exam. Insider threats have been more challenging than outside infiltrations as a result of this persistence and shirking. There is a significant amount of work being done to ensure that affiliations’ inclinations toward insider attacks are covered. The massive financial, reputational, and organizational consequences of insider attacks necessitate fundamental considerations from individuals and organizations. In order to handle such issues, the experts have made insid-

er threat a working zone of assessment by proposing a few approaches, especially in the latest decade. Likewise, a couple of affiliations, like the U.S. Problem Service, put overall around there of the examination. Regardless, while numerous systems have been implemented to resolve insider vulnerability concerns, insider attack attacks have not been properly addressed. As a result, effective and more cautious responses are needed when dealing with insider threat issues. Our analysis of the new plans reveals that they can be divided into circumventing and divulging steps. The renouncement approaches block unapproved exercises of mystery data (e.g., find the opportunity to, copy, change, eradicate, etc.). They send to find the opportunity to control parts like a certification to crush insiders’ maltreatment. A sensible methodology interweaves a certification instrument to see a crude unforeseen development and rolls out an improvement to stop probably attacks. For any organizations, there are many assets, some of them are valuable and some of them are not. The organization needs to identify the data owners and line-of-business stakeholders, the valuable data should be categorized properly and then it should be properly located.

As showed by a progressing study, that around a quarter of all cybercrime incidents were suspected to be executed by insiders. Insiders may know the weaknesses of the passed on systems and business structures. It is moreover amazingly hard to recognize an insider peril. Thusly, this endeavor will help in recognizing insider

threats by planning catchphrases entered by any agent. This research has addressed the insider attacks in an organization by identifying the weak gaps and vulnerabilities. To address the recognized holes and merge the data contained a more comprehensive and forward-thinking writing set, new undertakings related watchwords, organization data and catchphrases identified with digital assaults for accessing delicate/private data.

## 2. Related Work

Insider threat is an amazing danger on affiliations because of their insight on the connection and its security shows, their embraced access to the association's points of interest, and the trouble of seeing the direct of an insider risk from a common worker's behavior<sup>[2]</sup>. In an examination report by the Ponemon Institute on the expenses of cutting edge security assaults, insider danger positions as top like cost, its effect isn't restricted to budgetary incidents in any case may hazard the thriving of people and the notoriety of affiliations<sup>[3]</sup>. Because of the chance of the issue, challenges ascend in seeing eccentricities started by poisonous insiders and those truly mirroring a change in direct addressing a test in overseeing fake positives and affirming assaults. Insider-chance distinctive verification systems contrast from those of outer ambushes. They are either signature-based, or variety from the standard divulgence techniques<sup>[4]</sup>. Insider danger in the creating are not new, and there is a remarkable social affair of information in this wide field. In the most recent decade, there have

in like way been a few endeavors to think about this field. Regardless, in the wake of assessing such works, we experienced different needs and saw the need for a front line, intelligently complete survey.<sup>[5]</sup> the partition among hurtful and accidental insider types just searches useful for ramifications of insider danger, as they necessitate that some activity be performed. Most existing ramifications of insider chance unquestionably expect a dangerous game plan of this threat.<sup>[6]</sup> According to an Insider Report 2018, the list of IT assets that are vulnerable to insider attacks are shown in Fig 1, in which 50 %<sup>[7]</sup> of the databases are vulnerable to insider attacks whereas 25% mobile devices are on target of insider attacks. In<sup>[8]</sup>, the makers encouraged a making revision by building the hurtful insiders into two classes: backstabbers (a reasonable customer inside an affiliation) and impostors (aggressors who take the accreditations of legitimate customers). They referenced the researching sources and differentiating AI counts subject to have based, organize based, and consolidated customer profiling. Hunch and Probst<sup>[9]</sup> analyzed the implications of insiders, insider threats, and applicable issues. They furthermore depicted the insider peril approaches into different areas (dynamic, socio-thought, and centered). The makers acknowledged that the guaranteed structure to see and arrange insider risks requires a mix of mental, socio-centered, and thought techniques. In<sup>[10]</sup>, a bit of the disclosure approaches is assessed rapidly from a game-plan of perspectives (Intru-

sion-attestation based, System-call-based, Data-driven, Honeypot, Dynamical-structure speculation based, Anti-circumlocutory exfiltration and Visualization) correspondingly as presenting two or three their upsides and disservices. Azaria et al. [9] orchestrated insider threat certification strategies into different classes: variation from the norm based, mental and social speculations, honeypot-based, graph based, and game theory based.

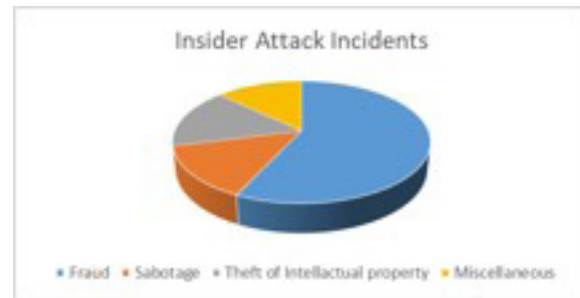
Fig. 1. List of Vulnerable IT assets to Insider attacks



They in like manner presented their social evaluation of insider risk (BAIT) [11] structure using a game on Amazon Mechanical Turk (AMT) to survey the course of confirmed insiders and hazardous ones who endeavor to pass on the data from their affiliation. Fig. 2 shows the division of insider attacks incidents in which the major part is fraud and is responsible for data and financial loss on various organization. Next, is the theft of intellectual properties and comprised of around 16% of the total insider attack incidents. After that, sabotaging is responsible for the insider attacks and rest other types comes under the mis-

cellaneous category. In [12], An investigation into insider attacks is raised focused on the user's anomaly in cybersecurity. For insider vulnerability identification by analysts, the data analysis and anomaly detection algorithms are completed.

Fig. 2. Insider attacks incidents



The enormous money related, reputational and operational impacts of insider ambushes require essential thought from individuals and affiliations. To address such issues, experts have made insider risk a working domain of assessment by proposing a couple of plans, especially in the latest decade. In addition, a couple of affiliations, like the U.S. Puzzle Service, put commonly here of investigation. However, various strategies have been proposed to address insider risk issues, insider attack events in spite of everything have not been tended to enough. Consequently, there is a prerequisite for strong and more exact responses for experience insider risk issues capably. Through our review on the current plans, they can be arranged into both contravention and distinguishing proof moves close. The expectation approaches thwart unapproved exercises of private data (e.g., access, copy, modify, eradicate, etc.). They pass on access control parts like check to thwart insiders' maltreatments. A shirking

game plan fuses a revelation part to perceive questionable activity and makes a transition to stop potential attacks. It was seen that there is little work in the composing that prevent insider ambushes. The most neutralization approaches known as Data Leakage Prevention Systems (DLPS) are locked in to thwart data spillage scenes. In [13], The identification approach assesses how reliable an analyst is with various activities and warns you to severe incoherence. A standardization method is used to compare the analysers in a community and indicates that noise is minimized and inconsistencies exacerbated due to deceptive behavior are reduced.

### 3. The Proposed Approach

The systematic process for developing an advanced insider tool involves a step-by-step flow that may be helpful for any organization to identify the insider threat. The main flow diagram of the proposed approach is shown in the Fig.3, whereas the technical part (phase 7) is as below:

**Step 1:** The first step in the working is the installation of a keylogger in all the systems of the employees. A keylogger is used to record keystrokes and ultimately it can monitor and captures the keystrokes activities of the employee's system. Keyloggers that are installed on the systems of employees present in the organization will captures the keystrokes. Therefore, it will monitor keystrokes entered as there can be some commands related to data stealing.

**Step 2:** The organization's systems are sensitive as they contain some crucial data. Database and sensitive keywords related

to unreleased projects and the research and development team and admins record cyber-attacks. After storing the keystrokes, keywords are matched and predicts the threat of an attack after analyzing the percentage of keywords matched.

**Step 3:** Next, the sensitive regular expressions (regex) are fetched from the database that is already stored and the security personnel will keep them updating time by time.

**Step 4:** After that, the keystrokes entered by the multiple users are matched with the regex fetched from the database at the back end. Then, if the keywords are sensitive then it will ask for some options like what type of report do you want and the report will be generated in the desired format at last and it will show whether there is a match or not.

**Step 5:** On the other side, if keywords are not sensitive then the report will be generated as it is and it will highlight the IP address or person within the organization who has tried to use the sensitive words or commands. A threat percentage is calculated, if the threat percentage of keywords matched reached up to a limit, an alert is generated.

**Step 6:** All the activities that are unusual will be recorded and administrators will be informed at regular intervals. In this way, the insider attack can be detected in an organization and an alert or flag can be generated.

The entire process of proposed approach is explained a below:



**Phase 1:** Initially, the valuable resources of an organization are highlighted.

**Phase 2:** The working group related to the insider threat is designed so that they can be targeted easily.

**Phase 3:** The higher level executives are included in the working group so that monitoring can be done effectively.

**Phase 4:** The attack surface and insider attack vectors are defined.

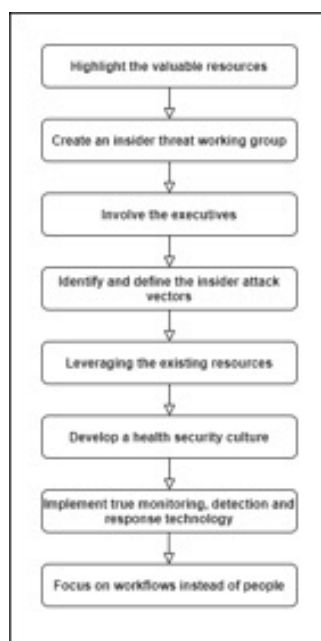
**Phase 5:** A survey on existing resources are done and they can be leveraged (if required).

**Phase 6:** A health security culture is developed

**Phase 7:** This is the main phase in which the true monitoring, detection and response technology is implemented

**Phase 8:** The main focus should be on the workflow instead of the people. Therefore, if there is any glitch in the workflow then it can be sorted out immediately.

Fig. 3. The Proposed Approach



#### 4. Conclusion

There are various instances in the past where the insider caused serious damage to the organization. Therefore, this issue should be addressed properly with a systematic approach that can help the organization in identifying the malicious insiders. Those difficulties must be considered cautiously when building down to earth frameworks. The insider danger occurrences have expanded in the most recent decade bringing about gigantically legitimate and money related misfortunes. This makes insider danger a functioning exploration territory. Such factors incorporate the kind of entertainers who submitted the assaults whether they are vindictive insiders or impostors. The disregarded CIA of a benefit (privacy, trustworthiness, or potentially accessibility). The recognition technique for an assault (inconsistency based, abuse based, or consolidated). The component areas of location draws near (have based, organize based, or half-and-half). The measurable/AI method of arrangement. The OS stage and programming devices of exploratory work. The quantity of mimicked situations. The presentation and precision measurements; and the constraints. At last, the difficulties for sending this present reality insider attacks identification framework and a few proposals are additionally introduced.

#### Conflict of Interest

None declared

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# Production of Jatropha Biodiesel in Laboratory Scale

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## Abstract

The paper presents how to convert jatropha curcas oil into biodiesel in Sudan. It Concerns about the depletion of fossil fuel reserves and increasing prices of oil. The negative effects of fossil fuels on the environment and on human health have necessitated the creation of sustainable biofuels that will reduce our reliance on fossil fuels. Biodiesel which is made from animal fats and non-edible plant oil sources is classified as a sustainable, renewable and ecofriendly source for biofuel. The method used consisted of two-steps process, first the esterification then followed by transesterification process. There were some important factors that affected biodiesel production like molar ratio, temperature, and catalyst amount. The molar ratio of oil to methanol (1:6) with 5% (weight) of NaOH concentration was examined at reaction temperature of about 60oC. The produced biodiesel's specifications were analyzed and addressed. Kinematics viscosity was found to be about 5.251 mm<sup>2</sup>/s at 40oC, flashpoint value was 200oC, density obtained was 0.8852 g/cm<sup>3</sup> at 15oC and the cloud point was found to be +9. The produced biodiesel was characterized and compared to standards biodiesel physical and fuel properties (D6751ASTM Standards). The work presented here introduces jatropha oil as a sustainable feedstock for biodiesel and may fill the gap of diesel production in the future.

**Keywords:** Trans-esterification; Jatropha oil; Biodiesel; renewable energy ; biofuel .

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## 1. Introduction

Energy is one of the major issues in the area of economic development. As it is well known the energy is required in every sector of the country. In Sudan, the implementation of the economic development plans needed a huge amount of energy so the utilization of different energy types in-

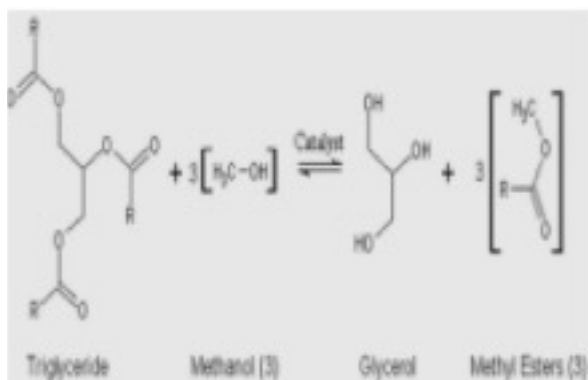
creased all over the country. Energy consumption has also led the country to become heavily dependent on other fuels, such as gas and oil. Increasing fossil fuels prices and possible shortages led to thinking about how to let the energy required for Sudanese economic development to be sustainable. From another side of view,

the use of fossil fuels often causes environmental problems<sup>[1]</sup>. In Sudan, the increased demand for high-speed diesel (HSD) with a lack of fossil oil production caused a major problem in the transportation sector, in addition to increasing the consumption of fossil oil by other industrial sectors.<sup>[2]</sup> Responsibility for the depletion of fossil fuel sources and environmental degradation has led to increase researches in this area, so that to identify and select alternative fuel sources to be widely applied, bearing in mind that alternative and unconventional energy sources used in the transportation sector will play a major role in the generation and consumption of energy in the future.<sup>[3]</sup> Biofuels, especially biodiesel and ethanol have become more used in some countries. Biofuels have the advantage of durability due to its production from renewable sources and thus provide energy security for a long time to the country. It also provides more job opportunities in agricultural management and processing fields. It also saves foreign currency spent on buying fossil fuels. The use of biofuels is not yet applicable in most countries. This needs to promote institutions involving the cultivation of energy crops, biofuel production, marketing and consumption which will take some time. The blending of different ratio of biofuel in fossil fuel is developed by many countries to match market demand and supply. To help vehicle manufacturers in modifying engines to offer stability during biofuel usage, the practice of plant and animal oil or fats as diesel's substitutes are called bio-

diesel which has given attention all over the world. The increase in the prices for petroleum fuel products cause the biodiesel's demand increase respectively<sup>[4]</sup>. Some studies have confirmed a reduction in CO<sub>2</sub> emissions of about 78% when compared to petrodiesel fuel<sup>[5]</sup>. Vegetables and animal fats are similar in that they contain long-chain hydrocarbons and both of them are friendly to the environment but some evaluations need to be done separately to ascertain the potential of each<sup>[6]</sup>. Many researchers<sup>[7]</sup> have advocated for the use of non-edible feedstock from plants, especially alike *Jatropha curcas* because it is considered one of the most suitable types for the production of biodiesel as it meets European Union standards. Others investigate non-edible crops, such as *R. communis* and *M. azedarach* which considered as high concentration oil sources<sup>[8]</sup>. In the aspect of the private investors, there is a new energy crop available which is evaluated to produce biodiesel and be cheaper than others like soybeans and rapeseed. Also Microalgae conducted as alternative feedstock for biodiesel and met a high attention, because of it's a high quality production<sup>[9]</sup>. This argument is based on the availability of low-cost labor and land in Africa. Anyhow, the *jatropha* production to use as feedstock to produce biodiesel has been developed by private sections, non-governmental organizations and overseas development assistance agencies working in Africa such as Kenya. It is within the context of this background that we looked at the possibility for *jatropha* in Sudan as a share of the Sudan

Biofuels Roadmap-Aeronautical Research Centre (ARC –Sudan, July 2013). The *Jatropha* plant height is about 5 m and the yield of its seed is about 7.5 to 12 tons for every hectare annually. Oil contents of whole *Jatropha* seeds are 30-35 % by weight<sup>[10]</sup>. The methods for producing biodiesel include pyrolysis, micro emulsification and transesterification. Transesterification is done by reacting the vegetable oil or animal fat with alcohol. Different catalysts can be used such as enzymes, bases and acids or determined out under special conditions in the presence of a catalyst.<sup>[11,12,13]</sup> The use of ethanol, which is less cost has great consideration<sup>[14]</sup> and can be obtained from biomass. For all that, higher conversions to biodiesel was obtained using methanol which is low sensitive to water when using the process of alkali catalyst compared with ethanol. Commercial biodiesel generated from plant oil was created mostly by alkali catalyzed- transesterification shown in Fig 1.

Fig. 1 Transesterification Reaction for Biodiesel Production



The reaction between plant oil and alcohol gives alkyl esters (biodiesel) as a basic product and glycerol as a by-product. The

glycerol purity is around 50% with excess alcohol and catalyst<sup>[15]</sup>. Glycerin must be refined in other manufacturing processes before using in order to purify it from impurities<sup>[16]</sup>. On the other hand, some researchers worked on the model of multi steps in a cold flow effect in gas distribution from biomass which was affected by the flow rate of the gas and the used materials<sup>[17]</sup>. In addition to, many simulation reactors were investigated using gasification reactor. The cold flow of the mixture of gas and solid were studied using software programming such as (ANSYS Fluent)<sup>[18]</sup>. The work objective is to establish a *jatropha* biofuel production, compares it with diesel petrol and calls for more studies to involve *jatropha* oil as a sustainable raw material in the biodiesel industry.

## 2. Material and Methods

### 2.1. Materials

The *Jatropha* oil which was used in this process was obtained from the local market (planted & extracted in local area). Oil was used with alcohol. Methanol is alcoholic solvent of 99.8% purity with density of 0.79 g/ml. Sodium hydroxide is a base which was adopted as a catalyst. Sulphuric acid of 98% purity was used to neutralize the feedstock oil from high fatty acid. Other reagents were used for analytical steps.

### 2.2. Apparatus

A lab-scale apparatus was developed for the technique. It consists of a reactor flask placed on a hot plate which is attached to a water bath with r.p.m. controller to control the speed and a condenser. A thermometer for measuring the temperature and another

volumetric flask were used.

### 3. Experimental procedure

#### 3.1. Neutralization

The oil of jatropha contains approximately (14-19.5%) of natural free fatty acids<sup>[19]</sup>. Before being taken into the actual process of conversion, it must be carefully purified. The result of 15.9 % of free fatty acid makes Jatropha oil unacceptable for the development of industrial biodiesel. Stirring up the dehydrated oil with a 2% H<sub>2</sub>SO<sub>4</sub> solution for an hour and then 20% methanol amount was added. This approach brings the content value of free fatty acid below 2 % which is a great achievement to the biodiesel industry. The oil was filtered to isolate the waste from it. The reaction rate is then preheated at 35oC to remove the water content which can negatively affect the process. To find the range of NaOH catalyst concentration, the oil was titrated.

#### 3.2. Trans-Esterification process of Jatropha oil.

To commodity a methyl ester (biodiesel), the Jatropha curcas oil trans-esterification method was used<sup>[20]</sup>. The process was taken place in a reactor (glass equipment) fitted with a reflux condenser and a thermometer. Also, a mechanical stirrer and sample port were used. The reactor was constructed to undergo a 60oC temperature at atmospheric pressure with a molar ratio of 1:6 (oil to methanol) with 5% weight concentration NaOH catalyst. Firstly the oil was put into the reactor. The catalyst and methanol were put in a volumetric flask and a magnetic stirrer was used for 15 minutes. The stirred mixture was put in the reactor and mixed

up for about 60 minutes to enable the transesterification reaction to take place. When the process ended and the feedback completed, the solution was spread in a flask and settled about 12 to 24 hr to isolate methyl ester and glycerol . Then the methyl ester was washed and stirred for 15 minutes using distilled water. Using a rotary vacuum evaporator<sup>[21]</sup>, the excess solvent was removed. The product was analyzed using gas chromatography (GC) in order to determine the kinematic viscosity, density and flash point. Referring to the American Society for Testing and Materials (ASTM), the methyl ester results were compared. Fig. 2 shows the product sample.

Fig. 2. Sample of the product



#### 3.3. Analysis of Biodiesel by Gas-Mass Chromatograph Equipment

The GC is used to separate the components of the solution. The distinction is based on the holding of the measurement between two phases (the mobile gas phase and the stationary liquid phase). The interface of GC Column points into the mass spectrometer which consists of three components:

1. Mass filter
2. Ion source
3. Quadruple and Detector (continuous dynode electron multiplier).

The system components are controlled via MS-DOS Chem. Station. The software data contains programs to calibrate MSD acquire data, data processing, file management and Editing.

Instrument information:

Name: GC.MS Detector, mass spectrometer  
Model: GC.MS-QP2010 Ultra.

Company: Shimadzu from Japan.

Column Rtx-5MS, length (30m), Diameter (0.25mm), thickness (0.25 $\mu$ l) and Carrier gas is Helium.

Peak report Tic obtained from GC show that the main ester produced is 9, 12-Octadecadienoic acid (z,z)-methyl ester with an area of about 36.77 % and retention time is 17.553 min. The analysis was done at UMST University of medical science & Technology, Khartoum- Sudan.

#### 4. Results

The results of jatropha oil properties were obtained in IRCC laboratory, Sudan and measured by titrimetric method. Below are the chemical analysis results of jatropha oil.

Table 1. Chemical analyses results of Jatropha oil

Item	Value
Viscosity cP	$\pm 91$
Moisture %	$\pm 0.1242$
Acid value%	$\pm 31.8$
FFA%	$\pm 15.9$
Density (g/cm <sup>3</sup> )	$\pm 0.959$

Table 2. Yield results of Jatropha biodiesel produced under selected method conditions

Item	Yield Result%
Biodiesel produced	80
Glycerol	28

N.B: The product percentage is calculated as:  
Product % = output/input  $\times$  100

Table 3: Jatropha Biodiesel Analysis results compared with standard specifications

Test name	Test method	unit	Jatropha biodiesel Result	ASTM D6751
Density at 15 ° C	ASTM D4052	g/cm <sup>3</sup>	0.8852	-
S.G	ASTM D4052	-	0.8861	0.95 max
Kinematics viscosity at 40° C Flash Point	ASTM D445	Cst	5.251	1.9-6.0 (mm <sup>2</sup> /s)
	ASTM D93	C	< 200	130 min
MCR	ASTM D4530	Wt%	0.00	-
Cloud point	ASTM D2500	C	+9	40 max
Water content by a distillation	ASTM D95	V%	0.00	0.5 max

\*Samples analysis was done in Sudanese Petroleum Corporation (SPC), Petroleum laboratories, Research and studies in Khartoum-Sudan.

#### 4.1. Discussion of Results

The results obtained from the experimental procedure were currently involving jatropha oil as a sustainable feedstock for biodiesel production. Analysis results of jatropha oil samples showed in table (1) show that the results of different physical and chemical properties of the produced jatropha oil are in the range of its standard specifications and mentioned as ( $\pm$ ) due to standard deviations values. As obtained, the moisture content is  $\pm 0.1242$  % which considered as a critical property. If the oil sample has high moisture content, the soap formation quantity will be more and there will be a problem in the separation of the by-product (glycerol). Acid value is also a significant property with a rate of  $\pm 31.8$



% and the free fatty acid is about  $\pm 15.9$  %. Both parameters are within the range of the standard values. The jatropha oil Viscosity is found to be  $\pm 91$  cP which is greater than the standard specification and it must be improved before taken into the actual transformation process. The percentage yield 80% of biodiesel in table (2) is acceptable and near to result reached by previous study, which about 79.5%[20]. The chemical reaction that yielded the biodiesel was carried according to the standard conditions. The biodiesel tests were analyzed at the (SPC) laboratory in Khartoum, Sudan. The results were presented in table (3) compare with the corresponding limit set in the last Column in table (3) for (ASTM D6751) methods . The obtained biodiesel flash point which is about 200oC is considered as high value when compared to diesel. This causes it to be safer for users and stores. Biodiesel viscosity is 5.251cst, which is higher than diesel but still within the range of ASTM standard. The high viscosity has a large tendency to cause problems but diesel blends solve this problem. The produced biodiesel cloud point test result is +9 which is not higher than petrodiesel. This makes the biodiesel performance acceptable in the cold season in addition to the nil water which help to avoid the contamination and other problems that may happened in the operating system. The temperature, agitation, actual quantity, catalyst value and Methanol ratio are the pass- key parameters for the best biodiesel production quality.

## Conclusions

All the above results confirmed that Jatropha oil is a good and sustainable raw material to produce biodiesel. Jatropha can be planted in any area for a long life period .It yields about 30% oil which is economical so it is a sustainable feedstock for biodiesel besides it is non-edible oil. The experimental result showed about 80% biodiesel yield. The promising research field of alkaline-catalyzed transesterification classified it as a suitable process to produce biodiesel on a large scale. Used oil from the restaurants' kitchens can be reused but in small scale biodiesel production. The glycerin which is a 20% by-product, can be sold to cover a part of the high cost of biodiesel production. Materials used in the production process are available and no addition for special equipment is required. Jatropha biodiesel which is obtained from green material make it eco-friendly to the environment. Finally the chemical and physical properties of Jatropha biodiesel make it competitive in bio-energy fields.

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# Performance Analysis of Open-Source Image Steganography Tools

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## Abstract

In the present epoch, where technology is rising fast with new developments, the main challenge for the sender is to ensure that information is sent in a correct and covert mode that only the receiver is capable to recognize. Steganography is the art of concealing and transmitting secret information through carrier multimedia without being exposed. In this paper, four open-source image steganography tools are analyzed and compared on basis of image features like the type of cover image, the dimension of stego image, type of secret information, type of output image, the technique for concealing secret information, encryption support, hashing, data compression, etc. The comparative analysis of these tools based on specified parameters represents their strengths, limitations, applicability, and scope for future work as well. OpenStego image steganography tool performs amazing among the researchers and the professionals. This paper also put efforts to explore the working of the OpenStego tool on some unexplored parameters to authenticate and validate its performance.

**Keywords:** Security System; Steganography tools; Watermarking; OpenStego.

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## 1. Introduction

Depending on the kind of carrier file used, steganography is categorized as text, image, audio, and video [1]. Text steganography is the simplest technique with less information concealing capacity and low imperceptibility. It will provide a double level of security when a secret key is used. It causes a problem in rewriting, modifying line-height, addition, or removal of words. Image steganography is much more powerful than text steganography in terms

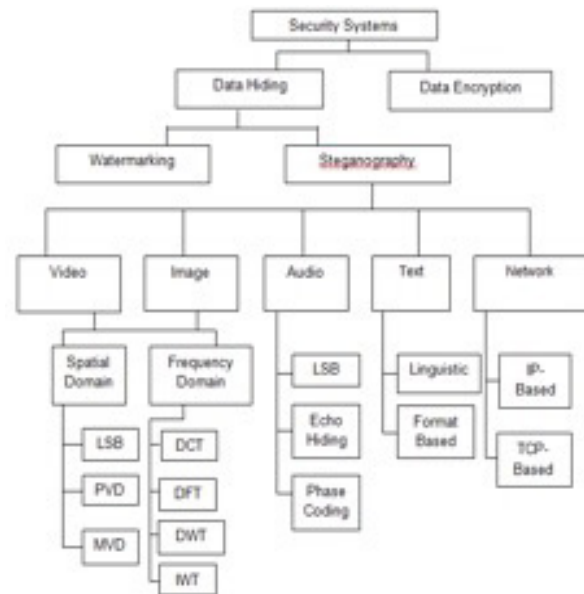
of security and information concealing capacity. In image steganography concealed information does not stand out by making a slight change to the color values of an image. For providing better security to concealed information in image steganography usually, more padding needs to be done around secret information. Audio steganography examines inaudible frequencies for concealing secret information [2] [3]. Video steganography has the option of concealing secret information inside inau-

dible frequencies and images as well. Further video and image steganography are divided mainly into two parts based on their domain: Spatial and Transform domain. In the spatial domain, some of the bits in a pixel are substituted by the secret information. Some commonly used spatial domain techniques are PVD (Pixel Value Differencing), RPE (Random Pixel Embedding), EBE (Edges Based Information Embedding), MPD (Multi-Pixel Differencing), LSB (Least Significant Bit), etc<sup>[4]</sup>. Whereas transform domain working is based on altering Fourier transform. Transform domain-based techniques are not easy to understand. These techniques first find the complex region for concealing secret information and then hide secret information in these regions. Some of these techniques are DCT (Discrete Cosine Transform), DWT (Discrete Wavelet Transform), IWT (Integer Wavelet Transform), and DFT (Discrete Frequency Transform)<sup>[5]</sup>.

In image steganography, the location of secret information may vary. Secret information can be spread uniformly over a full image or can be concealed into complex parts where it is challenging to detect a minor change. Complex areas carry high frequency in which concealing of secret information causes minor changes in colour intensity values. Concealing secret information in the spatial domain has a great payload capacity, though this method is breakable, disposed to statistical image processing attacks. The transform domain method of image steganography is based on concealing coefficient in the frequency

domain. It is much stronger against image processing attacks and compression<sup>[6]</sup>. During communication information can be secured by different methods shown in Figure 1.

Fig.1. Security system



In section II of this paper, a literature review of steganography techniques, tools, and steganalysis techniques are discussed. In section III metrics for measuring the performance of the steganography tools are explained. In section, IV steganography tools are analyzed and compared on basis of image features like the type of carrier image, dimension of stego image, type of secret information, type of output image, the technique for concealing secret information, encryption support, hashing, data compression, etc. In section V some of the observations on stego images are done in terms of PSNR and SSIM. Histogram, Entropy, and Frequency Spectrum are also plotted to compare the original secret image and stego image. At last, in sec-

tion VI conclusion for this paper is given along with some valuable suggestions for further work.

## 2. Literature Review

Steganography is the art of concealing secret information in carrier files in such a way that hackers cannot detect concealed secret information. In case concealed secret information is detected, a tool needs to be invented to confirm that secret information remains secret. A lot of research has already been done on image steganography tools related to the theoretical, mathematical, and technical development of steganography techniques. Many steganography tools exist in the market to conceal secret information inside digital carrier file. For the steganography process to take place successfully both of sender and receiver need to install the same tool at their end. These tools are categorized as to whether it is used to conceal secret information or it is used to detect the concealed secret information. Literature survey of some of these tools is listed below:

### 2.1 Steganography tools

### 2.2 Steganalysis tools

*2.1 Steganography tools:* Steganography tools conceal secret information in such a way that no one can detect it. Based on the type of cover file these tools are divided into Text, Image, Audio, and Video steganography tools.

In paper<sup>[7]</sup> have used the text steganography tools (SNOW DOS 26 and wbStego4.3open) to conceal secret information. The author has chosen a carrier file and generated a stego output file with the help

of these two tools by providing the different sizes of secret information. They also compared these two tools in terms of concealing capacity. They found wbStego4.3 steganography tool is better for concealing secret information. Image steganography tools can conceal a large amount of secret information as compared to text steganography tools. In paper<sup>[8]</sup> proposed Stego tools and compared different tools available freely. An image has been taken as a cover file for measuring the performance of various tools available online. Moving forward in<sup>[9]</sup>, have focused on various steganography tool processes. Based on their exploration of steganography processes they divide tools into five categories: Spatial domain, transform domain, Type of document, Video compression encoding, and File structure. To provide better security in<sup>[10]</sup>, focused on the traces leftover when steganography tools were installed, run, and then uninstalled. Through these leftovers, they detected concealed secret information.

Again, comparison of different image steganography tools based on various parameters was carried out in paper<sup>[11]</sup>. They also introduced a robust and high payload steganography algorithm. Performance of steganography tool depends on the amount of secret information concealed, security, robustness, and imperceptibility. With the size of carrier file and its type performance of steganography tool varies. In paper<sup>[1]</sup>, have carried out a comparison of the performance of various steganography tools. The author focused on carrier files during

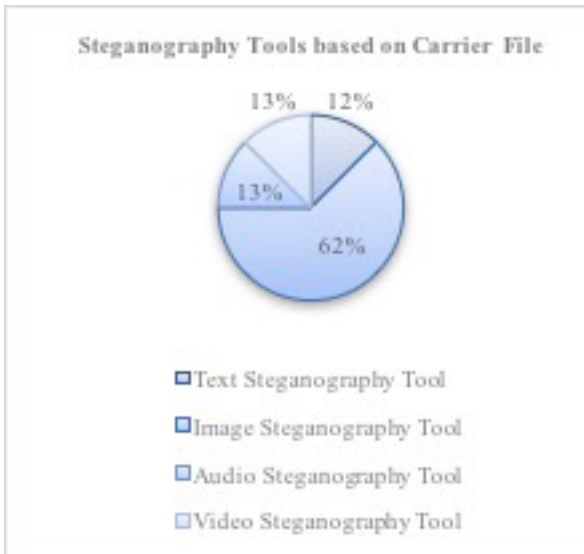
communication over the network. Graphical inspection and statistical assessment methods were used to evaluate the performance of the tools. Based on different steganography algorithms in paper [12], have compared various image steganography tools. Authors have used the same input image to conceal secret information through different steganography tools and got different output stego images produced by particular tools. These stego images are then compared in terms of their PSNR value to find the best tool. Edges in cover file carry no significant information. So, author in [13], have presented image steganography where edges in the cover image are used to conceal secret information. The author analyzed that to conceal more secret information weaker edges can be used. Experimental outcomes prove that the above technique can efficiently sense MP3Stego with low concealing capacity. In [14] authors have presented a summary of broadly used open-source and freeware steganography tools. They gave information about types of a carrier file, secret information, technique used to conceal secret information, encryption provision, data compression, hashing, etc. In paper [15], a steganography tool was created by for concealing secret information. This tool works in VB (Visual Basic) environment, the author has created, implemented, and detected concealed secret information. Spatial domain techniques have a large concealing capacity but are less robust against image processing attacks. In [16], authors have concealed secret information through the StegCure

steganography tool using the LSB technique. The enhanced LSB technique was used for good robustness against various attacks. StegCure tool compromises user-accessible functionality along with cooperative GUI (Graphical User interface) and cohesive navigation abilities. Again, LSB substitution technique was utilized in [17] for concealing secret information on the OpenPuff tool. For analyzing the performance of the OpenPuff tool several image formats were tried. Stego images produced by the OpenPuff tool were compared on various structures for the finest output regarding format. Different file formats are tried and tested by researchers to avoid geometric attacks.

The transform domain-based DCT technique was used by the author for concealing secret information. In [18], have introduced an overview of steganography techniques for concealing secret information in several image formats and also presented a novel system of data transmission within Microsoft word documents through JPEG (Joint Photograph Expert Group) images earlier handled by tool StegApp 1.1.0. This tool works on the conversion of the JPEG image by a domain transformation algorithm through restrictions gained by DCT.

After literature review, it is concluded that image steganography is the main focus among scholars, also shown in figure 2. Image steganography tools are secure; robust against image processing attacks, and has high concealing capacity. Some of these tools can handle any type of im-

Fig.2. Categorization of Steganography Tools



age format. Working with multiple image formats provides flexibility to image steganography tools.

**2.2 Steganalysis tools:** Steganalysis tools can determine the existence of concealed secret information as well can detect steganography tool through which you concealed secret information in carrier file [1]. In [19], have concealed secret information through the use of existing steganography tools. The author also provided a comparison between various image steganography techniques. After concealing secret information using steganography tools, steganalysis to detect the concealed information was also done. Continuing contribution to the research on steganalysis tools [20], has stated that steganography is used to conceal secret information during communication while Steganalysis tools detect the concealed secret information. A study of various open-source steganography tools was presented by the authors. A carrier file is the one that can carry secret information with itself. In [21], has delivered

an acute review of steganalysis techniques existing to examine features of various stego media and analogous carrier media. They also gave a perfect representation of current development in steganography so as we could improve and invent appropriate steganalysis algorithms. Moving to the transform domain, [22] have developed the F5 algorithm which is a steganography tool offering high concealing capacity, resists against graphical and geometric attacks. F5 tool processes matrix encoding for increasing capacity of information concealing. They found that their tool is strong against some graphical and statistical attacks.

LSB is the simplest technique for concealing secret information in [23] the carrier file. have discussed experimentally various well-known steganalysis techniques for the LSB flipping method. To assess the effect of concealing through various steganalysis techniques, 20%, 50%, 70%, and 100% concealing rates were implemented. DCT techniques work in the transform domain providing better security and robustness to secret information. Authors in [24], have analyzed F5, PQ (Post Quantum Encryption Tool), and Outguess tools. They compared the robustness of these tools against different image processing attacks. SVM (Support Vector Machine) and NNP (Neural network processes) recognition tools are used for the extraction of sensitive features from the DCT domain. Their performance results show Outguess tool can bear image processing attacks as compared with F5 and PQ tools. introduced real-time image



steganalysis. They combined DNN (Deep Neural Network) and CNN (Convolutional Neural Network) techniques to detect concealed secret information. For multi-user scenarios, they analyzed a useful real-time image steganalysis function based on the outlier detection technique. Video steganography tools can conceal secret information in form of images and audio as well. In [25], authors have created an IMStego tool that requires java-based platform and conceals information in images using the LSB technique. IMStego tool provides good security and it is user-friendly with interactive GUI (Graphic User Interface). IMStego tool works well with BMP (Bitmap Images) and PNG (Portable Network Graphics) image format. Audio steganography tools are utilized in [26]. The author proposed an MP3 (Moving Picture Expert Group) audio steganalysis tool. They figure out that concealing secret information causes disturbance in an inherent correlation of quantized MDCT (Modified DCT) coefficients.

### 3. Metrics for Measuring Performance

The performance parameters measure the excellence of the output stego image. The utmost property of steganography tools is that third parties should not get suspicious about the presence of secret information. Another property of these tools is robustness which shows how the steganography tool fit resists extraction of concealed information. PSNR (Peak Signal to Noise Ratio) and SSIM (Structure Similarity Index Measure), Histogram, Entropy, and Frequency Spectrum are the techniques

for measuring excellence of output stego image. MSE (Mean Square Error), PSNR, SSIM, Entropy and Histogram can be calculated by equation 1, 2, 3, 4, and 5 respectively as follows in [27]:

**3.1 MSE:** In the case of MSE, signals are matched pixel by pixel starting from left to right and top to bottom over several rows and columns. MSE is the average of the square of the difference between the original and test image. MSE is simple to calculate and it is parameter independent [28].

$$MSE = \frac{1}{n} \sum_{i=0}^{i=n} [I(i) - J(i)]^2 \quad \dots \text{eq. 1}$$

I(i)=Carrier File, and

J(i)=Stego File

**3.2 PSNR:** It is an engineering term for the ratio between the maximum possible power of a signal and the noise is the error introduced by compression the power of corrupting noise that affects the fidelity of its representation. PSNR is usually expressed in terms of the logarithmic decibel scale [29].

$$PSNR = 10 \log_{10} \left( \frac{MAX_I^2}{MSE} \right) \quad \dots \text{eq. 2}$$

MAX\_I=Maximum Possible Power of a signal, and

MSE=the power of corrupting noise

**3.3 SSIM:** It is a grouping of components: luminance comparison, contrast comparison, and structure comparison [20]. It is a newer quality metrics compared to PSNR and MSE. Several research reports state that SSIM performs relatively better than

its opponents [30].

$$SSIM(x, y) = [l(x, y)^\alpha \cdot c(x, y)^\beta \cdot s(x, y)^\gamma] \quad \dots \text{eq. 3}$$

$l(x, y)$ =Luminance of samples  $x$  and  $y$ ,

$c(x, y)$ =Contrast of samples, and

$s(x, y)$ =Structure of samples

$\alpha, \beta, \gamma$  denote the relative importance of each component

**3.4 Entropy:** The entropy of an image is average information produced from its pixel's values in [29]. It would be well-defined as a statistical measure of the unpredictability that may be used to describe the quality of that image.

$$E = - \sum_0^{N-1} p_k \log_2(p_k) \quad \dots \text{eq. 4}$$

Where  $N$  is the number of levels and  $p_k$  is probability connected with level  $k$ . The maximum value of entropy is achieved when probability distribution is uniform. In other words, if  $N = 2^n$ , then  $p_k$  is constant and given by

$$p_k = 1/N = 2^{-n}$$

**3.5 Histogram:** A histogram is a graphical illustration of the distribution of statistical facts. It displays statistical facts using bars of different heights. Larger bars show that more statistical facts lie in that range [31].

$$\text{Histogram} = \frac{\sum_{i=1}^n (His(c) - His(s))^2}{\sum_{i=1}^n His(c)^2} \quad \dots \text{eq. 5}$$

Where  $His(c)$  and  $His(s)$  are histograms of original cover and corresponding stego respectively.

**3.6 Frequency Spectrum:** The spectrum

is generated by the Fourier transform and is also called as frequency domain. It can spread both phase and amplitude of an image [32].

#### 4. Image Steganography Tools

There exist many image steganography tools that enable the user to conceal information in the carrier image. All these tools should fulfill some requirements [8]:

a) Steganography tool must maintain the integrity of secret information even after it is extracted by a third-party user.

b) Output stego image should look similar to the carrier image.

c) Changes like editing, cropping, pivoting in output stego image should not affect concealed information.

d) Always accept that hackers may identify the existence of concealed secret information.

e) Steganography tool must be able to conceal secret information in any type of image format.

f) After concealing secret information file size should remain the same otherwise hackers may detect secret information.

The steganography tool will not be successful if a hacker suspects a carrier file [33]. While using these tools, one must guarantee whether the concealing algorithm used by these tools are prevailing all kinds of exposure by a hacker. A tool is said to be more reliable and successful if it prevents exposure of secret information concealed. Some of the image steganography tools are given below:

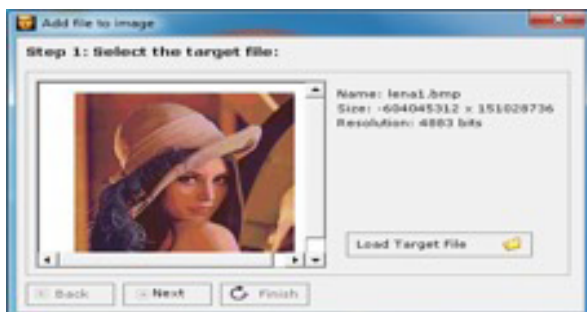
4.1 Xiao Steganography: This is an open-source window-based tool having a size of 2.14 MB. It was released on 4th July 2006. It is an image steganography tool used for concealing secret information in BMP images or WAV (Waveform Audio) archives [35].

How to use the Xiao Steganography tool:

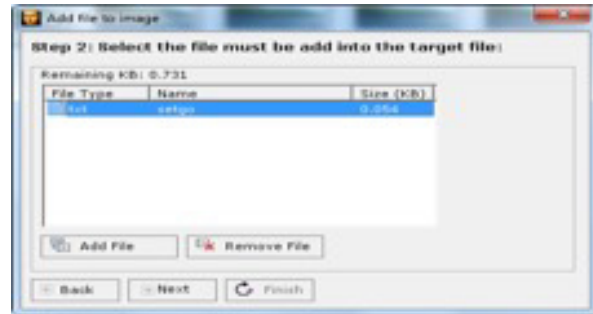
- This tool is user friendly, load any BMP, GIF (Graphical Interchange Format), JPEG, JPG, PNG image, or WAV file to its interface.
- Add an image or wav file, which acts as secret information.
- It also supports encryption providing a double level of security.
- For encryption, the purpose selects any of the algorithms from RC4, Triple DES (Data encryption standard), DES, Triple DES 112, RC2 (Rivest Cipher), and for hashing SHA (Secure Hash Algorithm), MD4 (Message Digest), MD2, MD5.
- After selecting any one of the encryption algorithms from the list save the target file.
- Then decode concealed secret information, after decoding it is visible to the user.
- This tool is available on Url: [https://download.cnet.com/Xiao-Steganography/3000-2092\\_4-10535494.html](https://download.cnet.com/Xiao-Steganography/3000-2092_4-10535494.html).

The working of this tool is shown below in figure 3:

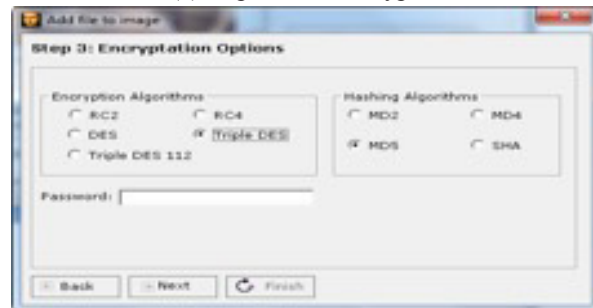
3(a) Target File



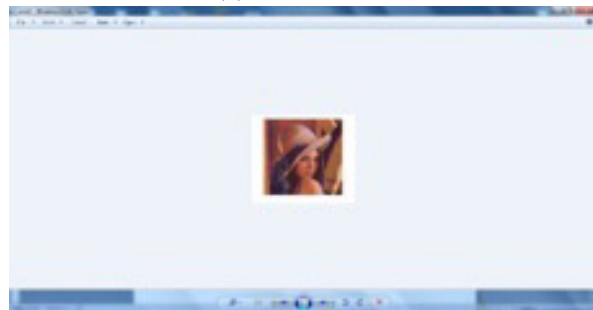
3(b) Secret File



3(c) Triple DES Encryption



3(d) Extracted File



4.2 OpenStego: This tool was released on 12th April 2007. Its size is 1.36 MB and compatible with Windows 2007. OpenStego tool is another good option for image steganography [36].

How to use the OpenStego tool:

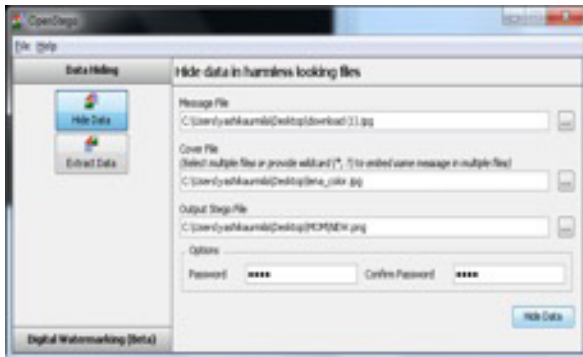
- This is an open-source image steganography tool and developed on the Java platform.
- Images having format BMP, GIF, JPEG, JPG, PNG and WBMP (Wireless BMP) could be concealed with this tool.
- It always gives output in the form of JPG and PNG files only.
- For extraction of secret information this

tool requires a password resulting in a more secure process of concealing and decoding information.

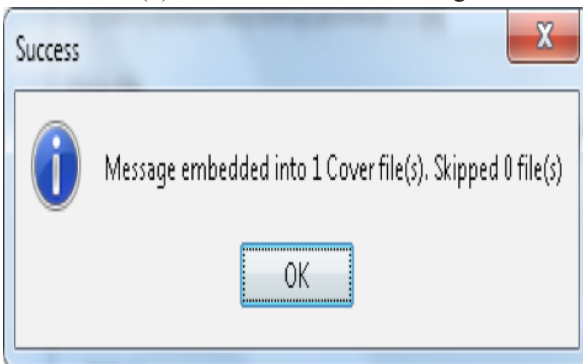
- It is available on the link: <http://sourceforge.net/projects/openstego/files/>.

The working of the OpenStego tool is shown below in figure 4:

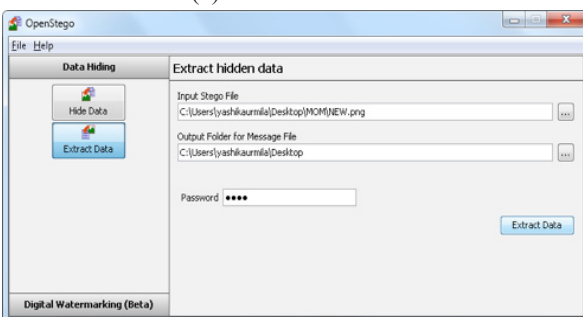
4(a) Source File



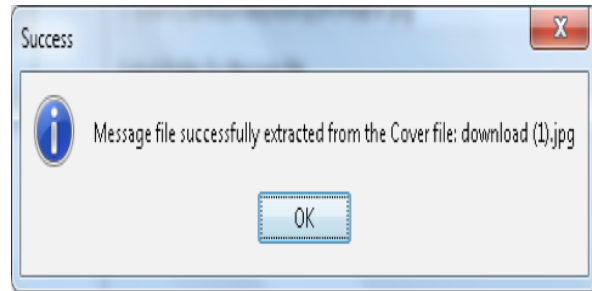
4(b) Secret File and Embedding



4(c) Extraction of File



4(d) File extracted successfully  
Fig.4. Working of OpenStego Tool



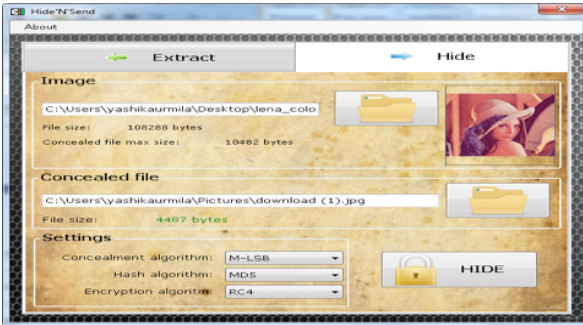
**4.3 Hide’N’Send:** This tool was released on 29th May 2012 and is 530.09 KB in size. Specification for this tool is Windows 2007/XP/VISTA with .NET framework 2.0. This is a small and extremely simple image steganography tool for concealing any type of secret information behind JPEG images [37].

How to use this tool:

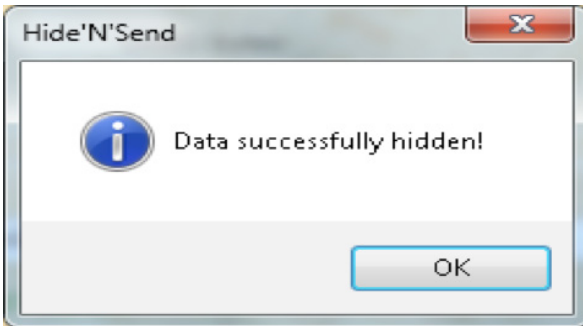
- Run the utility, select secret files, type of encryption algorithm, type of embedding algorithm, and type of hashing algorithms.
- For encryption purposes, any of the algorithms may be used: AES (Advanced Encryption Standard), RC4, RC2. The encryption key can be developed from the user password through the support of one of the subsequent hash functions: RIPEMD (RIPE message digest), SHA512, and MD5.
- Hide’N’Send tool uses recent steganography algorithms - F5 and LSB; select one among them by matrix coding. These algorithms conceal information directly inside the carrier image, instead of concealing in file structure as other popular tools do.
- After selecting encryption and embedding techniques click on the hide data button.
- This tool has just two tabs one for concealing secret information and the other for extraction of concealed information.

This tool is available on URL: <https://www.softpedia.com/get/Security/Encrypting/Hide-N-Send.shtml>. Working of Hide'N'Send tool is shown below in figure 5:

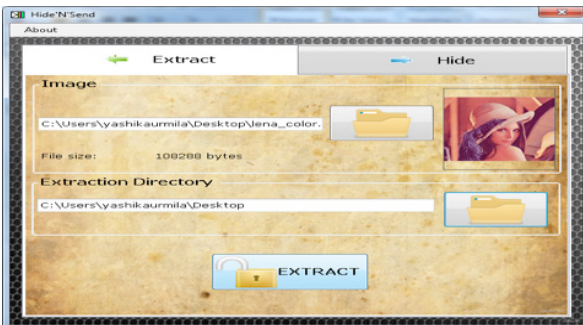
5(a) Embedding of Source File



5(b) Successfully Hidden

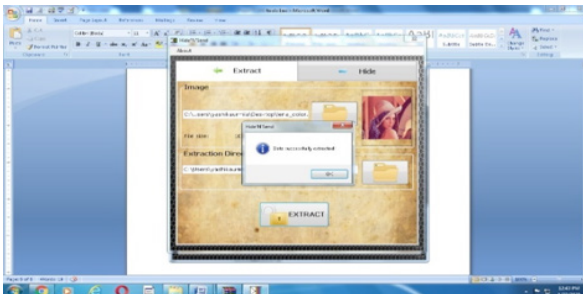


5(c) Extraction Process



5(d) Extracted Successfully

Fig.5. Working of Hide'N'Send Tool



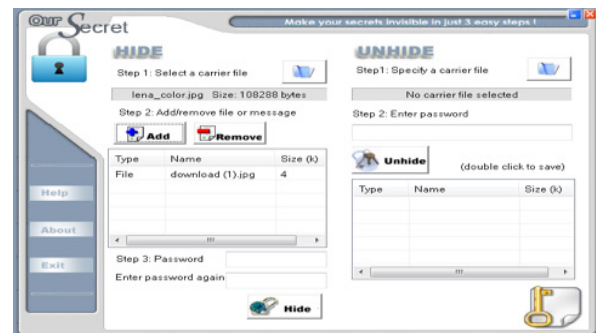
4.4 OurSecret: This tool was released on 7th Dec 2016 and is 3.26 MB in size. Specification for this tool is Windows XP/2007. OurSecret is also an image steganography tool that is used to conceal secret information in the carrier image. Its interface has two parts, the first part conceals secret information and then another part extracts the concealed secret information [38].

How to use this tool:

- A carrier file is selected for concealing secret information by the user.
  - Now secret information needs to be concealed inside the carry file. This tool is capable to conceal any type of digital multimedia information.
  - This tool applies encryption on secret information and then conceals secret information in the carrier image.
  - Secret information is extracted from the stego image by clicking on the extract button.
- This tool is available on URL: <https://our-secret.soft112.com/>.

The working of the OurSecret tool is shown below in figure 6:

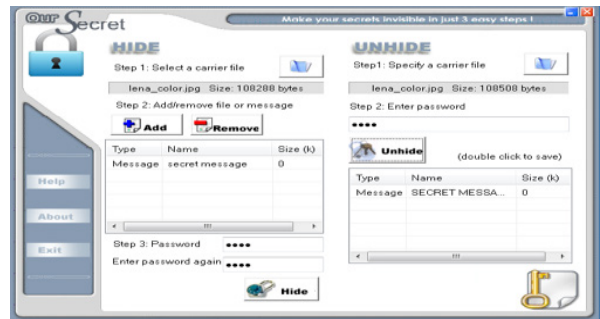
6(a) Source File



6(b) Password Protection



6(d) Extracted Secret Message  
Fig.6. Working of OurSecret Tool



6(c) Extraction of Secret Message



Table 1. Steganography Tools Comparison

Tool Name	Concealed Data Type	Stego Image Properties		Additional Information
		Image Size (Increase by)	Output Image File	
Xiao Steganography	Any File Type	Remains Same	Any Type	Encryption Algorithm
OpenStego	Any File Type	2 Time	PNG	Encryption, Compression, Password Protection
HideSend	Any File Type	Remains Same	JPG	Encryption Algorithm
OurSecret	Any File Type	1 Time	JPG	Password Protection

Open-source software permits operators to easily run, transform program as per their requirement, and also allow distributing replicas of the original version or their improved version. In Table 1 some open-source image steganography tools which are frequently used for concealing secret information are analyzed and compared. Information is listed year wisely according to the evolution of tools. It describes the comparison of tools based on image features like the type of cover image, the dimension of stego image, type of secret information, type of output image, the technique for concealing secret information, encryption support, hashing, data compression, etc. It has been found that

OpenStego is one of the best tools among these four tools for concealing and extracting secret information. It can work efficiently with any image format without degradation in stego image quality. Carrier and secret image both are taken as JPG image, Stego image has PNG as well JPG format. This tool has the following properties:

- This tool uses 24-bit images because they offer good flexibility when used in steganography where they allow concealing more information than 8-bit images without disturbing the quality of carrier and stego images.
- This tool also provides password protection for concealing and extracting secret

information.

- Original and stego images are look similar in all aspects like color, size, contrast, intensity, and brightness, etc. So, no visual distortion may lead to the detection of secret information.
- Extracted secret information maintains its integrity when the key entered is correct.
- Concealing and extraction time for the secret image taken by this tool is small.
- It works on Windows platforms with a java environment.
- It works well with different image formats such as BMP, GIF, JPEG, JPG, PNG, and WBMP. Some of these formats are lossless like PNG, TIFF, and GIF so when image compression is required then information loss does not occur.
- Furthermore, some of the software tools used had restrictions for the format of the carrier images. These restrictions meant that the initial image had to be converted to a different format thus altering the quality of the stego image.
- This tool provides an interactive GUI.

## 5. Results and Observations

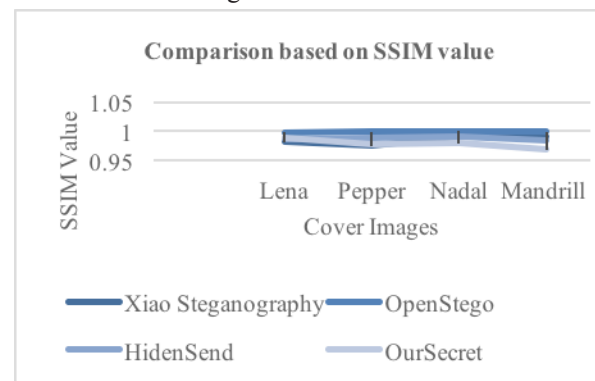
Image steganography tools namely Xiao steganography, OpenStego, Hide’N’Send, and OurSecret are studied and compared their performance. By taking four different carrier images (“Lena”, “Pepper”, “Nadal” and “Mandrill”) concealed secret information in the form of text. Imatest 4.5.13 is used to calculate SSIM and PSNR value of different stego images. Entropy, Histogram, and Frequency Spectrum are calculated in MATLAB. Different output

stego images produced by the tools are compared by their SSIM, PSNR, Entropy, Histogram, and Frequency Spectrum. With the advancement in features of particular tool time and space complexity increases. Carrying more advanced features means need more memory to store. Time to complete the process of information concealing and retrieval also increases. Among the mentioned tools OpenStego has additional features so it is more complex compared to other tools.

Table 2 shows the SSIM values of steganography tools: Xiao, OpenStego, HidenSend, Oursecret. From the table one can observe that there are small variations in SSIM values of the tools discussed.

Cover Image	Xiao Steganography	OpenStego	HidenSend	Our-Secret
Lena	.9812	.9981	.9867	.9886
Pepper	.9745	.9988	.9887	.9776
Nadal	.9911	.9997	.9913	.9790
Mandrill	.9899	.9984	.9851	.9681

Fig.7. SSIM values



Mainly there are two approaches through which image quality can be evaluated: The objective method and the subjective method. The subjective method is the human finding method that is not based on the reference images. Whereas in the objective method mathematical comparisons

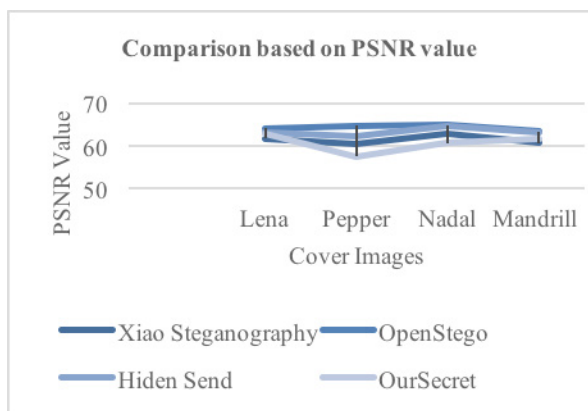
need to be done among reference image and distorted image. SSIM is a good metric to find the quality of original and stego images compared to PSNR metric. SSIM finds the similarity between the original carrier image and the stego image. Table 2 along with Figure 7, shows OpenStego tool represents the highest values of SSIM for all the inputted images. This tool gives SSIM very close to 1. SSIM value 1 means the original carrier image and stego image are almost similar in all aspects. Change in brightness and contrast of the image is not an effective element to SSIM.

Table 3. Comparison of PSNR values

Cover Image	Xiao Steganography	OpenStego	HiddenSend	OurSecret
Lena	61.73	64.04	63.23	62.77
Pepper	60.56	64.71	62.27	57.56
Nadal	62.71	64.89	64.61	60.71
Mandrill	60.68	63.27	63.23	61.68

Table 3 along with Figure 8, shows the PSNR value of all the four steganography tools for same images.

Fig.8. PSNR values



The highest value of PSNR means the OpenStego tool is better among all the four tools. A PSNR value greater than 35 shows the good quality of the output stego

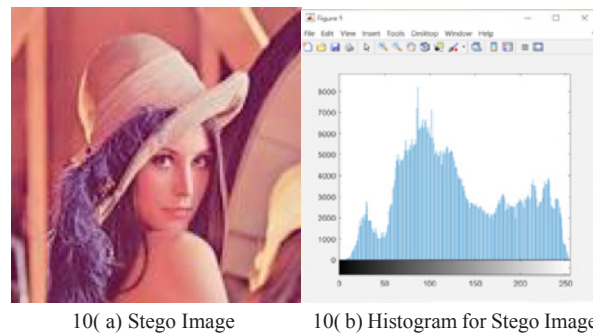
file [34]. PSNR compares the original secret image to the extracted secret image. PSNR is generally communicated in terms of the logarithmic decibel scale. Change in brightness and contrast of the image is a very effective element to PSNR.

Figure 9 and 10 shows the comparison of original carrier image with stego image based on histogram values. The difference can be recognized by a change in the frequency of histogram values.

Fig.9. Histogram for Carrier Image



Fig.10. Histogram for Stego Image



By comparing the histogram of carrier and stego image in Figure 9 and 10 respectively what we can see is there is a negligible change that can be neglected by naked human eyes. The histogram is used to see the distribution of information for checking whether a process change occurred from one time period to another. If there is slight or no change in information distribution of



carrier and stego image then we can say our steganography tool is robust.

Entropy could be defined as the disorder or status of the concentration level of specific pixels in an image. Entropy efficiently analyzes an image/frame in a video. It quantitatively analyzes and evaluates individual image details. In steganography, entropy can identify the texture, contrast, color, brightness, etc. of an image. As disorder in an image increases entropy increases and can be easily identified by the hacker.

Fig.11. Entropy before Concealing Secret Information

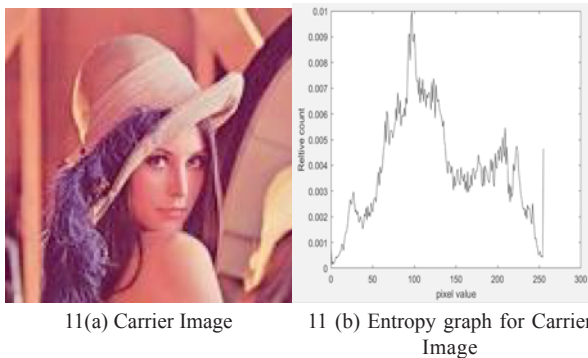
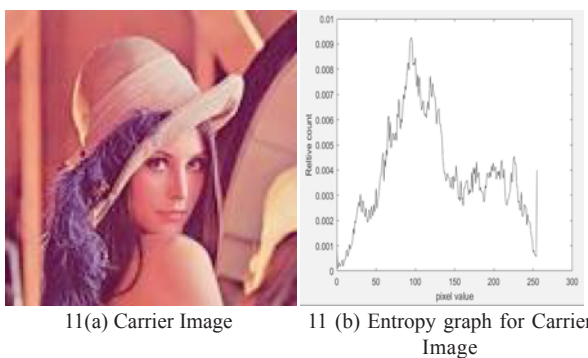


Fig.11. Entropy before Concealing Secret Information



The entropy of carrier image and stego image is calculated in MATLAB and there is a small variation that is even not noticeable. Carrier image and stego image are shown in Figures 11 and 12 respectively along with their entropy graph. From the experimental result entropy of the carrier

image was found to be 7.77774 and for the stego image frame are 7.78416.

Spectrum signifies how pixels are changing in terms of color, intensity, contrast, etc. in both amplitude and phase.

Fig.13. Frequency Spectrum before Concealing of Secret Information



13(a) Carrier image

13(b) Frequency Spectrum graph for carrier image

Fig.14. Frequency Spectrum after Concealing of Secret Information



14(a) Stego Image

14(b) Frequency Spectrum graph for Stego Image

The frequency spectrum of carrier image and stego image is calculated in MATLAB and there is a small variation that is even not noticeable. Carrier image and stego image are shown in Figures 13 and 14 respectively along with their spectrum graph.

## 6. Conclusion

This paper presents a comparative analysis of open-source steganography tools based on image features like the type of carrier image, dimension of stego image, type of secret information, type of output image,

the technique for concealing secret information, encryption support, hashing, data compression, etc. to the provides-depth assessment of tools. The realization of this study is to recognize the consistent and best tool accessible in the market for image steganography. Some of the basic tools existing in the market were chosen based on their frequent use; these tools were tried using the same input. Experimental results expose that all four tools were comparatively performing at the same level; however, some software achieves better than others. Out of all the above four image steganography tools used for comparison, —OpenStego image steganography tool was considered to be the most efficient one because of good SSIM and PSNR values. Histogram, entropy, and spectrum graph are also drawn in MATLAB to compare the quality of the stego image from the original image. In the case of OpenStego steganography tool file has advantages over all the other tools in that it supports all the image formats and does not change the image features as well as does not reflect the visible changes. For improved information security, we inspire more researchers to pay effort on steganalysis as future scope.

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