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Section A
CIVIL, ENVIRONMENTAL, ARCHITECTURE, TRANSPORTATION ENGINEERING, CITY AND REGIONAL PLANNING

Study of Environmental Impact Assessment (EIA) Process in Scotland, Malaysia and Pakistan

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***Abstract*-**Environmental Impact Assessment, known by its abbreviation EIA, is a planning tool to sustain the natural environment in its outstanding place by evaluating the consequences of a planned activity before putting into practice. Today the developed countries as well as the developing countries are undertaking EIA as the precautionary measure to judge the aftereffects of new developments at the planning stage ensuring the wellbeing of ecosystems. The origin of EIA took place in 1969 in the form of a domestic law by United States through initiating National Environmental Policy Act. Over the time period of many years, now many countries including the third world countries have started following the US set example by incorporating the study of EIA into their officially authorized system. In addition to this, a number of researches have revealed that EIA can play important role in contributing sustainable environment by supporting the technical and scientific understanding and their improvement in different fields, providing guidance in design of development projects, enhancing the governance of system and most importantly by modifying the attitudes of the society. For this reason, the role of EIA in the social, physical and environmental sectors has become significant. This paper will look into the mechanism of three different nations as how they are implementing this concern in their institutions. The paper, therefore, concisely reviewed the substantive processes of EIA, in the cases of Scotland, Malaysia and Pakistan.

***Keywords*-**Assessment, Environmental Impact, Malaysia, Scotland, Pakistan

I. INTRODUCTION

Environmental impact evaluations started formally in early 1960s, as part of increasing environmental awareness. "In the United States, environmental impact assessments obtained formal status in 1969, with performing National Environmental Policy Act" [i]. Now EIAs have been used gradually across the world. The development projects, of macro and micro scales have different impacts before the execution and may have the strength to alter the environment by construction works involving digging the ground and concreting the soft lands, use of heavy automobiles, landfills causing soil erosion, noise pollution, hazardous emissions and effluents causing air and water causing air pollution and water respectively. In addition to this, unhealthy socio-cultural collisions also expected to take place.

To identify the potential threats and minimize the adverse aftereffects due to such development projects, the Environmental Impact Assessment (EIA) has been a mandatory for any project, which is subjected to cause any potential negative changes in the environment.

Developed and developing countries have formulated regulations requiring EIA as major consideration for any development project appraisal, which has created demand for specified environmental assessors. "Impact assessment frameworks are gaining increasing attention as a procedure to integrate sustainability concerns in national policy-making" [ii].

In addition to this, the regional affiliated countries have now high levels of awareness for environmental protection. In Asia, Pakistan is going through immense urbanization prospects due to current execution of China Pakistan Economic corridor (CPEC). Also, political competition has made public leaders to go beyond the set criteria of upgrading urban infrastructure and these studies of environmental impacts do not consider the realistic feasibility of such costs on such public projects. It would be interesting to compare the practice of EIA process in Pakistan with Scotland (one developed country) and Malaysia (a developing country with rapidly growing economy). An analytical review of EIA process has been carried out based on secondary data. Also, a comparative analysis is included as part of study to mention the insufficiencies in the EIA process of Pakistan.

II. ENVIRONMENTAL IMPACT ASSESSMENT

To understand the thorough framework of EIA, the first step to start with is to know the definition of this

terminology. Different scholars and researchers have defined EIA according to their own understanding. Few definitions of EIA have been stated as following:

- "EIA as a systematic tool that can be used in considering the possible impacts of a project specifically on the environment before decisions are taken by the respective authority on whether or not to accept the project proposal" [iii].
- "EIA as an efficient process of evaluating and documenting information on the potentials, capacities, and functions of natural systems and resources in order to facilitate sustainable development planning and decision making and at the same time, to anticipate and manage the adverse effects and consequences of proposed undertakings" [iv].

Hence, Environmental Impact Assessment is about shielding of the current environment from potential problems caused by a development project by determining the degree of expected alteration in environment.

A. Phases of EIA
The whole process of EIA is segmented into two phases based on preliminary and detailed modes of study.

Initial Environmental Examination (lEE)
IEE concerns about possible impacts on environment due to proposed project. The study of IEE is concise briefing of significant issues of environment on the basis of available information and can be used premature stage of project planning. IEE also gives suggestion for further deep studies to be taken into account at later stage.

Environmental Impact Statement (EIS)
An EIS is a deep study of possible important positive and negative effects, which a proposed development might have on the environment after execution. This document provides the findings of EIA study and often regulated through environmental laws to ensure the project proceeding. Usually, consultants specialized in field of EIA prepare EIS or EIA report considering the issues and problems related to decision-making process [v].

B. The Framework of EIA

Baseline study
The first step is to carry out baseline study involving essential facts and figures of scoped issues. The current condition of environment, which is expected to get affect adversely through the proposed project, is taken as basis of this first step.

Screening
Second step is the screening and it is an important part of EIA process which involves the responsible authority to give permission for proposed projects to go for EIA procedure. This depends upon the nature, magnitude or location of the project considering the expected impacts on the environment.

Scoping
After the concluding on requirement of formal EIA, the next step is to identify the concerns and issues to be considered. This is called scoping, on which the effectiveness of EIA depends primarily. Local councils and authorities, public organizations and consultants may be involved at this stage, also the contribution of communities is also encouraging for identifying issues.

Terms of Reference (TOR)
Terms of Reference provide an appropriate direction for preparing EIA and it is preferable to include potential impacts spotted during scoping (Fig.1).

- A description of the project
- A list of the agencies or ministries responsible for overseeing the EIA process and making decisions
- The geographic area to be studied (also called the 'impact zone')
- EIA requirements in applicable laws or regulations
- Impacts and issues to be studied
- Mitigation and/or monitoring systems to be designed
- Provisions for public involvement
- Key stakeholders
- Timeframe for completing the EIA process
- Expected work product and deliverables
- Budget for the EIA

Fig. 1. Model for Terms of Reference (TOR) [vi]

Public Involvement
The best way to practice EIA successfully is to involve the public at various points during the whole process with mutual exchange of information and ideas. Public involvement can be achieved through meetings, public hearing and giving opportunity to their concerns about proposed development.

Complete EIA study
This step generates a full and complete report that considers the perspectives and comments of all the involved stakeholders incorporating the consideration of justifying measures to evaluate the act anticipated to check, evade or reduce definite or possible important adverse effects to be caused by the development project.

Review

Review is about judging the sufficiency of EIA prior to decision making and addressing its allegations for project execution.

Decision-Making

Decision – making is a significant step in EIA process which plays very important role in endorsing or refusing the proposed project. The decision-making may involve certain condition to be fulfilled like submitting a Environmental Management Plan.

Monitoring

The step of Monitoring in EIA involves observing the project execution and procedure and ultimately inspection of the development after being completed. Despite a legal prerequisite, monitoring takes place only in response of complaints. The reporting system or self-monitoring outlined in the environmental management plans (EMPs) is hardly adopted by project proponents.

C. Benefits and Constraints of EIA
The advantages of EIA include:
- Better design and scheme of project
- Knowledgeable decision making
- Environment-oriented approach towards decision making
- Improved degree of reliability and transparency of whole development process
- Less damage to the environment
- Better in coordinating and integrating of development projects into the respective social setting
- Efficient nature in regard of accomplishing objectives financially and socially
- Long-lasting working of projects
- Effective and comprehensive EIAs play important role in order to generate a balance between public sector, politicians and proponents of the projects and the environmentalists and conservationists' concerns

The EIA represents a constructive contribution towards achievement of sustainability in the environment. However, the study of EIA effectiveness revealed a variety of complications, although not relevant on universal basis.

Some of such noted constraints have been discussed below:
- EIA mostly considers biophysical issues as center of attention due to poor meager terms of reference. The EIA related aspects are not always focused in integrated manner when environmental, social and financial aspects are focused (International Institute for Environment and Development – IIED, 2008).
- The small projects are often not included in many EIA structures even if they have a possibility of increasing impacts over period of time.
- Deficient methods for ensuring the EIA reports to be considered in decision-making process.
- Limited public participation.
- Partial knowledge of respective functions of baseline study and impact prophesy.
- Fragile connections between project execution, operation and recommendations of EIA study on alleviation and observation.
- Inadequate competence on technical and managerial level in most countries for implementing EIA [vii].

III. RESULTS & DISCUSSIONS

A.   EIA Process - Case of Scotland
The legislative background of Environmental Impact Assessment – EIA states that it is introduced in Scotland due to strong instructional framework from European Community (EC). The conditions of EC instructions are transmitted into Scot law on the basis of regulations formulated by the Scottish Government. The EIA regulations assists the public authorities in process of decision making confirming the status of projects to carry on or revise their planning schedule to minimize the adverse effects on environment. This is carried out by providing the Environmental Statement or 'ES' accompanying with the constructive feedback from legal environmental associations and public.

A dramatic shift has been observed in the form of rejection of planning consents by the legal courts. As a result of this, football stadiums, industrial & farm buildings, power stations and many mega housing projects have been added to the list recently [viii]. This implies that over time, EIA has become very important tool for avoiding unwanted development contributing to the sustainable environment.

The EIA framework in case of Scotland contains various steps [ix]. These are discussed below:
- Screening Process
- Scoping process
- Preparation of Environmental Statement (ES)
- Prediction of environmental impacts
- Submission of EIA
- Consultations and Promotion
- Incorporating Additional Environmental
- Information and Modifications to the Project
- Decision Making Stage
- Implementation and Compliance

Screening Process

The relevant authorities 'screen' every project proposal and are responsible for giving consent to carry on with the project. The screening, as described earlier, depends upon scale, nature, location and type of significant impacts on the environment. It is the

deciding stage whether EIA is necessary or not. The proponents of project can request the authorities for the 'screening opinion' Scottish Ministers are empowered in this regard for issuing the 'screening direction'.

Scoping Process

This is the most important stage in the whole EIA process which has to be fulfilled by every project proponent by applying for a 'scoping opinion' to the competent authority. The scoping is issued normally after five weeks in Scottish framework of EIA. This step ensures that EIA process is relative to the project and its impacts on the current environmental condition.

Preparation of Environmental Statement (ES)

According to the Handbook the primary purpose of ES is to guide the decision makers of environmental obligations of the proposed project. ES is prepared by proposer of the project in accordance to the 'baseline information' and the preparation of ES is subjected to specific regulations for the content the statement. This step further involves the prediction of impacts through use of methodologies and models available and then assessment of significance of predicted impacts on rational basis taking into account of sensitivity towards transformation of environment.

Submission of EIA

ES is required by capable authorities and the Scottish Ministers in cases, where proposed development is subjected to undergo EIA procedures. So after preparing the ES, it is then submitted to concerned authorities making beneficial for all stakeholders by introducing contact and liaison at the beginning. This makes the decision making a speedy process and EIA process more efficient.

Review of ES

After the ES submission, it is then reviewed by competent authority by considering all the environmental information and evaluates the scope of environmental statement to grant consent for carrying out EIA to proposed project. The response from EIA consultants is also integrated in reviewing ES at this stage. This forms basis for dialogue between consultants, authorities and project proposer which further improve the understanding of the project along with giving attention to public comments.

Incorporating Additional Environmental Information and Modifications to the Project

After the review based on the recommendations and suggestions, the competent authority demands for further information to be added for positive modification of the project which has to be fulfilled by project proposer. It is then followed by advertisement and promotions under the provided regulations.

Decision Making Stage

Competent authorities carry out decision making by adopting the available knowledge and scientific information as precautionary measure for consideration of environmental impacts and fulfillment of government policies. Researchers have concluded that EIA is very powerful in deciding the future of projects [x].

"An analysis of studies of the outcomes of environmental impact assessment (EIA) indicates that its role in consent and design decisions is limited, due primarily to passive integration with the decision processes it is intended to inform. How much EIA helps sustainable development is largely unknown, but it is hypothesized that it is more than is typically assumed, through a plethora of causes, including emancipation of stakeholders and incremental change in the bureaucracy, companies and scientific institutions" [xi].

Though the influence of EIA on the projects has been significance. For example, a study analyzed how often did EIA impacted the decision making in UK and results showed that in 54% of the assessed projects did the EIA prevent environmental damage beyond without which would be achieved without assessment and in around 25% of the projects the EIA ensured that the development is placed on a sustainable basis.

Implementation and Compliance

The endorsement of compliance and implementation is to be issued by the competent authority has control to implement compliance. However, the degree of monitoring the fulfillment of EIA with terms and conditions is judged on the nature of different cases and varies accordingly. The individual nature of every case is the fundamental principle for checking the compliance of rules & regulations. However, the conservation of environment is ensured through planning of every project proposal.

B.   EIA Process - Case of Malaysia

In the year 1998, Malaysia launched the Environmental Impact Assessment (EIA) as obligatory legislative prerequisite through Environmental Impact Assessment Order (DOE 1987). The law has empowered the Director General of the Department of Environment (DOE) to improve and secure the quality of environment. The objective was to get an idea about the advantages and adverse impacts from development projects to the Malaysians. Being a highly resourceful country with abundant woodlands in tropical region, Malaysia is facing many environment-oriented problems, for instance, deforestation, land deprivation, water pollution, haze, solid waste management issues. For this reason, Malaysian government has been active in enacting various laws for environmental conservation, of which the most significant is EIA for identifying the expected positive and negative outcomes from proposed physical development.

Practice of EIA in Malaysia

The practice of EIA in Malaysia largely follows the internationally developed process. However, two categories have been adopted by Malaysian government: namely preliminary and detailed assessment. Preliminary EIA is required in every project application and decision will be made by Department of Environment (DOE) whether the next stage of detailed assessment is required or not on the basis of future impacts of development on environment. The chief objectives of Preliminary EIA is to choose the most suitable option for project, to integrate moderating measures into planning and to spot important environmental impacts for ensuring detailed assessment. Ramli, Mohamed, & Zahari (2012) discussed the three main steps adopted in carrying out EIA [xii]. A brief account of them has been given below:

Preliminary Assessment

It involves the primary assessment of impacts based on prescribed activities of proposed development. The pre-feasibility stage of any project should be accompanied by preliminary assessment at the beginning. For identifying the potential outstanding environmental impacts, expertise can be hired from public or private agencies to prepare preliminary report which is to be reviewed by technical committee of DOE.

Detailed Assessment

After the preliminary assessment assured the significance of environmental impacts to undergo further study, then detailed assessment steps in. the ideal placement for carrying out in-depth assessment is during the feasibility phase when approval has been issued by respective government (Federal or State) for executing the project. After this, the detailed EIA is then submitted to Director General of Environmental Quality for approval. The DOE Director General then selects review panel which carries out the detailed assessment according to particular Terms of Reference (TOR). The last step is the preparation of the EIA Report after the review from authorized Review Panel.

Review

After examining the EIA reports in the Review Phase, the Ad-hoc Review Panel puts forward recommendations and suggestions based on the review and evaluation which are then passed on to the relevant development project. This allows authorities to make considerations for final decision on the project. Normally, the time duration is one month in reviewing the preliminary assessment report and two months for detailed assessment report.

Effectiveness of EIA

In case of federal government, the legal restriction of EIA processes on its jurisdictions is relative to managing the environment, which puts significant constraint on its effectiveness. In fact, the authority of each Malaysian state to pass laws extends the resource management system beyond the reach of Environmental Quality Act (EQA) and the function of Department of Environment (DOE). This is one of the major reasons for making government decisions on State level as politically-oriented decisions for allocating and managing natural resources and eventually Federal government has to keep cautious vision to avoid interfering situations into State affairs. The case of Borneo States of Sarawak and Sabah in East of Malaysia is one such example has been documented in 163 where special considerations were made in the Constitution to becoming members of Federal Parliament on the basis of distinctive ethnicity.

Moreover, to some extent the inclusion of public participation is given due consideration for ensuring effective EIAs. Integration of developmental and environmental objectives in decision-making by using tools such as EIA is certainly now becoming important. For example, the new 2400MW Bakun hydroelectric project was evaluated under new Sarawak EIA procedures and it was noted that, public participation is explicitly provided in the federal guidelines, and a valid EIA assessment cannot be prepared without some form of public participation [xiii].

C. EIA PROCESS – Case of Pakistan

Pakistan, like many other developing countries, is now implementing environmental protection laws and regulations to avoid adverse effects in environmental as well as social sectors. In 1983, the Environmental Impact Assessment, has been first launched by Pakistan Environmental Protection Ordinance (PEPO). Before introduction of EIA in the country, Initial Environmental Examination (IEE) of the proposed projects was compulsory requirement by the Ordinance to identify the necessity and scope for EIA report. In 1997, the Pakistan Environmental Protection Act (PEPA) replaced the ordinance and within the same year environmental assessment plan was also released which comprises of following guidelines:

- Preparation and evaluation of environmental reports
- Public Participation
- Applying to sensitive and crucial areas
- Developing particular sectors including roads, industrial estates, study of oil and gas etc.

EIA Process

According to Pakistan Environmental Protection Ordinance (PEPO), before conducting an EIA, the Ordinance required an initial environmental examination (IEE) to be carried out to assess the need and scope for an EIA. The PEPO defines IEE as, "Initial environmental examination means preliminary

environmental review of the reasonably foreseeable qualitative and quantitative impacts on the environment of a proposed project to determine whether it is likely to cause an adverse environmental effect for requiring preparation of an environmental impact assessment" [xiv]. Thus, IEE was supposed to supplement the screening and scoping mechanisms. According to Pakistan Environmental Protection Act 1997 the project proposer, whether a public or private organization, is obliged to undertake on EIA whenever project has the possibility to affect environment adversely; if so, EIA is mandatory for the review and consent of the project prior to execution. However, in reality after the execution of project started, EIA is carried out after repetitive calls from concerned EPA. "Reasons behind preparation and approval of EIA after the initiation of public sector projects is the role of Planning and Development Departments (P&Ds) in screening and political pressure to expedient EIA clearances" [xiv].

In 2000, review of IEE/EIA regulations were disseminated, which contain compulsory requirements and procedures for the public hearing [xv].

Government of Pakistan declared The Executive Committee of National Economic Council (ECNEC) as authorized body for of the conceding financial approval to public mega-development projects on 27th July, 2004 stating that Pakistan is now taking EIA report of mega projects as a compulsory part to get approval. For development projects with implications of environmental impacts (minor or major), submission of EIA report is now mandatory in addition to project file for getting approval [xvi]. The project proponents and local authorities were not practicing IEE and EIA, during 2000-2004 Fig. 2.
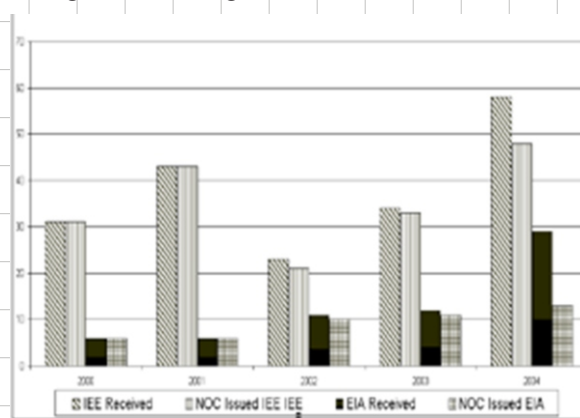
Fig. 2. IEE and EIA evaluations during 2000-2004 [xvii]

There is a huge shift in trend in implementing IEE and EIA processes as shown in Fig. 3.

Year	EIA	IEE	General	Total
2013	72	625	595	1492
2014	95	961	653	1709
2015	49	466	362	877
2016	21	154	531	706
2017(uptill September)	101	680	581	1362
Grand Total	338	3086	2722	6146

Fig. 3. IEE and EIA evaluations during 2013-2017
Source: Punjab EPA, 2017

The EIA process and practice in Pakistan is comprised of following steps:
- Specification of screening categories
- Screening
- Scoping
- Consideration of alternatives
- Specification of EIA report contents
- Review of EIA report
- Public participation
- Decision-making and approval
- Environmental management plans
- Mitigation of impacts
- Requirement for monitoring of impacts

Screening
The step one in EIA process involves environmental screening and for this purpose, the Pakistan Environment Protection Agency has categorized development projects into two schedules.

Development projects including agricultural activities, livestock, fisheries, manufacturing, mega building and city planning projects, water supply and water disposal plants, transportation, dams, industrial projects are mandatory to have Initial Environmental Examination (IEE).

Projects including the same list as of Schedule I but apart from agriculture, livestock and fisheries and projects based on environment wise critical areas have compulsion to carry on complete and in-depth EIA report. The screening step is the deciding factor at the beginning of the environmental studies, based on financial scope and capacity of proposed project, to go for in-depth EIA or carry on with the project execution by going through IEE only.

Scoping
In Pakistan, the determination of scope for either IEE or EIA is a derivation of sectoral guidelines, which are accessible for projects like industrial estates and roads etc. This step also involves the meetings among the potential stakeholders along with information collected from relevant departments to discuss considerable alternatives and to examine the knowledge gaps.

Reviewing the EIA Reports

The project proposer is advised by the relevant Environment Protection Agency (EPA) to fulfill the condition of satisfactoriness of EIA report within time period of 10 days after receiving acknowledgment receipt from EPA. EPA carries out the review process within three months after confirming the competence of the EIA report. However, the EIA process in Pakistan is not accompanied by audit for true value of EIA due to which the EIA process has still not gained strength in its framework.

Public participation

The participation of communities through conducting meetings and public hearings is necessary only during the review of EIA report. However, in Pakistan the project proponents are not obliged to engage the public for preparing EIA report.

"Public participation is mandatory under section 12 (3) of the Pakistan Environmental Protection Act (PEPA) of 1997 needs to take place during the competent authority review stage of EIA" [xviii]. "Furthermore, the Pakistan Environmental Protection Agency (Review of IEE and EIA) Regulations 2000, required that the public notice or invitation for participation to be published in an English or Urdu national newspaper and a local newspaper for general circulation in the project affected areas 30 days before the hearing" [xiii]. "The public notice is also required to contain information on project type, location, name and address of the proponent and the places at which the EIA report can be accessed. Formal public consultation does not generally take place during EIAs, except on socio-economic impacts of projects, taking the form of an opinion survey. The competent authority normally carries out EIA review in-house" [xix].

Mitigating Measures and Monitoring of Impacts

Introducing Mitigating measures and monitoring is the last step to be followed in EIA process which is still not adequate in terms of its working through implementing Environmental Management Plans (EMP) in case of Pakistan. On getting approval for project execution after submitting EIA report, the project proposers are least concerned to undertake mitigation measures, however in some cases they do go for mitigating of impacts cannot manage to do it properly due to insufficient equipment. While Monitoring is mostly carried out only in cases of criticism and objections

Case of Orange Line Metro – Lahore

Orange line metro is mega mass transit project in Lahore city of Pakistan, started two years back. EIA reports were submitted before executing the project. In prospect of this, the concerned department of Environment (EPA) is anxious about environmental-friendly implementation of project and is in consultation with experts for execution [xx] Major plantation has been cut during the construction works throughout the route. The promise of planting 6200 trees as a green substitute is mentioned in the report [xxi]. However, it has not been implemented after the project construction started. In addition to protection of natural environment, built heritage has also needed to be considered for EIA study of such projects. It is major expectation of the project proposal that two significant monuments namely Chauburji and Shalamar Gardens will lose their grandeur due to blockage of views [xx]. This shows that a project can immensely affect the environment either it comes under built or natural scope. The lack of concern among different stakeholders of the project can also be one of the major reason for not implementing the safety measures which were mentioned in the EIA report of Orange line Metro project of Lahore.

IV. CONCLUSIONS

The EIA preparation and review processes of all the three countries namely Malaysia, Scotland and Pakistan have been summarized in the following table to highlight the common similarities and distinguished features of each process.

TABLE I
COMPARATIVE ANALYSIS OF EIA PREPARATION AND REVIEW PROCESSES IN MALAYSIA, SCOTLAND AND PAKISTAN

EIA-Malaysia	*EIA Scotland*	*EIA Pakistan*
Preliminary assessment Preparation of TOR Preliminary assessment Review by DOE	Screening Process	Screening
	Scoping process	Scoping
	Preparation of Environmental Statement (ES)	Requirement for consideration of alternatives
	Prediction of environmental impacts	Specification of EIA report contents
Detailed assessment Brief by review panel of DOE Preparation of document Public comments Review by review panel	Submission of EIA	Review of EIA reports
	Consultations and Promotion	Public participation
	Incorporating Additional Environmental Information and Modifications to the Project	Decision making and approval
Approving authority	Decision making stage	Public participation
Project implementation & monitoring	Implementation and compliance	Mitigating measures and monitoring

Some of the limitations of the EIA processes of Scotland and Malaysia are as follows;

- The plurality is problematic when considering theory advancement and evaluative research: firstly, a decision must be made concerning the philosophical construct on which to base EIA theory; and, secondly, the term effectiveness cannot be reduced to simplistic statements of purposes and outcomes because its definition varies among individuals.
- The amalgamation with decision, with the EIA report, has significantly reduced its functional outcomes.
- Comparatively minute consideration has been given to the liaison between sustainable development and EIA;
- Simplifying assumptions employed to reduce the concept of sustainable development have ignored the wider institutional framework within which EIA has to operate.

Following weaknesses in EIA process of Pakistan can be highlighted:

- Poor organizational set up
- Limited public concern
- Insufficient screening and scoping
- Limited vision for review of EIA reports
- Weak synchronization between stakeholders including EIA consultants, relative authorities, project proponents, EPAs
- Little practice of mitigation measures and Monitoring
- A limited allocation of money and time by the proponents for conducting EIA
- Absence of baseline information or data
- Inadequate technical experience of EIA consultants
- Limited involvement of the stakeholders during preparation of EIA reports
- Heavy reliance on qualitative analysis of impacts significance
- Inadequate consideration of project alternatives [xxii].

Pakistan is facing serious environmental issues of noise and air pollution due to neglected implementation of EIA process in comparison to Malaysian and Scotland. It is surprisingly to observe that Malaysia and Scotland, has managed to regulate and implement EIA process for urban projects to greater extent. Pakistan is can also carry out EIA process in the right direction with implementation of some legal restrictions on some mega projects. Intense interest is needed to protect and conserve the environment of megacities of Pakistan. Projects like orange line metro have provided detailed EIA documentation and conducted public hearings. Still, the implementation is needed to be regulated on more practical grounds.

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Quality Assessment of Refuse Derived Fuel Produced from Municipal Solid Waste of Ravi Town, Lahore

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*Abstract-*The present study aims to convert municipal solid waste (MSW) reject into refuse derived fuel (RDF) and estimate its quality by physical and chemical analysis. A model was set for all four seasons of the year (spring, summer, autumn, winter). A sample of 30,000 kg of MSW was investigated to project combustibles (162.14 tons/day) used for RDF production. The samples were shopping bags (SB) (38.45 %), textiles (TX) (23.56 %), paper and cardboard (PC) (17.29 %), other combustibles (OC) (12.51 %), *polyethylene terephthalate* (PET) bottles (4.86 %), tetra-pack packaging (TP) (2.69 %) and other plastic (OP) (0.63 %). The results of the ultimate and proximate analysis of the RDF samples were in the favour of the RDF production with high volatiles and lower ash contents. Plastic polymers showed highest volatile matter (93.64±1.32 % to 81.61±8.06 %). C/H ratio was found maximum for PET (14.77±0.23) followed by TX (11.5±73.97). Chlorine content was negligible that also reduced the potential damage risk to the RDF processing equipment. Net calorific value, moisture content, ash content, chlorine content, sulphur content, mercury, arsenic, cadmium, nickel, lead, copper and chromium complied EURITS RDF standards. Through this study it is established that production of RDF addresses the MSW management problems sustainably.

*Keywords-*municipal solid waste, refuse derived fuel, RDF quality standard, major combustibles, RDF potential, RDF projection, RDF pellets, Ravi Town Lahore Pakistan.

I. INTRODUCTION

The population explosion, services to compete with the modern technology and the rapid trend towards urbanization have resulted in many environmental concerns. The current generation is deeply concerned about the constant depletion of natural resources to meet their needs and the rising trend in different types of the wastes. Solid waste (SW) is one of its kind, dealing mostly with wastes that are solid or semi-solid in nature. Municipal solid waste (MSW) is an important branch of SW that is produced from residential, commercial and institutional areas. This type of waste includes food waste, rubbish, ashes, construction and demolition waste and occasionally special waste. It is the integral part of any society [i]. Development of international markets for packaged goods and foods have also dramatically added to the global MSW problems in the past years.

In developing countries, MSW is increasing exponentially with the passage of time posing a huge threat to the environmental conditions. Ground and surface water contamination, outbreak of plagues, greenhouse effect, air and land contamination and many more related issues need to be addressed due to the improper municipal solid waste management (MSWM). Many human diseases like cholera, diarrhoea and lung infections are attributed to poor MSWM [ii, iii]. Contemporary, landfill gas is one of the key greenhouse gases (GHGs) resulting in atmospheric pollution and climate change [iv-vi].

One of an attractive option to deal with the ever increasing environmental pollution and MSW, is to transform this into refuse derived fuel (RDF). The waste derived fuels (WDF) are considered to be the resource drawn from solid waste that has potential to transform into energy without producing threat to the environment. The term RDF is mostly used for MSW that has undergone some kind of process resulting in increased calorific value. In many European countries RDF is used as an alternative fuel [vii].

Principally, RDF constitutes the combustible portion of MSW, e.g. paper and cardboard, different types of plastics, textiles, etc. The waste is shredded and transformed into pellets using a variety of pelletizing machines using heat, temperature or both. Since, there is a seasonal, spatial and temporal variation among the MSW statistics, it is very important to know the RDF quality of the region under consideration. The RDF quality is mainly dependent on the energy content of the feedstock and lesser the moisture content higher will be the derived energy [viii].

Thesaurus on resource recovery terminology explains, there are seven types of RDF according to ASTM STP 832-EB [ix] as given in Table I. Solid

waste without any treatment is itself a fuel, but it has a higher energy value of about 4000 kcal/kg when processed into RDF [x, xi]. The most frequently used RDF type is RDF-5 that is in the form of pellets [xii]. In general, RDF is concocted from the combustible fraction of MSW that is capable of subjecting to thermal treatment and drawing energy from it.

TABLE I
RDF CLASSIFICATION ACCORDING TO ASTM STP832-EB

RDF-1	Wastes used in as discarded form.
RDF-2	Wastes processed to coarse particle size with or without ferrous metal separation such that 95% by weight passes through a 6 in square mesh screen, namely Coarse RDF.
RDF-3	Wastes processed to separate glass, metal and inorganic materials, shredded such that 95% by weight passes 2 in square mesh screen, namely Fluff RDF.
RDF-4	Combustible wastes processed into powder form, 95% by weight passes through a 10 mesh screen (0.035 in square), namely Powder RDF.
RDF-5	Combustible wastes densified (compressed) into the form of pellets, slugs, cubettes or briquettes, namely RDF slurry.
RDF-6	Combustible wastes processed into liquid fuels (Pyrolysis), namely RDF slurry.
RDF-7	Combustible wastes processed into gaseous fuels (Gasification), namely RDF syngas.

Source: [ix].

Recycling and composting activities divert the MSW from the landfill, but a huge amount of waste rejects end up there. It is very important to know the prospects of resource in the rejected waste. The MSW processing into RDF is most commonly used for waste to energy purposes. This process also helps to reduce the volume of waste and handling is made easy. The heating value of MSW is 6-14 MJ/kg and its global energy potential estimate is considered to be 13 to 30 EJ by 2025 and conversion of MSW to RDF increases the calorific value [xiii]. Since, it is heterogeneous in nature, it may be hazardous or non-hazardous, Thus, there exists a need to investigate the physical and chemical nature of the waste to seek its potential to be used as a resource. The RDF standards vary from country to country. Currently, the European standards (CEN 343) are considered to be the most relevant standards of the time [xiv].

The major utilization of RDF is in the industrial sector. The industrialized countries are mainly concerned about the quality of RDF that is produced from MSW or its reject. It needs to follow two basic rules: (1) ensure the protection of the processing equipment; and (2) the final product should be environmental friendly. To estimate the RDF potential, it is very essential to know its physical, chemical and thermal behaviour [xv]. These properties need to follow environmental specifications defined by some standards. Few industrialized countries like Finland, Germany and Italy have developed their own RDF standards. In Germany the RDF standards are governed by RAL-GZ [xvi]. Physical and chemical properties are categorized by medium and high quality RDF, in Italy and regulated under UNI 9903 [xvii]. SFS 15358 [xviii] is the governing technical standard in Finland that defines three levels of quality assessment for all parameters. Other European countries like UK, Spain and Switzerland give RDF standards specifically for combustion or co-combustion in cement kilns. These standards are administrated by the European Association of Waste Thermal Treatment Companies for Specialized Waste [xix]. It is to be noted that the RDF standards for the use in cement kilns are more stringent than the other ones [xx].

Cement Industry is one of the developed sectors in Pakistan. There are twenty nine cement plants producing a total of forty four tons of cement annually contributing significantly to the gross domestic product (GDP) [xxi]. Similar to the European countries, Pakistan has also developed guidelines for processing and using RDF in Cement Industry [xxii]. Millions of tons of MSW is dumped on the land as a reject. Somewhat, the energy generation through MSW fabricated RDF may be a better option than throwing into the dumps. Keeping in view, the energy crises in Pakistan, foreign investors have signed an agreement to invest 10 million Euros to build RDF plant in Rawalpindi [xxiii]. The Fauji Cement Company Ltd. (FCC), is the pioneer to set a RDF plant in Pakistan with a capacity of 10 tons/hr using MSW. Furthermore, Cherat Cement Company, DG Khan Cement Company Ltd. and Best Way Cement are next on using RDF as a resource. These studies indicate that there is a room for research to use RDF in other sectors of Pakistan for energy production.

The aim of this study was to develop an efficient and beneficial municipal solid waste management system for *The Ravi Town, Lahore, Pakistan,* as a case study. Explicitly, the conversion of combustible MSW components into RDF and its evaluation in compliance with the available RDF standards was also in focus.

II. MATERIALS AND METHODS

A. Study Area

Lahore is the second largest city of Pakistan. It is the capital city of the most populated province of Punjab. The Ravi Town is at the entrance of Lahore, situated in its North and subdivided into 19 Union Councils (UCs). It has a total population of 1156218 approximately, representing middle and lower income groups. The total area of Ravi Town is about 30828668 m^2 with almost 320000 households. A total quantity of 849 tons (approximately) of solid waste is being brought forth daily, dumped at the Saggian dump site. The 19 UCs are further divided into three

administrative Zones; (1) Zone 1: Shahdrah and adjoining areas; (2) Zone 2: Badami Bagh and adjacent areas; and (3) Zone 3: Walled City of Lahore [xxiv]. The mentioned conditions indicate that the Ravi Town exhibit the lowest economic conditions with the highest population among the other towns in Lahore. Previous studies have clearly explained that the quantity and quality of the MSW increases with the income levels [iii, xxv]. Thus, if the results of this study prove to be significant, MSW statistics of the Ravi Town may be taken as an example. The models and examples are set for the worst of the conditions to optimize the best SWM technique available. The geographical information system (GIS) population map of the Ravi Town is given in Fig. 1.
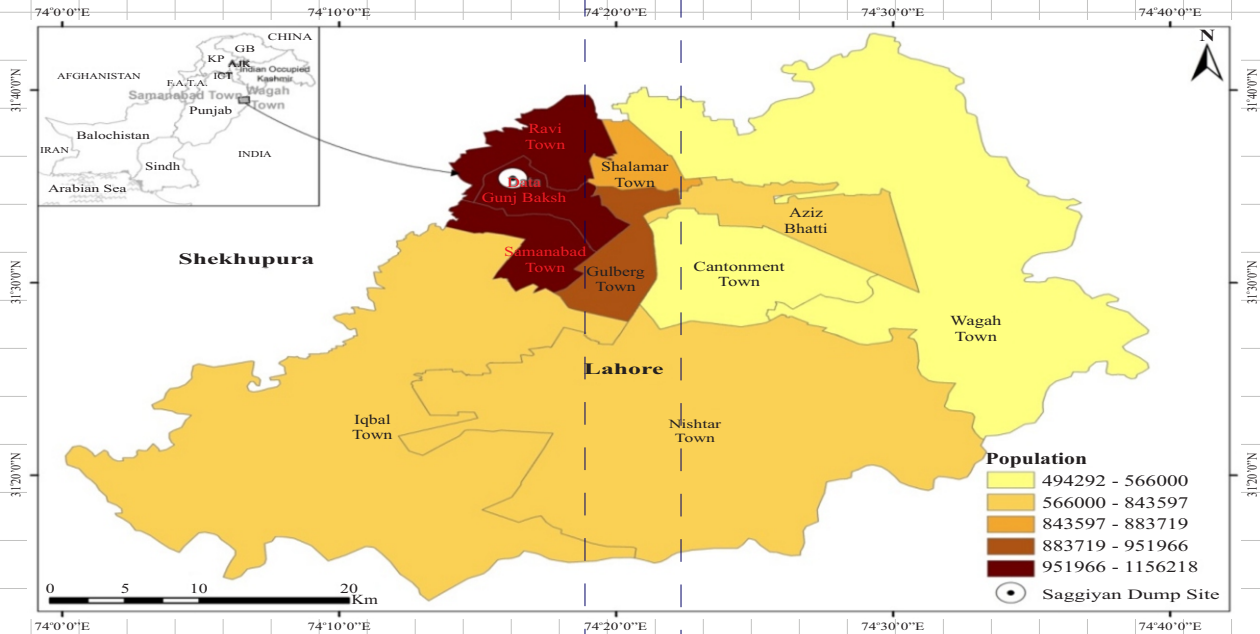
Fig. 1. GIS map of the sampling area

B.   *Compositional Analysis of MSW in the Study Area*

   1) Sampling Site Description
   The sampling of the MSW was carried out at the Saggian dump site. It is situated in the suburbs of Lahore and the resting place of MSW reject collected from the Ravi town and a few other towns. The MSW reject include the final reject that has gone through every possible segregation carried out at different stages of the MSWM. Thus, it has no further use and official status. The LWMC and private contractors collection vehicles bring the waste to the dump site. This site, with an area of 25 ha has been in operation since 1995. Its exact location is pointed on the map given in Fig.1.

   2) Sampling and Sampling Techniques
   The field surveys for the characterization of MSW of Ravi Town were carried out periodically for four seasons, Spring, Summer, Autumn and Winter in the months of April (2011), July (2011), October (2012) and December (2012), respectively.
   To increase the level of accuracy, the sampling was carried out according to the joint approach of *Stratified Random Sampling* (taking seasons of the year as strata) and *American Society for Testing Materials*

international standard *ASTM D5231-92 (2003)*. According to the standard, a representative sample was drawn from each truck load approaching from Ravi Town, Lahore. The following formula was used to calculate the representative number of loads i.e. *n*:

$$n = -\frac{b\,R}{1.0516} \qquad (1)$$

   Where, $t^* = 1.645$ (student t distribution statistic), against $(1-\alpha) = 90\%$ the desired level of confidence), $\alpha = e = 0.10$ (the desired level of precision), $s = 0.03$, and $\bar{x} = 0.10$ [xxvi]. Where, s (standard deviation) and $\bar{x}$ (mean) were selected on the basis of the governing component, i.e. food waste in the city of Lahore [iii, xxv]. The number of sample loads, $n = 5$ were calculated using equation (1) and validated according to *ASTM D5231-92 (2003)*. Thus, for component analysis, segregation of 5 truck loads was taken as statistically significant. Randomly, five truck loads were selected from those coming from the 19 UCs of the Ravi Town. They were unloaded, loosely mixed and a sample of about 200 lb or 100 kg was selected after coning and quartering. This process was repeated daily for fifteen days extended over four seasons. Thus, for physical characterization, approximately 100 x 5x15x4

=30,000 kg of MSW reject was segregated as a representative sample.

The segregation process was mainly based on the major combustibles and non-combustibles fractions of the MSW reject of Ravi Town, Lahore. The MSW reject may not have any other use than converting to RDF. Most of the components which have any other potential use as recycling or composting, they do not end up in the dump sites. Such components are segregated in the upper tiers of the MSWM hierarchy or picked up by the scavengers. Only the rejects fall to the dump sites. Thus, the MSW reject was segregated into two major categories with seven sub-categories each. The first category was major combustibles: paper and cardboard (PC), shopping bags (SB) that are made of *low density polyethylene* (LDPE), other plastic (OP), p*olyethylene terephthalate* bottles (PET), tetra-pack food and beverages packaging (TP) that is made up of three raw materials: cardboard (about 75%), aluminium foil (about 5%) and LDPE (about 20%) [xxvii], textiles (TX) and other combustibles (OC). The PET bottles included coke, sprite and mineral water bottles. Other plastic comprised of *polystyrene* and other combustibles included toffee, biscuit and potato chips wrappers (mixture of LDPE, *high density polyethylene* (HDPE) and aluminium foil). The second category was taken as others: e-waste, green waste, diapers, metals, hazardous waste, glass and miscellaneous. Seasonally, the weights of the segregated components (hand sorting) were averaged (using mean) and the variability among them was also calculated using standard deviation (SD). Finally, Combined average and combined standard deviation was calculated for all four seasons. The projection of combustible elements was estimated for the refuse derived fuel (RDF) potential.

C. Laboratory Samples and RDF Production

The laboratory samples for further analysis consisted of seven sub-samples of major combustibles labelled such as paper & cardboard (PC), shopping bags (SB), other plastic (OP), PET bottles (PET), tetra-pack (TP), textiles (TX) and other combustibles (OC). They were sorted and transported to the laboratory in sealed airtight plastic bags on the last day of each season. The samples were sorted by employing all the safety measure, i.e. use of safety goggles, gloves, masks and shoes.

First, the RDF-fluff was produced from the combustible portion of MSW for all four seasons. The seven sub-samples of PC, SB, PET, OP, TP, TX and OC (each was mixed for four seasons) were converted into RDF using ASTM E829-16 [xxviii] by dehydrating, shredding and then sieving through sieve with a 1 inch square mesh screen. In the second step, the RDF-fluff of the seven sub-samples (representing four seasons) were transformed into pellets by using a laboratory scale hydraulic press.

D. Quality Characterization of RDF

The following tests were performed to optimize the pellets quality. This will ensure their acceptability as fuel.

1) Sample Preparation

Each RDF pellet (PC, SB, PET, OP, TP, TX and OC) was frozen in liquid nitrogen and grounded immediately using a mill. Seven homogeneous samples were prepared. They were labelled and stored in airtight glass vials for further analysis.

2) Proximate Analysis

The Proximate analysis was used to estimate (a) Moisture Content (MC %) using ASTM E 790-15 (2015); (b) Volatile Matter (VM %) using ASTM E 897-88 (2004); (c) Ash Content (AC %) using ASTM E 830-87 (2004); and (d) Fixed Carbon (FC %) by subtracting VM % and AC % from 100. They evaluate the combustible characteristics of these RDF samples.

3) Net Calorific Value

Net calorific value (NCV) or lower heating value (LHV) is the latent heat energy, mostly used to represent the energy balances of waste derived fuels. It is 5 % to 6 % lower than the gross calorific value for solid and liquid fuels [xxix]. The higher heating value (HHV) or gross calorific value (GCV) is the gross energy that can be released through complete combustion of fuel in MJ/kg. Digital Bomb Calorimeter of LECO Corporations AC 500 was used for GCV estimation in RDF samples. The NCV was estimated by subtracting 5 % of GCV from the original value.

4) Ultimate Analysis

Ultimate analysis provides the elemental composition of carbon (C %), hydrogen (H %), nitrogen (N %), oxygen (O %) and sulphur (S %), that gives a better understanding of fuel value and its characteristics. Elementar Analysensyteme GmbH-vario MICRO CHNS Elemental Analyzer (serial number: 15095076) was used for the estimation of the elements in RDF samples. Oxygen value was estimated by subtracting the sum of (C, H, N and AC) percentages from 100 [xxx].

5) Chlorine Estimation

Chloro content in the RDF samples was estimated using *Sintering* method [xxxi]. In this process the RDF samples clumped into larger particles. More importantly, the organic Cl converted to inorganic chloride, such as Sodium Chloride (NaCl) and Zinc Chloride (ZnCl$_2$), that is leached from the residues with water. Extraneous metal ions were removed from the samples by a cation exchange column, and then the purified eluent was analyzed for Cl using the Volhard titration methodology.

6) Heavy Metal Analysis

Since, MSW is heterogeneous in nature and it is commingled including both hazardous and non-hazardous materials. In the current study major combustibles were segregated, but the traces of heavy metals leached from other MSW components may be found. The microwave digestion method was used to estimate the metal concentration in the RDF samples. Europen standard EN 13656 [xxxii] was used: 1.0 gram of sample was mixed with concentrated 3 ml Hdrochloric acid (HCl), 1 ml of Nitric acid (HNO_3) and 5 ml of Hydrofluoric acid (HF); Then the sample was digested in the microwave under 70 watt power for 10 minutes; A 5 ml of concentrated HNO_3 was added in the hot solution and digestion process was repeated for 5 minutes; After that another 5 ml of concentrated HNO_3 was added in the hot solution and digestion process was repeated for 5 minutes; Then 5 ml of concentrated HCl was added in the hot solution and same process of digestion was repeated for 5 minutes; At the end 40 ml (4 % m/m) Boric acid (H_3BO_3) was added to reduce acidic conditions of the solution and microwave digestion was carried out for final 5 minutes. The hot solution was cooled down and filtered for further analysis. The whole process was repeated for all seven RDF samples, and each sample was triplicated to reduce variability. Afterwards, the samples were neutralized using Sodium hydroxide (NaOH) and PerkinElmer Analyst 800: Atomic Absorption Spectrophotometer was used for estimation of Mercury (Hg), Arsenic (As), Cadmium (Cd), Nickel (Ni), Lead (Pb), Copper (Cu) and Chromium (Cr).

All the above mentioned parameters were compared with EURITS RDF Standards given in Table II.

E.   Graphical Presentation and Statistical Analysis

TABLE II
RDF STANDARD LIMITS

Parameters[*]	EURITS Limits
NCV (MJ/kg)	>15
MC (%)	< 25
AC (%)	< 5
Cl (%)	< 0.5
S (%)	< 0.4
Hg (mg/kg)	< 2
As (mg/kg)	< 10
Cd (mg/kg)	< 10
Ni (mg/kg)	< 200
Pb (mg/kg)	< 200
Cu (mg/kg)	< 200
Cr (mg/kg)	< 200

[*]*Parameters: Net Calorific Value (NCV), Moisture Content (MC), Ash Content (AC), Chlorine Content (Cl), Sulphur Content (S), Murcury (Hg), Arsenic (As), Cadmium (Cd), Nickel (Ni), Lead (Pb), Copper (Cu), and Chromium (Cr)*

Source: [xix]

The OriginPro 2016 ® software was used to estimate average (mean) values and their corresponding standard deviations (SD). Pie Graph and Bar graphs were also constructed through this software. The parameters with higher and lower concentration levels were grouped separately for better understanding and resolution. All numerical values were rounded off to two decimal places.

III. RESULTS AND DISCUSSION

A.   Compositional Analysis of MSW for RDF Yield

The first step of this research was to investigate the quantity of different components present in the MSW reject collected from Ravi Town, Lahore. The RDF projection of this reject was estimated at the Saggian dump site where the waste is dumped after collection. Table III reveals the MSW reject compositional trend envisaging the RDF yield.

Table III shows that there was a total of 19.09 % of major combustibles present in the MSW reject of Ravi Town, Lahore. A similar study was conducted at Data Gunj Baksh Town, Lahore and the results are comparable to the current study as paper (5.04 %), film plastic (12.94 %), rigid plastic (5.55 %), textiles (1.00 %), glass (2.10 %), ferrous metal (0.02 %), non-ferrous metal (0.47 %), organics (67.02 %) and others (5.77 %) [iii]. A matching trend was observed in a review article on MSW management of Indian cities. Calcutta is a metropolitan city of India with MSW composition detected as: paper (10 %), textile (3 %), leather (1 %), plastic (8 %), glass (3 %), organic matter (40 %) and others (35 %) [xii].

TABLE III
MSW (REJECT) PHYSICAL COMPOSITION OF RAVI TOWN, LAHORE

Sr. No.		Components	% by wt[*]
1		Paper & Cardboard	3.30±2.04
2		Shopping Bags	7.34±2.09
3		Other Plastics	0.93±0.26
4	Major Combustibles	PET bottles	0.12±0.08
5		Tetra-pack	0.51±0.13
6		Textile	4.50±1.76
7		Other Combustibles	2.39±0.86
		E-Waste	0.15±0.10
8		Green Waste	66.40±6.33
9		Diapers	6.87±2.01
10	Others	Metals	0.18±0.67
11		Hazardous Waste	0.81±0.44
12		Glass	4.29±3.71
13		Misc.	2.27±1.82
14		E-Waste	0.15±0.10

[*] *values are expressed in mean±standard deviation*

Table III clearly explained that major combustibles can further be elaborated. Their individual percentages may be calculated with reference to 19.09 % of total combustibles shown in Fig. 2.
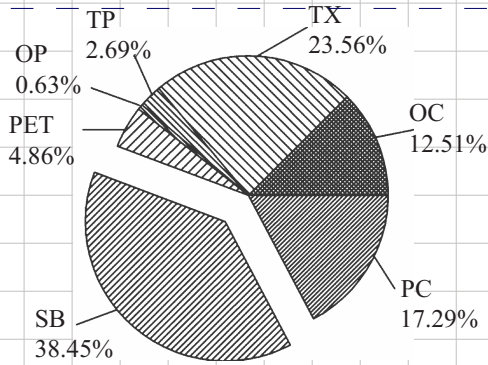
Fig. 2. Combustible raw material for RDF production

From Fig. 2. it is very clear that shopping bags were found in abundance (38.45 %) followed by textiles (23.56 %), paper & cardboard (17.29 %), other combustibles (12.51 %), PET bottles (4.86 %), tetra-pack (2.69 %) and other plastic were in the least amount (0.63 %). In a similar study carried out in a developed city of Vancouver, the RDF raw material was projected to be 52.8 % and the individual percentages were calculated as paper (49.24 %), plastics (36.33 %), leather (4.36 %), wood (1.89 %), textiles (5.49 %), rubber (0.38 %) and fines (2.46 %). Surprisingly, it can be observed that plastics and textiles RDF potential is very much the same. That portrays, the plastic consumption follow the same trend world wide.

The quantity of fresh garbage coming from Ravi Town is 849.32 tons/day [xxiv]. The daily raw material projection for RDF production is calculated below:

Total MSW reject generated = 849.32 tons/day
Combustible percentage = 19.09 %

$$\text{Combustibles per day} = \frac{849.32}{100} \times 19.09$$
$$= 162.14 \text{ tons/day} \tag{2}$$

Fauji Cement RDF plant is the first of its kind that was set in Pakistan in 2008. It has a capacity of processing 12 tons of raw material per hour [33]. If it works for the whole day, for 8 working hours it may process 96 tons/day. Thus, equation (2) projects a feasible amount of raw material for RDF processing.

B. RDF Production

The process for the production of RDF-fluff for each seven sub-samples of PC, SB, PET, OP, TP, TX and OC was followed as explained in materials and methods section. Using RDF-fluff samples, pellets were produced using a laboratory scale hydraulic press. The pellets of each sample are shown in Fig. 3.

C. Quality Characterization of RDF

The results of ultimate analysis and proximate analysis of PC, SB, PET, OP, TP, TX and OC are given in Table IV. Table IV shows that the results are in the favour of using these samples as RDF. They have higher volatiles, followed by fixed carbon and lower values of the AC [xxxiv-xxxv]. Textiles have highest value of volatile matter, i.e. 91.98 %. Fixed carbon is highest in paper and cardboard, i.e. 21.97 % and shopping bags have the least ash content, i.e. 0.01 %. Paper and cardboard have a high cellulose content and it can be realized from the basic elemental values given in Table 4. The estimated amount of carbon (38.84 %), hydrogen (5.49 %), nitrogen (4.66 %), oxygen (43.60 %) and sulphur (0.15 %) are comparable to the ones estimated in a similar study as 35.5 %, 4.6 %, 0.45 %, 35.96 % and not detected respectively [xxxiv].
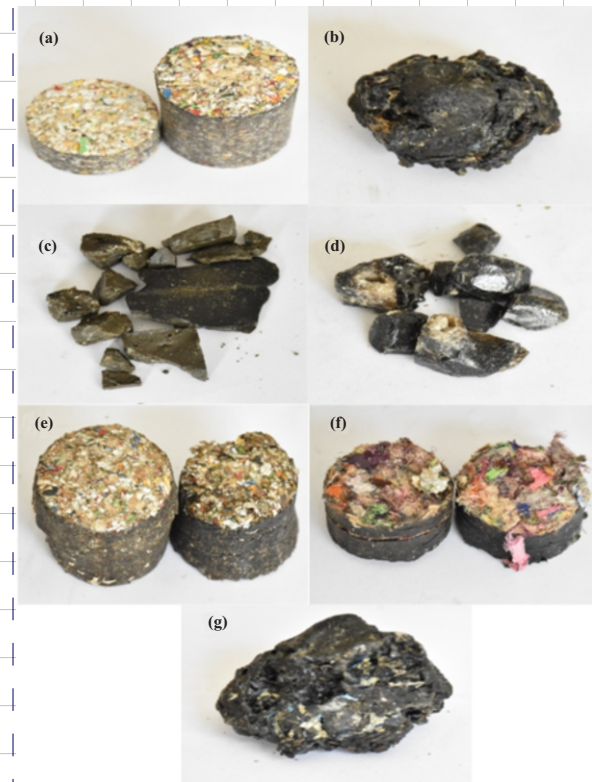
Fig. 3. RDF Pellets of (a) paper and cardboard, (b) shopping bags, (c) PET bottle, (d) other plastic, (e) tetra-pack, (f) textiles and (g) other combustibles

Synthetic polymers (SB, PET, OP) have carbon content (61.13 % to 78.57 %), hydrogen content (4.14 % to 12.98 %), nitrogen content (2.41% to 5.36%), Oxygen content (3.08 % to 31. 90 %) and negligible content of Sulphur. These values are quite similar to other research with related approaches to investigate the thermal behavior of combustible municipal solid waste [xxxv].

The elemental characteristic of textiles waste given in Table IV exhibited values as good as a study on the pyrolysis of textiles waste, i.e. carbon content (53.60 %), hydrogen content (7.28 %), nitrogen content (0.30 %), oxygen content (38.80 %) and sulphur content (0.005 %) respectively [xxxvi].

Table IV also displays tetra-pack carton elemental characteristics in the favour of a study on pyrolysis of tetra-pack carton packaging with carbon content (48.17 %), hydrogen content (7.54 %), nitrogen content (<0.01 %) [xxxvii], oxygen content (39.04 %) and sulphur content (not detected) [xxxiv]. Other combustibles are the mixture of remains with interesting results and promising RDF characteristics.

The quality check of the RDF produced was carried out by comparing the key parameters with the EURITS standard [xix] given in Table II. The graphical comparison in Fig. 4. reveals that all the RDF quality parameters (mean±SD) of (a) paper & cardboard: NCV (29.97±1.77 MJ/kg), AC

TABLE IV
PROXIMATE AND ULTIMATE ANALYSIS OF THE RDF SAMPLES

RDF Sample [a]	Vm [b]	Fc [c]	Ac [d]	S	C	H	N	O
PC	70.62±2.51	21.97±1.84	7.42±0.81	0.15±0.11	38.84±5.04	5.49±0.56	4.66±2.39	43.60±5.63
SB	81.61±8.06	18.37±8.06	0.01±0.02	0.15±0.11	78.57±2.7	12.98±0.55	5.36±4.37	3.08±2.94
PET	91.82±3.64	7.76±3.59	0.42±0.39	0.02±0.03	61.13±0.16	4.14±0.06	2.41±0.28	31.90±0.24
OP	93.64±1.32	4.41±1.24	1.95±0.15	0.11±0.05	74.49±1.84	11.81±1.55	4.45±1.32	7.31±4.20
TP	66.76±3.94	31.05±3.16	2.18±1.28	0.01±0.01	47.32±0.78	7.14±0.19	2.6533±0.81	40.70±1.56
TX	91.98±1.82	7.10±1.60	0.93±0.30	0.53±0.19	53.42±8.68	4.88±1.15	3.78±1.42	37.00±6.37
OC	80.25±11.84	17.82±11.07	1.94±0.99	0.15±0.14	77.40±0.41	12.41±0.16	3.93±0.57	4.99±0.94

[a] PC=paper & cardboard: SB=shopping bags: OP=other plastic: PET=PET bottles: TP=tetra-pack; TX=textile: OC=other combustibles
[b, c, d] VM=volatile matter %, FC=fixed carbon %, AC=ash content %

(7.42±0.81 %), MC (17.01±11.99 %), Cl (0.02±0.01 %), S (0.15±0.11 %), Hg (0.29±0.07 mg/kg), As (3.84±1.45 mg/kg), Cd (6.11±0.07 mg/kg), Ni (31.23±1.47 mg/kg), Pb (0±0 mg/kg), Cu (47.47±2.55 mg/kg) and Cr (65.48±2.95 mg/kg); (b) shopping bags: NCV (29.57±0.89 MJ/kg), AC (0.01±0.02 %), MC (6.38±4.01 %), Cl (0.43±0.02 %), S (0.15±0.11 %), Hg (0.34±0.03 mg/kg), As (4.30±1.38 mg/kg), Cd (5.65±0.16 mg/kg), Ni (29.63±0.93 mg/kg), Pb (0±0 mg/kg), Cu (38.27±3.52 mg/kg) and Cr (64.00±1.22 mg/kg); (c) PET bottles: NCV (31.14±0.97 MJ/kg), AC (0.42±0.39 %), MC (2.14±1.54 %), Cl (0.17±0.04 %), S (0.02±0.03 %), Hg (0.43±0.07 mg/kg), As (4.81±0.62 mg/kg), Cd (7.33±0.59 mg/kg), Ni (41.07±2.12 mg/kg), Pb (0±0 mg/kg), Cu (40.05±2.10 mg/kg) and Cr (75.33±0.73 mg/kg); (d) other plastics: NCV (56.90±0.46 MJ/kg), AC (1.95±0.15 %), MC (5.05±2.27 %), Cl (0.39±0.16 %), S (0.11±0.05 %), Hg (0.29±0.03 mg/kg), As (3.60±1.20 mg/kg), Cd (6.00±0.51 mg/kg), Ni (31.15±4.80 mg/kg), Pb (0±0 mg/kg), Cu (41.94±4.17 mg/kg) and Cr (66.75±3.1 mg/kg); (e) tetra-pack: NCV (29.95±1.03 MJ/kg), AC (2.18±1.28 %), MC (10.303±7.83 %), Cl (0.04±0.02 %), S (0.01±0.01 %), Hg (0.32±0.04 mg/kg), As (3.68±1.55 mg/kg), Cd (5.84±0.59 mg/kg), Ni (33.81±1.79 mg/kg), Pb (0±0 mg/kg), Cu (42.27±2.53 mg/kg) and Cr (71.00±4.12 mg/kg); (f) textiles: NCV (29.4±0.44 MJ/kg), AC (0.93±0.3 %), MC (25.18±24.81 %), Cl (0.04±0.04 %), S (0.53±0.19 %), Hg (0.28±0.02 mg/kg), As (5.03±1.25 mg/kg), Cd (3.59±0.27 mg/kg), Ni (37.02±1.05 mg/kg), Pb (0±0 mg/kg), Cu (43.12±4.50 mg/kg) and Cr (69.42±4.48 mg/kg); and (g) other combustibles: NCV (58.53±1.37 MJ/kg), AC (1.94±0.99 %), MC (11.29±3.51 %), Cl (0.02±0.01 %), S (0.15±0.14 %), Hg (0.35±0.03 mg/kg), As (4.78±0.05 mg/kg), Cd (4.21±3.42 mg/kg), Ni (47.29±3.14 mg/kg), Pb (0±0 mg/kg), Cu (64.71±5.44 mg/kg) and Cr (78.73±6.27 mg/kg).

The above mentioned results were observed in accordance with the EURITS standard given in Table II. The standard deviation values of moisture content, detect that there is a large variation among MC of all the RDF samples but still, they are within the standard limit of < 25 %. Previously, a study carried out to estimate the potential of refuse derived fuel production from Bangkok municipal solid waste showed parallel results [xxxviii].

Similar studies on rejected fraction of Purtoguese municipal solid waste and energy potential from Saudi Arabia also gave similar trends in their results [xxxix-xl].

IV. CONCLUSIONS

In this study the waste was collected from Saggian dump site that is the resting place of MSW reject coming from different parts of Lahore, Pakistan, including Ravi Town.

A representative sample of 30,000 kg of MSW was evaluated for this study. It was segregated into two categories as (1) major combustibles and (2) others. These categories were further elaborated to seven sub-samples each. This study was based on the major combustibles (PC, SB, PET, OP, TP, TX and OC) found in the MSW reject of Ravi Town Lahore as a case study. The RDF projection from this kind of MSW was estimated to be 162.14 tons/day. When compared to Fuji Cement RDF plant feedstock capacity, it was

found feasible for further processing. Higher percentage (on combustible basis) of shopping bags (38.45 %), textiles (23.56 %) and paper and cardboard (17.29 %) in the municipal waste stream makes RDF production as an appealing integrated municipal solid waste management (IWM) strategy and reducing burden on the land dumping. Moreover, these samples were dried and shredded to pass 1 inch square mesh size sieve. Seven RDF pallets were produced for each combustible component.

After quantifying and RDF production, it was important to know if these pellets have any qualitative potential to be used as RDF. The EURITS RDF

standards were used to assess chemical characteristics of these samples. The results were dynamic and in the favour of RDF production.

The findings of this study can be a reliable database for the policy makers to design an integrated MSWM approach for the city of Lahore and other parts of Pakistan. The city district government and federal government of Pakistan can plan ahead to use MSW as resource, transform into RDF and use for energy production. Since, the present study is modelled for the worst conditions as a case study, the results may be useful for other countries too.
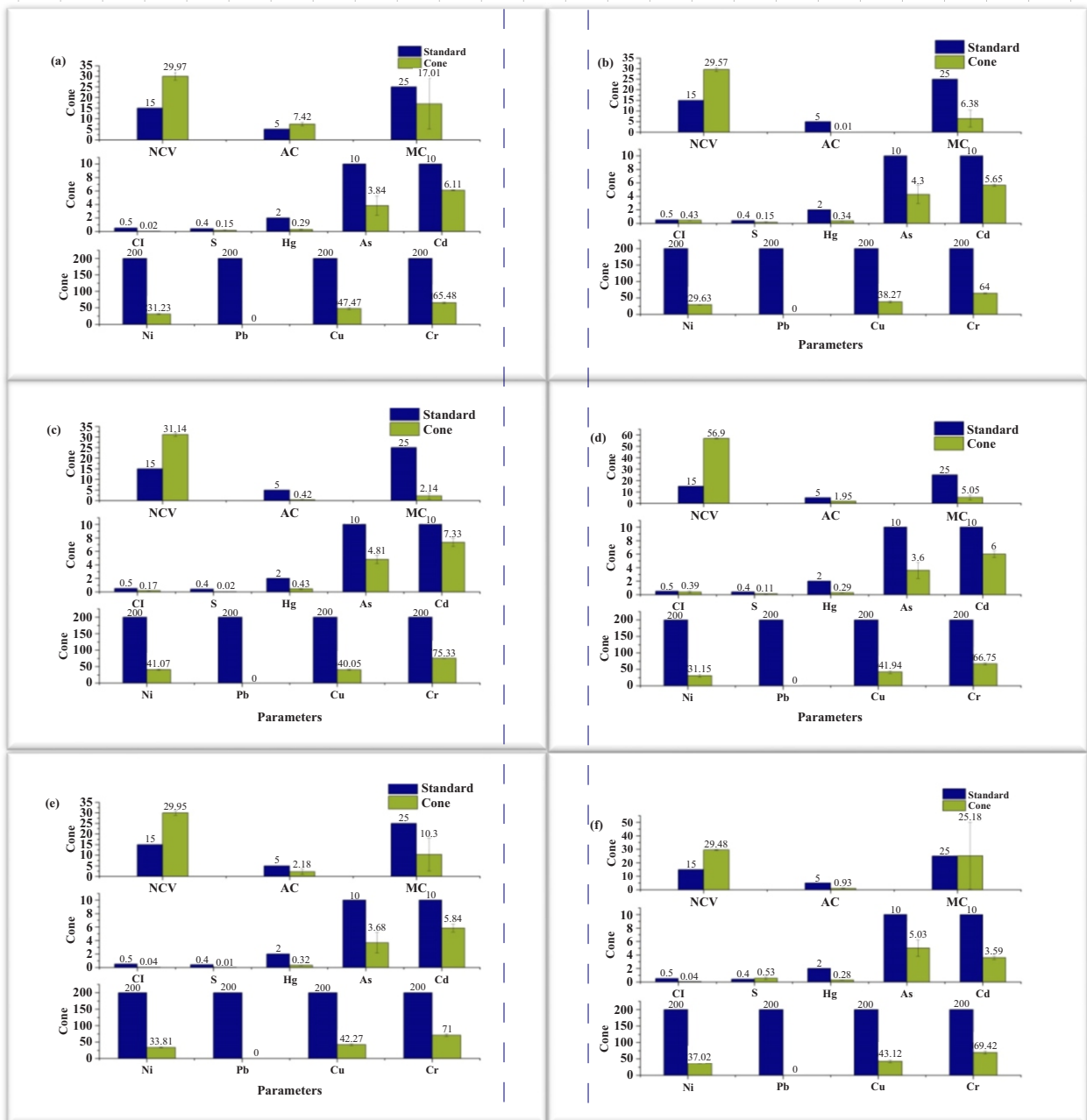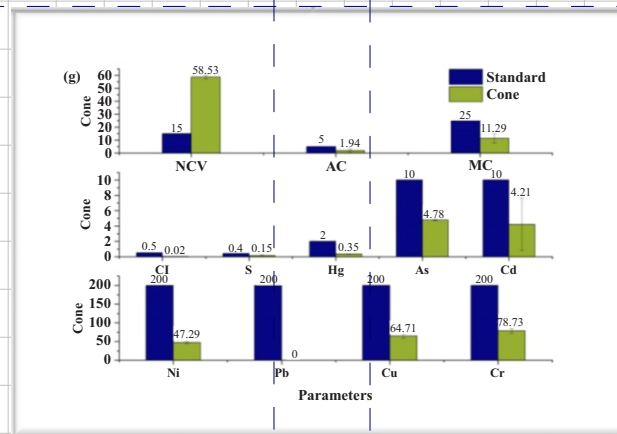
Fig. 4. Concentration of NCV (MJ/kg), AC (%), MC (%), Cl (%), S (%), Hg (%), As (mg/kg), Cd (mg/kg), Ni (mg/kg), Pb (mg/kg) Cu (mg/kg) and Cr (mg/kg).

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Experimental Study on Compressive Strength of Concrete by Partial Replacement of Cement with Eggshell Powder

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*Abstract-*In this research work, influence of eggshell powder (ESP) as partial replacement of cement in concrete was investigated. Cement was replaced by ESP by an amount of 5, 10, 15 and 20% by weight; all other parameters of mixture were kept constant. Workability of fresh concrete and compressive strength of hardened concrete were evaluated and compared with conventional concrete. Compressive strength of all types of mixture was investigated after 7, 14, 28 and 63 days of standard moist curing. Workability was decreased with the increase in amount of ESP; whereas delay in strength gain was observed with the increasing amount of ESP. Compressive strength of specimens with ESP is comparable with conventional concrete after 63 days of age. However, a huge difference was observed between compressive strengths to age of 28 days. It concluded that ESP has the potential to be used as partial replacement of cement and can also be used as retarder in concrete production.

*Keywords-*Eggshell Powder, Cement Replacement, Workability, Compressive Strength.

I. INTRODUCTION

Concrete is considered as the back bone of construction industry and has major role for the development of infrastructure. Currently, developing countries are taking major steps for the development of infrastructure and for fulfilling this aim, huge amount of concrete is required. Portland cement is one of the major ingredients of concrete and is generally very expensive. It is also a big source of environmental pollution as 1kg of cement production emits about 0.8 to 0.9kg of carbon di-oxide (CO_2)[i]. Large amount of cement is manufactured in Asia. Previous studies showed that out of total production of cement in the world 60% cement is produced in Asia and annually almost 900 million metric tons of cement is produced. Out of which only 18 million tons are produced in Pakistan [ii].

Efforts are made by different researchers for sustainable development of construction industry and solving the problem of waste management, simultaneously, by replacing cement by various waste materials [iii-xiii]. Physical and chemical composition of a non-treatedavian eggshell waste specimens were analyzed and examined its usage in wall tile paste. Different tests were performed to analyze the chemical composition of specimen and it was concluded that eggshells are rich in $CaCO_3$ and has the potential to be used as an alternative raw material in the production of wall tile materials [iii]. Cree and Rutter worked on eggshell powder and tries to industrialize the application of eggshell powder. The eggshell membrane was heated and grinded to form $CaCO_3$. Pure calcite was produced by heating at 300 ℃ for 2 hours [iv]. Kumar et al. studied experimental study on partial replacement of cement with eggshell powder (ESP) and investigated the effect on strength of the concrete [v].Vinothan et al. also replaced cement successfully with ESP by 5, 10 and 15%. Increase in mechanical properties (compression, tensile and flexural strengths) were observed with the increase in the amount of ESP [vi]. Gowiska et al. had increased the amount of ESP upto 25% by an interval of 20% and 5% replacement of cement with ESP showed the best results in term of mechanical strength as compared to other specimens [vii]. Eggshells can also be used as a shielding against radiations. Concrete with eggshells was prepared and check their performance against the radioactivity and recommended to use such concrete walls which resist the radioactive areas [viii]. ESP was also used to produce light weight concrete by using Porcelanite as aggregate and contribution of 5% ESP had minor effect on the mechanical properties of such concrete and increase in the amount of ESP may improve the mechanical strength and durability of light weight concrete [ix].

Silica fume was also added to enhance the strength of concrete and its addition was 5, 10 and 15%, whereas ESP addition as partial replacement of cement was10, 20 and 30%by weight. Improvement in compressive strength was observed with the addition of ESP and was

further improved with silica fume addition. The flexural strength of the concrete having ESP also increases with the addition of ESP [iv]. Pliya & Cree worked on the performance of white and brown chicken eggshell waste powders as potential replacements of conventional quarried limestone in Portland cement mortars [x]. Compression and flexural strength tests were carried out on mortar specimens with partial replacement of Portland cement by limestone and it was found that eggshells derived limestone powder have inferior properties even with 5% replacement as compared to natural conventional limestone [v].

Instead of cement replacement, ESP was also used as partial replacement of sand and 20% replacement of fine aggregate was observed in one research work [xi-xii]. The compressive strength, split tensile strength, and flexural strength were carried out. The strength properties obtained were compared with the conventional concrete after the curing period of 7, 14 and 28 days. It was observed that the waste of ESP used in the concrete was comparatively low in cost when compared with normal concrete and the concrete with the addition of different percentages of polypropylene fiber by weight of concrete with 20% constant replacement of fine aggregate by ESP had given the better result when compared with the conventional concrete. The weight of concrete was also reduced by using ESP due to lighter unit weight of ESP [ix].

Based on these findings it is investigated that ESP has the ability to be used as partial replacement agent of cement powder in concrete. On the other hand disposal of eggshell is a major concern and using large amount of land to fill with it. Consequently by using the ESP as cement replacing material not only play important role in reducing the cost of construction but also put major step for solving the problem of environmental pollution that the whole world is facing now a days. With these objectives, tests were performed in different stages as per normal test processes. In first stage, physical properties of materials, chemical compositions, and categorization of ESP and cement were accomplished. Second stage comprised of casting of concrete by incorporating ESP by different amounts and investigating fresh properties of concrete. The third phase included evaluation of compressive strength test on concrete specimens at different ages, and comparison was made with the conventional concrete.

II. EXPERIMENTAL PROGRAM

To investigate the behavior of concrete with ESP, experimental plan was established to evaluate the properties of constitutive materials of concrete, fresh and hardened properties of concrete were evaluated. Details of material and tests performed on those materials are explained in following sub-sections.

TABLE I
PHYSICAL PROPERTIES OF CEMENT AND EGGSHELL POWDER

Physical Properties	Cement	Eggshell powder
Particle size	8% retained on sieve # 200	11% retained on sieve # 200
Colour	Grey	White
Type	ASTM Type1	-----
Specific gravity	3.15	2.27
Standard consistency (%)	31	-------
Initial setting time (Minutes)	95	-------
Final setting time (Minutes)	165	-------
Fineness	3656 cm^2/g	2157.25 cm^2/g

A. Materials

Regionally accessible materials were used for concrete casting. Ordinary Portland cement of ASTM Type-I in compliance with ASTM C150 [xiv] was employed. The physical properties of cement are given in Table I. Locally available river sand passing through 4.75 mm was used as fine aggregate. The coarse aggregate was regionally available compacted Margala crush, passing through 12.5 mm sieve and retained on 4.75 mm sieve compliant to ASTM C-136 [xv]. Physical properties of both aggregates are presented in Table II. Eggshells were procured from local market of Faisalabad city of Pakistan. Eggshells were cleaned completely to remove dust and organic properties. These shells were dried in sun light for 5 to 7 days followed by grinding and sieving to a very fine powder before used Table I.

TABLE II
PHYSICAL PROPERTIES OF CONVENTIONAL AGGREGATES

Physical Properties	Coarse aggregate	Fine aggregate
Source	Margala	Lawrence pur
Particle size	½ inch down	Fine
Water absorption test (%)	0.93	0.3
Loose bulk density kg/m^3	1358.31	1579.5
Compacted bulk density kg/m^3	1555.24	1757.08
Impact value (%)	16.23	Not found
Specific gravity	2.85	2.74

B. Comparative analysis of properties of ESP and Cement

Before using ESP as cement replacement agent several comparative tests were performed. The morphology and texture of the ESP particles and cement particles were examined by field emission scanning electron microscopy (FESEM). Images of respective materials were captured at magnification of 50-X to 200-X, as shown in Fig. 1. Results were also verified by fineness test as presented in Table I.

TABLE III
AMOUNT OF OXIDES IN CEMENT AND ESP

| Oxides	Chemical Name	Cement	Eggshell powder
CaO	Calcium oxide	62.18	50.7
SiO_2	Silicon dioxide	20.65	0.09
Al_2O_3	Aluminum oxide	5.12	0.03
MgO	Magnesium oxide	2.05	0.01
Fe_2O_3	Iron oxide	3.19	0.02
Na_2O	Disodium monoxide	0.32	0.19
So_3	sulfur trioxide	1.93	0.57
P_2O_5	Phosphorus pentoxide	—	0.24
SrO	Strontium oxide	—	0.13
So_3	Sulfur trioxide	0.45	0.57
Cl	Chloride ion	0.15	0.219

Chemical examination for oxides composition of cement and ESP were determined by X-ray diffraction test followed by ASTM C 1365 [xvi]. Table III illustrates the chemical composition of ESP and ordinary Portland cement, which shows that calcium oxide (CaO) contributes about 51% in ESP which seems quite comparable with cement. ESP specimen also contained small amounts of aluminum oxide (Al_2O_3), silicon dioxide (SiO_2), iron oxide (Fe_2O_3) and sulphar trioxide (SO_3) reporting only 1.5% of total composition. These oxides are present in high quantities in cement which are conscientious for early age strength.
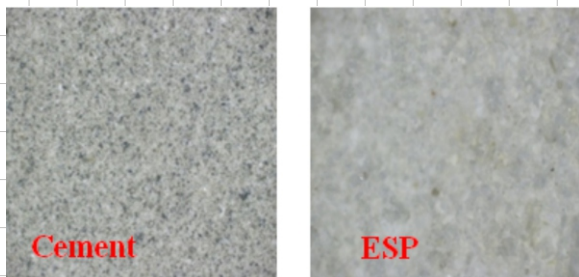
(a) 50-X magnification
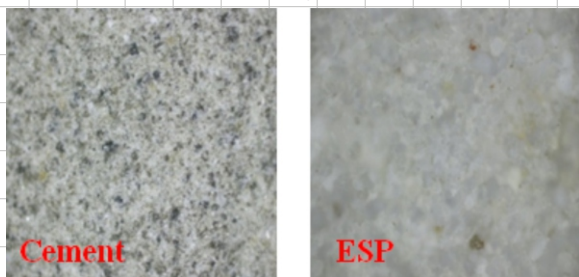
(b) 100-X magnification
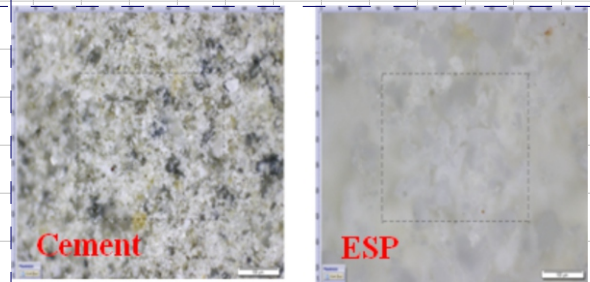
(c) 200-X magnification
Fig. 1. FESEM images of cement and ESP at different magnifications.

Fig. 2. Dry mixing of Eggshell powder

C. Mix design and casting of concrete

Ordinary Portland cement of ASTM type-I was partially replaced with ESP by an amount of 5, 10, 15 and 20% by weight. The volumetric ratio of cement: sand: aggregate used was 1:2:4. ESP was mixed in cement and sand in dry condition for 3 to 5 minutes Fig. 2. After the addition of aggregate water was added and mixed for 5 to 10 minutes. Each substitution along with the control mix were prepared with a water to binder (water/(cement + ESP)) ratio of 0.6. Five batches of concrete cubes were fabricated and were referred as: the control mixture without ESP were presented as ES-00 and ES-05, ES-10, ES-15 and ES-20 containing 5, 10, 15 and 20% of ESP, respectively. The mix proportions for each batch for one cubic meter are presented in Table IV. Twelve cubes of size 100 mm were casted for each mix design to find out compressive strength at 7, 14, 28 and 63 days. After 24 hours of casting each cube was demoulded and cured at room temperature in wet condition.

Workability of fresh concrete was measured by slump test and compacting factor test according to guidelines [xvii-xviii]. All cubes of concrete specimens were cured for 7, 14, 28 and 63 days at room temperature. The specimens were taken for testing under compression test by following ASTM C-39 [xix]. Summary of the test performed along with number of specimens used are given in Table V. All specimens were tested under uniaxial compression at different

days. Influence of curing age and influence of replacement of cement are investigated in detail and explained in following sections.

TABLE IV
MIXING PROPORTIONS FOR ALL TYPES OF CONCRETE

Materials	Specimen identification				
	ES-00	ES-05	ES-10	ES-15	ES-20
Cement (kg/m³)	529	503	476	450	423
Aggregate (kg/m³)	2116	2116	2116	2116	2116
Sand (kg/m³)	1055	1055	1055	1055	1055
Water (litter)	317	317	317	317	317
ESP (kg/m³)	0	26.5	53	79	106
Cement (kg/m³)	529	503	476	450	423

TABLE V
SUMMARY OF CONDUCTED TEST AND NUMBER OF SPECIMENS

Specimen	S.V[a]	C.F[b]	Compressive strength(days)			
			7	14	28	63
ES-00	2	1	3	3	3	3
ES-05	2	1	3	3	3	3
ES-10	2	1	3	3	3	3
ES-15	2	1	3	3	3	3
ES-20	2	1	3	3	3	3

S.V[a]= slump value; C.F[b]= compacting factor

III. RESULTS AND DISCUSSION

Test performed on fresh and hardened properties of concrete with ESP were investigated and detail discussions are given in following sub-sections.

A. Workability of concrete

Workability of all types of concrete was measured by slump test and compacting factor test. It was observed that inclusion of ESP as partial replacement of cement reduces the workability of concrete. Reduction in workability was observed with 5% ESP substitution and further decreases by increasing the amount of ESP. The specimen ES-20 confirms minimum workability among all mixtures and there was almost 100% reduction in workability as compared to standard mixture. However all mixtures countered very well to mechanical vibration and could be placed and compacted easily with fewer efforts. Comparison was made between workability and replacement amount of cement with ESP and presented in Fig. 3.

ESP particles are coarser than cement particles so by increasing the amount of ESP, the fineness of mixture decreases which reflect great impact on workability of concrete. As the fineness of concrete mix decreases workability also decreases and there occurs a gradual fall in workability of concrete with increasing amount of ESP.
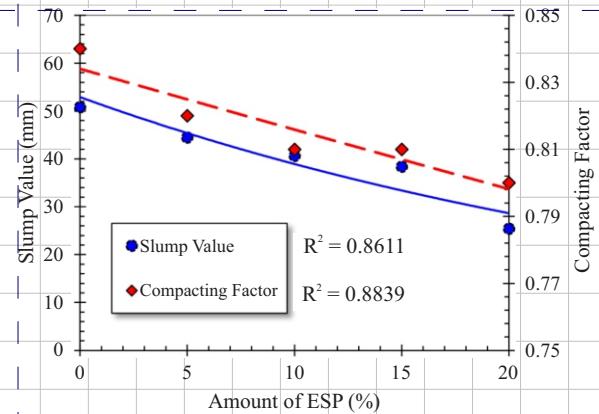

Fig. 3. Amount of ESP (%) versus workability.

B. Compressive strength of concrete
1) With Respect to Curing Age

Evaluation of the data for compressive strength at 7, 14, 28 and 63 days of curing age disclose the fact that the compressive strength of control mixture continue to increase with age. Tri-calcium silicate $(3CaSiO_2(C_3S))$ and tri-calcium aluminate $(3CaOAl_2O_3 (C_3A))$ are formed after the reaction of aluminum (Al) and SiO_2 with CaO, which are the primary motive of early age strength [xx]. The behavior of ESP concrete was quite different from the control specimen. The 7 days compressive strength of all specimens containing ESP are lesser then that of the normal concrete and this strength further decreases at the age of 14 days. However, improvement was recorded after 28 days by ES-15 as the compressive strength attains the roughly identical strength as that of control specimen and at the age of 63 days the mix depicted perfection in compressive strength results. The compressive strength boosted when 15% cement was replaced with ESP and proves superior comparative strength to control mixture. But in case of ES-20 the strength again declined as compared to control mixture.

It is crystal clear that early age compressive strength of all specimens containing ESP is less as measure up to normal concrete. For instance, adding 5%, 10% and 15% of ESP decreased the compressive strength by 33%, 32%, and 37% at 7 days from that of concrete without ESP. Consequently, mixtures ES-10 and ES-15 shows 4% and 18% enhancement in compressive strength at an age of 63 days as depicted in Fig.4. Fine cement filler particles are responsible to accelerate the hydration of concrete and subsequently increase the early strength. Cement powder had smaller particles than the eggshell powder and therefore results in high quality fineness and more surface area was available to react with water. So the coarser particle size of ESP adversely affects the early age compressive strengths of concrete, moreover Si and Al particles are present in very small quantities in ESP as compared to cement powder, generally responsible for the formation of C_3S and C_3A. The observable fact can be verified from another study [xxi]. Thus reduction in

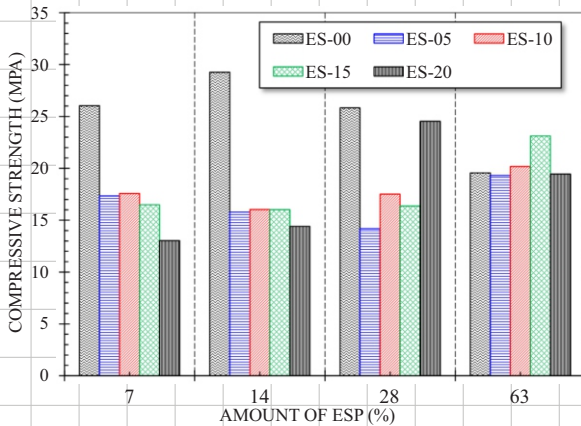strength at 7 days could be explained by this phenomenon.

Fig. 4. Comparison of compressive strength at various ages of all mixtures.

2) With Respect to Amount of ESP

To find out the optimum percentage of ESP as cement replacement agent, comparison was made between amount of ESP (x-axis) and compressive strength (y –axis) Fig. 5 and analysis were made.

Replacing the cement powder with ESP affected the compressive strength of all mixtures. It is observed from the Fig. 5 that the mixes of all proportions containing ESP show poor results of compressive strength at the age of 7 and 14 days when compared to control specimen and this reduction become more pronounced as the percentage increases. Decrease in early age compressive strength may be due to the lower amount of cementing properties of the eggshell powder and increased quantity in non-cementing materials. The reason lies in reduction of strength was explained in a recent research [xxii]. It was found that limestone cement mortar was not completely hydrated even after 28 days of curing age [xxii]. Beyond 28 days of age, it was noticed that compressive strengths of ESP incorporated mixtures are higher than that of control mixtures. The mix ES-15 confirms almost identical strength when compared to control concrete at the age of 28 days. And at 63 days the value boosted up and proves 14% increment to control mix. In case of mix ES-20 the 28 and 63 days strengths were slightly reduced as compared to control mixture. Conversely the strength was satisfactory to meet the requirements of ASTMC-39 [xix]. It is also concluded that the ratio 5and 10%of ESP showed lower compressive strength results values than control mixture and these values are not sufficient to meet the compressive strength requirement of ASTM standards of concrete. On the other hand the results are in agreement with another research which showed that up to at an age of 28 days compressive strengths of limestone−silica fume mortars were lower than that of controlled mixture. However, at later ages; 90 and 180 days, limestone-silica fume mortars showed similar compressive strength values compared to control mortar. It is believed that opposite results were recorded due to the pozzolanic effect of silica fume [xxiii].Silica fume is a highly pozzolanic material which forms additional calcium silicate hydrate by reaction with calcium hydroxide formed upon cement hydration. This results in increase in the strength of the blended cement. Since at early ages of hydration of cement sufficient amount of calcium hydroxide is not available, the early strength of blended cements is lower than that of ordinary cements. But at higher age sufficient amount of calcium hydroxide was available, which was the main reason of opposite results obtained at this age as compared to early age.
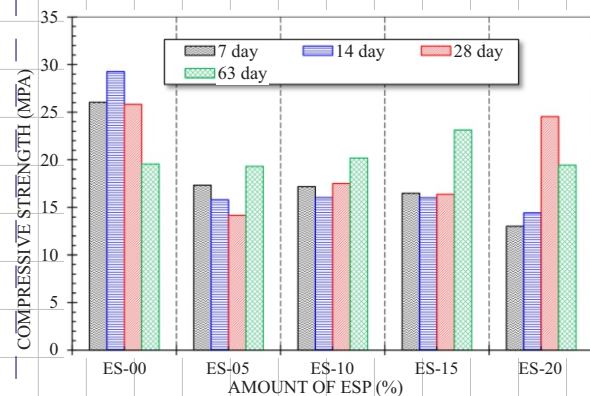
Fig. 5. Comparison of compressive strength at various amount of ESP.

3) With Respect to Normal Concrete

To make the results more clear it was necessary to compare the strength of all specimens containing ESP to the conventional concrete specimens. For this reason comparison was made between the compressive strength of percentage replacements of cement with ESP and normalized compressive strength. The comparative behavior of all mixtures with control mixture is shown in Fig. 6.

From Fig. 6, it is clear that compared to control mixture, compressive strength of concrete containing different content of eggshell powder reduced at early ages and these reductions continues with increasing ESP content. At 7 days of age the strength ratio of ES-05 was 0.69.For the same curing time, as amount of ESP were increased to 10%, the reduction was more pronounced with the strength ratio value of 0.65 and the value kept on decreasing with increasing ESP content. Similar trends were obtained for strength ratio at 14 days of curing age. As it is noticed that strength ratio through ES-05 to ES-20 concrete specimens constantly reduces with enhancement in ESP substitution content and the maximum recorded value of normalized compressive strength was 0.539 by mixture ES-05.The results recorded at 28 days of curing age were quite different from results obtained at 7 and 14 days. The maximum value evidenced by specimen ES-20 was

0.95 which demonstrates the strength of specimen at that age was almost equal to normal concrete. Beyond 28 days the results were more favorable for ESP concrete. It can be concluded that the addition of ESP improves the compressive at the age of 63 days. Strength ratio was 0.98 in case of ES-05 and superior results were observed for ES-10 and ES-15 with the recorded value of 1.03 and 1.18 respectively. The value again decreases to 0.98 in case of ES-20. It can be derived from the results that difference between compressive strength values of control mortar and ESP incorporated mixtures were generally higher at early ages compared to those at later ages. Considering the compressive strength values of concrete, the optimum percentage of eggshell powder as partial replacement of cement in concrete is 10 and 15%.
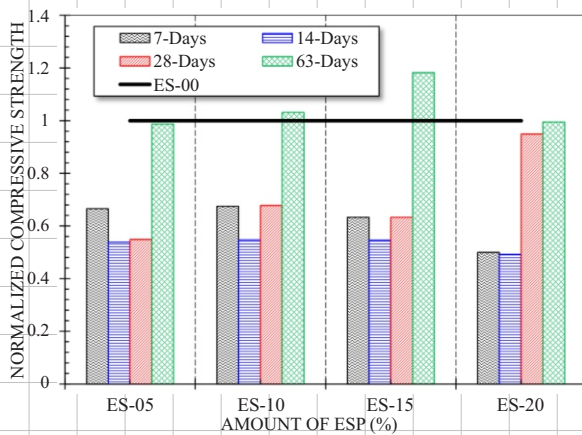

Fig. 6. Comparison of normalized compressive strength with various amount of ESP.

IV. CONCLUSIONS

Experimental investigations were conducted to determine the characteristics of normal strength concrete with 5, 10, 15 and 20% replacement of cement by eggshell powder (ESP) by weight of the cement. Workability and compressive strength were evaluated and following conclusions were extracted from entire work.

1. The workability of concrete having eggshell powder was less than conventional concrete and further reduced by increasing in the amount of ESP.
2. Particle size, quality and amount of eggshell as cement powder replacement are the major parameters affecting on the strength of concrete.
3. It was observed that gain in strength of concrete with ESP was delayed as compared to conventional concrete because ordinary Portland cement concrete had better accelerated hydration at 7 days as shown by the early strength gain as compared to ESP concrete.
4. The negative effect of eggshell powder on compressive strength of concrete was compensated up to some extent at later ages. Because beyond the age of 28 days the compressive strength observed by mix ES-15 was higher than that of control mixture (0% eggshell concrete).
5. Concrete replacing 10% and 15% of cement with ESP has the potential to be used as retarder in areas where temperature is low and early hardening of concrete causes problem.

Although eggshell based concrete (as partial replacement of cement) led to inferior compressive strength properties at early ages. Addition of eggshell powder to cement could lower the amount of cement content in concrete which reduces the CO_2 and energy consumption both related to cement production. Concrete made with ESP addition is also relatively less expensive than normal concrete. So it is recommended that projects where strength may not be the primary requirement could potentially be used provided further testing is conducted on their plastic and durability properties.

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Section B
ELECTRICAL AND ELECTRONICS ENGINEERING

A Planar UWB Antenna with Triple Notched Bands

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*Abstract-*This paper presents a rectangular planar monopole antenna with triple stop bands for ultra-wide band Applications. The antenna is compact size (24mm x 24mm x 1.6mm) and is covering the entire UWB band with VSWR < 2 except the band of WiMAX range from 3.07 — 4.73 GHz, the WLAN band range from 5.14 — 5.97 GHz and the ITU frequency band range from of 7.92 — 8.61 GHz. The three slots are added to this antenna to stop various bands. Different shaped slots i.e. inverted Z, C and U are introduced in radiating element to stop WiMAX, WLAN and ITU respectively. The antenna is simulated using High Frequency Structure Simulator (HFSS) using FR4 as a substrate.

*Keywords-*ITU band, WLAN, VSWR, WiMAX, HFSS, Ultra-wide band

I. INTRODUCTION

These days wireless communication is under consideration for researcher all over the world and advancing at a very rapid pace. Antenna is an important part of any communication system which is used as a filter/radiator; it can transmit/receive signals at certain frequencies. There is also a need of high gain antennas on both transmitter and receiver sides; in addition, multi-path environment emphasizes the use of multiple antennas. Due to continuous development in wireless communication system and the need of high data rate transmission, the use of microstrip fed printed monopole antennas (PMAs) has become popular in wireless communication systems.

Today's wireless communication is a need of human life. Mostly the electronic devices around are using wireless communication systems. Antenna is an essential part of such kind of systems, example include radars, television, spacecraft, wireless computer networks, satellite communications, and wireless phones etc. The demand of compact and low profile antennas are increasing day by day. The use of multiple antennas in wireless system like MIMO has also increased the demand of small size antennas.

The authorization of UWB band (3.1-106GHz) was given by Federal Communication Commission (FCC) USA in 2002, for commercial applications [i]. The implementation of UWB with low profile antennas has been under consideration by researchers since last decade. UWB is larger bandwidth as compared with narrowband and wideband, but UWB communication systems have interference problem with existing narrowband communication systems, the existing narrow bands are WiMAX, WLAN and ITU frequency band. These bands are stopped with the help of band-stop filter in order to reduce electromagnetic interference. However, the complexity and limitations are increased due to these filters. Therefore, the PMA with notched characteristics is required to reduce the interference, which is very simple, low profile, compact in size, easy in installation and fabrication.

The aim of the research is, to design microsrip fed rectangular planar monopole antenna which is used for UWB applications and will stop various bands such as WLAN (5.15—5.82 GHz), WiMAX (3.3—3.7 GHz) and ITU 8 GHz (8.025—8.4 GHz). Various methods and techniques are used to reduce the electromagnetic interference, these techniques are split ring resonator (SRR), electromagnetic-band gap (EBG) and complementary split ring resonator (CSSR), pair of open loop resonator, embedding T-shaped stub and pair of U-shaped parasitic strips [ii-v]. The stop bands are also achieved by etching slots in planar monopole antenna such as semi-elliptical slot, E-shaped slot, U-shaped slot, symmetrical elliptical slots, L-shaped slot, fractal shaped slot, circular slot, C-shaped slots, rectangular slot and inverted C-shaped slots [vi-xiii].

Recently various planar monopole antennas with stop bands are reported. Zhen hong et al. presented a circular shaped printed antenna with dimensions of 34mm x 35mm x 1.6mm, and stopped only two bands with the help of U shaped and C shaped slots [xiv]. Aiting Wu and Boran Guan proposed an UWB antenna with size of 32mm x 32mm x 0.508 mm and stopped dual bands [xv]. A. Chaabane et al. developed UWB printed antenna with size of 31mm x 31mm x 1.6mm and rejected two bands with the help of slots, which are etched in radiating patch and feed line [xvi]. Ronghua Shi et al. designed a UWB Antenna with size of 35.5mm x 30mm x 1.6mm, etched H shaped slot in the

radiator and narrow slots in the ground to stop the bands of WLAN and WiMAX [xvii]. Guoping Gao et al. fabricated U shaped UWB antenna with CSRR and T shaped slot to stop the bands of WiMAX and WLAN, the size of antenna is 24.6mm x 38.1mm x 1.5mm [xviii]. Manas Sarkar et al. propounded a printed antenna with size of 24mm x 34.6mm x 0.8mm, and with triple notched bands, the stop bands are achieved with the help of pair of slots and CSRR [xix]. The antennas discussed in literature have larger sizes and maximum antennas have dual notched bands.

In this paper rectangular UWB planar monopole antenna with three stop bands is presented. The stop bands are due to various slots, these slots are inverted Z, inverted C and inverted U. The inverted Z slot is used to stop the band of WiMAX, the inverted C slot is used to stop the band of WLAN and the inverted U slot is used to stop the ITU frequency band. The simulations were carried out in HFSS using FR4 as a substrate.

II. ANTENNA DESIGN

The rectangular planar monopole antenna with triple stop bands is designed by using a microstrip fed technique. The presented design is printed on a FR4 low cost dielectric substrate, with thickness of 1.6mm, loss tangent of .02 and permittivity of 4.6. The slots are added to stop various bands. The inverted Z shaped slot is used to stop the band of 3.07 — 4.73 GHz used for WiMAX applications. The inverted C shaped slot is used to stop the band of 5.14 —5.97 GHz used for WLAN applications. The inverted U shaped slot is used to stop the band of 7.92 — 8.61 GHz (ITU frequency band). After the optimization of the design and slot position, the final design is obtained which is shown in Fig. 1. Simulated VSWR is depicted in Fig. 2 and simulated S_{11} (dB) is also shown in Fig. 3. The dimensions of slots depend on notch frequency and substrate permittivity ϵr. The length of slots are half wavelength or quarter wavelength at notch frequency. The length of slots are determined from the equations (1) and (2) [xx].

$$Ls = c/(4f_n \, \varepsilon_c) \qquad (1)$$

or

$$Ls = c/(2f_n \, \varepsilon_c) \qquad (2)$$

Where L_{s1} is the inverted Z slot length (mm), L_{s2} is the inverted C slot length (mm), L_{s3} is the inverted U slot length (mm), c is the light speed (3×10^8 m/s) and f_n is the notch frequency (GHz) and ε_r is a unit-less constant known as relative dielectric constant of the material.

The dimensions of design are 24mm x 24mm x 1.6mm. The dimension of inverted Z shaped slot is 14.8mm x 0.4mm. The dimension of inverted C shaped

slot is 19.6mm x 0.3mm. The dimension of inverted U shaped slot is 10.8mm x 0.2mm. The crucial part of the design is the gap between radiator and ground, which is 0.4mm. Various Table I summarizes various design parameters.
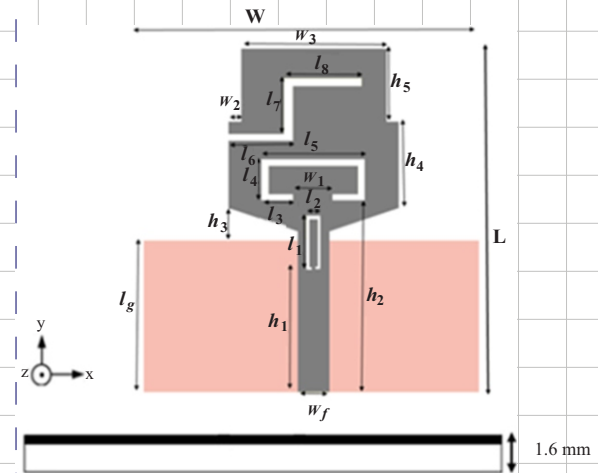

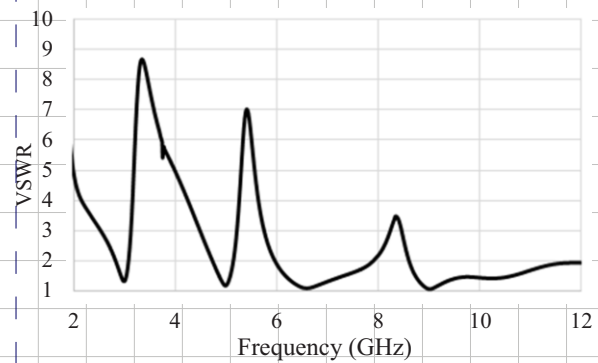Fig. 1. Design of the proposed triple stop bands Antenna

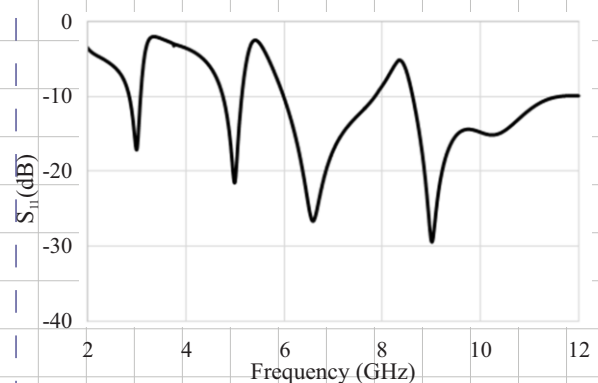Fig. 2. Simulated VSWR of the proposed antenna with triple stop bands.

Fig. 3. Simulated S11(dB) of the proposed antenna with triple stop bands

TABLE I
DESIGN PARAMETERS OF THE ANTENNA

Parameter	Value (mm)	Parameter	Value (mm)
L	24	l_g	10.7
W	24	h_1	7.8
l_1	4.6	h_2	13.2
l_2	1.2	h_3	2.1
l_3	3.1	h_4	6.1
l_4	2.7	h_5	5.1
l_5	8	w_1	1.8
l_6	4.4	w_2	0.9
l_7	4.5	w_{13}	10.2
l_8	5.9	w_f	2.2

III. RESULTS AND DISCUSSION

The antenna is resonating in the entire range of UWB band with VSWR < 2 except the band of WiMAX range from 3.07 — 4.73 GHz, the WLAN band range from 5.14 — 5.97 GHz and the ITU frequency band range from of 7.92 — 8.61 GHz, which is justified from Fig. 2. Fig. 4 shows the gain of the antenna. The gain at stop frequencies are -12 dBi, -5 dBi and -5 dBi respectively, which is very poor as compared with other frequencies. Similarly, the radiation efficiency is poor at notched frequencies which is shown in Fig. 5. The radiation patterns at various frequencies are illustrated in Fig. 6. The solid line represents E-plane (phi = 00) and dash line represents H-plane (phi = 900) radiation pattern, which is nearly omnidirectional.

The front and back view of the fabricated design is shown in Fig. 7. The measured and simulated VSWR are given in Fig. 8. & Fig. 9 shows simulated vs measured coefficient. From the result, a slight shift in notched frequencies is noted, it may be due to fabrication errors or due to connector losses. In the measured results antenna is resonate from 2.90 GHz to 11 GHz, the stop band of 7.92 — 8.61 GHz (ITU frequency band) is shifted to 7.92 — 9 GHz, the stop band of 5.14 — 5.97 GHz is shifted to 5.15 — 6.05 GHz, the stop band of 3.07 — 4.73 GHz is not shifted.
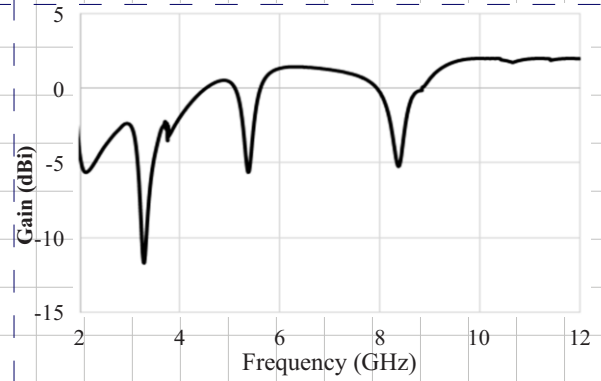
Fig. 4. Gain Distribution of the proposed antenna
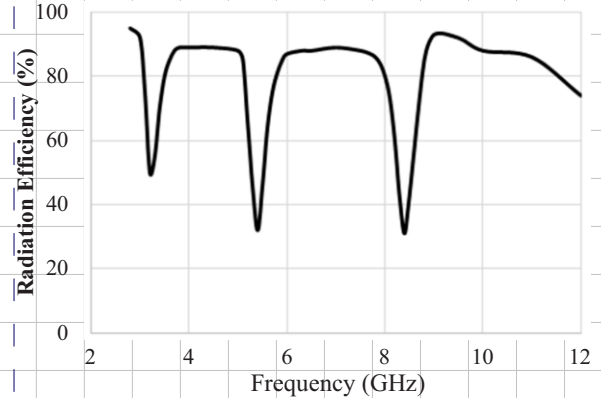
Fig. 5. Radiation efficiency plot

(a)
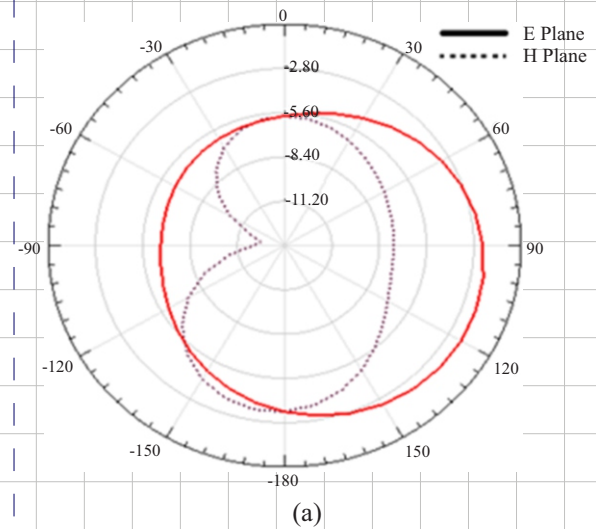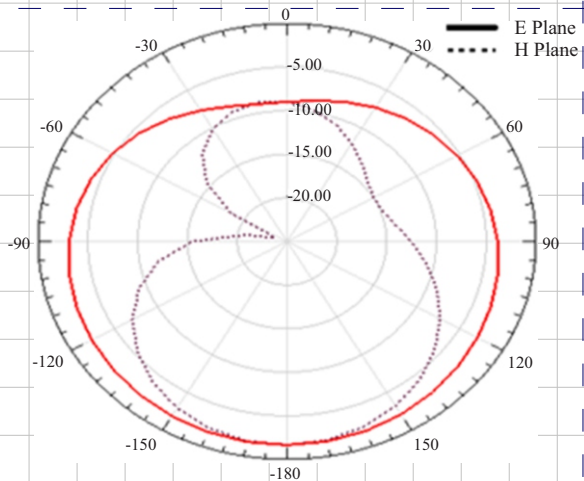
(b)
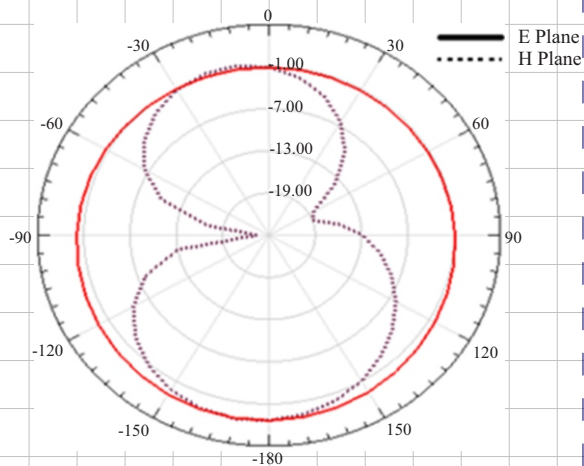
(c)
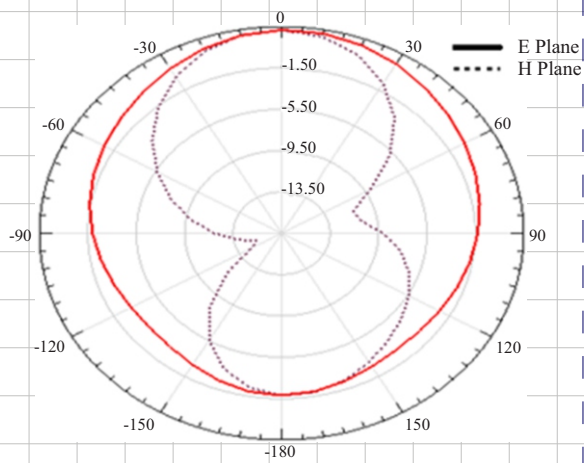
(d)

Fig. 6. Radiation patterns of proposed antenna with triple stop bands (a) 3.2 GHz (b) 5.5 GHz (c) 6 GHz (d) 8.2 Ghz
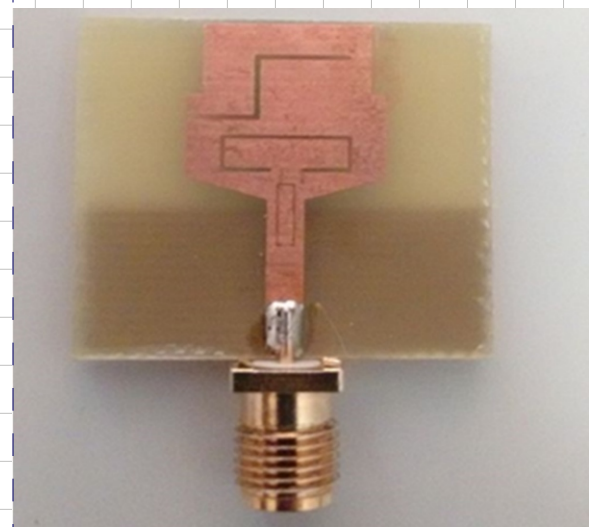
Fig. 7. Fabricated image of proposed antenna with triple stop bands: Front View and Back View
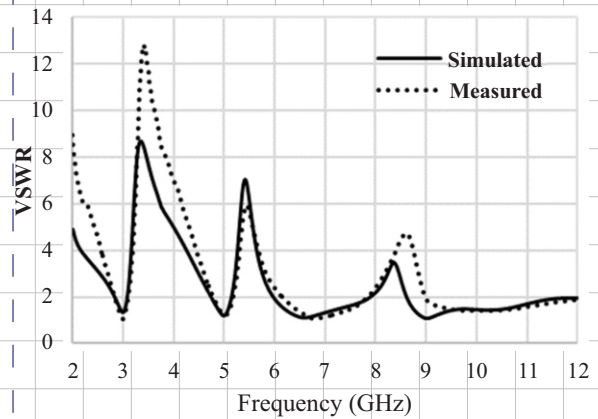
Fig. 8. Comparison between measured and simulated VSWR of proposed antenna with triple stop bands
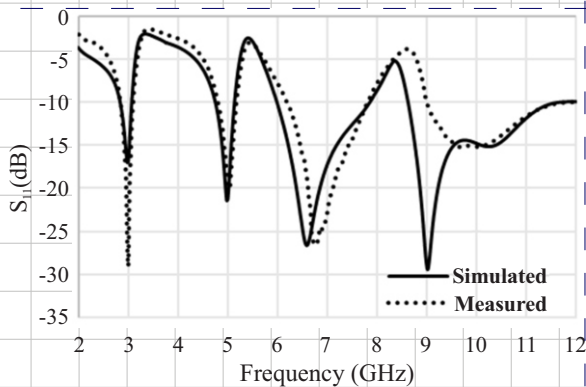
Fig. 9. Comparison between measured vs simulated S$_{11}$ (dB) of proposed antenna with triple stop bands

IV. CONCLUSION

In this paper, rectangular planar monopole antenna with triple stop bands is presented for UWB applications. Antenna is resonating from 2.90 GHz to 12 GHz. Inverted Z, inverted C and inverted U shaped slots are used to stop the bands of WiMAX, WLAN and ITU 8 GHz. The proposed design is simulated and tested in ANSYS HFSS, the design is also fabricated and measured. The small size, simple structure and easy integration and fabrication, are some of the key characteristics of this antenna.

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Enhanced Performance of Two Phase PMSM and Univariate Non-Stationary Growth Models Through Statistically Linearized Kalman Filter

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*Abstract-*Traditional schemes of non-linear estimation includes extended Kalman filter (EKF). However due to several shortcomings caused by Jacobian linearization the usage of EKF is problematic. To avoid the problems linked with Jacobian linearization, this paper presents Kalman filtering technique based on statistically linearization. The derivation of this nonlinear estimation scheme has been achieved by steps similar to standard Kalman filter (KF) techniques. The system is linearized through statistical linearization rather than Taylor series. This statistically linearization is implemented to obtain the state of two important models, namely two phase permanent magnet synchronous motor (PMSM) and univariate non stationary growth model. It has been shown that the schemes has generated improved performance than EKF. Various performance indeces have been shown for performance comparison. Results obtained through two estimation techniques are compared with the actual state values. The results obtained through proposed scheme are significantly improved compared to the results obtained for existing schemes. In consequence, the error linked with proposed estimation techniques has been greatly minimized through the use of statistically linearized KF.

*Keywords-*Nonlinear Filter, Extended Kalman Filter, Statistical Linearization, Global Approximation, Jacobian Matrix, Taylor Series.

I. INTRODUCTION

The process of filtering and estimation has remained one of the most investigated phenomenon in numerous engineering applications. For example, a standard Gaussian noise may corrupt the health and quality of radio communication signals in various perspectives. An efficient and robust algorithm would be the one that could retain information while discarding the unwanted signal. A notable example is UPS (Uninterruptible Power Supply) which are designed to rectify line-voltage for smoothing purposes. These removed fluctuations might hinder the performance of equipment and affect the life span of connected devices. In this connection. Kalman filter is a well-known, abundantly employed and an established optimal estimator for linear system. Kalman filter has the beauty that it can handle both transition and measurement system noises [i]. The propagation of Gaussianity via system dynamics is the central operational point of KF.

The development of Kalman filter has modernized the field of estimation, and has a massive impact on the design and development of accurate navigation systems [i]. It has been used in almost all modern control and communication systems, both military and space technology such as in inertial guidance systems in aircraft [ii], missile autopilots, submarines, phased-array radars to track missiles, the Global Positioning System(GPS) [iii], the space shuttle, rockets [iv] and in separating the speech signals under additive white Gaussian noise channel [v].

However, in majority of applications, the system under observation is nonlinear. Hence filtering schemes were immediately modified to cope the situations including nonlinearity. In modern era, nonlinear filtering and estimation have been a subject of active research such as signal processing, navigation, control, target tracking, neural network training and majority of electrical/electromechanical systems [vi-viii].

For handling nonlinear functions nonlinear estimation tools including the extended Kalman filter (EKF) [ix-x] and unscented Kalman filter (UKF) [xi] are widely used. Generally speaking, in estimation theory EKF may be called the nonlinear adaptation of the linear KF as it linearizes a nonlinear function of the system model around the current state estimate. In this nonlinear estimation scheme, the predicted state is approximated through a GRV that propagate analytically through first order Taylor series. Since EKF employs a posterior mean and covariance entities so it may lead to sub-optimal results. This may cause divergence of filter ultimately. Proposed work in this article that is statistically linearized Kalman filter (SLKF) deal with the mentioned problem resulting optimal estimation. Another dilemma associated with EKF is that, numerical Jacobians are required in the

absence of analytical Jacobians. As in linearization of the nonlinear system EKF uses first order Taylor series so it encounters issues with both accuracy and stability.In contrast to this SLKF uses statistical linearization which avoids majority of problems related to first order Taylor series. In addition to this EKF also needs complex evaluation of Jacobian matrices of the nonlinear system dynamics and measurement functions which are not required in SLKF. Another drawback of EKF is that it fails in some cases, where Jacobian matrices of measurement functions become zeros [xii-xiii], while SLKF has the ability to estimate in such cases.

UKF is a derivative free alternative to EKF and is proposed by Julier and Uhlman [xiv-xv], addresses these problems by using deterministic sampling approach. The approximation process of state. The approximation process of state distribution is repeated through GRV which is depicted by a minimal set of carefully selected points called sigma points [xvi]. Sigma points convey the actual mean and covariance of the associated GRV. These points when proliferated through any nonlinear system, conquers the subsequent mean and covariance exactly to 3rd order (Taylor series expansion) for any nonlinear system.

On the other hand, EKF, only provides 1st order Taylor series accuracy. In this regards, UKF has superior performance in comparison to linear Kalman filter and EKF [xiii], as it does not need of evaluation of Jacobian matrices [xvii]. The proposed work completely avoids Taylor series and hence there is no complexity of evaluation of Jacobian matrices

The EKF linearizes a nonlinear function in the vicinity of current state estimate and consequently the state theoretically preserves its Gaussianity in course of the whole time interval. On the other hand, UKF approximates expectation and covariance matrix of the nonlinearly transformed state which creates non Gaussian distribution of the state. Since the Gaussianity can be manipulated in designing the optimal filter so EKF is effective. However, UKF provide improved state estimation than EKF using unscented transformation techniques. Approaches where state Gaussianity is needed UKF are not applicable. For this reason, statistical linearization (SL) technique is proposed which is expected to be superior in managing the nonlinear functions over the Taylor series truncation approach of the EKF.

The paper is presented as follow: Section II declares the problem statement and some shortcomings of EKF and UKF. This section also include the proposed solution and familiarizes some necessary work about statistical linearization and statistically linearized Kalman filter (SLKF). In section IV two case studiesnamely two PMSM and univariate non-stationary growth model are implemented and states are estimated using EKF and SLKF. In section V a conclusion is drawn and the performance of the two

models using EKF and SLKF are discussed.

II. PROBLEM FORMULATION

In this paper, the estimation problem associated with Extended Kalman filter, (where Taylor series is employed for linearization of the non-linear function)has been address. This issue is solved using the statistical approach of linearization which is equally applicable to both linear systems and as well as nonlinear systems. The EKF is often considered to be an excessively complex algorithm, which is difficult to implement as it requires huge computational efforts. Unusually computational complexity of UKF' and EKF is of the same order [xiv]. In EKF, 1st order Taylor series is used for linearization of the nonlinear functions, and has some serious limitations [xii-xiii, xviii] as listed below.

- EKF uses 1st order Taylor series for linearization of the nonlinear system so it encounters issues with both accuracy and stability.
- Secondly, the EKF gives poor estimation in case of highly nonlinear systems.
- Third limitation is to calculate complicated Jacobian matrices of the nonlinear system and measurement functions.

It fails in cases where Jacobian matrices of measurement functions are not of full rank.

In order to avoid these limitations of EKF and to obtain a better state estimation of a system, in this paper an improved nonlinear Kalman filter called equivalent linearization Kalman filter (EqKF) is proposed. Since the approach adopted in this proposed scheme is based on statistical linearization, it can also be called Statistical-Linearized KF or SLKF [xiv]. The EqKF or SLKF is presented as an alternative to EKF and UKF. The statistical linearization approach was developed by Kazakov, et al [xx], Caughey, et al [xxi] and others have improved and analyzed various nonlinear stochastic dynamic systems.

This research paper attempts to implement the SLKF for the case study of two phase PMSM and to avoid the limitations associated with EKF. In order to show that the proposed SLKF algorithm covers the limitations of highly nonlinear system, another case study -- the univariant non-stationary growth model, a highly nonlinear system has been tested to compare the performances.

Linearization procedure is discussed in the next section.

A. Statistical linearization for Gaussian approximation

There are two ways, where a nonlinear system can be linearized: statistical linearization and unscented transformation. The later one is adopted in Unscented Kalman filtering. The unscented linearization varies from system to system as it is not a series based method and is a complicated technique [xxii]. For such reasons, in this paper we are considering statistical linearization.

In this section, a brief mathematical review of statistical (or equivalent) linearization for nonlinear function is given. Let $x \in R^n$ be a Gaussian random vector with mean $m_x \in R^n$ and covariance matrix $P \in R^{n \times n}$. Let a nonlinear function be $y = h(\mathrm{x}) : R^n \to R^p$. We derive a linear unbiased minimum variance estimate y-hat of y as shown in Fig. 1:
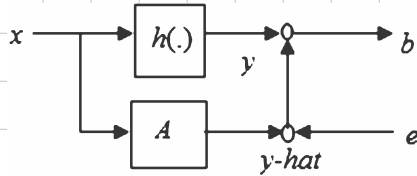

Fig. 1.

Let $\hat{y} = b + Ax$, where $A \in R^{p \times n}$, $b \in R^p$ then the unbiasedness of $\hat{y}$ implies that $E[y - Ax - b] = 0$, so that $b = m_y - Am_x$, where $m_y = E[y] = E[(x)]$.

Let $x \sim N(m,p)$ and $y = h(x)$, then linear approximation is: $h(x) \approx b + A\delta +$, where $\delta x = x - m$ and m is mean value of x.

The basic purpose of this method of linearization is to replace the nonlinear components in a model by linear forms where the coefficients of linearization can be set up centered on a particularized criterion of linearization. The coefficients of linearization are chosen in such a way that the error in the approximation method becomes a minimum. The mean squared error can be minimized as follows without using Taylor series [xxii]:

$$MSE(b, A) = E[h(x)] - E[(h(x) - b - A\delta x)^T$$
$$(h(x) - b - A\delta x)] \qquad (1)$$

Expounding the MSE expression results in:

$$MSE(b, A) = E[h^T(x)h(x) - 2h^T(x)b$$
$$- 2h^T(x)A\delta x + b^T b - 2b^T A\delta x + \delta x^T A\delta x \qquad (2)$$

The values of A and b are found in such a manner that minimize the mean square error.

$$\frac{\partial MSE(b, A)}{\partial b} = -2E[h(x)] + 2b \qquad (3)$$

$$\frac{\partial MSE(b, A)}{\partial A} = -2E[h(x)\delta x^T] + 2AP \qquad (4)$$

Equating the derivatives in equations (3) and (4) equal to zero yields:

$$b = E[h(x)] \qquad (5)$$
$$A = E[h(x)\delta x^T]P^{-1} \qquad (6)$$

The values in Eq. 5 and 6 will yield minimum possible error. Now if the covariance of x is P and A is a known matrix then covariance of $h(x)$ is given by:

$$Cov[h(x)] \approx APA^t = E[h(x)\delta x^T]P^{-1}$$
$$E[h(x)\delta x^T]^T \qquad (7)$$

Equation (7) can be obtained simply by substitution of Eq. (6).

In case of joint distribution of x and $y = h(x) + q$ where $x \sim N(m,p)$ and $q \sim N(0,Q)$, the statistically linearized Gaussian approximation is given as:

$$\begin{pmatrix} x \\ y \end{pmatrix} \sim N\left(\begin{bmatrix} m \\ \mu_s \end{bmatrix}, \begin{bmatrix} P & C_S \\ C_S^T & S_S \end{bmatrix} \right) \qquad (8)$$

where $\mu_s = E[h(x)]$ \qquad (9)

and C_s is given by:
$$C_s = A^t = E[h(x)\delta x^T]^T \qquad (10)$$

which is the mean of $h(x)$.

$$S_s = Cov[h(x)] + Q = E[h(x)\delta x^T]P^{-1}E[h(x)\delta x^T]^T + Q \qquad (11)$$

In Eq. (11) Q is the covariance matrix.

Now it will be shown that the linearization used in EKF is local method while the linearization used in SLKF is global method. There are two schemes for linear approximation of a nonlinear function $[h(x)]$, in which one is local approximation, i.e.

$$h(x) \cong h(m) + \left[\frac{\partial h(x)}{\partial x} \right]_{x=m} (x - m) \qquad (12)$$

and the other is global approximation:

$$h(x) \cong E\{h(x)\} + E\left\{ \frac{\partial h(x)}{\partial x} \right\}(x - m) \qquad (13a)$$

$$= E\{g(x)\} + \frac{\partial}{\partial m} E\{g(x)\}(x - m) \qquad (13b)$$

It is well recognized that the EKF is derived by means of local approximation of Eq. (12), whereas the SLKF is derived by mean of global approximation of Eq. (13).

B. Statistically Linearized Kalman Filter (SLKF)

In this paper, it is shown that employing SLKF gives better estimation compare to the existing EKF scheme. A numerical model of a two-phase permanent magnet synchronous motor (PMSM) is considered for evaluating the performance of both schemes. First order linearization of EKF is a local method as it is derived using a local approximation while statistical linearization of SLKF is a global method because it is derived by using a global approximation. Similar to standard KF, the SLKF works in two steps given below [xxv]:

Prediction expectations with respect to $x_{K-1} \sim N$ (m_{K-1}, P_{K-1}) is given by:

$$\overline{m}_k = E[h(x_{k-1})] \qquad (14)$$

where 'm' is mean value of vector and 'P' is error covariance. The covariance matrix is based on prediction as follow:

$$\overline{P_k} = E[h(\overline{x_{k-1}})\delta\overline{x}_{k-1}]P_{k-1}^{-1}E[h(\overline{x_{k-1}})]\delta\overline{x}_{k-1}^{T}]^{t} + Q_{k-1} \quad (15)$$

where Q is the covariance matrix.

Update (expectations w.r.t. $x_k \sim N(\overline{m}_k, \overline{p}_k)$)

$$v_k = y_k - E[h(x_k)] \quad (16)$$

In equation (16) v_k is residual and y_k is the output.

$$S_k = E[h(x_k)\delta x_k^T](\overline{P_k})^{-1} E[h(x_k)\delta x_k^T]^T + R_k \quad (17)$$

where S_k is the residual covariance used in updated step as shown below:

$$K_k = E[h(x_k)\delta x_k^T]^T S_k^{-1} \quad (18)$$

$$m_k = \overline{m}_k + K_k v_k \quad (19)$$

$$P_k = \overline{P}_k - K_k S_k K_k^T \quad (20)$$

The SLKF scheme is claimed to avoid the limitations associated with EKF by approximating the Jacobian matrix of the system in a broader region centered at the state of the system. This type of methodology also has the advantage that it does not need the differentiability or continuity of the system and observation dynamics models. In view of the fact, it is not indispensable to calculate Jacobian matrices. These methods can offer benefits in terms of computational competence. However, the complete and honest analysis reveals a drawback that SLKF necessitates the nonlinear functions to be given in the closed form. In order to watch the performance of proposed SLKF, two case studies are tested in the subsequent section.

III. NUMERICAL MODEL

In this research work, two case studies are considered for implementation of EKF and SLKF algorithms. The first case study is a nonlinear system of two phase PMSM and the other case study is a highly nonlinear system of univariant non-stationary growth model. From the first case study, it has been revealed that under same conditions for the a system model, the SLKF algorithm gives better performance in various indexes as compared to EKF algorithm. Also, the proposed SLKF avoids the other limitations faced by EKF. A comparatively efficient estimation (in term of absolute error) can be achieved using proposed SLKF. In the second case study, it will be shown that the SLKF also gives better performance for a highly nonlinear system compared to EKF.

A. Two Phase PMSM.

State estimation of two-phase PMSM system is of greater concern because for regulation of control mechanism, knowledge of the states is of prior importance. It is supposed that currents of the motor windings (primary and secondary) are measured. The basic purpose is to implement EKF and SLKF for the stated case study. The electromechanical system of two-phase PMSM is given by the following equations [ix, xxi, xxiii].

$$\dot{I}_a = \frac{-R}{L}I_a + \frac{w\lambda}{L}\sin\theta + \frac{u_a + \Delta u_a}{L} \quad (21)$$

$$\dot{I}_b = \frac{-R}{L}I_b + \frac{w\lambda}{L}\cos\theta + \frac{u_b + \Delta u_b}{L} \quad (22)$$

$$\dot{\omega} = \frac{-3\lambda}{2j}I_a\sin\theta + \frac{3\lambda}{2j}I_b\cos\theta - \frac{F\omega}{j} + \Delta\alpha \quad (23)$$

$$\dot{\theta} = \omega \quad (24)$$

$$y = \begin{bmatrix} I_a \\ I_b \end{bmatrix} + \begin{bmatrix} v_a \\ v_b \end{bmatrix} \quad (25)$$

- The variables in the above equations are defined as give below:
- I_a is current in primary winding and I_b is current in secondary winding of the motor.
- θ is the angular position and ω is the angular velocity of the rotor.
- L represents inductance and R represents resistance of the motor windings.
- λ represents flux linkage constant.
- F symbolizes the coefficient of viscous friction which is acting on the motor shaft and the load attach to it.
- J represents moment of inertia of the shaft of the motor and its load
- μ_a and μ_b symbolizes the applied voltages across the two windings of the motor.
- $\Delta\mu_a$ is the noise terminus in μ_a and $\Delta\mu_b$ is the
- noise terminus in μ_b
- $\Delta\omega$ is a noise terminus because of uncertainty in the torque of the load
- y is the measurement.

Assume that measurements i.e. motor's windings currents are achieved through sense resistors only. In such case, measurements are degraded by measurement noise v_a and v_b, caused by quantities like electrical noise, uncertainty in sense resistance, and errors as a result of quantization in microcontroller.

The four states linked with the above system are

$$x = \begin{bmatrix} I_a \\ I_b \\ \omega \\ \theta \end{bmatrix} = \begin{bmatrix} x_{k1} \\ x_{k2} \\ x_{k3} \\ x_{k4} \end{bmatrix}$$

Initially, EKF is employed to estimate the states. Thereafter, for performance evaluation SLKF is also employed for the same case study. Simulation results are shown in the following Figures
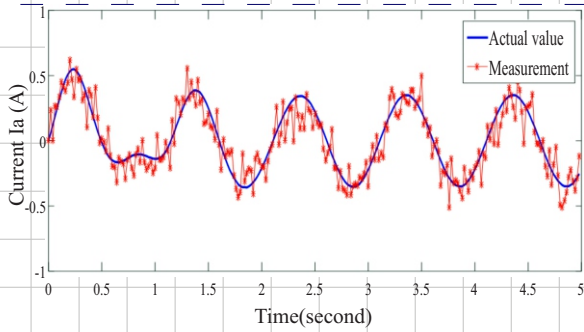
Fig. 2. Actual and noisy measurement current value for first winding of the two-phase PMSM.
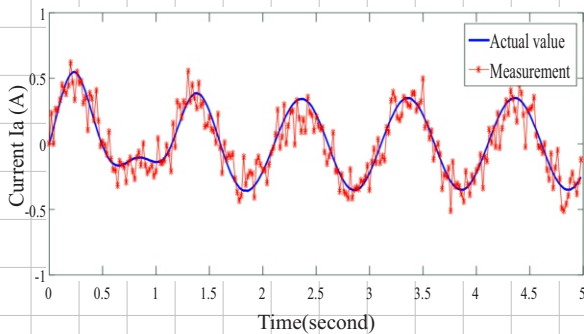
Fig. 3. Actual and noisy measurement current value for second winding of the two-phase PMSM (Measurement of winding currents are prevailed once per millisecond).

Figures 2 and 3 represent the actual and noisy data of the two winding currents wherein the continuous line (in blue color) shows the actual state and dot-marked (red) line represents the measured data. As shown in the Figures the measured data is interrupted by noise. Although the measurements comprise only winding currents but we will use EKF and SLKF for estimation of other states as well (i.e. position and velocity of the rotor) associated with the case study. These states are estimated as shown in the subsequent results.
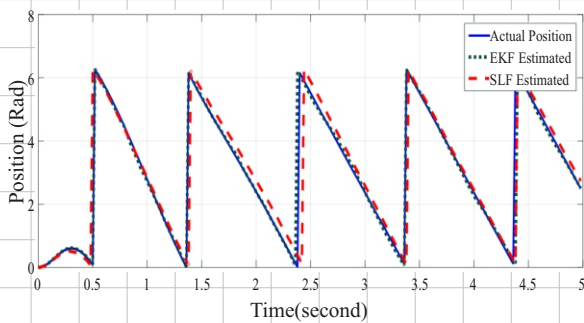
Fig. 4. EKF and SLKF Estimated position of the rotor of a two-phase PMS
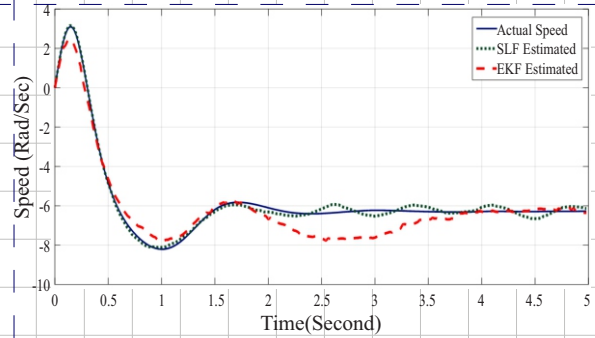
Fig. 5. EKF and SLKF Estimated position of the rotor of a two-phase PMSM
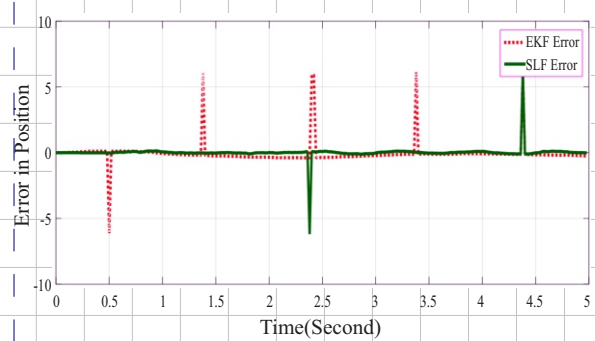
Fig. 6-A. Error analysis in the position state

Figures 4 and 5 show the estimation results for EKF and SLKF for the position and speed of the two-phase motor. These Figures show the actual states and estimated states generated by both EKF and SLKF. In the figures continuous line shows the actual states, dashed lines represents estimation by EKF and dotted line shows estimation by SLKF. The estimation results of the two schemes (dashed and dotted lines) are compared with the actual value (continuous line). It can be seen that the proposed model based on SLKF tracks the actual state much better than that of EKF algorithm.
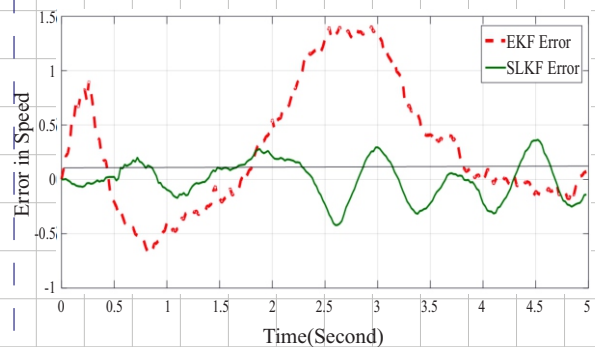
Fig. 6-B. EKF and SLKF Error results for two-phase PMSM
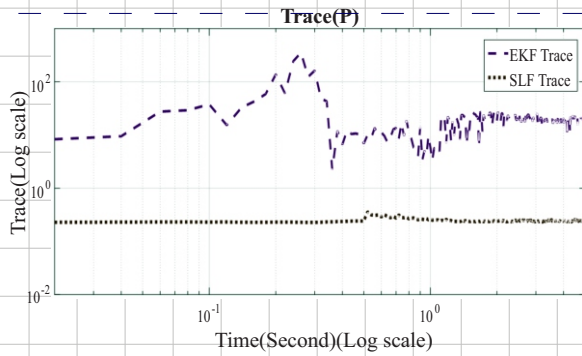
Fig. 7. EKF and SLKF Trace results

Another view of the performances of the proposed filter and existing EKF can be seen in Figures 6-A and 6-B. This figure reveals the corresponding errors signal resulted by the two algorithms under-consideration. Frequent spikes and large error can be observed in the existing EKF algorithm. However, in the results obtained for SLF, the error is quite improved by reducing its values.

Similarly, Figure 7 which is actually the trace or error covariance shows that the sum of square of errors of SLKF is much smaller compared to EKF, in estimating the states of a two phase PMSM. From Figures 6-A, 6-B and 7, the improvement made through proposed model is 12.34% approximately compared to the existing EKF scheme.

The results shown in this section justifies the enhanced performance of proposed SLKF over the exiting EKF. The system discussed in this section is not so highly nonlinear system. In order to testify the performance of the proposed scheme for a highly nonlinear system, another case study, which is univariate non-stationary growth model is considered.

A.   Univariate Non-Stationary Growth Mode.
In order to further evaluate the scope of this work, a highly nonlinear system has been taken into consideration. Non-stationary model can occur in many ways such as non-constant means, non-constant variances and seasonal models, etc. Seasonal series can be described by a strong serial correlation at the seasonal retardation. Univariate non-stationary growth model has been used extensively in literature to authenticate the performance of nonlinear filters because of its excessive nonlinearity and popularity in econometrics [xxv]. Nonlinear process and measurement equations of this case study can be formulated as [xxiv]

$$= 0.5x_{k-1} + 10\frac{x_{k-1}}{1 + x_{k-1}^2} + 8\cos(1.2k) + w_{k-1} \quad (27)$$

$$z_k = \frac{xk^3}{20} + v_k \quad (28)$$

Where $x_0 = 0.1$ is the initial actual state, $\hat{x}_{0|0} = 0$ is

the initial estimated state, $P_{0|0} = 1$ is the gibing initial estimate error variance, W_k is the process noise, and V_k is the measurement noise. Both the noises are assumed to be uncorrelated zero mean Gaussian white process with $Q_k = 10$ and $R_k = 100$. Simulation time is taken to be T = 10(years). The model under consideration is actually seasonal model of artificially generated monthly data. Implementing EKF and SLKF for univariate non-stationary growth model the results obtained are given below:
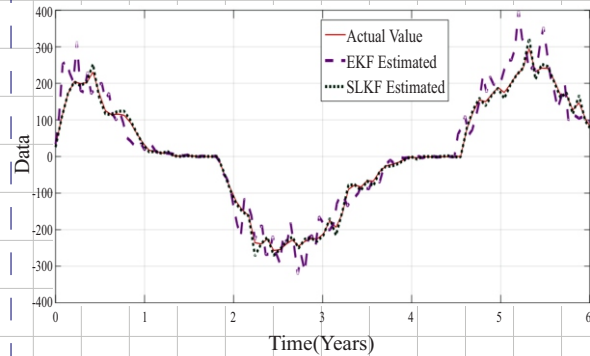
Fig. 8. EKF and SLKF Estimated states for a univariate non-stationary growth model.

Fig. 8 depicts the performance of the two mentioned techniques namely extended Kalman filter (EKF) and statistically linearized Kalman filter (SLKF). Estimation results obtained through both techniques are compared with the actual value as a reference signal. In this Fig. continuous line shows the actual state, dotted line represents the estimated state by SLKF and dashed line shows the estimation by EKF. The result obtained through SLKF scheme is significantly closer to the actual value compared to the results obtained from EKF. Fig. 9 reveals the performance of SLKF and EKF in the index of absolute error signal.
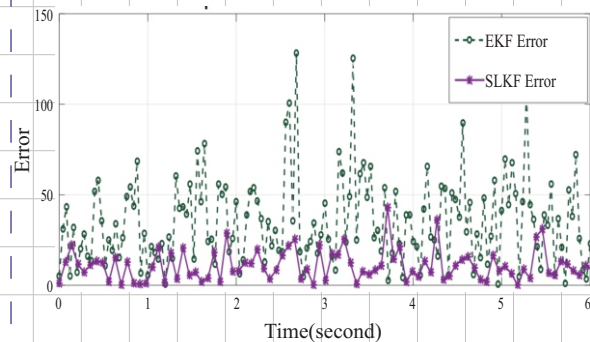

Fig. 9. EKF and SLKF error results for a univariate non-stationary growth model.

It can be seen that the results achieved through SLKF method (Dotted line) have smaller error than the results obtained through EKF technique, which

manifest superior performance of SLKF. A Monto-Carlo of 1000-run reveals an estimated error of 1.92% for the proposed scheme while for the EKF 5.43%. It shows that the proposed model has reduced more than three (03) fold error compared to the existing one.

IV. Conclusion

In this paper, implementation of statistically linearized Kalman Filter for two case studies namely two phase permanent magnet synchronous motor and the generalized univariant non-stationary growth model is presented. The core purpose of this paper was to avoid the shortcomings associated with standard extended Kalman filter, especially in dealing highly nonlinear systems. Efforts were made to take maximum feature of the mentioned two schemes of estimation into account. The simulation results have shown an enhanced performance of SLKF compare to EKF. Error in estimation of SLKF is much lesser than EKF and also the Trace for the SLKF is much better than EKF. It is also obvious from simulation results that the SLKF gives better performance for highly nonlinear system than EKF. Finally, it has been brought to a conclusion that instead of using EKF for estimation of a system's states, one can get better performance using SLKF.

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Section C

MECHANICAL, INDUSTRIAL, MATERIAL, ENERGY ENGINEERING, AND ENGINEERING MANAGEMENT

Investigation and Design of Undershot Hydrostatic Pressure Converter for the Exploitation of Very Low Head Hydropower Potential in Pakistan

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*Abstract-*In this paper, different types of zero head or run of the river scheme micro hydro turbines with their design methodologies have been discussed. These are considered to be ideal for hydropower production with very low head (VLH) differences between 0.5 and 5 m. Punjab has a total low-head hydel potential of 600-1000 MW on canals and barrages. Already developed technologies are much costly and are suitable for large potential sites only. For sites with low potential need is to develop a novel technology that can be manufactured locally to use this potential. These small resources, if exploited efficiently, can contribute to overcome the short fall of electricity in rural areas of the province of Punjab. A design of Undershot Hydrostatic Pressure Converter (U-HPC) for a specific site in Punjab has been also been presented.

*Keywords-*Hydrostatic Pressure Converters, Hydropower, Micro Power Plants, Very Low Head

I. INTRODUCTION

Hydropower is a renewable, non-polluting and environmentally benign source of energy. Pakistan is rich in both large and small hydropower resources. The electrification access in Pakistan was 62.4% in 2009, leaving more than 63.8 million inhabitants without access to electricity. Electricity consumption per capita is estimated at 465 kWh per year. Whole country is facing severe energy crisis. Within these conditions, small hydropower plants with locally manufactured turbine technologies can contribute a large to improve the current situation.

The hydropower is categorized in some divisions. Power ranging upto 10 KW is considered as Pico Hydro Power and from 10 KW to 300 KW is considered as Micro Hydro Power. [i]

Various techniques have been developed to harness the energy of flowing water. In 18th century, to extract water energy water wheels were used. [ii] Finally the advancement in the water wheel desoign brought the new projects like Poncelet and Zupinger water machines [iii]. The water wheels have 33 to 66 percent cost of the conventional turbines [iv]. Overshot water wheels are recommended for 2.5 to 10 m water fall, Breastshot water wheel for 1.5 to 4 m and Zuppinger water wheel from 0.5 to 2.5 m water fall. [v].

Middle shot water wheels with high filling ratios and large cells show low revolution per minute in comparison to the wheels with low filling ratios and smaller cells. The efficiencies of such type of water wheel ranges up to 85 percent [vi]. A. U. R. water turbine is after name of its inventor Aliter Ure Reidand was patented after his name in 1975. The details of the design of this engine was published with the design of new technology known as Salford Transverse Oscillator [vii]. Archimedes Screw is a used to uplift water from lower level to upper level and using this concept in reverse a technology was developed to produce power and is known as Archimedes Screw 287BC-212BC [viii]. A submerged type of the turbine is known as Sundermann turbine. This turbine is suitable for unilateral flow direction. This machine is designed by an Austrian engineer. The high velocity by the specific path at the mid of the vortex produced is used by a router mounted at the middle of vortex. Efficiency upto 50% has been shown by a prototype constructed. Due to fixed shrouds inside the machine itself and other specific arrangements make the technology known as Aqualienne to have filling ratio of one. The efficiency of such machine has been claimed up to 80 percent and range of head is among 1-5. Salford Transverse Oscillator is application of positive displacement machine for the scenario of run of the river [viii]. Staudruck machine is the machine for which initial design was with some defects and were removed by the later design known as rotary hydrostatic pressure machine. Marcel K and Wright

investigated a non-rotating very low head water turbine and compared the results with a rotating hydel turbine with same size. They found that non-rotating turbines may be a good option for initial exhibiting and optimization of very low head turbine implementation in future [ix]. A. Alidai and I. W. M. Pothof developed a model to find the efficiency for a hydro turbine connected to a siphon. They found very low efficiency. For a head of 1.25 m and a flow rate of 4500 cubic meter per second the power generated is 4 MW [x].

A. Hydrostatic Pressure Converters

Hydropower machines may exist which are predominantly driven by hydrostatic pressure acting on a non-horizontal working surface, moving with a horizontal component. Such an operational mechanism has not been analyzed theoretically.
The two forms are defined as:

'Type One' HPCs:

Hydropower machines where the working surface extends from the channel bed to *the upstream water surface*. Such machines include the undershot waterwheel operating in non-impulse conditions, the Salford Transverse Oscillator, the Sundermann Turbine and the Archimedes Screw.

'Type Two' HPCs:

Hydropower machines where the working surface extends from the channel bed only up to the downstream water surface. This is possible by mounting or rotating the working surfaces or blades beneath a central hub or dam like structure which retains the head differential. Such machines include the *Zuppingerrad*, the *Aqualienne* and the *Staudruckmaschine*.

1) 'Type One' HPCs

The theory is ideal, being based on the fundamental geometry of such machines, whilst assuming no design related losses such turbulence. The ideal models used in this theory do not account for the change in kinetic energy observed between the upstream and downstream of actual `type one' HPCs such as the Salford Transverse Oscillator. This increase in kinetic energy is assumed to be the result of a process which does not directly contribute to the power output of `type one' HPCs.

II. FORCE AND POWER CALCULATIONS

A. Force Calculations (For Type One)
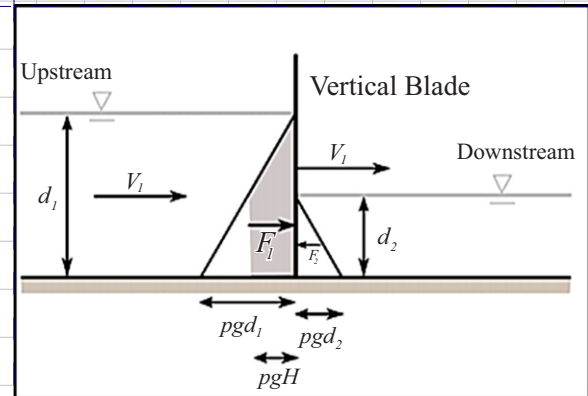
Fig. 1. Type one' HPC nomenclature

Fig. 1. depicts a simple vertical blade which extends from the channel bed to slightly beyond the upstream water surface. Here V_1, d_1, F_1 are upper stream velocity, upper stream total depth and net force acting on blade from upper stream side. Similarly V_2, d_2, F_2 are lower stream velocity, lower stream stream total depth and net force acting on blade from lower stream side.

This blade is the working surface on which the hydrostatic pressure of the water acts, and has width W into the page. The blade is shown to be partially submerged in the downstream, the depth of which, d_2, is between zero and the upstream depth, d_1

$$F_1 = \rho g \frac{d_1^2}{2} w \tag{1}$$

$$F_2 = \rho g \frac{d_2^2}{2} w \tag{2}$$

$$F_1 = \rho g \frac{d_1^2 - d_2^2}{2} w \tag{3}$$
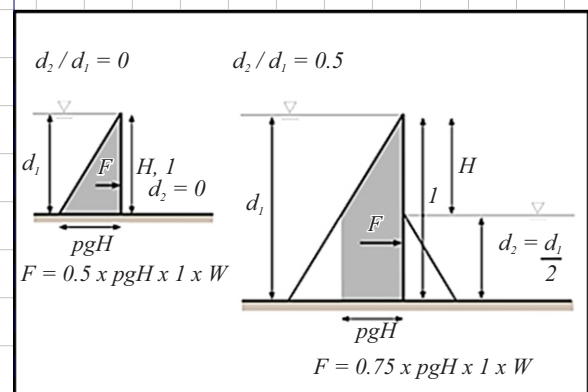
Fig. 2. Type one' HPC, demonstration of relationship between force and the ratio d_2/d_1

The relationship between the ratio d2/d1 and the force applied to the blade is thus critical. As the ratio d_2/d_1 tends towards a value of 1, the maximum pressure $\rho g H$ is applied to an increasing proportion of the blade area. Technically, the maximum pressure will be

applied over the entire length of blade when d_2/d_1 equals 1, however this is trivial as the head and thus the pressure differential at this point would equal zero.

B. Power and Efficiency Calculations

If the blade upon which the force is exerted extends from the channel bed to the upstream water surface and the upstream depth is to be maintained, then the blade must move with the same velocity as the upstream water, v_1. Accordingly, the output power, P_{out}, of a `type one' HPC is as under

$$P_{in} = \rho g\,(d_1 - d_2)(v_1 d_1 W) \qquad (4)$$

$$P_{out} = F v_1 = \rho g\,\frac{d_1^2 - d_2^2}{2} W v_1 \qquad (5)$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{1}{2}\left(1 + \frac{d_2}{d_1}\right) \qquad (6)$$

The efficiency, η of a `type one' HPC is shown in above equation. This equation shows that the efficiency, just like the force and output power equations, is a function of the ratio d_2/d_1. The implications of this are shown in the Fig. 3 & 4.
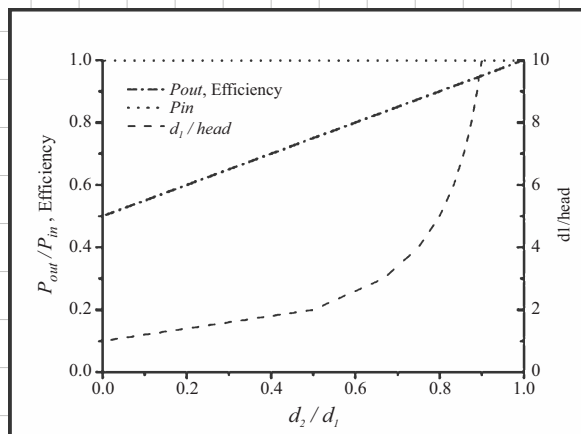
Fig. 3. Type one' HPC theory with constant head and flow rate, but variable d_2/d_1 ratio
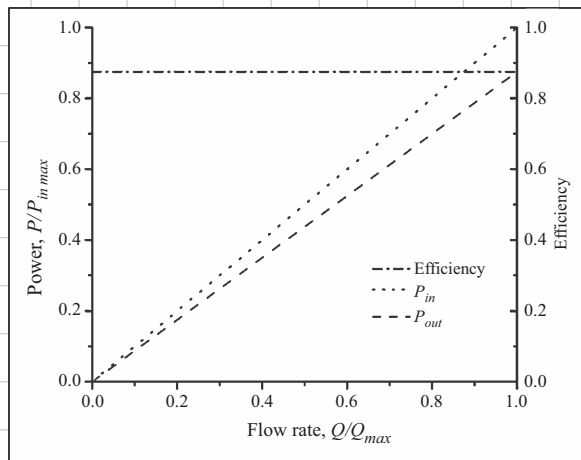
Fig. 4. 'Type one' HPC theory with ratio d2=d1= 0.75, constant head and variable flow rate

C. Evacuation and the resulting kinetic energy change

When considering actual `type one 'HPCs such the **Salford Transverse Oscillator**, the velocity of the downstream flow, v_2, would be greater than that of the upstream, v_1, as the downstream water depth is less than the upstream, whilst the flow rate is common. This is demonstrated by equation

$$v_2 = \frac{d_1}{d_2} v_1 \qquad (7)$$
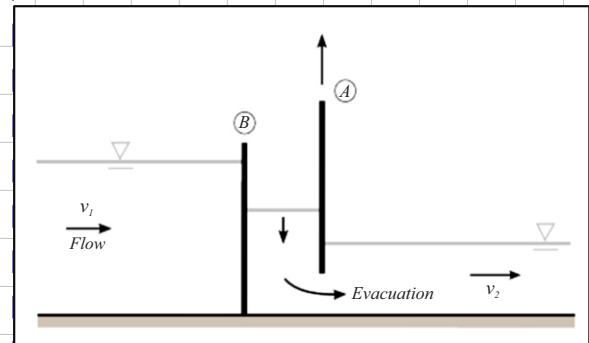
Fig. 5. Depiction of `evacuation' process

The power associated with the evacuation process per unit width, P_{evac}, is shown in Equation given below. When plotted along with the P_{out} estimate from the ideal theory against the ratio d2/d1 as in Figure-5.8, it can be seen that the P_{evac} accounts for the remaining input power, P_{in}, which was not exploited by the `type one' HPC.

$$P_{evac} = \rho g\,\left(\frac{d_1 - d_2}{2}\right)\left(\frac{d_1 - d_2}{d_1} v_1 d_1\right) \qquad (8)$$

Fig. 6 is graph plotted using the relations (equation 4, 5, 6 & 8) of power input, power output and power loss related to evacuation process.
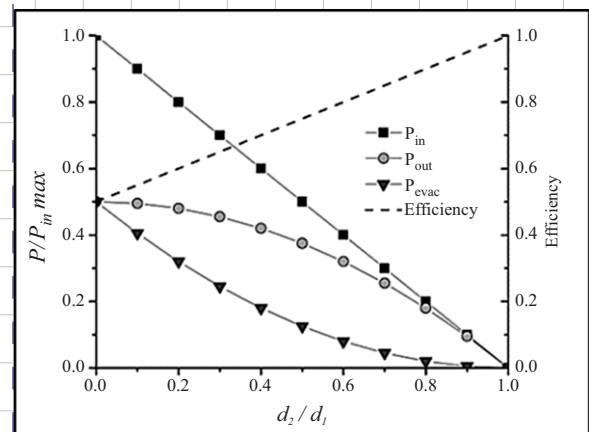
Fig. 6. Power associated with `evacuation' resulting in increased flow velocity [xii]

III. SITE ANALYSIS AND DESIGN CALCULATIONS FOR U-HPC

A. Site Overview (Gogera Branch Lower)

Gogera Branch Lower is an irrigation canal in Punjab with the region font code of Asia/Pacific. It is located at an elevation of 195 meters above sea level. Its coordinates are 31°25'60" N and 73°31'60" E in DMS (Degrees Minutes Seconds) or 31.4333 and 73.5333 (in decimal degrees). Its UTM position is CQ67 and its Joint Operation Graphics reference is NH43-02.

1) Site Parameters

Available Head= 1.58 m
Average Flow Rate = 66 m^3/s (66x10^3 liter/s)
Estimated Power Potential= 1.0 MW

Fig. 7. Gogera Branch Lower, Faisalabad District, Punjab, Pakistan

B. Design Calculations

1) Shroud Length
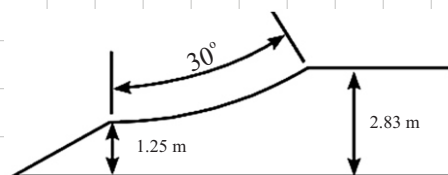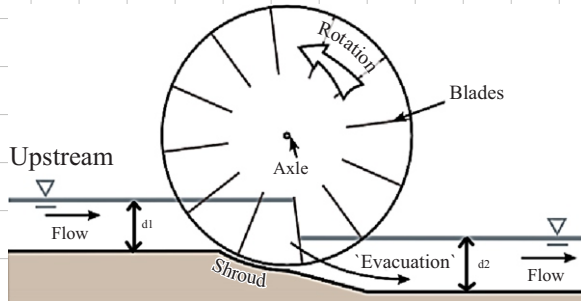
Fig. 8. Shroud Length

H=d_1-d_2=1.58 m
d_1= 2.83 m
d_2= 1.25 m
Blade Length=L= 1.58 m

Number of Blades = n= 12
Blade space (Arc Angle) =θ=30^0

$(360/12=30^0)$
Then Shroud Arc Length= S= Lxθ=1.58xΠ/6
S=0.827 m

2) Channel Design & Upstream Velocity v_1

Total No of passages= n =6
Total flow rate = Q_T= 66 m3/s
Flow through each passage = Q_1=Q_T/6=11 m3/s
Width =W= 5 ft =1.54 m
Now at upstream level, Q_1= $A_1 v_1$= (d_1W).v_1
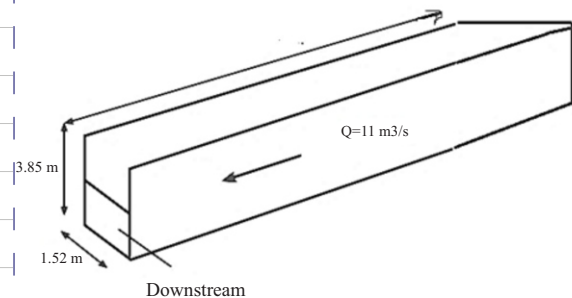
Fig. 9. Channel Design

11= 3.83x1.54xv_1
Upstream velocity v_1=1.86 m/s

1) Resultant Force on Blade

F=ρg $[d_1^2$-$d_2^2]$/2.W
ρ=1000 kg/m^3
g= 9.81 m/s^2
d_1=3.83 m
d_2=1.50 m
W= 1.54 m
So,
F = 1000x 9.81x [3.83^2-1.25^2]/2 x1.54
F = 48,694.8 N
Force = F= 48.694 kN
Power Input (Ideally available on site)
P_{in} = ρg (d_1-d_2) v_1 d_1 W
P_{in} = 1000x 9.81x 1.58x 1.86x 3.83x 1.54

P_{in} = 170.042 kW

4) Power Output at Full flow rate

Power Output is given by:

$P_{out}=F.v_1= g\,[d_1{}^2-d_2{}^2]/2.W.v_1$

P_{out} = 48,694.8x1.86 W = 92,572 W = 92.571 kW

P_{out} = 92.571 kW

Efficiency = P_{out}/P_{in}

η= 90.57/170.042 = 54.40 %

IV. GRAPHS AND RELATIONS FOR VARIOUS FLOW RATES IN COMPARISON WITH:

A. Power Output Consideration

TABLE I
POWER BASED ON IDEAL THEORY AND CONSIDERING LEAKAGE EFFECTS

Q/Q_{max}	P/P_{in} max	Q_{total}	$Q_{leakage}$	V_b	$P_{out, leakage}$ adjusted
0	0	3	2.341	0.659	6.76
0.167	0.165	6	2.341	3.659	55.6
0.333	0.33	9	2.341	6.659	76.4
0.5	0.5	12	2.341	9.659	99.9
0.666	0.658				
0.833	0.823				
1	1				

Fig. 10. shows the relation of flow rate with power input. Power input increases with increase in flow rate.
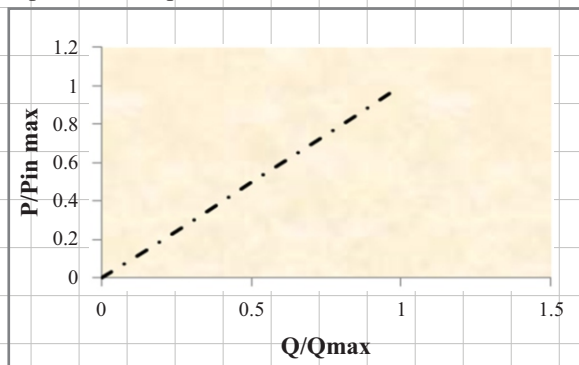
Fig. 10. Power input at various flow rates
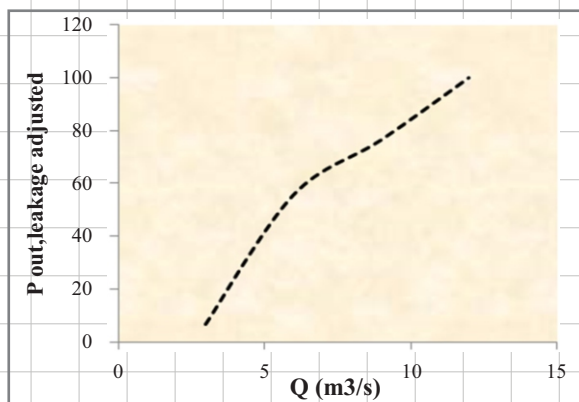
Fig. 11. Power output with leakage losses at various flow rates

B. Efficiency Consideration

TABLE II
EFFICIENCY BASED ON IDEAL THEORY & CONSIDERING LEAKAGE EFFECTS

$Q(m^3/s)$	η $_{(Ideal)}$	$Q_{leakage}$	V_b	η
0	0	2.341	0.659	3.97
3	0.72	2.341	3.659	32.5
6	0.72	2.341	6.659	45.8
9	0.72	2.341	9.659	57.76
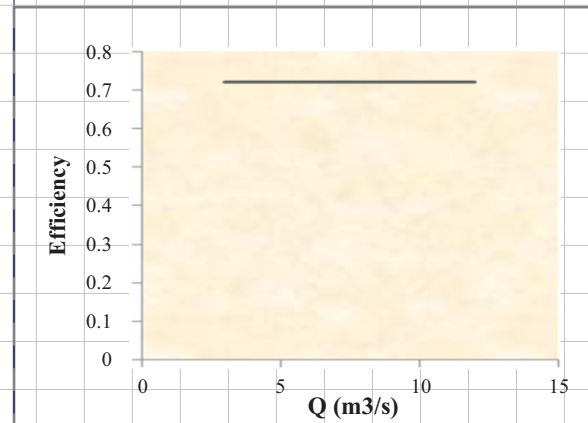
Fig. 12. Efficiency (Ideal) at various flow
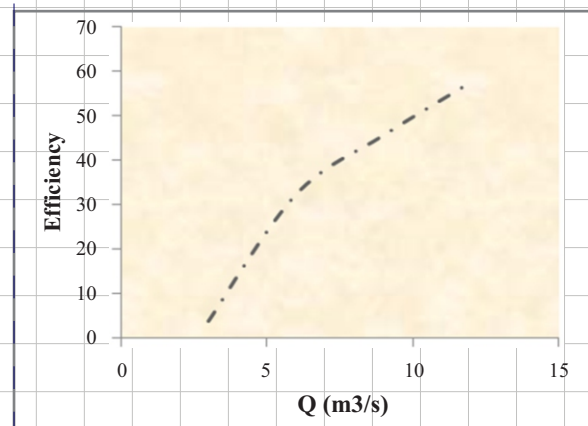
Fig. 13. Efficiency (leakage) at various flow rates

Fig. 12 shows variation of efficiency with respect to the flow rate. As the flow rate increases the efficiency increases but the rate of increase is not uniform. Initially the efficiency increase is more, then the rate of increase decreases gradually. The reason is that at higher flow rates the turbulent losses and eddy formation losses are more. Fig. 13 shows the variation of efficiency corresponding to the leakage losses. Since leakage losses are related to the geometry and it remains constant so efficiency change due to leakage losses is not prominent.

V. Calculations for Power Output & Efficiency After Considering Leakage Losses
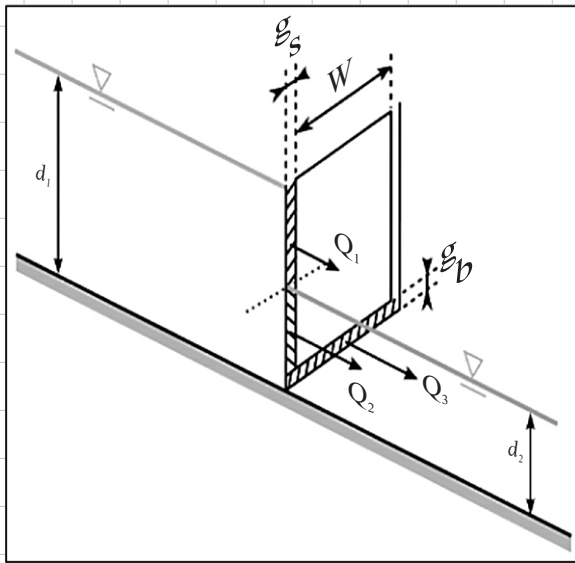
Fig. 14. Analysis of Leakage Losses

$Q_{leakage}$ = (velocity of flow) x (area of gap)

$$Q_1 = \left(\int_{d2}^{d1} \left(\sqrt{2gd} \right) dd \right) gs =$$

$$\frac{\sqrt{2g}\left(d_1^2 - d_2^2\right)^{1.5}}{1.5}\left(g_s\right)$$

$$= \frac{\sqrt{2 \times 9.81}\left(3.83^2 - 1.5^2\right)^{1.5}}{1.5}\left(0.05\right)$$

Q_1 = 0.525 m³/s

$$Q_2 = \sqrt{2g\left(d_1 - d_2\right)}\left(d_2 g_s\right)$$

$$= \sqrt{2 \times 9.81\left(3.83 - 1.5\right)}\left(1.5 \times 0.05\right)$$

Q_2 = 0.507 m³/s

$$Q_3 = \sqrt{2g\left(d_1 - d_2\right)}\left(g_b\left(W + 2g_s\right)\right)$$

$$= \sqrt{2 \times 9.8\left(3.83 - 1.5\right)}\left(0.02\left(1.54 + 2 \times 0.05\right)\right)$$

Q_3 = 0.227 m³/s

$Q_{leakage}$ = 2 (0.525 + 0.507) + 0.227

$Q_{leakage}$ = 2.341 m³/s

$Q_{wheel} = Q_{total} - Q_{leakage}$

Q_{wheel} = 9 - 2.341 = 6.659 m³/s

$$V_b = \frac{Q_{wheel}}{Wd_1} = \frac{6.659}{1.54 \times 3.83}$$

V_b = 1.13 m/s

$$P_{out;\ leakage\ adjusted} = \rho g \frac{d_1^2 - d_2^2}{2}v_b$$

$$= 1000\ X$$

$$9.81\frac{3.83^2 - 1.5^2}{2}1.13$$

$P_{out;\ leakage\ adjusted}$ = 68.83 KW

$$\eta_{leakage\ adjusted} = \frac{P_{out,leakage\,adjusted}}{P_{in}}$$

$$\eta_{leakage\ adjusted} = \frac{68.83}{170} = 40.4\ \%$$

VI. Gear Box Losses

There is a disadvantage of this technique that it gives low rpm. To enhance the rpm of the converter as per requirement by the electric generator to produce electricity in accordance to the particular frequency a sophisticated gear box is required between the shaft of the converter and the shaft of the electric generator. So, gear box losses must be taken into account. Let the gear box be four stages with coaxial shafts assembly then its efficiency would vary between 80 to 90 percent [xi].

$$P_{out;leakage,gearlossadjusted} = (68.83)(0.90)$$

$$= 61.95\ KW$$

$$\eta_{leakage,\ gear\ loss\ adjusted} = \frac{61.95}{170} = 36.44\ \%$$

VII. Conclusions

From the review of the literature on hydropower converters for very low head differences i.e. below 2.5 m it is found that the Undershot Hydrostatic Pressure Converter are most suitable for very low head at various sites in Punjab. Furthermore, combined with its potential for improved sediment transport and fish passage, the U-HPC could satisfy the demand for a new economically and ecologically acceptable technology. A typical design of U-HPC for Gogera Branch Lower irrigation canal in Punjab has been made that shows a potential of 1 MW at 40.4% efficiency.

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Characterization of EDM Surface Morphology of Al-6061 using different dielectrics

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*Abstract-*The effect of discharge current and pulse duration during the electric discharge machining of Aluminum alloy 6061 T6 is studied using copper electrode with paraffin oil and distilled water as a dielectric medium. The electric discharge machined surface is characterized by surface roughness (Ra), crack intensity, and average white layer thickness (AWLT). The behavior of material removal rate (MRR) and electrode wear rate (EWR) is also considered under varying conditions of EDM. AWLT and surface roughness is found to be dependent on the orientation of surface, pulse current, pulse duration, dielectric medium and electrode material. A new method of AWLT and surface roughness measurement through optical microscope is described. The results of surface roughness by this method are verified by conventional roughness tester.

*Keywords-*EDM, AWLT, Surface Roughness, Heat Affected Zone*,* MRR, Cracks Formation

I. INTRODUCTION

Electrical discharge machine (EDM) is a non-conventional machining process uses thermal energy to remove material through erosion process of electrically conductive materials [i-ii]. Erosive properties of electric discharge were invented by English chemist Joseph Priestly in 1770 and in 1943,Lazarenko used damaging properties of electric discharge for productive purpose [iii]. In 1950 and later such properties were used for successive development EDM models [iv]. This type of material removal produces different heat effected zones which typically categorized as white layer, heat effected zone and parent metal surface. Some part of molten material left during flushing process of EDM and re-solidified on machined part of specimen. During formation of recast/re-solidified/ white layer (WL) composition is changed so this layer has different mechanical properties as compared to base material[v-vi]. So study ofWL and surface roughness is most important because after EDM this layer has direct affect the service life of component.

Surface morphology directly affected with EDM parameters such as pulse duration (Pon), peak current(I), open gap voltage, electrode material, electrode geometry and dielectric medium used for EDM [vii,viii]. It is known that AWLT is associated with EDM parameters and it is harder than base metal. Peak current/pulse current and pulse duration is directly related to AWLT, surface roughness and material removal rate and inversely related to surface crack density [ix-xiv]. However the thickness of white layer increases with increasing pulse current but higher pulse current the thickness of layer decrease due to breakdown of white layer [xv-xvi]. AWLT is affected by electrode material, work material grain size, dielectric medium and pulse duration. Ultra-fined grain size of aluminum has greater effect on recast layer, heat effected zone surface crack density as compared to coarse grains[xvii-xviii]. EDM with distilled water has high WLT and MRR and more dense packed with less cracks and as compared to aluminum powder mixed with water [xi] . At lower pulse duration WLT using distilled water as a dielectric medium is lower as compared to paraffin oil and at high pulse duration only water oil emulsion has high thickness. Distilled water produced high MRR, lower tool wear ratio, better surface finish at higher pulse energy then paraffin oil. Although distilled water has lower machining accuracy. Distilled water form oxide layer on work piece while paraffin form carbide layer. Carbon and oxygen in oxide and carbide layers comes from dielectric mediums respectively[xix-xxiii].

EWR is almost zero and MRR is high when EDM is done with gas as dielectric and with the increase of oxygen concentration in air, the MRR increased[xxiv]. EWR can also be achieved to using tap water and copper electrode with negative polarity [xxv]. MRR depends on thermal properties of work material and it is also measured of productivity [xxvi]. Geometry of electrode material has great influence on MRR, irrespective the EDM processing parameters and processing variables. [xxvii-xxix]. High strength aluminum alloys has lot of application in aerospace and automobile industry because of high strength to weight

ratio. EDM is preferred for machining of complex shapes on aluminum alloy. Therefore current study is performed to explore the altered characteristics of the aluminum alloy after EDM under different conditions.

II. EXPERIMENTAL SETUP AND METHODOLOGY

The Experiments are performed using NEUAR sinking EDM with thick hollow copper electrode. EDM with distilled water is performed in separate tank with water pumping system so that paraffin oil should contaminate with distilled water as shown in Fig.1.
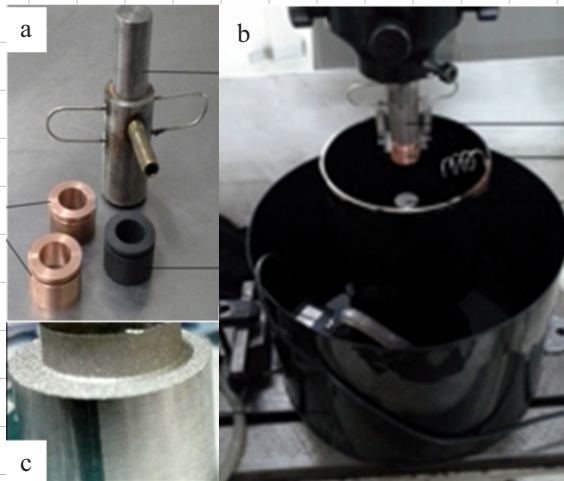
Fig 1. (a)Electrodes with holding fixture,(b) separate tank for machining with distilled water, and (c)sample obtained after machining which contained HS, VS and CS surfaces.

EDM is performed with processing parameter of pulse current and pulse duration keeping all other electrical parameter constant. Aluminum specimens are machined with copper electrode in the presence of kerosene dielectric and distilled water respectively. Thirty samples of work material Al-6061 are machined and hallow electrode produce the horizontal, vertical and corner between horizontal and vertical surface and design of experiment for machining sample is given in Table II.

TABLE I
EXPERIMENTAL CONDITIONS IN EDM

Work piece	Al 6061 (diameter= 22mm)
Dielectrics	Paraffin oil and distilled water
Pulse current (A)	6, 9, and 12
Electrode material	Copper
Gap (mil)	2
Pulse duration (μs)	15, 20, 30, 45,and 60
Pulse off time (μs)	7

TABLE II
DESIGN OF EXPERIMENT FOR EDM

Pulse Current (A)	Copper electrode with paraffin oil	Copper electrode with distilled water
	Pon (μs)	Pon (μs)
Level (1) = 6amp	15	15
	20	20
	30	30
	45	45
	60	60
Level (2) = 9amp	15	15
	20	20
	30	30
	45	45
	60	60
Level (3) =12amp	15	15
	20	20
	30	30
	45	45
	60	60

Steps for sample preparation are shown in schematic diagram 2.

Cutting Cross-sectional view of EDM Specimen

Sample is placed into epoxy and dried

Grinding with Emery paper and polished with Diamond paste

Etching with Keller etchant to view grain boundary
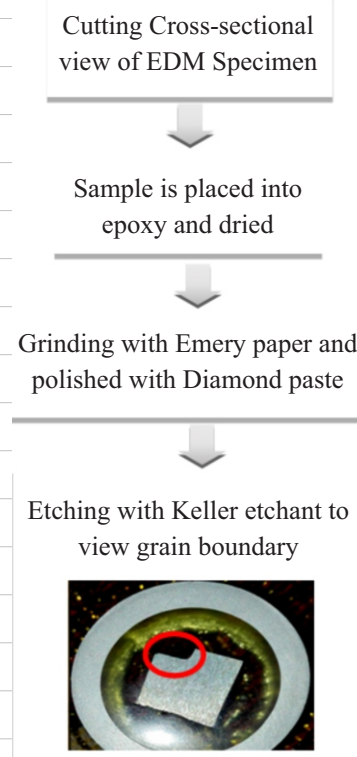
Fig. 2. Schematic procedure for sample preparation for optical microscope

After etching recast surface is observed under optical microscope OLYMPUS BX51 at 50X and 20 µm resolution, and10-15pictures of each sample including horizontal (HS) and vertical surface (VS)and the corner surface (CS) region between horizontal and vertical surface is also consider because it is important region for service life of EDM machined components. AWLT calculation using image processing technique, module Image J, by calculating area of white layer by selecting the recast layer. AWLT is calculated dividing area of white layer to its length. For each sample 6-10 values of AWLT are taken at different machined surface including horizontal and vertical and curved surface between these two. Finally mean value of both horizontal and vertical surfaces is taken. Surface roughness is measured by selecting surface profile using Engauge Digitizer 2.12 module. In Engauge Digitizer we defined scale and the coordinate system and marking the set of data points on the curve profile as shown in Fig. 3.
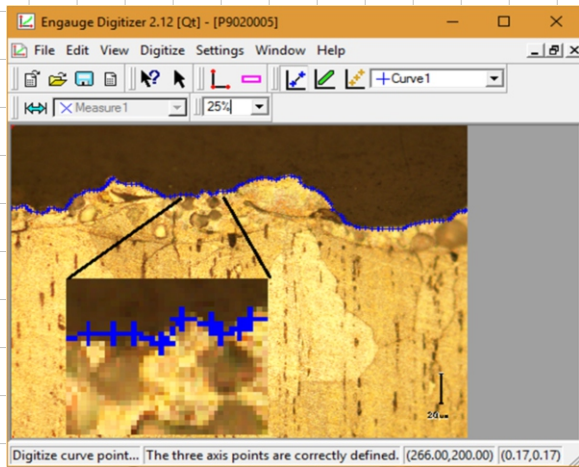
Fig. 3. Surface roughness calculation using Engauge Digitizer

These set of data points are imported into Microsoft Excel and the surface roughness (Ra) is calculated by formula

$$Ra = \frac{1}{n}\sum_{i=1}^{n}|yi - m| \qquad (1)$$

Where;

y = height of crest/trough from reference line

m = height of mean line from reference line

n = total no. of data points

For each sample 10 times surface roughness are measured 5 times for horizontal surface and 5 times for vertical surface at different position of machined surface and finally mean value of Ra is taken for each horizontal and vertical surfaces. These values of surface roughness are compared with the conventional portable surface roughness tester Mitutoyo SJ-410.

III. RESULTS AND DISCUSSION

For varying condition of pulse current and pulse duration, the results are categorized into two groups.

A. Copper Electrode and Paraffin Oil as a Dielectric

The behavior of white layer and surface roughness at varying condition of pulse current and pulse duration is observed simultaneously using copper electrode with positive polarity and Al 6061 work piece with negative polarity and paraffin oil is used as working fluid. Fig.4 shows that the AWLT increases with the increase of pulse current at same pulse duration. It is also observed in fig.4that with the increase of pulse duration at same current the thickness of white layer increase. So AWLT increases with the increase of both pulse current and pulse duration. It has been seen that horizontally machined surface has slightly greater thickness value as compared to vertical surface, and corner surfaces show irregularities with increasing trend. It has also been observed that at higher current of 12A and pulse duration 60 µs the AWLT is decreased.
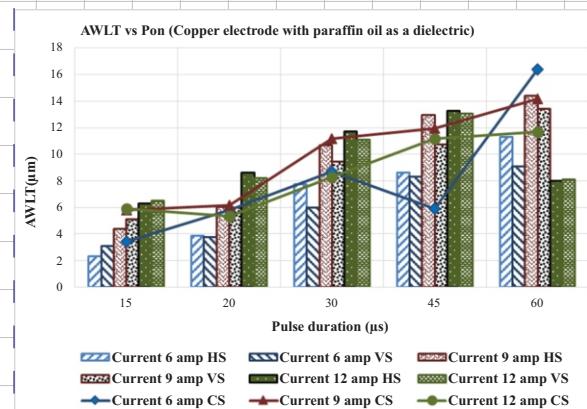
Fig. 4. AWLT variation with respect to pulse current and pulse duration

Cross-sectional view of Fig. 5(b)shows discontinuity in white layer thickness is so much. It can be thebreakdown of white layer. Fig 3(b) also shows that heat affected zone (HAZ) is slightly visible andwhite layer cross sectional area has large quantity of porosity like in the surface. Sharp break of WL, Cavities and globules with cavities formation is also observed. Fig 5(a) shows that at low pulse current 6A and low pulse duration 15 µs, the visibility of WL is seen at some place of EDM surface and at some point ofmachined surface, WL is invisible.
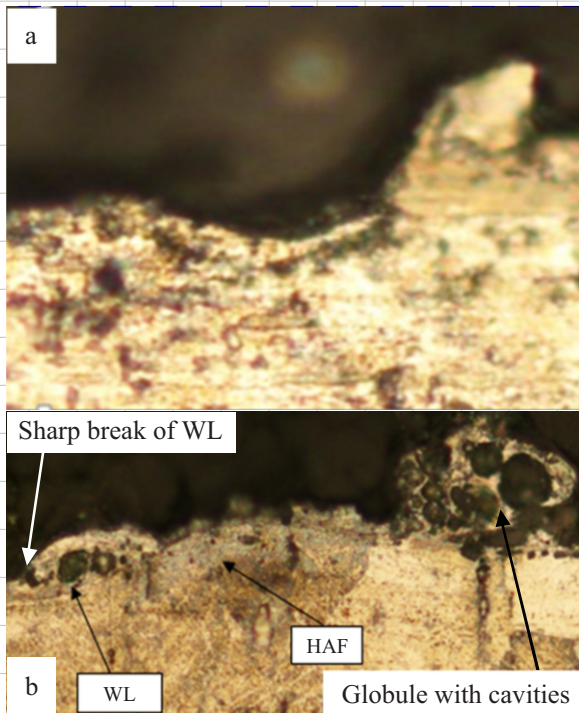
Fig. 5. White layer surface with paraffin oil at, (a) 6A with 15µs and (b) 12A with 60µs (50X+crop)

Surface roughness measured through digital image process analysis (DIP)is compared with conventional roughness testing machine. Table 3 shows that in most values, the variation is about one micron that may be vibrational effect of environment. The overall percentage error from roughness tester measured value is 9 %.

TABLE III
COMPARISON OF HORIZONTAL SURFACE ROUGHNESS DATA OBTAINED BETWEEN DIGITAL IMAGE PROCESSING METHOD AND CONVENTIONAL ROUGHNESS TESTING MACHINE

Pulse Current (A)	Copper with paraffin oil			Copper with distilled water		
	Pon (µs)	Ra (DIP) (µm)	Ra (µm)	Pon (µs)	Ra (DIP) (µm)	Ra (µm)
Level (1) = 6A	15	5.898	5.15	15	3.961	3.42
	20	5.065	5.20	20	6.806	3.79
	30	6.216	7.07	30	4.984	4.34
	45	6.869	7.00	45	4.980	4.11
	60	10.63	7.66	60	5.100	4.74
Level (2) = 9A	15	3.517	3.43	15	5.486	5.03
	20	6.043	6.17	20	5.776	5.57
	30	6.608	6.01	30	5.822	6.15
	45	8.355	8.61	45	6.847	6.62
	60	7.284	7.00	60	6.452	5.98
Level (3) =12A	15	5.954	5.83	15	4.981	4.68
	20	5.989	6.07	20	6.022	5.68
	30	6.900	7.53	30	6.851	6.35
	45	8.432	8.50	45	7.044	6.97
	60	9.040	9.98	60	5.569	5.68

Fig. 6. shows that surface roughness value increases with the increase of pulse current and pulse duration. It is also observed that at 6A current horizontal surface roughness values are slightly higher than 9A pulse current at various pulse duration. It is observe that at 12A vertical surface roughness has slightly straight line which indicate vertical surface roughness has not much variation with pulse duration. It can be seen from Fig. 6 that the overall surface roughness slightly increased with increase of both pulse current and pulse duration.
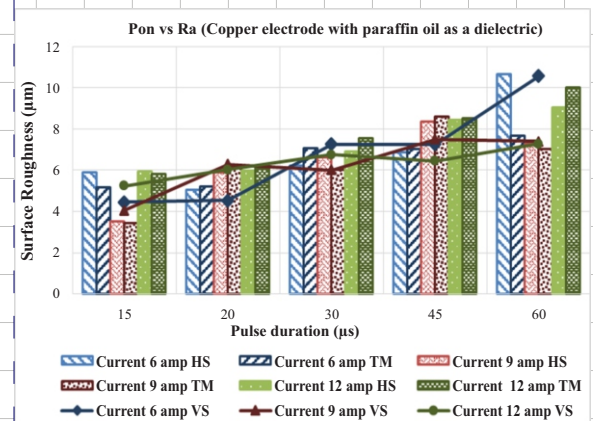
Fig. 6. Surface roughness behavior at different condition of pulse current and pulse duration

B.   Copper Electrode with Distilled Water as Dielectric

Using same EDM parameters as used for copper elelectrode by replacing distilled water from paraffin oil as a dielectric medium. The over all AWLT trend is similar as described above for copper electrode with paraffin oil, however few exceptions have been seen. The magnitude of AWLT values is greater then the paraffin oil as shown in Fig 7. AWLT values of corner surface at 12A current shows decreasing behavior with inreasing pulse duration. AWLT of corner suface at 6A show zigzage behavior with increasing pulse duration. Similarly at 12A pulse current and 60µs pulse duration the value of AWLT decreased to much even decreased from 15µs pulse duration and 12A current which indicate the disintigration of white due higher pulse energy and pulse duration.
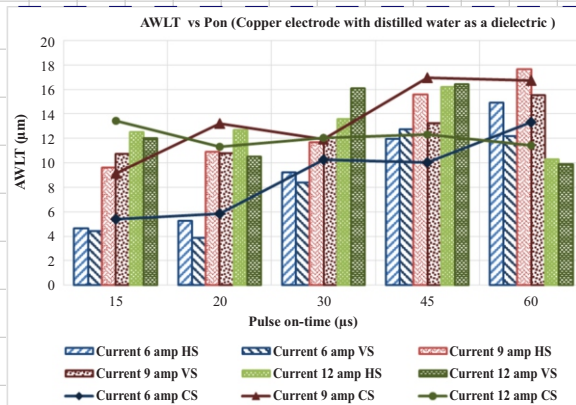
Fig. 7. AWLT variation, using copper electrode and distilled water as dielectric

Dense nature of AWLT is observe using distilled water as compared to paraffin oil which means not too much cavities and air bubbles entrapped in white layer and very less globule formation is observed as represented in fig.8. It has been observe that with increasing pulse duration and pulse current, heat affected zone and micro cracks also visible. It can also be observed from fig.8 and Fig. 5(b) that micro cracks generated in white layer are penetrating into heat affected zone and intensity of these micro crack is much greater then cracks generated using paraffin oil
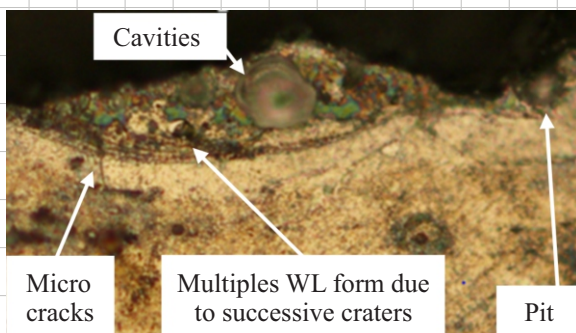
Fig. 8. White layer at 6 amp I and 60µs Pon with distilled water (50X+ crop)

Surface roughness measured with the variation of pulse current and pulse duration using distilled water is shown in Fig 9. It is observed that at 15µs and 60µs pulse duration, the value of surface roughness of 9A pulse current is greater then 12A. The surface roughness at 20µs Pon with 6A current is much greater, which can be improrper flushing. It is also observed that surface roughness values for 9A and 12A pulse current at pulse duration 60µs and 45µ are almost equal. However over all trend of surface roughess is increansing with enhancing the pulse current and pulse duration. But the surface roughness obtained using distilled water as a dielectric is lower than the surface roughness obtained using paraffin oil as a dielectric.
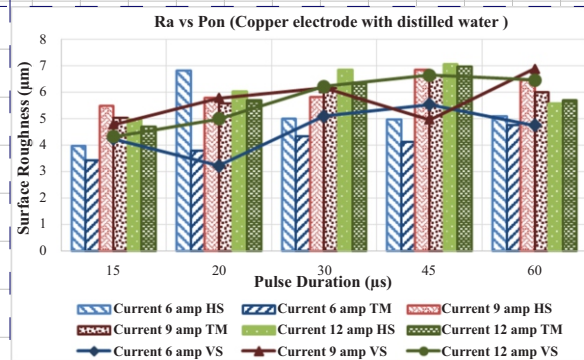
Fig. 9. Surface roughness behavior at different condition of pulse current and pulse duration

C. Material Removal Rate and Electrode Wear Rate Using Copper Electrode

Weight difference in the before and after machining of specimen and electrode determines MRR and EWR as shown in Table IV and Table V respectively.

TABLE IV
MRR (MM^3/MIN) OF AL-6061

PON	Kerosene			Distilled water		
µs	6A	9A	12A	6A	9A	12A
15	32.6	53.6	84.4	30.1	43.2	45.7
20	55.6	80.7	119	33.3	60	67.8
30	71.9	103	147	35.3	78.5	75.3
45	71.1	119	181	37	54.8	61.5
60	72.2	124	199	32.8	54.1	48.1

TABLE V
EWR (MM^3/MIN) OF COPPER ELECTRODE

PON	Kerosene			Distilled water		
	6A	9A	12A	6A	9A	12A
15	0.749	1.7	2.81	0.524	1.87	3.6
20	0.524	1.7	2.25	0.75	1.27	4.04
30	0.674	1.6	1.35	0.45	1.5	3.18
45	0.449	1	0.899	0.75	1.69	2.25
60	0.225	0.4	0.674	0.524	1.24	2.02

MRR of Al alloy is observed using copper electrode with paraffin oil and distilled water as a dielectric as shown in Fig.10.
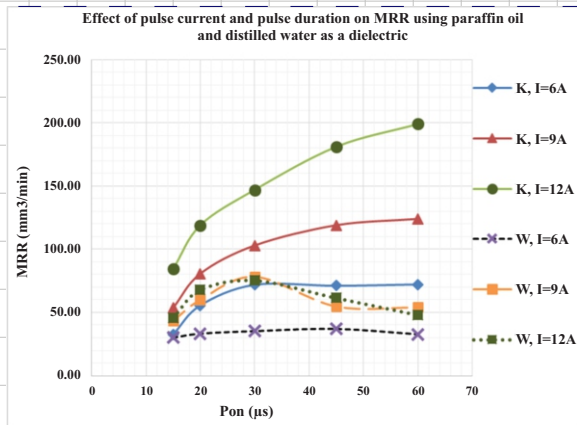
Fig. 10. MRR vs Pon at various current

It is observed that MRR increased with the increase of pulse current and pulse duration using copper electrode and paraffin oil as dielectric. But in case of distilled water as a dielectric the MRR is increased with increase of pulse duration up to 30μs, then it start to decrease with the further increase of pulse duration. It also shows that material removal rate is higher when paraffin oil used as dielectric as compared to distilled water as a dielectric. It is already observed that the AWLT is greater when distilled water used as a dielectric as compared to paraffin oil. So MRR and AWLT have relationship with each other when copper electrode is used. Fig.11 shows EWR of copper electrode, which shows the reverse behavior of MRR. It shows that EWR of copper electrode with distilled water at 12A current is much higher and decreased with increase of pulse duration. Overall decreasing trend is observed with the increase of pulse duration. In case of copper electrode, EWR increases with increasing current. As higher currents produce more thermal energy thus it removes more material from electrode. So paraffin oil has greater MMR and lesser EWR as compared to distilled water with increase of pulse current and pulse duration because the thermal conductivity of paraffin oil is grater then distilled water.
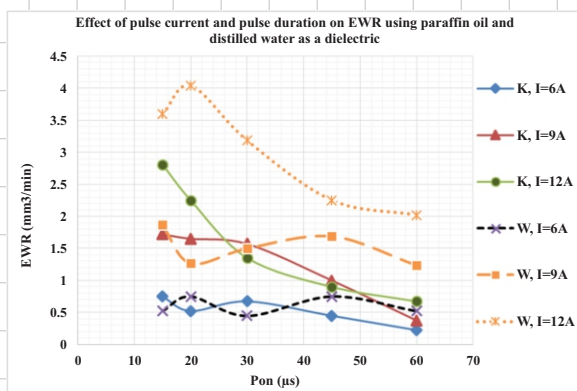
Fig. 11. EWR using copper electrode with paraffin oil and distilled water as dielectric

IV. CONCLUSION

The EDM of Al 6061 is done under varying condition of pulse current and pulse duration using copper with paraffin oil and distilled water as dielectrics. MRR, EWR, AWLT, and surface roughness are characterized under varying the EDM processing parameters.

AWLT increases with the increase of pulse current and pulse duration. At higher pulse current and pulse duration breakdown of white layer occurs. Dielectric medium also affect the magnitude of AWLT. Thicker white layer is obtained using distilled water as a dielectric medium as compared to paraffin oil.

Surface roughness behavior is not much varied, however with the increase of pulse duration and pulse current slight increase in surface roughness is observed. Magnitude of surface roughness is greater in paraffin oil as compared to distilled water. Similarly better surface finish and dense-packed nature of surface is observed using distilled water as dielectric. Surface crack intensity and heat affected zone increases with increasing pulse current and pulse duration. Surface cracks intensity and their penetration into HAZ using distilled water is greater than paraffin oil. Similarly HAZ is greater using distilled water.

MRR is more using paraffin oil than the distilled water. MRR also increased with the increase of pulse current and pulse duration. EWR using distilled water is higher than paraffin oil.

V. ACKNOWLEDGEMENT

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Characterization of Tidal Current Turbine Dynamics Using Fluid Structure Interaction (FSI)

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Abstract-Global climate change is one of the greatest challenges faced by the humanity. There is a growing awareness among the world population about the need of reducing the greenhouse gas emissions. This in fact, has led to an increase in power generation from renewable sources. The tidal current energy has the potential to play a vital role in a sustainable energy future if the applicable technologies are developed. The main objective of this paper is to investigate the horizontal axis tidal current turbine (HATCT) dynamics using fluid structure interaction (FSI) modeling. Vibration in tidal current turbine is produced due to hydrodynamic forces. The vibration causes resonance and dynamic loads on the structures which leads to failure of the structures. To prevent the TCT from failure and to increase the annual energy production its dynamic analysis is important. In order to achieve this aim a number of key steps were performed. Using computational fluid dynamics (CFD), flow passing through the turbine rotating in a rectangular channel was modelled. The National Renewable Energy Laboratory (NREL) developed code HARP_Opt (Horizontal Axis Rotor Performance Optimization) was used for Blade element momentum (BEM) Design of turbine in support of CFD. The pressure exerted on the turbine blade modelled in CFD was transferred to finite element model (FEM) through Fluid structure interaction (FSI) module in Ansys. Transient structural analysis module of the Ansys work bench was used to investigate the structural response of tidal current turbine. The modal analysis, pre-stressed vibration analysis and forced vibration analysis were performed for the structural response of tidal current turbine. The performance curves obtained from CFD and BEM showed a very good match. The modal analysis showed that neither of the natural frequency is critical and it is expected that the structure of the designed turbine is not prone to resonance. The techniques used in the research provided excellent results that will be crucial in understanding the physics governing the operation of Tidal current turbine (TCT) in tidal currents.

Keywords-Tidal Current Turbine, CFD, BEM, HARP_Opt, Finite Element Model.

I. INTRODUCTION

The tidal current energy is a form of hydropower extracted from tides. The tides are produced due to relative motion of earth and moon. The sun also contributes to the generation of tides. Because of the proximity to the earth, the lunar gravity is the primary driver for the generation of tides [i].

Several turbine design concepts for the extraction of tidal current energy have been studied during the past decade [ii]. However, the Horizontal Axis and Vertical Axis turbines have attracted most of the research focus. The shape of rotor of horizontal axis turbine is of propeller type [iii].

Tidal Current Turbines (TCT) must be designed in a way to provide reliable electrical energy production in a subsea environment with minimal maintenance [iv]. Blades are one of the major component of this system. The two blades turbine have lower cost, easy to install and required small size gear box but creates higher wake [v]. Three blades turbine satisfies the minimum number of wings required to be stable. Three blades turbine can run at low flow velocity and reduce the chances of cavitation [vi]. Some of the prototype tests of TCT have showed early blade failures [vii-viii]. It is therefore very important to understand the behavior of TCT against the complex loading imposed by tidal currents. The Failures related to the TCT, especially turbine blades, will have a significant impact on the overall cost-effectiveness and reliability of developed technology [ix]. Extensive research have been carried out for investigating the effects of structural loads on turbine blades [x]. Experimental approaches were developed by Liu et. al for the modal/vibrational analysis of TCT, that produces the Edgewise mode shapes of the blade on the basis of blade vibration and time [xi]. Along with experimental techniques, numerical modeling techniques have also been widely used to study the dynamic response of the turbine structure. One way FSI model was used to study the interaction between the rotating blade and pressure on the surface of the turbine rotor [xii-xiii]. The pressure around the turbine blade was investigated by considering the accurate motion of vibrating blade. The study revealed that there is no significant deviation of pressure between the casing surface and blade tip. A similar numerical study [xiv], was conducted on the

dynamic analysis of different configuration of wind turbine. The results revealed that the effect of elastic foundation and hydro-dynamic plays vital role in highlighting the dynamic response of the structure. Blades of the turbine are continuously under the influence of repeated hydrodynamics loads that causes resonance and ultimately lead to failure of the blades [xv].

The current study is conducted for the characterization of tidal current turbine dynamics by using the numerical technique of fluid structure interaction (FSI). The vibration parameters are determined that shows the efficiency as well as the structural reliability of TCT and is the novelty of the current work. The main focus of current research work is to analyze the behavior of tidal current turbine rotor against dynamic loads. Natural frequencies and mode shapes will be analysed for the modal response of tidal current turbine.

II. COMPUTATIONAL FLUID DYNAMICS

A 3-bladed turbine based on the work of [ix] was modelled. This was a 0.50 m turbine modelled in autodesk inventor as in Fig.1, according to the design sequence available in the original work.
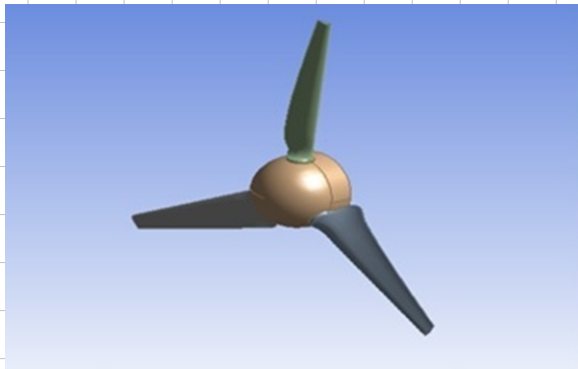
Fig.1. Solid 3D Model of TCT (ISO View)

The geometry was meshed in ansys ICEM CFD using tetra meshing as shown in Fig. 2. The overall mesh consisted of 4.7 Million tetrahedral elements. A dense prism-layer consisting of 197474 elements and 99266 nodes was generated around the blade in order to predict the torque on blade. Unstructured mesh having 3979481 elements and 1312011 nodes for the inner and 541280 elements and 102214 nodes was selected for the outer domain as shown in Fig. 2.
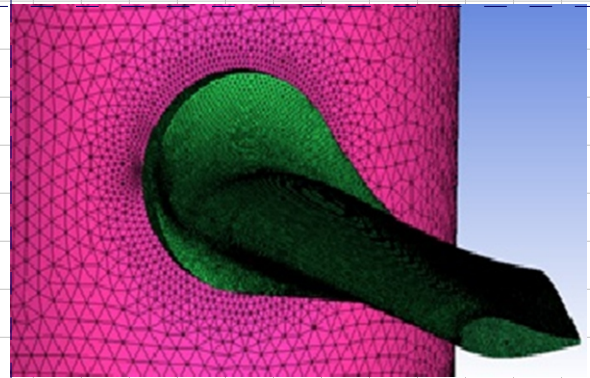
Fig. 2. Grid system of the rotor

The unstructured mesh was selected for this study because complex geometries like TCT can be meshed easily by this method. Also the unstructured mesh reduced the computational cost and has faster convergence. And more accurate solution can be obtained easily by using this method.

For CFD analysis of TCT the flow field is divided into a rotating and a stationary domain. The external stationary domain where the fluid flows is modeled in a rectangular shape having length of 5.0 meter, width 1.0 m and height of 0.80 meter which are also the dimensions of the experimental circulating water channel. The internal rotating domain where the turbine rotates is a cylindrical shape having diameter of 0.6 meter and height of 0.11 meter as shown in Fig 3.
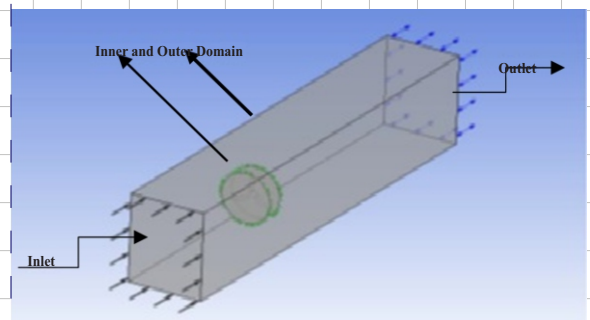
Fig. 3. Specification of external and internal domain

Condition at the inlet of external domain was normal speed condition with incoming velocity of 1.0 m/s, which is also the design velocity. An opening condition was used at the outlet area of the external domain so that according to the flux change due to the turbine it can be calculated. The wall conditions that were similar to the environment of the circulating water channel were used at the walls and floors of the external domain. Free slip condition was used for the channel top. Meeting part of the internal rotating area and the external area used the general connect - frozen rotor as the interface condition, while the mesh connect method used the GGI condition. No slip wall condition was used on the blade. Steady state CFD analysis was

carried out with a rotating reference frame (RFR) with medium intensity. The shear stress transport (SST) model was selected. In solver control setting, maximum number of iterations was set to 300 with auto time scale. For residuals, the criteria for convergence was set to 1.0 E^-04. And ANSYS CFX Postprocessor was used to calculate the torque. The analysis in the proposed work was performed on the Dual core CPU with 64-bit operating system with 8 GB RAM. And a single simulation takes 3 to 4 hours to complete.

III. HYDRODYNAMICS OF TIDAL CURRENT TURBINE

In this research work BEM and CFD methods were used to analyse the full rotor comprising of three blades and hub in order to predict the torque generated by the turbine at different tip speed ratios (TSR). The performance curve using a design velocity of 1.0 m/s is shown in Fig.4 Using function calculator of ANSYS-CFX torque values were calculated for eight repetitive analysis. These analysis were performed for TSR 2 to 8.
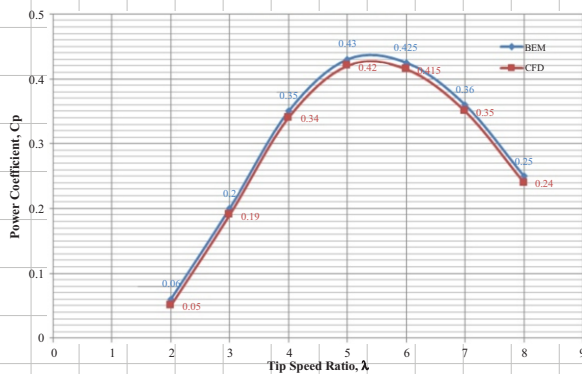
Fig. 4. Performance Curve of TCT

The Fig 3 shows both BEM and CFD analysis. The values of power coefficient increasing linearly at TSR 2 - 4. The maximum power coefficient (Cp) 0.43 occurs at a TSR 5 in BEM analysis, while maximum Cp 0.42 occurs at TSR 5 in CFD analysis. Further increase in TSR decreases the Cp value in both cases. The CFD and BEM analysis are in good agreement and produce reasonable estimates of power output.

IV. FSI MODELS

When the flowing fluid comes in contact with a deformable structure, it will exert some forces on structure and the structure will deform, as a result this deform structure will influence the flow. Such type of interaction is called fluid structure interaction. Advancement in the computational field has made it possible to analyse the complex fluid structure interaction problems. This approach is widely used in wind turbine industry to study the response of structure to wind. TCT installed in a flowing fluid can be regarded as fluid structure interaction problem.

When the fluid forces act on the blade surface it produce the torque due to which the turbine rotate. The blades of the turbine also deform when the fluid exerts pressure on the blade. This Deformation of turbine blades will change flow field around the blades. In order to find out the resulting variation in hydrodynamic forces and deformation of turbine blades the CFD models were coupled with finite element model.

FEA is a numerical technique used for the solution of complicated problems and used for structural analysis. The accuracy and physical response of this method is based upon discretization and boundary conditions. The method has ability to handle complex and irregular geometries simply. Handle the static and transient loading condition easily, they have the ability to handle large number of boundary condition.

The equation of motion for the structural response used in ANSYS are given as [xvi]:

$$[M]\{\ddot{u}(t)\}+[C]\{\dot{u}(t)\} + [K]\{u(t)\} = \{F(t)\}$$

Where:
$[M]$ = Structural mass matrix
$[C]$ = Structural damping matrix
$[K]$ = Structural stiffness matrix
$\{\ddot{u}(t)\}$ = Nodal acceleration vector
$\{\dot{u}(t)\}$ = Nodal velocity vector
$\{u(t)\}$ = Nodal displacement vector
$\{F(t)\}$ = Applied load vector

In above equation, the $[M]$, $[C]$ and $[K]$ matrices are the properties of the system, $\{u\}$ is the behavior and $\{F(t)\}$ is the action or applied force.

V. MODAL ANALYSIS OF TCT

The phenomenon of resonance due to excessive vibratory motion arises in many structures. It is necessary to find out the quantity and quality of the frequency to analyze the vibration related problems. The response of the structure can be investigated using the Modal analysis by applying the boundary conditions to the structure. The mode shapes and natural frequencies of the structure are simulated for analyzing the vibration response.

For Modal analysis of rotor, the constraints are applied on back side of the rotor in all degrees of freedom and the rotor are analyzed in static conditions. First six mode shapes and natural frequencies are calculated by using ANSYS workbench, shown in Table I and in Fig. 5 to 10.

TABLE I
MODE SHAPES AND NATURAL FREQUENCIES

Modes	Natural Frequency [Hz]
1	126.04
2	171.93
3	177.02
4	460.02
5	548.92
6	550.41
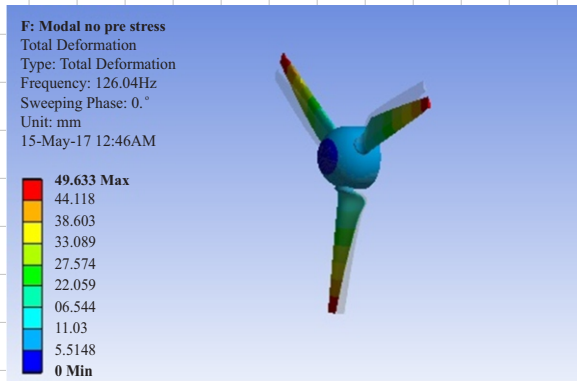
Fig. 5. Modes Shapes For Frequency 126.04 Hz
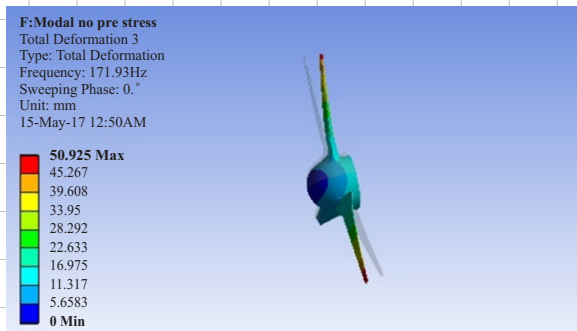
Fig. 6. Modes Shapes For Frequency 171.93 Hz
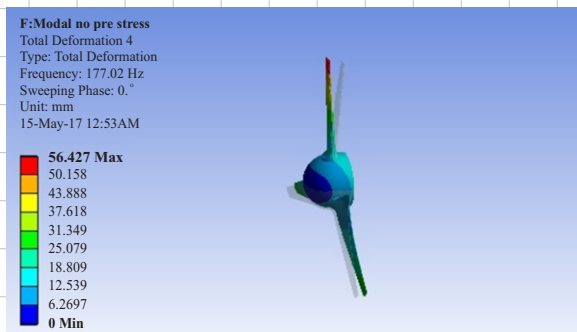
Fig. 7. Modes Shapes For Frequency 177.02 Hz
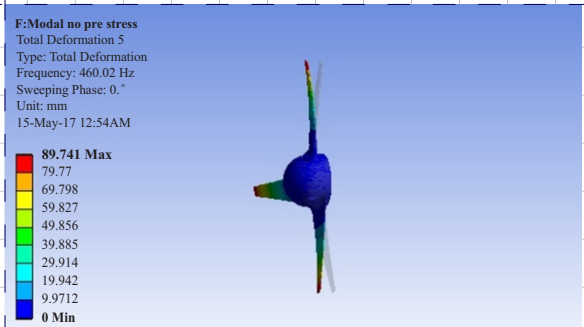
Fig. 8. Modes Shapes For Frequency 460.02 Hz
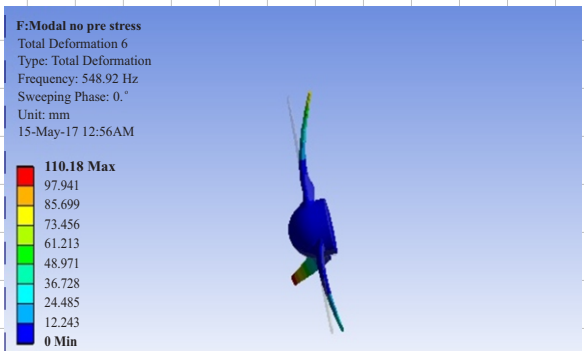
Fig. 9. Modes Shapes For Frequency 548.92 Hz
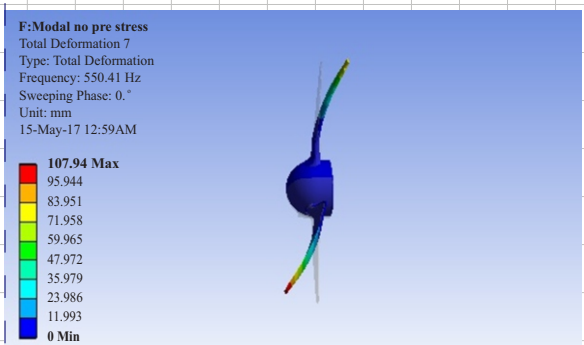
Fig. 10. Modes Shapes For Frequency 550.41 Hz

The full rotor is simulated at an RPM of 191resulting the forcing frequency of 20 Hz at rotor. The natural frequency and forcing frequency of the rotor should not match. If this forcing frequency of the rotor matches the natural frequency, then the structure of the rotor will resonate causing the increase in amplitude of vibration, which may leads to the failure of the structure. By comparing the values of the natural frequencies in Table I with 20 Hz forcing frequency, no matching of natural and forcing frequencies are observed. Satisfying that the rotor will not resonate and also there is no potential failure observed in the structure of the rotor in modal analysis of TCT.

VI. FORCED VIBRATION ANALYSIS

For forced vibration the Transient analysis was

carried out in ANSYS workbench to analyze the structural response of TCT due to influence of the hydrodynamic loads. This analysis was performed for a time duration of 0-3 seconds. The transient analysis results for forced vibration are shown in Table II, III and Fig. 11-12.

TABLE II
DIRECTIONAL DEFORMATION OF TCT

Directional Deformation (Transient Structural Analysis)		
Time (S).	Minimum(mm).	Maximum(mm).
0.20	-7.281E-02	2.910E-02
0.40	-7.302E-02	2.920E-02
0.60	-7.303E-02	2.920E-02
0.80	-7.305E-02	2.920E-02
1.0	-7.306E-02	2.920E-02
1.20	-7.308E-02	2.920E-02
1.40	-7.309E-02	2.920E-02
1.60	-7.309E-02	2.920E-02
1.80	-7.309E-02	2.920E-02
2.0	-7.300E-02	2.920E-02
2.20	-7.300E-02	2.920E-02
2.40	-7.300E-02	2.920E-02
2.60	-7.300E-02	2.920E-02
2.80	-7.300E-02	2.920E-02

E: Transient Structural
Directional Deformation
Type: Directional Deformation(Z Axis)
Unit: mm
Global Coordinate System
Time: 3
01/15/2017 11:19 PM

0.029181 Max
0.017829
0.0064768
-0.0048751
-0.016227
-0.027579
-0.038931
-0.050283
-0.061634
-0.072986 Min
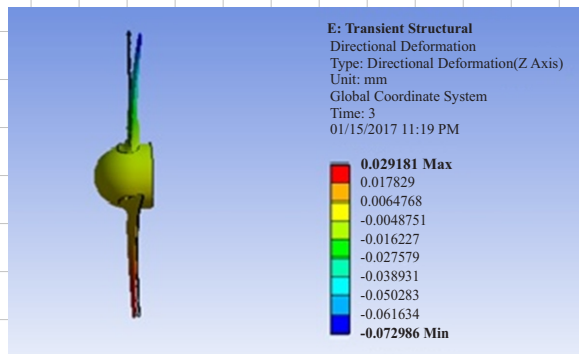
Fig. 11. Directional deformation of TCT

TABLE III
TOTAL DEFORMATION OF TCT

Total Deformation obtained from Transient Structural Analysis		
Time (S).	Minimum(mm)	Maximum(mm)
0.20	0.00	7.48E-02
0.40	0.00	7.50E-02
0.60	0.00	7.50E-02
1.0	0.00	7.50E-02
1.20	0.00	7.50E-02
1.40	0.00	7.50E-02
1.60	0.00	7.50E-02
2.0	0.00	7.50E-02
2.20	0.00	7.50E-02
2.40	0.00	7.50E-02
2.60	0.00	7.50E-02
2.80	0.00	7.50E-02
3.0	0.00	7.50E-02

E: Transient Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1.2
15-May-17 1:43 AM

0.075037 Max
0.0667
0.058362
0.050025
0.041687
0.03335
0.025012
0.016675
0.0083375
0 Min
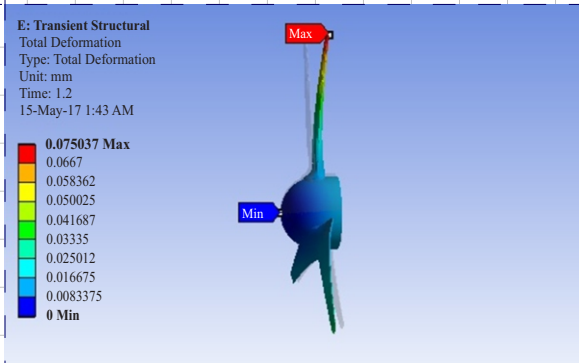
Fig. 12. Total Deformation of TCT Rotor

The above performed analysis showed that TCT blade has low natural frequency for natural mode excitation. To suppress the vibration, flexible joints are recommended and in this manner the TCT can be prevented from failure. It must have damped vibrations earlier before any natural modes can activate.

VII. CONCLUSION AND FUTURE RECOMMENDATIONS

The performance curves obtained from CFD and BEM showed a very good match. They showed an error of 1% for TSR 2 to 8. The modal analysis showed that neither of the natural frequency is critical and it is expected that the structure of the designed turbine is not prone to resonance. The one way analysis showed that deformation caused by the vibration is not critical to cause any power loss or failure to turbine blades. The techniques used in the research work proved to be very efficient and the results produced were quite good.

It is recommended that a full model of the TCT including the Nacelle and tower structure may be studied for its dynamics properties using fluid structure interaction. Moreover, a transient flow model may be used instead of a steady state rotating frame of reference model to more accurately capture the behavior of the flow. A two way FSI model may be used to investigate the effect of fluid pressure on the turbine and at the same time the effect of the vibration produced in the turbine on the wake of the turbine. The study of the effect of the vibration on the wake will be important for the design of tidal arrays. The real sea condition like randomness of the current, wave current interaction and velocity shear etc., may be included in the future model to get a more realistic understanding of the physics governing the operation of a tidal turbine in tidal currents.

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Section D

TELECOMMUNICATION, COMPUTER, SOFTWARE ENGINEERING AND COMPUTER SCIENCE

Middleware Application for Alerting Forest Fires using Wireless Sensor Network

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*Abstract-*Wireless Sensor Network (WSN) has become one of the most important aspects for environmental monitoring, i.e. wildfire monitoring, Landslide detection and many others. Many wildfires causes massive forest damages every year in different parts of the world. This paper presents an effective approach based on wireless sensor network to identify and monitor wild fires in forest. The proposed work presents an intelligent system that provides early warning of potential forest fires as well as to provide an effective evaluation of fire scale and fire intensity. The main objectives of the proposed intelligent sensor based network is to measure the environmental attributes such as temperature (t), relative humidity (h); rain (r) and wind speed (WS) etc. The data of these parameters are acquired via wireless sensor network from different geographical locations and transfer to third party application for processing. The research presented the conceptual framework to intelligently estimate "scale and intensity" of the forest fires. The proposed system is effective and reliable to identify and monitor forest fires. It can easily be integrated with third party applications.

*Keywords-*Conceptual Framework, Forest Fires, Intelligent, System Architecture, Wireless Sensor Network (WSN)

I. INTRODUCTION

Forest fires or wild fires cost a loss of millions of dollars each year in different parts of the world [i]. Forest fires are a major source of massive damage to houses, buildings, and human lives each year[ii]. Beside preventive measures, the identification of forest fires at early stage and its suppression are the only ways to minimize the damages and casualties cause by the wild or forest fires" [iii]. Researchers have explored this area in great deal and contributed in this domain with various solutions [iv-ix] to provide alert and monitoring services for forests fire identification and propagation. This area always keeps researchers interested to propose novel and effective solutions as human lives and nature are affecting from this problem. There exist a room to propose effective and efficient solutions to save the human lives and natural resources all over the world. Beside plenty of room for research, forest fire identification and monitoring is a challenging task [x].

There are various sources that contribute to initiate and propagate forest fires, some of them are natural but unfortunately most of the time the forest fires are caused due to the human carelessness such as Lighting, Aridity [xi].

A. Real time Application

To design and develop a real time application for forests fire monitoring is a critical and challenging task. Existing research work [xi, viii] have been proposed to design effective solutions for the detection of forest fires at early stages. Researchers have also contributed in this domain and proposed various solutions [xi] to address the problem of forest fires propagation at rapid speed. These systems are designed by using different types of information and communication technologies [xii]. Rapid advancement in technology and ease of information access has resulted in the development of effective solutions for real time environments such as "forest fires detection [xiii], building security system [xiv], and home automation [xv-xvi] etc. Even though much work has been proposed in this area but the challenging environment and nature of disasters has demanded to propose more effective solutions to meet the current real time challenges in forest fire identification and propagation [xvii].
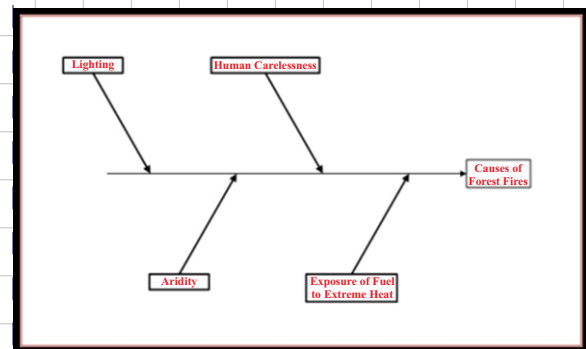

Fig. 1. Causes of Forest Fires

In past, large number of tools and techniques are being utilized for design and implementation for monitoring of the real critical environment such as Agent based forest fires [xviii], MRISR, Osborne fire finder etc.

This paper presents a solution to identify and monitor the propagation of forest fires by using wireless sensor networks (WSN) for forest fire control. The proposed solution is divided into three layers and each layer consists of specific components. These components are designed to perform specific task such as "Fire detection"[xix]. However, all the components are integrated together so that the overall performance and efficiency of the proposed solution can be increased.

Smart sensor technology has been used in various domains to propose effective solutions for real world problems [xx]. Existing research is also being conducted to achieve better performance and efficiency by using smart sensor technology. Wireless sensor network (WSN) technology has been in practice since many years in various daily life applications [xxi]. Smart sensors are part of various portable devices these days such as cell phones, PDA etc. which are used for data collection [xxii]. Sensor frequency identification devices transfer the data using wireless medium of communication. Existing systems [xxiii] have also been designed in the field of communication and information technology (ICT) specifically focusing on WSN. Wireless sensor network (WSN) is considered as a low cost inexpensive solution and can easily be integrated with any system or application in various domains [xxiv].

We have designed a sensor-based network for the identification and detection of the forest fires. However, we have presented a conceptual framework that can be integrated in various software applications. The base station of the network act as a web service. Fire Weather Index (FWI) is used for the identification of the forest fires.

Developing a real time critical system for the real time environment of forest fire is a challenging task. We have presented the system for the identification and detection of the forest fire. The following section presents the desired objectives.
1. Early detection of forest fires.
2. An intelligent estimation mechanism for scale and intensity of fire.
3. Fire Index calculation based on Fire Weather Index (FWI). Fire Weather Index model is presented in [xiv].
4. Design and development of dynamic web application for integration with alerting system

There are number of challenges which we have faced during the design and development of a system for the identification and control of forest fires. Few of the design challenges are mentioned below:
1. The identification and detection of the forest fires

is based on the number of the component such as measuring temperature, Fire Intensity, Routing Path so that the estimated scales and intensity are identified.
2. The identification of the forest fires should be based on the number of parameters such as Scale, FWI, FFMC [xiv]

This paper presents a conceptual framework for the identification and control of forest fires. Wireless sensor network is used to design the proposed framework. The proposed solution implements a conceptual frame work with a capacity to identify forest fires at early stage, and intelligently estimate 'scale and intensity' of the forest fire.

Section II presents a critical analysis of existing state-of-the-art. Section III presents the architecture of the proposed framework and analysis on its core parameters. Experimental results are discussed and evaluated in Section IV. Section V presents the conclusion of the proposed system.

II. LITERATURE REVIEW

Most of the existing systems used nowadays for forest fire detection rely either on satellite imagery or watch towers. These systems suffer from limited operations under bad weather conditions that can result in a loss of visibility. This affects the overall performance of the detection accuracy of forest fires. This section presents the critical analysis of existing state-of-the-arts. The open research problems are also identified. The design and architecture based on different approaches, tools and techniques of existing state-of-the-arts are also elaborated in detail.

A. Forest Fire Detection Systems

The design and architecture of existing forest fire detection systems heavily rely on traditional implementation techniques such as "Digital Image Processing (DIP), satellite imagery or watch towers" [xxv]. There exist many limitations in existing systems. The existing systems have limited operations under bad weather conditions such as "Fog, Rain, Smoke etc.[xxvi]. Loss of visibility is another core issue that affects the performance of existing systems to accurately detect forest fires. Existing forest fires detection systems have a high ratio of "errors and inaccuracy" because these systems mainly depends on traditional approaches [xxvii].

B. Wireless Sensor Network

This sub-section presents the information related to existing forest fires detection systems [xvii, xxiv] based on wireless sensor network approaches. The details regarding wireless sensor networks and transmission medium are also discussed here.

Wireless Sensor Network (WSN) is considered as an alternative to the traditional approaches for forest

fires detection. Existing forest fire detection systems [xix, xxii] that are based on wireless sensor networks have reported better detection accuracy to detect forest fires at early stages as compared to traditional approaches. The benefits of wireless sensor networks such as less power consumption, self-organized architecture, less effort in maintenance have been reported in [xxiv].

The skyline approach is designed by using greater values of sensor readings such as maximum temperature and high wind speed. The skyline data are sent to the sink that are then used to identify forest fires [xvii]. Sink process the data according to the recommended algorithm in [xvii] and produces an energy efficient and rapid detection solution for forest fires. Each sensor consists of the receiver and sender and transfers all the information to the receiver or sender [xxii].

The proposed framework uses wireless sensor network (WSN) technology to detect and control the forest fires. The performance of the proposed system architecture in terms of identifying issues related to the design and implementation of a conceptual framework for real time applications is also evaluated. The main objective of the proposed system is to detect forest fires at early stages and provide an accurate estimation of the scale and intensity of forest fires. The research objective is to provide forest fire detection of an effective, state of the art, service support software based on Microsoft platform and any other open source technology. For the sake of verification and validation (V&V),a couple of simulation [xviii] are performed as well.

Energy is considered as the core aspect in the real time critical applications. To increase the overall performance of the network and the other components, the energy sources must be identified so that the specific monitoring and surveillance can be performed without dropping or failing down the devices [xxix] or other components integrated with it. The energy sources can be provided to WSN sink node. These sensors are usually equipped with the battery.

C. Photovoltaic Devices

The Photovoltaic Device is considered as the source of energy. These devices can also be integrated in WSN based sensor. The elementary photovoltaic device is also commonly known as photovoltaic cell. These cells are composed of two main layers. Each layer is made of semiconductor [xxx]. These semiconductors are separated by metal contact [xxxi]. The two adjoining layers of semiconductor are separated with the help of metal contacts that have been doped. After doping, an n layer is created (n = negative) with a surplus of electrons followed by a "p" layer (p = positive) with an electron deficiency. In the photovoltaic devices, the electron flows from n layer to p-layer and creates an "electrical field" or "space charge zone". These fields are created inside the semiconductor structures [xxxii].

D. Energy Considerations

There exist many constraints for energy or battery sources. The battery size of the WSN based sensor is directly proportional to the capacity. As the battery size increases, the capacity of the sensor also increases, or vice versa. Wireless sensor network based technology sensors are smaller in size, so they have low capacity to improve the overall network lifetime. An easy way to increase the network or battery lifetime is to use battery scheduling algorithm. The selection of the optimal transmission power is also an important parameter to consider for energy constraints.

The energy consumption is also directly proportional to the transmission power. The transmission power is functional between the communication nodes. It helps to transfer the information or data from one node to another node. As the transmission power increases, the energy consumption and the transmission power decreases. "Optimal transmission power decreases the interference among nodes, which in turn increases the number of simultaneous transmissions." [xxxiii]. The reduction in the transmission power increases the frequency to reuse the better channel utilization. Power control is considered as an important part of the CDMA-based applications or systems [xxxiv].

We have presented a framework that uses wireless sensor network based on fire weather index system to resolve the issues of energy constraints in forest fires detection systems.

III. PROPOSED SYSTEM

The proposed framework based on wireless sensor network is designed to detect the pattern, scale and intensity of forest fires at early stages. The proposed framework has many benefits as compared to existing systems. The architecture of the proposed framework is designed by using fire weather index (FWI) as compared to forest fire danger index system (FFDI) that are used in existing systems. The fire weather index uses four parameters that are, *Temperature, Humidity, rain* and *wind speed* to predict the patterns, scale, and intensity of forest fires. It also facilitates in the identification of the Initial spread index as well as the build-up index of the forest fires.

In this section, we have provided an overview of the system architecture, system components, system features, and a detailed discussion on wireless sensor networks.

A. System Architecture

The system architecture is always considered as a baseline to lay the foundation for the overall system implementation. The proposed system consists of three main components namely, wireless sensor network,

middleware, and web application. Wireless sensors are used to collect and transmit the data to the detection system. Fire weather index (FWI) model [xvi] is used for data calculations. The system automatically generates an alert in case the FWI values exceeds the threshold. Moreover, the information is collectively shared with the corresponding administrator. Shown in Fig. 2 is the architecture of the proposed framework.
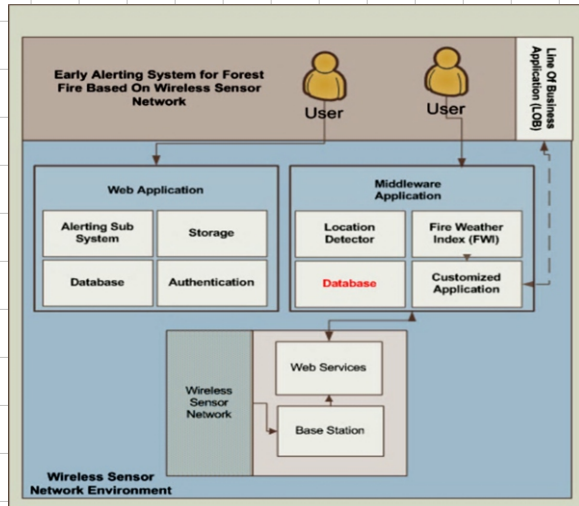
Fig. 2. Architecture of Proposed Framework

The proposed framework is more flexible and requires little effort in maintenance as compared to existing systems [viii, xx, xxiv, xxviii].The proposed system can be deployed easily. Web Application can be integrated for quick response. The application is based on the web based architecture that can easily be accessed from different locations with the internet connectivity. The system is much reliable as it is based on the Fire Weather Index. Warning alert is only generated in case if FWI level exceeds the threshold value up to 85.The minimum and maximum values of FWI as a candidate for potential ignition are presented in Table I.

TABLE I
FWI VALUES

Ignition Potential	Minimum Value	Maximum Value
Low	1	75
Moderate	76	85
High	86	89
Very High	90	92
Extreme	92	93+

False alarm rate of the proposed system for forest fire detection is significantly low as compared to existing systems [viii, xx]. The proposed system can be deployed in large zonal areas and provides an immediate response regarding indicators of fires. The proposed system is more flexible as it is based on the

sub components of middleware and web application. The architecture of fire weather index is shown in Fig. 3.
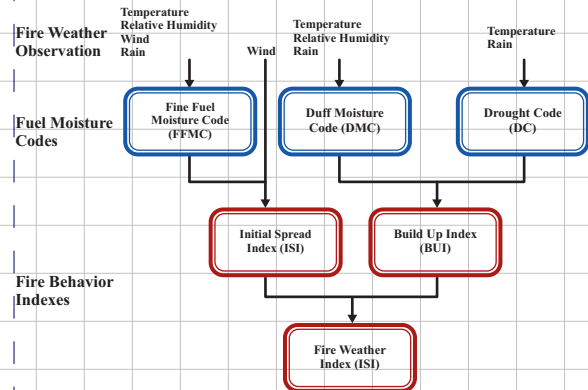
Fig. 3. Fire Weather Index System [xvi]

B. Wireless Sensor Network

Wireless sensor network is composed of a large number of tiny sensor devices that are used for specific data calculations from the environment or monitoring locations such as "wind speed, rain, humidity, temperature, heat etc. [x]. The sensor devices transform the environmental data into radio signals followed by transmission to the base station. The base station act as a wireless gateway [xiv]. Shown in Fig. 4 is the architecture of the wireless sensor node.

The significance of wireless sensor based networks cannot be denied nowadays because of their benefits in monitoring the location. These sensor instruments can be deployed in the critical and real time environment for forest fire monitoring [xxxvi]. Wireless sensor networks are more efficient to perform in real-time and challenging weather conditions. This wireless sensor requires less maintenance and has high efficiency and long life. Radio frequency identification based sensor network is normally used in various domains such as Medical application (diagnosis, physiological data), military applications (intelligent missiles, battlefield surveillance), Environmental monitoring (traffic, habitat) Industrial monitoring (factories, supply chains) etc. These radio frequency operated sensor networks continuously monitors the environment and report the data back to the base station. Radio frequency identification based sensor networks measures and obtain the coordinates of the location of fire ignition.
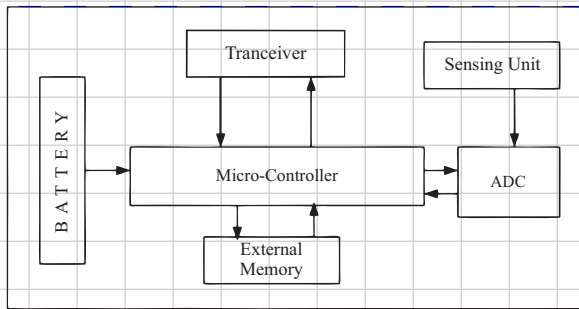
Fig. 4. Wireless Sensor Architecture

Fig. 5. Performance Comparison of FFMC and FWI

Radio frequency identification based sensor is used in many applications such as medical, military, environment and industrial monitoring   etc. The sensor can be used in the form a sensor network or dynamic web. These networks can be deployed in the specific location for the environment monitoring. The entire sensor network uses the static or dynamic routing protocol depending upon the position of the sensor location [xxxv]. These routing protocol transmit the data to the designation. WSN transmits all the data to the base stations. The base station is connected with the monitoring application. WSN has many benefits such as reduction in cost monitoring by limiting the need for wires, communication channel etc.

IV. Experimental Results

Performance evaluation of the proposed system is measured via objective evaluation. We have evaluated various aspects of middleware and web application for the forest fire detection. Middleware collects the data from the nodes that are deployed in the forest. The middleware calculates the coordinate of each sensor node that facilitates accurate computation of fire ignition location. The middleware also calculates the fire weather index based on processing input data from each sensor. Shown in Fig. 5 is the accuracy comparison between the FFMC and FWI. High values of fire weather index indicates fire ignition and demands to mitigate fire ignitions by the authority. The nature of fire spread, scale, pattern of fire propagation and intensity are investigated in detail to take appropriate measures to control forest fires. This detailed study is useful to decide the outcome of either taking appropriate measures for fire mitigation.

In order to overall increase the performance and capacity the Multi-Listing technique is utilized to overall discard the repeated packages that are flooded in wireless network. However, in this research the energy efficiency goal is achieved by using agent based approach.
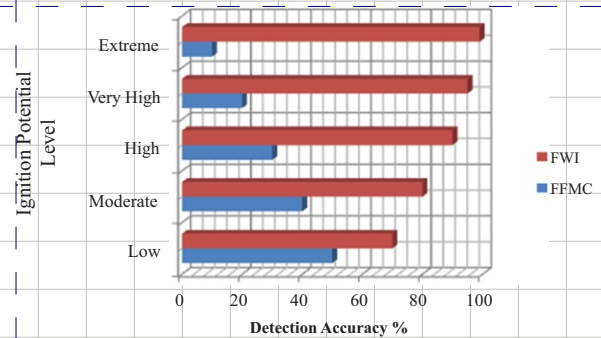
In Fig. 5 the experiment has been conducted to measure the performance of the FFMC and FWI. The detection accuracy has been measured on the five Ignitions Potential Level defined on the x-axis of the fig 5. It can be analysed from the experiment results that within the context of the detection accuracy the FWI is most accurate and efficient as compared to FWI. These values has been driven from the dataset presented in Table II

TABLE II
FFMC AND FWI Value

Ignition Potential Level	Humi-dity	Temp-erature	FFMC	Humi-dity	Temp-erature	Wind-Speed	Rain	FWI
Low	30%	17 C	50	30%	17 C	5 mph	0	70
Moderate	45%	20 C	40	45%	20 C	18 mph	0	80
High	65%	25 C	30	65%	25 C	23 mph	0	90
Very High	43%	30 C	20	43%	30 C	30 mph	0	95
Extreme	32%	43 C	10	32%	43 C	50 mph	0	99

C. Relationship of Fire Intensity and FWI
Shown in Fig. 6 is the relationship between the fire intensity and fire weather index. Fire intensity indicates the energy output measured in kilowatts/meter of the frame length on the base region of the fire.
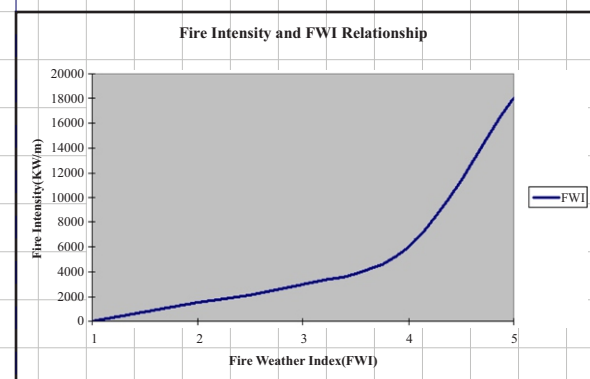
Fig. 6. Relationships between Fire Intensity

D. Measuring Time Detection
In our next experiment, we have evaluated various aspects of middleware application that has been

designed to measure the effectiveness of the proposed framework. Fire detection time metric is used to evaluate the performance of the proposed system. Moreover, the detection time of the proposed system is compared with existing state-of-the-arts to signify the effectiveness of the proposed system as compared to existing systems [viii, xx, xxiv, xxviii]. Shown in Fig. 7 is the fire detection time measure of the proposed and existing state-of-the-arts. It can be observed from the results that the proposed framework successfully detect the forest fires more swiftly as compared to existing systems.
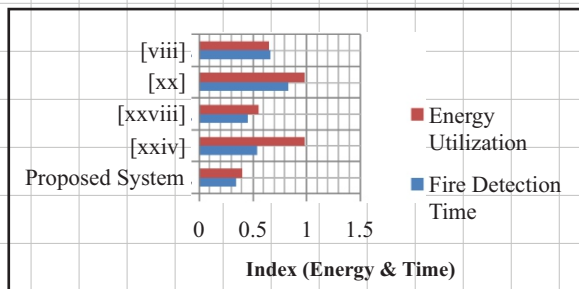
Fig. 7. Comparison between Existing Times

In Fig 7, the comparison based on the energy and time has been conducted with the existing solution [viii, xx, xxiv, xxviii] and proposed system. It can be analysed from the experimental results that the proposed system within the context of time is energy consumption is much more efficient as compared to the existing system. The dataset for the experiment has been presented in Table III.

TABLE III
PERFORMANCE COMPARISON OF FIRE DETECTION TIME

Systems	Fire Detection Time	Energy Utilization
Proposed System	0.34	0.4 J
Son et al. [xxiv]	0.54	0.98 J
Belani et al. [xxviii]	0.45	0.55 J
Estrin et al. [xx]	0.83	0.98 J
Hefeeda et al. [viii]	0.66	0.65 J

It can be analysed from Table III. that the proposed system detects fire ignition rapidly as compared to existing state-of-the-arts. The identification of forest fires at early stage is one of the main contributions of the proposed system.

E. Early Warning of Potential Forest Fires

Fine fuel moisture code (FFMC) indicates the relative ease of ignition and flaming fuel category due to exposure to extreme heat. To analyze the system we have investigated FFMC on different data inputs. The fine fuel moisture code is a positive integer with values in the range of (0 to 101)ignition rate. FFMC is the only component of the fire weather index with the open-

ended scale. In general, fire ignites at around 60-70 % and it can shoot at maximum up to 96 %. High value of FFMC is an indicator of possible fire ignition and vice versa.
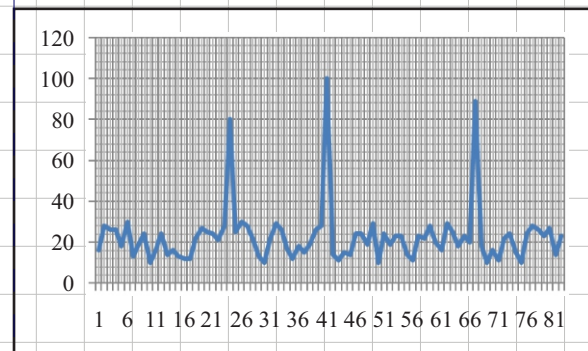
Fig. 8. Temperature Analysis

F. Estimate the scale and intensity of the fire if it is materialized

Fire weather index is used to estimate the scale and intensity of the fire, if it is materialized. FWI estimates the fire intensity by merging the rate of fire spread. Initial spread index is used to calculate the fire spread rate.
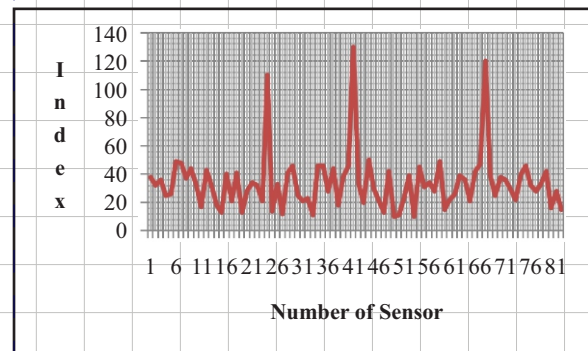
Fig. 9. Fire weather index changes as the temperature increases

A high value of the fire weather index indicates fire ignition, if value of FWI exceeds the specified threshold. FFMC and FWI are computed from the input data such as temperature, wind, relative humidity, rain etc. acquired from the sensors.

Relationship Temperature and FWI
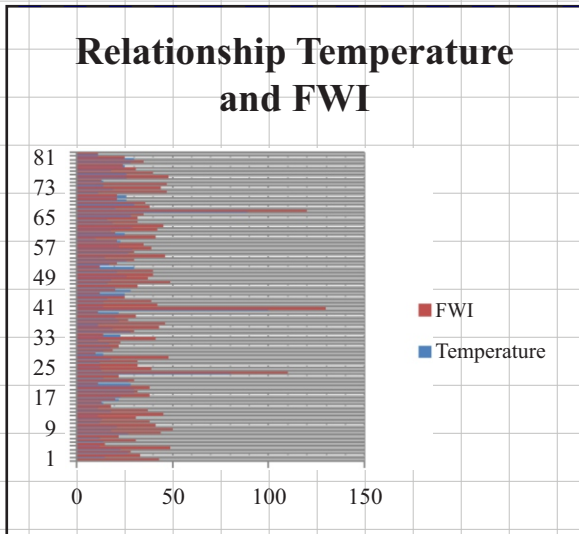
Fig. 10. Relationships between Temperature and FWI

Shown in Fig. 10 is the relationship between the temperature and FWI. The temperature values are plotted in combination of FWI values to give the indication of a direct relationship between these two parameter values. It can be observed that where the temperature is high the FWI values are also high. At some point in Fig. 10 the temperature and FWI strike rate is high. So it can be assumed from the Table IV dataset that Temperature and FWI are directly proportional to each other.

TABLE IV
RELATIONSHIP BETWEEN TEMPERATURE & FWI

T	FWI	T	FWI	T	FWI	T	FWI
13	26	27	29	21	13	29	45
18	28	80	110	13	21	30	43
19	29	21	33	20	44	29	36
15	31	30	33	16	23	10	25
27	45	29	21	12	15	89	120
15	49	20	13	16	44	29	17
24	12	15	50	13	31	18	18
11	39	20	46	25	18	14	46
19	28	10	43	28	29	23	41
14	30	28	18	29	14	17	25
21	11	21	46	19	31	20	44
11	18	13	43	29	49	18	38
24	33	17	12	25	25	16	18
10	34	11	13	15	32	18	31
30	13	25	47	21	18	17	23
19	23	16	35	26	47	19	28
15	20	21	49	11	25	29	43
29	13	14	19	18	13	23	24
24	23	100	130	18	40	11	46
25	25	17	20	18	10	26	45
15	16	27	29	21	13	29	45
22	26	80	110	13	21	30	43

The proposed research work demonstrates the utilization of wireless sensor network as opposed to traditional technologies like watch tower for forest fire detection. Database is used for storage information which can be effectively utilized for the process of operationalization and verifications. The proposed system acquires the input data from the sensors at real time and effectively identify the location of forest fire ignition and generates a warning message to administrator.

The design and implementation of the proposed framework is based on Dynamic System Development Method (DSDM). Real time application testing is the most challenging task to evaluate the performance of the proposed framework. The proposed system utilizes fire weather index and identifies the location of fire ignition. The proposed forest fire detection system consists of a large number of inexpensive and small WSN nodes. The detection accuracy of the proposed system is significantly better as compared to traditional approaches [xi]. Moreover, the proposed system can detect forest fires more rapidly. Shown in Fig. 11 is the application interface of the proposed framework.
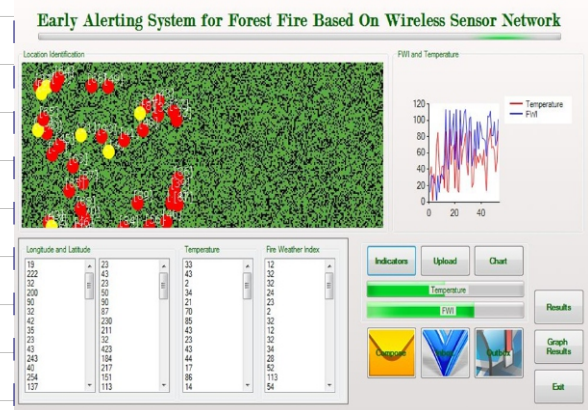
Fig. 11. Application Interface

The systems can intelligently estimate the scale and intensity of the forest fires. Existing system uses the FFMC index system. FFMC indexing systems utilizes humidity and time environmental variables, whereas the proposed framework uses four main variables (wind speed, rain, humidity, temperature). The existing system cannot be integrated with the third party open source application however the proposed solution can also be integrated with third party application. WSN identification can easily be located as compared to the [xx] sensor network. However, there still exists a demand to propose efficient real-time solutions to detect forest fires in different geographical locations around the globe.

V. CONCLUSION

The proposed system presents a middleware and

web application using wireless sensor network to detect forest fires at early stage. The proposed framework calculates the scale and intensity of the forest fires. Middleware is based on the fire weather index and successfully locates the position of fire ignition. Wireless sensor network technology is found to be more efficient as compared to traditional approaches for forest fire detection and estimation. It can be observed from the results that the proposed system detects forest fire immediately, and forecast about the forest fire danger rate with better accuracy. The proposed framework can be extended by incorporating the cloud technology and software as a service facilities to the existing solution presented in this paper.

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Prioritizing Critical Challenges for the Web Based Systems: A Software Quality Perspective

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Abstract-Web based application systems are rapidly evolving round the globe. Multi-platform approach along with their heterogeneous nature makes the web based applications huge and more complex. Moreover, assuring quality of the web based application systems is becoming critical due to complexity of the web based applications. Therefore, this study aims to identify the challenges encountered by the software community in order to assure the quality of web application from the existing literature. Empirical investigations have been conducted using survey questionnaire methodology to collect the data from experts working in software industry. Different statistical models like Principal Component Analysis and Kappa statistics leads this study to extract and rank the most crucial challenges associated with the quality assurance of web systems. Whereas, Cronbach's alpha has been used to ensure the reliability and consistency of the data.

Keywords-Quality, Quality of Web Systems, Challenges of Web Quality, Prioritization of Web Challenges.

I. INTRODUCTION

The WWW (World Wide Web) is mostly known as web which provides a multiple platform technology to run the software application programs anywhere. Therefore it is becoming an essential part of human life and cheapest mode of communication. There are some characteristics which make web based application systems different from the other conventional software applications such as design parameters, platform independence, content services through user interface, web browser etc.

Currently the enterprises or organizations via the private or public, small or big rely on web based application systems to support critical business functions. Those systems mostly consist of multi-tier applications like the business management process and Electronic commerce (E-Commerce). These organizations switch their services through www by using web applications. Due to this usability, diversity and popularity of web applications, the number of users like educationist, scientist, businessman and researchers are increasing every day to access the information worldwide [i]. That access can be the transaction oriented or information retrieval. It seems that web has reduced the need of traditional means such as paper, books etc.

Web applications are called with different synonyms such as web information systems, web based applications, web sites, web software's and web application software [ii]. The client server applications make use of web browser (client program) that provides the services through internet. These applications comprise of functional and nonfunctional requirements. The functional requirements include system requirements whereas performance, scalability, accessibility and security etc. include nonfunctional requirements [iii]. The components of web are interlinked with each other. Each component has its own specific design layout and architecture. The components include web browser, web server, web page, application server and database. Contents of the web applications are presented by the hypermedia controls using different web technologies such as HTML(Hypertext markup Language), XML (Extensible markup Language), DHTML (Dynamic Hypertext Markup Language) and Java Script etc.[iv].

The researchers [v-vii] introduce different types of web based application systems in different perspectives. These are simple types; the challenges identified in this study are not depended on these following types of web based systems. We have considered all types of websites. Some of famous types of web applications are given below[viii].

a) **Transactional**
   Services and products can be purchased by end users. Such as E-Commerce and Online Banking [ii].

b) **Instructive/Informtional**
   Provide the information to the end-user. Online newspapers, E-books, Service Manuals[ix].

c) **Data Warehouse**
   Queries are made from large collection of database. For example Search engines like Google [ii].

d) **Web Portals**
   Web portals provide access to other web

applications and contents such as electronic shopping centers[i].

e) **Customizable**
End users can customize the contents based on their preferences. For example email setting system[x].

f) **Service Oriented**
End users receive the online services on regular, monthly or annually basis [ii].

g) **Interactive**
These applications provide communication channel to the end users graphical user interface e.g. Business to business[ix].

h) **Database Access**
This application queries a database and retrieves information[viii].

i) **Online Communities**
Chat groups, market places, auctions, recommenders systems[i].

j) **Deliverable**
End users download information from the servers such as software up gradation[viii].

Quality assurance of web based application systems is vital for the success of any organization or business. As the dependency on the web based applications increase day by day, the scalability and complexity are also growing but the development cycle is becoming shorter. Due to that magnificent increase in web based application systems, there are numerous challenges being faced which can setback to the reliability, security, accessibility etc. for the quality assurance of web based application systems [xi]. Therefore, the objective of this paper is to identify and rank the critical challenges of web based application systems.

Rest of the paper is structured as follows: Section II presents background of web based application systems. Section III discusses the research method which is followed. Section IV discusses the results obtained from empirical investigation. Research Implications and limitations are described in Section V and the last Section which is VI state the conclusions of this work.

II. BACKGROUND

In the start when internet technology was developed, internet was used as a medium for exchange of information over networks. Early websites are just the set of loosely connected pages. Websites were only some hyperlinked documents containing text information so the quality of old websites is not good. If someone wants to access computing power then it is required to log in to terminal which is connected to a mainframe or server computer.

With the passage of time web based applications gained popularity and the size of the websites also increased and the number of web hosts reached over billions, so the organization of contents became fundamental requirement [xii]. Now a days web based application systems is not just the medium for sharing information, enterprises also offer their service through E-commerce. Therefore the web applications are designed for all types of people irrespective of their cultural, geographical, mental and physical capabilities but there are certain milestones for this purpose that are yet to be accomplished.

Various researchers came up with propositions of various challenges encountered by the quality of web based systems. An effort has been made by [xiii] addressing the cross browser issues in terms of different resources like time , effort, page layout and application functionality issue that are difficult to identify and do not have visible effect. Furthermore, [xiv] delineates the challenges of web security regarding the unauthorized access, vulnerabilities, and dangerous attacks that exploit the web applications. It has been urged by [xv] that when an activity or task not finish subsequently the highy qulaity of error reports are recived by the end users which are actuallty the cryptic error messages. Whereas [ii] highlighted the challenge of interoperability only, such as the components fail to meet the architectural constraints because the functional requirements are not fulfilled. On the basis of extensive literature review, no study has been found addressing web challenges associated with the quality assurance of such applications. Therefore this study contributes in a fashion to identify the challenges that are associated with the quality assurance of web systems. Furthermore, the extracted challenges of quality of web applications are prioritized on the basis of empirical study which has never been done before. In order to achieve the objectives of this study, following research questions have been formulated;

Rq1: What are the critical challenges of web based application systems?
Rq2: What challenges are crucial for quality assurance of web based applications?
Rq3: Which challenges are more crucial than others with respect to their severity?

III. RESEARCH DESIGN

A. Sample
85 questionnaires were sent to the sampled population targeted for this study. However, only 63 responses were received at the rate of 75%. Before sending the questionnaire, a pilot test was also conducted with four experts in order to check the validity and consistency of the items of the survey. The experts were selected from software industry on the basis of their experience in developing web based applications. It is pertinent to highlight that targeted experts are having at least 5 years of experience in the domain. Table I tabulates the demographic detail of the respondents.

TABLE I
DEMOGAPHIC PROFILE

Demographics	Frequency	Percent
Gender:		
Male	33	50.76
Female	32	49.23
Qualification:		
MS(CS)	10	15.38
Master	55	84.61
Designation:		
Web Developer	36	50.76
Software Engineer	29	49.23

B. Data Gathering

A list of challenges was formulated after reviewing various articles, books, and published research papers from the well-known journals. Questionnaire method is used to collect the response from the practitioners (respondents). The questionnaire is designed according to the research questions which are previously discussed in section III. Data was gathered by requesting the experts to rate each challenge by using Likert Scale from unimportant (1) to most important (5) according to their severity level. The scale values which was assigned to five responses as shown in Table II.

TABLE II
LIKERT SCALE

Scale Value	Agreement Level
1	Un Important
2	Least Important
3	Neutral
4	Important
5	Most Important

C. Data Analysis

In order to find answers to RQ1, an exhaustive study of existing literature was conducted and 22 challenges of web based application systems were identified as illustrated in Table III. The identified challenges encountered by developers in diverse perspectives like user, designing and development. In order to obtain the answer of research question RQ2, identified challenges are extracted which relate to the quality assurance of web based application systems. For this purpose PCA is deployed on the survey responses, the survey was conducted among the practitioners, the calculated results of PCA are shown in Fig. I and Table V. Whereas Table VI providing the answer of research question RQ3 i.e. prioritization of the extracted challenges with respect to their importance and cruciaity.

TABLE III
IDENTIFIED CHALLENGE OF WEB QUALITY

Identified Challenges	Literature
Interoperability	[ii, v]
Reliability	[xvi]
Scalability	[xvii], [xvi]
Security	[vi], [vii], [xviii]
Browser Compatibility	[xix], [xx]
Maintainability	[xiv]
Availability	[xxi]
Reusability	[xiii]
Performance	[xvi], [xxii]
Supportability	[xxiii]
Usability	[xxiv],[xxv],[xxvi]
Testability	[xxvii], [iii]
Limitation for Web Page Layout	[xxviii]
Navigation	[xxix]
Database Design	[xxx], [xxxi]
Content Design and Management	[xxviii]
User Interface Design	[xxxii], [xxxiii]
Control Flow	[xxxiv]
Integrating Different Technologies	[xxxv]
Network Load Management	[xxxvi]
Cryptic Error Message	[xxxvii]
Data Integrity	[xxxviii]
Socio culture	[xxiii]

D. Research Tools

Different statistical tools are used to analyze the data which is collected through survey such as Principle Component Analysis (PCA), Cronbach's Alpha, and Cohen's Kappa which are briefly defined below.

a) Principle Component Analysis (PCA)

PCA is used to visually assess which challenges have most variability in data. It is popular and common multivariate statistical method used for factor reduction. The purpose to deploy the Principle component analysis is to reduce the large number of challenges, the items with too small proportion (say$\leq$0.03) can be negligible [xxxix]. The challenges are extracted using PCA are shown in scree plot in Fig. I.

b) Cronbach's Alpha

Cronbach's alpha is used to measure the internal validity and reliability of the data. It ranges from 0.7 to 1.0. The greater value shows the higher reliability of the data [xl]. The value of our result is 0.87 which depicts that the data is reliable.

c) Cohen's Kappa

Kappa coefficient measures the categorical agreement between two ratters or methods [xli]. The strength agreement value of kappa statistics should be ≤ 1.0. The strengths of raters agreement obtained is 0.74 which is substantial according to [xlii] as shown in Table IV.

TABLE IV
LEVELS OF AGREEMENT

Agreements	Values
No Agreements	≤0
Slightly Agreement	0.01–0.20
Fair Agreement	0.21–0.40
Moderate Agreement	0.41–0.60
Substantial	0.61–0.80
Almost Perfect	0.81–1.00

IV. RESULTS

Mean values of responses which are collected through survey are arranged in descending order and are summarized in Appendix-A.

a) Extraction of Challenges

In Scree plot as shown in Fig. I, Eigenvalues are shown on the y-axis and challenges are displayed on the x-axis. As depicted in Fig. I, curve is straight after 12 challenges. So, it portrayed that 12 out of 22 challenges are most crucial on the mutual agreement based on the raters.
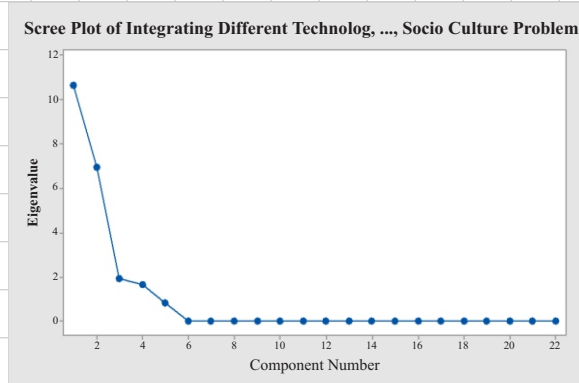
Fig. 1. Scree plot for the web based challenges

The proportion of the most crucial challenges of web based application systems is illustrated in Table V. Security is the most crucial challenge which have a big proportion value. The remaining challenges show very small proportion values and are likely to be unimportant.

TABLE V
PROPORTION LEVEL OF CHALLENGES

Variable	Proportion	Cumulative Proportion
Security	0.33	0.33
Reliability	0.16	0.49
Performance	0.12	0.61
Scalability	0.11	0.72
Availability	0.06	0.78
Usability	0.05	0.83
Supportability	0.04	0.87
Maintainability	0.02	0.89
Testability	0.02	0.91
Reusability	0.02	0.93
Data Integrity	0.02	0.95
Navigation	0.01	0.96

b) Ranking of Challenges

Mean values have been calculated for each challenge based on their raters' responses. To find the answer of third question, all challenges are then arranged in descending order as the challenges which are most significant are on the top as shown in Table VI. The total answers are five (Likert Scale) therefore the median of five values is 3. Those challenges attaining the score greater or equal to 3 are considered as crucial challenges. However, the challenges having mean value less than 3 are considered as least important challenges [xliii].

TABLE VI
PRIORITIZED CHALLENGES

Challenges	Mean
Security	4.38
Reliability	4.30
Performance	4.15
Scalability	4.13
Availability	3.96
Usability	3.95
Supportability	3.84
Maintainability	3.61
Testability	3.58

Reusability	3.50
Data Integrity	3.43
Navigation	3.40
Network Load Management	3.24
User Interface Design	3.00
Browser Compatibility	2.93
Database Design	2.90
Control Flow	2.78
Socio Culture	2.76
Integrating Different Technologies	2.73
Interoperability	2.72
Limitation for Web Page Layout	2.41
Content Design and Management	2.23
Cryptic Error Message	2.23

V. DISCUSSION

In this section the identified challenges of web based application system are described and the implications along with limitations of the study are also construed.

a) Implications

This research work furnishes various implications for the software industry in Pakistan. The prioritized challenges may be considered for the development of diverse web based applications like e-commerce, e-business, e-learning,e-banking and etc. in order to enhance the quality of applications.

b) Limitations

There are some limitations regarding the challenges of implementing web applications. The study is restricted to only one country i.e. Pakistan. Furthermore, this work is also limited by considering just the quality assurance challenges of web based application system. The most crucial challenges, extracted in this study are shown in table V providing the considerable influence on the quality assurance of web based application systems but that cannot be considered the final list of challenges.

VI. CONCLUSION

The pace of business life has become faster as compared to the past. Enterprises are exponentially burgeoning their business using web applications through internet or intranet. Consequently, web based application systems need to be developed much quicker and better as compared to earlier applications. The quality assurance of web application systems is a critical challenge to web developer because of its heterogeneous nature, and involvement of interlinked web components. Therefore, quality measurement of web based application system is not an easy task but at the same time it is crucial. There is no single design and ultimate solution for the quality of web based application systems. The research attracts the decision makers of web developers, designers and software engineers to assess the quality assurance of Web systems. Additionally, this research provides guideline to various stakeholders of web application systems for the quality assurance of their applications.

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Appendix-A

Challenges	5	4	3	2	1	Mean
Integrating Different Technologies	4	19	14	18	10	2.73
Scalability	26	27	7	3	2	4.13
Security	37	20	4	2	2	4.38
Browser Compatibility	3	13	30	15	4	2.93
Content Design and Management	6	4	11	31	13	2.23
Data Integrity	18	12	19	12	4	3.43
Reusability	23	11	17	7	7	3.50
Interoperability	7	10	16	25	7	2.72
Navigation	20	15	13	9	8	3.40
Supportability	22	25	6	9	3	3.84
Testability	24	17	9	7	8	3.58
Limitation for Web Page Layout	3	15	14	18	15	2.41
Usability	26	24	7	3	5	3.95
Database Design	6	15	15	25	4	2.90
Availability	20	27	14	2	2	3.96
User Interface Design	12	13	15	17	8	3.00
Control Flow	10	14	13	16	12	2.78
Maintainability	26	15	7	10	7	3.61
Network Load Management	10	23	13	13	6	3.24
Reliability	40	12	6	5	2	4.30
Cryptic Error Message	10	12	5	14	24	2.23
Performance	30	18	14	1	2	4.15
Socio Culture	6	10	16	29	4	2.76

Removal of Random-Valued Impulse Noise by Using Texton

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Abstract-Images usually get contaminated with random-valued impulse noise (RVIN) at the time of compression, transmission and during encoding of images. The RVIN corrupts the pixels with any value in the dynamic range of pixels (for 8-bit image the dynamic range is 0 to 255). In the proposed method, a novel approach of dividing-sliding-window (DSW) into sub-windows (textons) for identification and removal of RVIN is presented. The pixels are identified as noisy pixels on the basis of four textons median values. Noisy pixels are replaced with the median value of texton having minimum absolute inner difference. Experiments have been done on the state-of-the-art images with standard RVIN methods shows that the proposed method outperforms over standard methods. DSW can preserve the fine edges and image details in better way.

Keywords-Dividing-Slidng-Window, Textons, Sliding Window, Minimum Absolute Inner Difference.

I. INTRODUCTION

The most important concern in the field of image processing is de-noising. Images are corrupted with any kind of noise can affect the processing especially in medical, weather forecasting and aviation system etc. Impulse noise often arises in digital images during compression, acquisition, decompression, transmission and electromagnetic interference. Impulse noise is categorized into two main categories, random-valued impulse noise (RVIN) that is difficult to remove due to randomness and salt-and-peppers (SNP) noise that is easy to remove due to predictability. In SNP noise, only least or most values in the dynamic range of pixels contaminate the image pixels. (In 8-bit image the dynamic range least value is 0 and most value is 255) [i]. The pixel recovery in RVIN is difficult as image pixels are contaminated with any intensity value (In 8-bit image the dynamic range is 0 to 255).

Median filter (MF) [ii] is commonly used in RVIN removal. The performance of MF is appropriate for flat regions. However, it replaces all pixels values either noisy or noise free. Due to it blurring effect is prominent in recovered images. When MF came across to high-density impulse noise, results are

inappropriate. To overcome the problem of MF, an improved class of filters like Weighted Median Filter (WMF) [iii] and Centered Weighted Median (CWMF) [iv] filter are proposed. However, improved techniques also replace all image pixels uniformly. A new class of decision based filter is proposed that includes Adaptive Median filter (AMF) [v] and Adaptive Centered Weighted Median filter (ACWMF) [vi]. In AMF for each iteration a separate threshold is defined for every sliding strip and overcome the problem of median filter. ACWMF [vi] is adaptive filter and more weightage is assigned to central pixel for every sliding window. However Miss and false identification values are not satisfying. These filter overcome the problem MF. MF replaces all pixel values indifferently. AMF detects and replaces the noise pixel value. Accuracy depends upon detection procedure of AMF filters. An efficient procedure using Rank-Ordered Relative Difference (RORD) [vii] is proposed that preserves the edges using Rank-Ordered Absolute Difference (ROAD) [viii]. It compares the central pixel with sum of difference with central pixel and identify it noisy or noise less pixel. In [ix] Signal Dependent Rank-Ordered Mean (SDROM) [ix] is proposed. It operate on the pixels that are obtained by difference of input pixel and ROAD output in the sliding window. However it did not perform well for high-density impulse noise. Space Variant Median (SVM) [x] filter, Tri-state Median Filter (TSM) [xi] and Vector Directional Filter (VDF) [xii] are also proposed for the identification and removal of RVIN and not properly recovered the image details. A fuzzy based filter (FIDRM) [xiii] and fuzzy random filter (FRINRM) [xiv] are used for removal of RVIN. However uses fuzzy logic for enhancement of noisy pixels. ANN based detector [xv], Modified Progressive Switching Median (MPSM) filter [xvi] is mixture of PSM [xvii] and CWMF [iv] filter, Improved Adaptive Impulse Noise Suppression (IAINS) [xviii] and a fuzzy filter RUSSO [xix] often involved in miss and false identification of pixels. A New Method for Removal of RVIN using similar neighbors (SN) [xx] is based on four neighbors that could not differentiate if neighboring pixels are noisy. The removal of RVIN using local statistic (LS) [xxi] used small difference pixel in specified direction for noise removal. Results are not satisfactory if small difference among pixel is

not available. Removal of RVIN using sparse representation [xxii] method used to remove impulse noise however computational complexity is increased for high density noise method. In [xxiii] a group sparse (GS) method is used for restoration of images corrupted with RVIN and de-noised in second step. They have used ROAD [viii] method for the identification of corrupted pixels. The sparse method is used for removal of noisy pixels. The group sparse method is extended sparse method that utilized the detection filter [xxiv] for removal of RVIN and self-similarity measure. However, it faces the problem of false detection and miss detection. Under high density noise, patches are prominent in de-noised image. In [xxv] advance filter utilized adaptive dual threshold for restoration of noisy pixels. However result under high density noise are not appropriate.

In [xxvi] restoration of pixel noisy pixel is performed using Khalimsky grid and in [xxvii] weber's law method, however restoration process is expensive. The Khalimsky grid method used 7x7 mask size and preserve image details finely. However, does not perform well for low density noise. The weber's law method has high computational cost for every window. In [xxviii]. shearlet-based approach is used to restore noisy image. This approach is better under low noise density and for high-density noise the visual results are not appropriate. Various types of noise are introduced in images during acquisition and compression like multiplicative noise and impulse noise. The following filter address impulse noise [xxix-xxxi]. The results of following filter regarding RVIN are not satisfactory. The proposed DSW method addresses the impulse noise properly and recover the edges properly and image details also. In [xxxii] filter is introduced that uses directional rank order absolute difference the results of proposed filter is satisfactory and the adaptive approach makes this effective. In [xxxiii] the sparse representation based filter is introduced. The detection process is based on sparse representation and to detect noisy pixel GRT is used and noisy pixel is compared with sparse estimation.

The proposed DSW method is based on sub-windows or textons [xxxiv] that has been used for image retrieval. The contribution in the proposed work is we have used the concept of textons for the identification and removal of RVIN and proposed a new texton. The identification noisy or noise free pixel is done on the bases of textons median value. Dual threshold is defined using texton median values. The removal of RVIN is based on the textons or sub-windows having least sum of inner difference. The noisy pixel is recovered by median of texton having least sum of inner difference. The proposed DSW method performance is better as compared with previous existing approaches in term of PSNR. The proposed method restores image details and preserves edges effectively.

The rest of paper is arranged in subsequent portion. In Section II, the proposed DSW methodology is discussed; the experimental results on DSW method are described and compared in section III. As a final point, the precise conclusion is furnished in section IV.

II. PROPOSED METHODOLOGY

The dividing-sliding-window (DSW) method has two stages. First one is identification of RVIN and second stage is the removal of RVIN. In section A., identification of RVIN using sub-windows (textons) median value is briefly discussed. Section B. describes the removal of RVIN using texton having minimum sum of absolute inner difference of pixels. The sub-windows (textons) concept is introduce by [xxxii] for image retrieval. The image enhancement and restoration is accomplished in spatial and frequency domain. The proposed work of image enhancement has been accomplished in spatial domain. In proposed DSW method the texton concept is adopted for the identification and removal of RVIN. Fig. 1 explain the proposed methodology of DSW method. The division of 3x3 window into four textons is explained in Fig. 2-6. Fig. 2 describes a 3x3 noisy image window and Fig. (3-6) describes the four textons that are moulded from Fig. 2. The central pixel value is kept intact. The orientations of textons are describes in equation 1, 2, 3 and 4. The Textons T1, T2, T3 and T4 are moulded using Fig. 3-6. Only highlighted part of Figures (3-6) are defining textons. The values belongs to these highlighted position are part of textons.
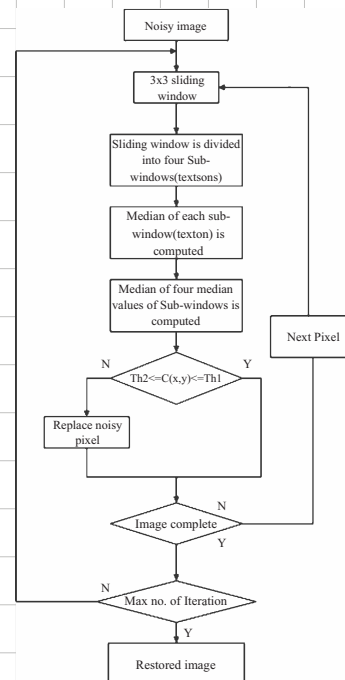

Fig. 1. is the flow diagram of proposed DSW method. Where C(x, y) is central values in the sliding windows and Th1 and Th2 are threshold value.
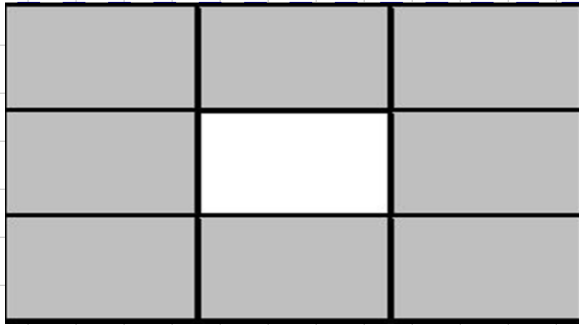
Fig. 2. Describe a 3x3 noisy image window / mask.
White cell indicate that central pixel is not used in
orientation of textons.

$$V = IR \qquad (A)$$

$$T1 = \{N(1,1) \quad N(2,1) \quad N(3,1) \quad N(3,2) \qquad (1)$$
$$T2 = \{N(31) \quad N(3,2) \quad N(3,3) \quad N(2,3) \qquad (2)$$
$$T3 = \{N(3,3) \quad N(2,3) \quad N(1,3) \quad N(1,2) \qquad (3)$$
$$T4 = \{N(1,3) \quad N(1,2) \quad N(1,1) \quad N(2,1) \qquad (4)$$

The textons T1, T2, T3 and T4 are the main component of the algorithm. The four textons extraction diagram is shown in Fig. 3-6.
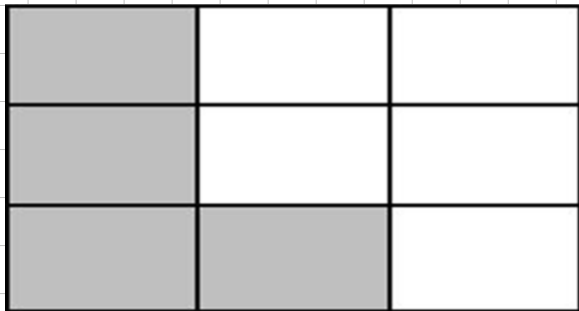

Fig. 3. describes the orientation of texton1 in a 3x3
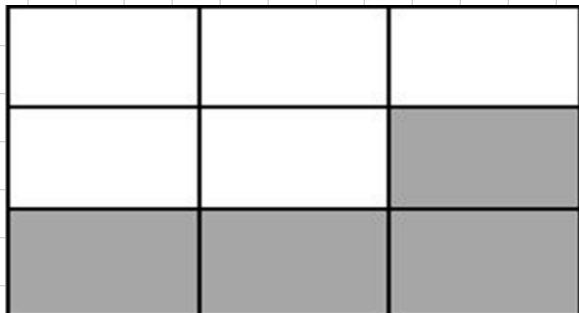mask. The highlighted part indicates texton1 pixel
positions.

Fig. 4. describes the orientation of texton2 in a 3X3
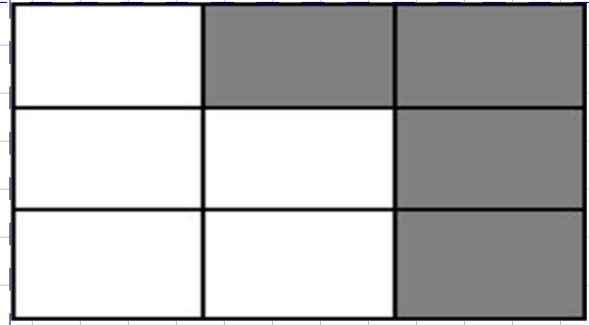mask. The highlighted part indicates the texton2 pixel
position.

Fig. 5. describes the orientation of texton3 in 3x3
mask. The highlighted part indicates the pixel
position of texton3.
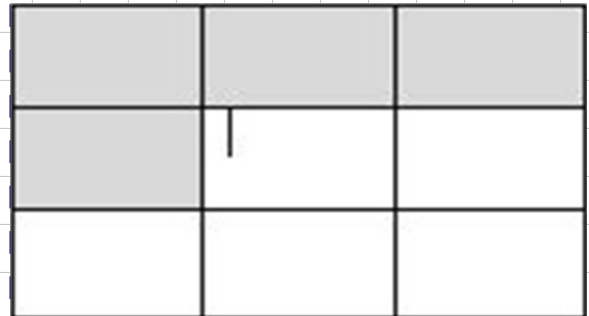
Fig. 6. describes the orientation of texton4 in 3x3
mask. The highlighted portion indicate the texton4
pixel position.

A. *Identification of Random-valued Impulse Noise*

In dividing-sliding-window (DSW) method, proposed procedure for identification of RVIN is described in the following steps. First the noisy image is divided into 3x3 sliding window. Then the 3x3 sliding window is divided into four sub-windows (textons) as shown in Fig. 2-6. The median of every sub-windows (textons) is computed. The four median of textons are obtained. The final median of the four textons median values is calculated and named as median of textons median value (MTM). In the MTM constant value is added and subtracted to define a dual threshold value. This threshold value decides the pixel value either noisy or remained intact from noise. If the pixel value is decided non-noisy remains the same. If it is noisy, restored in section B. of noise removal.

B. *Removal of Random-Valued Impulse Noise*

In dividing-sliding-window (DSW) method, the removal of RVIN is describes as follows. If the pixel is identified as noisy then it is replaced by using texton having least sum of absolute inner difference. Since 3x3 window is molded into four sub-windows (textons). For the removal of noise from pixels, the sum of absolute inner difference of every texton is determined. The texton having minimum sum of absolute inner difference of pixels is used for removal of noisy pixel value. The pixel declared as noisy is

recovered with the texton median having least sum of absolute inner difference.

The whole process is explained using equation (5) of noisy image window contaminated with 20% RVIN. The identification and removal of noisy pixel value is explained by following example. First a 3x3 image strip is obtained from contaminated image. The whole process is performed for central pixel. In our case central pixel is 057. To decide it whether it is noisy or noise free pixel, if identified as noisy pixel the noise will be removed.

$$N = \begin{bmatrix} 162 & 230 & 161 \\ 162 & 057 & 161 \\ 162 & 162 & 009 \end{bmatrix} \qquad (5)$$

Where N is noisy image window.

Then this 3x3 noisy image strip is divided into four sub-windows (textons) using equation (1), (2), (3) and (4) and replaced the position with correspondence values using equation (5).

$$
\begin{aligned}
T1 &= \{162 & 162 & 162 & 162\} & (i) \\
T2 &= \{162 & 162 & 009 & 161\} & (ii) \\
T3 &= \{009 & 161 & 161 & 230\} & (iii) \\
T4 &= \{161 & 230 & 162 & 162\} & (iv)
\end{aligned}
$$

Then the median of each texton is computed. The median1, median2, median3 and median4 are median of texton1 (T1), texton2 (T2), texton3 (T3) and texton4 (T4).
median1=162, median2=162, median3=161, median4=162. Then final median of four textons median values (162, 162, 161, and 162) is computed named as median of textons median value (MTM). That is equal to 162.

$$MTM = 162 \qquad (v)$$

Then threshold value is defined using MTM by adding and subtracting constant value in MTM. The constant value range is approximated from experiments. The constant values ranges from 15 to 30 are used in defining the threshold. The threshold value is computed in the following way.

$$Th1 = MTM + 30 \qquad (vi)$$
$$Th2 = MTM - 30 \qquad (vii)$$

If pixel value under experiment lies outside the dual threshold range then it is considered noisy. The threshold values are Th1=162+30 is 192 and Th2=162-30 is 132. So central pixel value is 57 that is under experiment (57) lies outside threshold range 132 to 192 is considered noisy. So the noisy pixel value is restored in noise removal phase.

In noise removal, the sum of absolute inner difference of every texton is calculated using equation 6, 7, 8 and 9

$$sid1 = |162\text{-}162| + |162\text{-}162| + |162\text{-}162| \qquad (6)$$
$$+ |162\text{-}162| + |162\text{-}162| + |162\text{-}162|.$$

$$sid2 = |162\text{-}162| + |162\text{-}009| + |162\text{-}161| \qquad (7)$$
$$+ |162\text{-}9| + |162\text{-}161| + |9\text{-}161|.$$

$$sid3 = |9\text{-}161| + |9\text{-}161| + |9\text{-}230| \qquad (8)$$
$$+ |161\text{-}161| + |161\text{-}239| + |161\text{-}230|.$$

$$sid4 = |162\text{-}162| + |162\text{-}230| + |162\text{-}161| \qquad (9)$$
$$+ |162\text{-}230| + |162\text{-}161| + |230\text{-}161|.$$

Where the $|\text{--}|$ is used to compute absolute difference. The following sid1 (sum of absolute difference), sid2, sid3 and sid4 are absolute inner difference of texton1, texton2, texton3 and texton4. So the sid1 has least value among the four textons. So median of texton having minimum sum of absolute inner difference is used for noise removal. At last the contaminated image pixel is recovered. So sid1=0. So median of texton1 is used for noise removal. The median of texton1 is 162. So the corrupted pixel (57) is recovered by 162.

The proposed DSW algorithm is as follows.
  Input=noisy image
1. The noisy image is converted into 3x3 image strips.

$$\text{Im}age\_strip = \begin{bmatrix} 1,1 & 1,2 & 1,3 \\ 2,1 & 2,2 & 2,3 \\ 3,1 & 3,2 & 3,3 \end{bmatrix}$$

2. The 3x3 window mask is divided into four sub-windows (textons).

$$
\begin{aligned}
T1 &= \{N(1,1) & N(2,1) & N(3,1) & N(3,2) & (11) \\
T2 &= \{N(31) & N(3,2) & N(3,3) & N(2,3) & (12) \\
T3 &= \{N(3,3) & N(2,3) & N(1,3) & N(3,2) & (13) \\
T4 &= \{N(2,1) & N(1,1) & N(1,2) & N(1,3) & (14)
\end{aligned}
$$

3. The median of every textons is computed.
   $$Median\_of\_Texton = median\ (T,2) \qquad (15)$$
   Where T represent texton.
4. Again the final median of four textons median is computed.
5. Decide the pixel value either noise free or contaminated with noise based on textons final median.
6. Replace the contaminated pixel value with textons median having least sum of absolute inner difference among pixels.
   Output=restored image

III. RESULTS AND EVALUATION PAREMETER

In dataset contains standard test images "Lena", "Barbara", "Baboon" and "Pepper" etc. The well-known evaluation metric Peak Signal to Noise Ratio (PSNR) is used. The PSNR is calculated by Mean Square Error (MSE) that is average of difference of original image pixel and restored image pixel.

$$PSNR = 10\log 10\left(\frac{Max^2}{MSE}\right) \qquad (10)$$

Where the max is maximum value in the dynamic range of grey level (255 for 8 bit image is Max). MSE equation is as follows.

$$MSE = \frac{1}{mxn}\sum_{i=1}^{m}\sum_{j=1}^{n}(O-R)^2 \qquad (11)$$

Where original and recovered image are represented by O and R. Small m and small n are defining image dimensions.

The Miss Detection (MD) refers to the noisy pixels that remain undetected during identification process. False Detection (FD) refers to noise free pixel that are considered noisy during identification process. The FD and MD are used as evaluation parameter. Lower the values of FD and MD refers to more accurate process.

A. Discussion and Comparison of results

The "Lena", "Peppers" and "Barbara" standard images are used for experimentation. The DSW and existing approaches results are in Table I, II and III.

TABLE I
PSNR VALUE OF DSW AND PREVIOUS EXISTING METHOD FOR BARBARA IMAGE.

Method	Barbara			
Noise%	10%	20%	30%	50%
MF	25.35	24.17	23.40	20.02
SDROM	25.89	25.74	24.65	22.42
Sparse	28.12	26.18	25.50	23.66
GS	31.57	30.34	28.25	25.25
Proposed	36.01	34.83	33.57	31.22
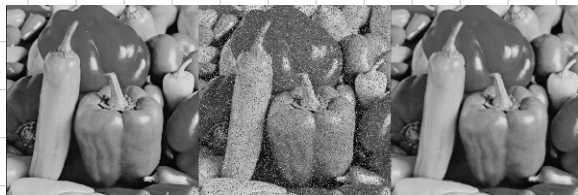
(a)   (b)   (c)
In Fig. 7, (a) is original image, (b) noisy image with noise density of 10% (c) is recovered image using DSW.

TABLE II
THE PSNR VALUE OF DSW METHOD AND PREVIOUS EXISTING METHODS FOR LENA IMAGE.

Method	Lena			
Noise%	10%	20%	30%	50%
MF	30.84	29.90	28.87	24.45
SDROM	34.29	33.55	31.06	26.01
Sparse	36.46	35.50	33.68	29.57
GS	37.12	36.12	34.37	30.92
Proposed	39.11	37.03	35.33	32.07

TABLE III
THE RESULTS OF PROPOSED AND PREVIOUS METHOD FOR MISS DETECTION AND FALSE DETECTION FOR LENA IMAGE.

Method	20%		40%		60%	
	Miss	False	Miss	False	Miss	False
ACWM	12863	541	30881	796	569	98625
MPSM	8498	3649	24112	6321	59595	2115
SDROM	11178	1580	30337	4322	49504	12406
RUSSO	15490	1518	31596	3135	58192	10107
FIDRM	3868	11598	13286	14768	55725	12778
DWM	4210	9820	8969	9099	15589	10524
FRINRM	4104	11774	7341	30779	16790	24982
IAINS	12119	1045	12476	15459	17,511	30243
ANN	6186	6407	8104	12619	17511	10226
Proposed	4324	4338	7154	6914	6752	6323

Finally, In DSW the details of images are preserved finely. DSW method performance is better than the previous methods. Table I and II describes experimental evaluation of PNSR and previous existing method and Table III explain miss and false detection performance of DSW and previous methods.

PSNR results of different methods compared with the proposed method on standard test image Lena and Barbara.
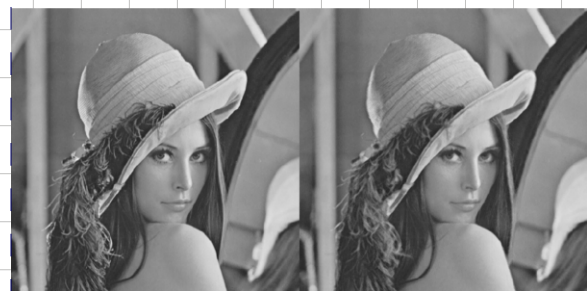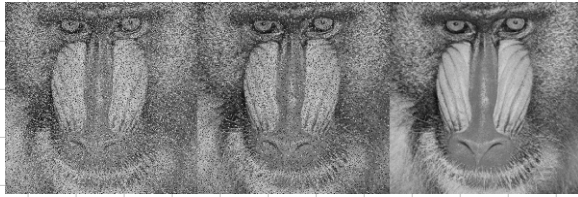

(a)   (b)

In Fig. 8, (a) is Lena original image (b) is recovered image that is recovered from 30% Noise.

| (a) | (b) | (c) |

In Fig. 9, (a) is Barbara original image (b) is 20% noisy image (c) is recovered image.

| (a) | (b) | (c) |

In Fig. 10, (a) result after first iteration (b) is result after second iteration and (c) is results after third iteration of "Baboon" image contaminated with 30% noise.

The window size is determined from experiments, as it shows the least value of miss detection and false detection of pixels. The other window size like 5*5 and 7*7 often miss identify the noisy pixel value when noise % less and false identify the noise free pixel when noise % is high. Also the values SSIM and PSNR are also better.

The proposed DSW method preserve edges finely because the edge pixels are clearly identified as noise free in the noise identification process. DSW method does not consider edge pixels as noisy because mask is divided into sub-windows and edges pixel belongs to texton having more edge pixel values. There is no need to apply sharping filter after de-noising. As sharping filter is required after the de-noising process if edges are get blurred. The proposed method preserved edges clearly as depicted in Figures.

DSW method Miss and False detection results are compared on Lena image with the existing methods. The DSW method performance is for better previous existing method. DSW define the threshold in refined way using median values of four textons. And in the removal of noisy value the noise free texton is used. The values of Miss Detection (MD) and False Detection (FD) are satisfactory as compared with previous approaches. The values of MD and FD indicate that noise identification process is better as compared with previous approaches. The PSNR values indicates that the noise removal also better as compared with existing filter. Visual result of proposed DSD method are in Fig. 7, Fig. 8, Fig. 9 and Fig. 10. Visual results also indicates that the visual performance of DSD method are satisfactory. Visual result indicate that fine details of image are recovered. The proposed DSW method uses 3x3 window size which is determined from experiments. The proposed DSW method

IV. CONCLUSION

In this paper, a novel method of dividing-sliding-window (DSW) is proposed for the removal of RVIN. The proposed method uses four texton median values for noise identification. And the removal of RVIN using texton having minimum sum of absolute inner difference of pixels. The proposed and previous methods Peak Signal to Noise Ratio (PSNR) can be observed from Table I and Table II. The PSNR of proposed DSW method is better than the previous compared approaches. Table III shows that MD and FD values of proposed DSW and previous methods. The MD and FD values are better and shows that the identification process is improved. The Fig.7, Fig. 8, Fig.9 and Fig. 10 are presenting the visual results of the proposed DSW method. The proposed DSW method also preserves fine details of image and fine edges. The preserving of fine edges is due to DSW method fine identification of pixels either noise or noise free. The least values of miss and false detection supports the strong detection procedure of proposed DSW method. The need of sharpening filter is in case of blurred results. The DSW method preserve fine edges, so the need of sharpening filter is accommodated.

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Optimizing Traffic Signal Cycle Lengths by Exploiting Already Deployed Smart Antenna Technology (OTSAT)

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*Abstract-*Traffic light control and coordination is a critical function in today's busy roadways. Typically traffic lights have been shifting from fixed timing to ones that are based on a variety of sensors. However, several shortcomings have been identified when considering these different approaches. In this paper, we propose a scheme for smart dynamic traffic lights that can adapt their signaling time according to the traffic density by exploiting Direction of Arrival(DoA) and Timing Advance information transmitted from cell-phones(carried by the car drivers)to the Smart Antenna installed on cellular base stations. The OTSAT is designed to address these challenges as it adaptively controls the traffic light timings. It dynamically manages the different traffic patterns and has the potential to attain the queuing reduction efficiency from 22% to 100% depending upon different traffic scenarios. Consequently, such an approach would reduce fuel consumption and pollution by avoiding queue (idling) on traffic lights.

*Keywords-*Angle of Arrival (AoA), Cell-phone, Direction of Arrival (DoA),Smart Antenna,3G/4G, traffic light management

I. INTRODUCTION

Mobile wireless service providers are deploying Smart Antenna technology in densely populated urban areas, where demand for high-speed data services is high. Smart Antenna offer an increase of three times for Time Division Multiple Access (TDMA) systems, five times for Code Division Multiple Access (CDMA) systems and much higher improvements for future systems (e.g. 100 Gbps) as the base stations begin to support Smart Antenna technologies [i]. Also Smart Antenna offers a mixed service capacity gain of more than 100%,and hence the required number of base stations can be reduced to less than a half [ii].

In recent years, there has been a shift from typical fixed timing traffic signaling to sensor based dynamic and coordinated control traffic signaling. In both of these approaches, smart traffic lights adapt the signaling time for green and red according to

traffic density [iii]. However, these solutions are (a) complicated because they involve direct communication between vehicles and traffic lights and (b) relatively expensive because they require dedicated components such as buried induction coils, cameras, sensors, optical fibers and computers, which also often have high installation cost since they require road construction.

Many intersections have some sort of mechanism for detecting vehicles as they approach the intersection. Most common mechanisms are based on induction loops [iv]. These are buried in the roadway and detect vehicles through changes in their magnetic field created by the metal body of passing vehicles. However, these are not cost effective. Other common methods are video detection which uses pixilation [v], microwave detection, and infrared detection among others [vi]. Some intersections have detectors on both the major and minor streets (fully actuated) and a controller has a programmed time to service all movements every cycle. Some intersections have the detectors on minor streets and major street left turns only (partly actuated). In such a setup, the major streets are programmed to operate at a fixed time every cycle and a controller services the other movements only when there is higher demand. These approaches require installation of new hardware at each intersection (e.g. sensors) and may provide a partial solution, i.e. on the major city roadways, as they can be cost prohibitive [vii]. Wireless sensor based systems, which provide road construction free deployment, have been proposed as an alternative technology [viii]. However cost of the sensors make it unviable. Another research approach uses synchronized traffic lights system to smooth traffic flow [ix]. This system requires synchronization among traffic lights and strict observance of speed limits.

An adaptive traffic signaling approach through smart phones using Floating Car Data to regulate traffic light systems, which requires instrumented vehicles (equipped with GNSS sensor and or local radio system) and the local radio signal emitter needs to be appropriately placed on the side of road network allowing the localization of instrumented vehicles

when satellite localization is not usable. Also smartphones must have a dedicated software, able to identify the vehicle position and communicate to the central control server [x].

We have previously proposed a technique that exploits the Smart Antenna technology for traffic light signaling optimization [xi-xii]. However it had few limitations for e.g. we considered that each vehicle carries only one cell-phone and the pedestrians on the walkways carrying cell-phones do not add any potential error. The objective of this paper is to address the above noted shortcomings and the limitations of our previous publications. The proposed design involves the following "4Cs":

a. **C**ollection and processing of valuable information from the Smart Antenna.
b. **C**alculation of total number of cell-phones and their specific location around intersections.
c. **C**onveyances of the above information to a dedicated sever.
d. **C**ommunication of the server with the traffic lights to adaptively adjust the signaling times so that the waiting time in front of red traffic light may be reduced as effectively as possible.

The rest of the paper is divided into four sections. Section II, provides an overview of Smart Antenna technology. Section III describes the proposed system. Section IV, presents the analysis results and Section V, conclusion.

II. SMART ANTENNA TECHNOLOGY

A Smart Antenna system in telecommunication context performs the following functions:

a. Estimates the Direction of Arrival (DoA) of all incoming signals including the interfering signals and the multipath signals using the DoA algorithms.
b. Identifies the desired user signal and separates it from the rest of the unwanted incoming signals.
c. Steers a beam in the direction of the desired signal to track the user as he moves, while placing nulls at interfering signal directions by constantly updating the complex weights.

These functions are further described below:

Adaptive Array Antenna: The Smart Antenna System is capable of automatically changing the direction of its radiation patterns in spatially sensitive manner in response to its signal environment. It consists of a set of radiating elements arranged in the form of an array (thus named adaptive array antennas), and smart signal processing algorithms to identify the DoA of the signal. The system uses this, and some additional information, to calculate beam forming vectors to track and locate the antenna beam on the cell-phone units. Since continuous steering of the beam is required as the cell-phone moves, high interaction between the cell-phone unit and base station is required. Traditional adaptive array systems enable a base station to form a main lobe toward individual users and attempt to reject interference from outside of the main lobe.

Direction of Arrival (DoA): The Smart Antenna system estimates the DoA of the signal using techniques such as Multiple Signal Classification (MUSIC), Estimation of Signal Parameters via Rotational Invariance Techniques (ESPRIT) algorithms [xiii], Matrix Pencil (MP) methods [xiv], or one of their derivatives. They involve the findings of a spatial spectrum of the antenna/sensor array and calculating the DoA from the peaks of this spectrum. These calculations are computationally intensive. Matrix Pencil is very efficient in case of real time systems and under the correlated sources.

Beamforming: It is the method used to create the radiation pattern of the antenna array by constructively adding the phases of the signals in the direction of the desired targets/cell-phones, and nullifying the pattern of the targets/cell-phones which are undesired/interfering targets. This can be done with a simple finite impulse response (FIR) tapped delay line filter (FIR filters are digital filters used in Digital Signal Processing (DSP) applications). The weights of the FIR filter may also be changed adaptively and used to provide optimal beam forming and actual beam pattern formed. The steepest descent and the LMS (Least mean square) [xv] are typical algorithms. The use of high-performance Digital Signal Processing (DSP), Embedded Processors (EPs) and Logic Elements (LEs) make the Beamforming adaptive.

Down Conversion: The signal from each receive antenna is first down converted to baseband, processed by the matched filter-multipath estimator, and accordingly assigned to different rake fingers. The Beamforming unit on each rake finger then calculates the corresponding (i) beam former weights and (ii) channel estimates, using the pilot symbols that have been transmitted through the Dedicated Physical Data Channel (DPDCH). The QR decomposition-based Recursive Least squares (QRD-RLS) algorithm is selected as the weight update algorithm because for its fast convergence and good numerical properties [xvi]. The updated beam former weights are then used for multiplication with the data that has been transmitted through the DPDCH. Maximal Ratio Combining (MRC) of the signals from all fingers is then performed to yield the final soft estimate of the DPDCH data.

III. DESCRIPTION OF THE PROPOSED SYSTEM

The proposed solution is based on exploiting Smart Antennas for optimizing traffic signaling times using Smart Antenna Technology (OTSAT). The overall concept is depicted in Fig. 1. As the title reveals, our objective to exploit the Smart Antenna technology to achieve the optimization in traffic light duration,

which is also explained in "Advanced algorithm for position location" [xvii]. Finding optimal signal timing for a large number of traffic signals is challenging because of the exponential increase in number of vehicles, and extensions in the road infrastructure. The OTSAT is designed to address these challenges, as it adaptively controls the traffic light timings and dynamically manages the different traffic patterns by using an efficient algorithm. The conceptual model and the algorithm is explained in the following paragraphs.
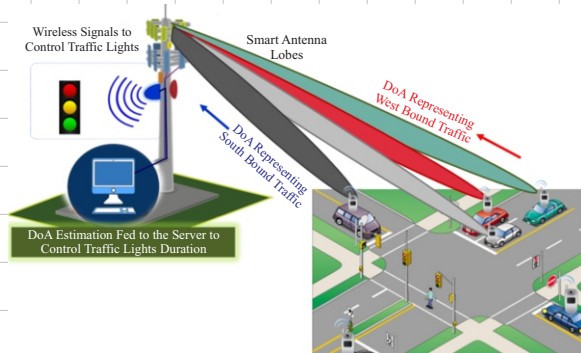

Fig. 1. Conceptual model of the application of Smart Antenna traffic light.

The proposed OTSAT system consists of the following three logical components:
1. Traffic Statistics Collector (TSC)
2. Traffic-light Duration Estimator (TDE)
3. Traffic-light Duration Controller (TDC)

However, physically these three components can be housed in a single entity or server. The functions of these components, in context with the algorithm shown in Fig. 2, are explained as follows:

1.   Traffic Statistics Collector (TSC)

TSC is a part of the OTSAT that is depicted by the blocks B and C in Fig. 2. We consider one TSC and few intersections to illustrate some selected scenarios; however, the system can be deployed over the entire city for all types of intersections/scenarios. The four key functions performed by TSC are listed below:
(i)   The TSC initially populates the latitude and longitude (from now on referred as LatLong) coordinates information about the:
    a)   Location of traffic lights
    b)   The extends of the paved roadways and
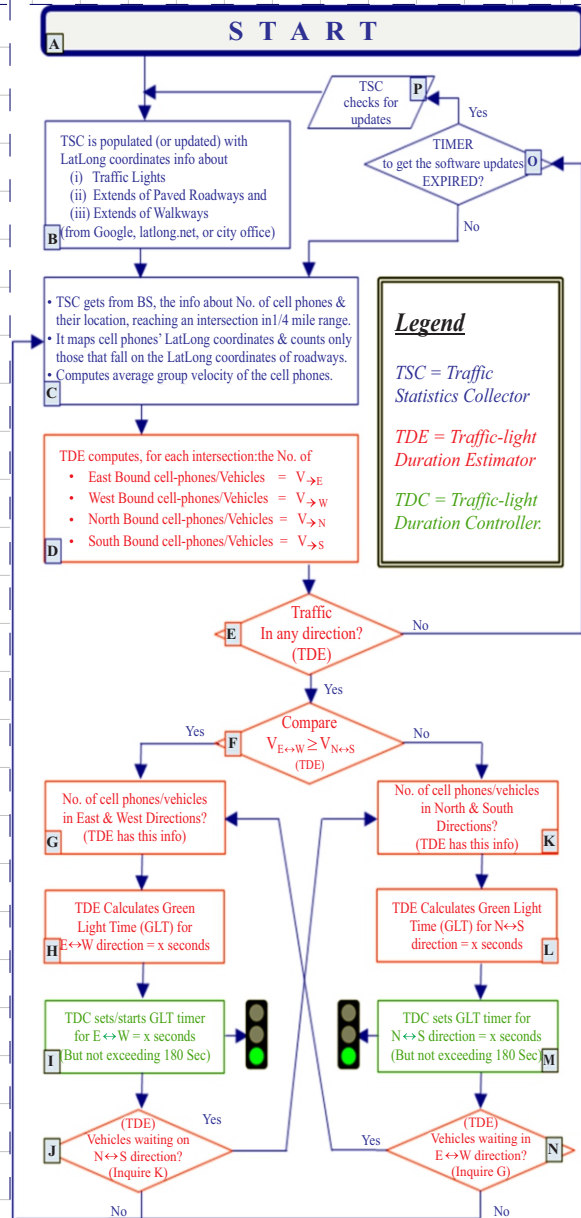   c)   The extends of the walkways

Fig. 2. OTSAT approach describing the functionality and optimization process

(ii)   The TSC retrieves the information from the Base Station (Smart Antenna) about the number of cell-phones and their location (in terms of Angle of Arrival-AoA, Timing Advance, etc.) approaching a specific traffic intersection in ¼ mile radius.
(iii) The TSC converts the cell-phones location information into LatLong coordinate format.
(iv) The TSC maps LatLong coordinates of cell-phones (available from step (iii) above) with the geo LatLong coordinates of the Roadways (available from step (i) above), and counts only those cell-phones which fall within the extends of the LatLong coordinates of Paved Roadways. It also counts as to how many cell-phones are in each

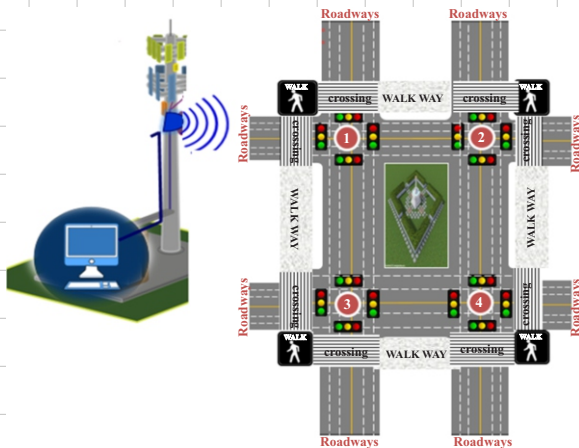lane (including through lanes, right turn lanes, left turn lanes).

Fig. 3. OTSAT approach depicting Multiple Intersections (MI)

The TSC initially populates, its database by acquiring the LatLong coordinates information about all the traffic lights location, as well as the length and extend of paved roadways, intersections, and concrete/paved walkways from google.com, the latlong.net or local public administrations to get the correct identification of the roadways and walkways extends, the traffic laws implemented on each intersection, such as number of through traffic lanes, number of lanes with indications of No Turn Allowed, Right Turn Allowed/Not Allowed on red etc. for the proper identification of a cell-phone as one carried by a pedestrian or one carried by a person in a vehicles.

For example, the LatLong coordinates for the highlighted rectangular area highlighted as ABCD in Fig. 4, acquired from http://www.latlong.net/convert-address-to-lat-long.html, shows the intersection of Rhawn and VerreeStr, Philadelphia PA. These are points A(40.072719, -75.076080), point B(40.072844, -75.075984), point C(40.072663, -75.076040) and point D(40.072776, -75.075909). Moving the mouse over the image on the actual URL, one can notice that each point on the map (Including Traffic Lights, Paved Roadways, Walkways, buildings, Parks, etc.) can be defined with its associated LatLong coordinates.

Lat Long	GPS Coordinates	Map Mouse Over Location
(40.072874, -75.075857)	40° 4' 22.3464" N 75° 4' 33.0852" W	(40.072759, -75.075658)

Fig. 4. Screen Print for Rhawn-Verree intersection in Philadelphia, PA, (http://www.latlong.net/convert address-to-lat-long.html).

The second task of the TSC is to extract continuously and recurrently the following information from the DSP (Digital Signal Processor) of the Smart Antenna in the Base Station for the uplink direction only[xviii-xix].

In the case of the 4G/LTE Base Station (eNodeB) the information retrieved is:
- Timing Advance (TADV)
- Angle/Direction of Arrival (AoA/DoA)
- E-UTRA Measurement Results List
- Evolved Cell Global Identifier (ECGI)/Physical Cell ID
- Reference signal received power (RSRP)
- Reference Signal Received Quality (RSRQ)
- UE (User Equipment) Receive – Transmit time difference

In case of the 3G/CDMA Base Station (NodeB) the information retrieved is:
- Timing Advance (TADV)
- Angle/Direction of Arrival (AoA/DoA)
- UTRA Measurement Results List
- UTRAN Physical ID
- Common Pilot Channel
- Received Signal Code Power (RSCP)
- Common Pilot Channel Ec/Io (the ratio of the received energy per chip and the interference level).

The TSC extracts the above noted information (ii) continuously and recurrently from DSP every 0.5 ms with that, a vehicle tracking resolution of about 0.5m can be achieved even if the vehicle is traveling at 45 mph. In Smart Antenna, the received signal (containing the above information) from the spatially distributed antenna elements, is down converted to intermediate frequencies, and then into digital format. The DSP processes it using different algorithms such as explained in[xx].

The third task of the TSC is to translate the above noted information extracted from the Smart Antenna's DSP, into the LatLong coordinates format. Thus the TSC knows the location of all cell-phones in terms of LatLong coordinates format. Finally the TSC maps LatLong coordinates of cell-phones with the LatLong coordinates of the roadways, walkways, buildings, parks, etc. and counts the cell-phones which happen to fall on the LatLong coordinates of Paved Roadways only, whereas it ignores all other, as it assumes they are cell-phones of pedestrians. From the available information, the TSC also knows the rate at which the cell-phones are traversing the geo LatLong coordinates (distance), thus the TSC can also compute the speed of the cell-phones and hence the vehicles as well.

In essence, the TSC contains all the information required to compute the speed (velocity) and direction of the cell-phones/Vehicles, and demarcate them as East, West, North and South bound with respect to each traffic light at each intersection.

The accuracy of the proposed system depends on the accuracy of the LatLong coordinates of cell-phones or in other words the accuracy of AoA/DoA acquired from the Smart Antenna. The proposed system's accuracy is between 1 to 5 cm, as currently deployed algorithms offer high level, commercial grade precision, demanded by the Smart Antenna. Among these Narrowband Model, MUSIC, ESPRIT, and specially Improved Orthogonal Matching Pursuit (IOMP) algorithms, proposed in [xvii, xx-xxi], offer high resolution DoA Estimation (i.e. the angle should be partitioned as fine as possible). This algorithm firstly obtains the initial estimated DOAs and then, utilizes an Iterative Local Searching process to improve DOA estimation accuracy. The simulation results from the above references demonstrate that the algorithm can distinguish two sources from the adjacent DOAs. Further, the Smart Antenna used for cell-phone communication demand higher location precision in both uplink, as well as in downlink, because Smart Antenna have to accurately locate the cell-phones. In our proposed application, the Smart Antenna demand accuracy in uplink direction only. Since the proposed technique does not mandate a two way precision, it further guarantees the desirable accuracy needed to distinguish closely placed cell-phones/Vehicles in adjacent lanes, or the walkways from the roadways, or passengers sitting in the same vehicle.

2. Traffic-light Duration Estimator (TDE)

The TDE (See Blocks D, E, F, G, H, J, K, L and M in Fig.2) is the integral part of the Server. The TDE collects the information from the TSC and performs the following tasks for any given intersection:

1. It computes and segregates the number of:
   East bound cell-phones/Vehicles $=V_{\to E}$
   West bound cell-phones/Vehicles $=V_{\to W}$
   North bound cell-phones/Vehicles $=V_{\to N}$
   South bound cell-phones/Vehicles $=V_{\to S}$
   Sum of East and Westbound cell-phones/Vehicles $=V_{E\leftrightarrow W}$
   Sum of North and Southbound cell-phones/Vehicles$=V_{N\leftrightarrow S}$
   These are the number of cell-phones/Vehicles either stopped in front of traffic light or moving towards the traffic light at any velocity, but in the range of ¼ mile radius measured from the intersection.
2. It compares the two directions, East-West $(V_{E\leftrightarrow W})$ versus North-South $(V_{N\leftrightarrow S})$and selects the one with greater number of cell-phones/Vehicles.
3. It computes the Green Light Time (GLT) for the direction with greater number of cell-phones/Vehicles (as selected in step 2 above) and multiplying it with the time needed for one vehicle to cross the intersection, as per following formulae.

$$GLT_{E\leftrightarrow W} = \left(V(LMax)_{E\leftrightarrow W}\right) \times TTP = x \text{ sec}$$
and

$$GLT_{N\leftrightarrow S} = \left(V(LMax)_{N\leftrightarrow S}\right) \times TTP = x \text{ sec}$$
where
$GLT = Green Light Time$
$V(LMax)_{E\leftrightarrow W}$ = The Farthest vehicle in the range of East or West at any given intersection
$V(LMax)_{N\leftrightarrow S}$ = The Farthest vehicle in the range of Northor Southat any given intersection.
TTP = Time required by one vehicle to cross the intersection.

TTP is dynamically calculated by TTP Calculator using $T= S/V$, where $S(m)$ is the length of a given intersection and $V(mi/sec)$ is the average group velocity of the vehicles at that intersection. The average group velocity (V) is calculated by using $V = S_V/T_V$, where S_V is estimated by using LatLong coordinates between the intersection and the last vehicle in the range at a given intersection and T_V is time taken to traverse the distance S_V. The above formulae are customized for each traffic intersection to suit particular requirements, dimensions, and conditions of that intersection. To check the validity of above formulae, and the working of algorithm, a few scenarios are discussed below:

Scenario 1: In this scenario we assume that the red light towards East-West bound and vehicles are stopped (i.e. their current velocity is zero mph). Let's consider the length of intersection is 300 ft. and has two lanes. East-West$(V_{E\leftrightarrow W})$ bound, has greater number of cars i.e. 25 vehicles (more specifically 15 vehicles are East bound $(V_{\to E})$, where $LMax$(10 vehicles) and 10 vehicles at West $(V_{\to W})$ bound), against 15 vehicles in North-South $(V_{N\leftrightarrow S})$ bound. Vehicles will start moving slowly, since waiting at red light and will resume with an average group velocity of 25 mph i.e. $(25\times5280 = 132,000$ ft/hr). Thus the TTP would be 300/132,000 = 8.1 s and The GLT would be assigned for 80.10 s (10 x 8.1 s) to clear the traffic for East-West $(V_{E\leftrightarrow W})$ bound. On the other hand the traffic light would be red for 80.10 s for North-South bound. In this case, the algorithm will follow the blocks C, D, E, F, G, H, I, and jump to K, L, M and N.

Scenario 2: Assume that there is already a green light and traffic is moving in North-South $(V_{N\leftrightarrow S})$ bound with Average group velocity of 45mph. Let's consider the length of intersection is 300 ft. with two lanes. North-South $(V_{N\leftrightarrow S})$ has heavy traffic i.e. 90 vehicles, with 60 vehicles North bound $(V_{\to N})$, where $LMax$(40 vehicles) and 30 vehicles in South bound $(V_{\to S})$. Thus the TTP would be 300/237,600 = 4.5 s and The GLT would be assigned for 180 s (40 x 4.5 s) for North-South $(V_{N\leftrightarrow S})$ bound. If we assume that there are no vehicles in East-West $(V_{E\leftrightarrow W})$ bound at all, the algorithm will again follow the blocks C, D, E, F, K, L, M, N, and back to C and continue extend the GLT for North-South $(V_{N\leftrightarrow S})$ bound to clear off the traffic until there is any vehicle on an alternate direction and threshold time of 180s (set limit) expires for waiting in front of red-light.

Scenario 3: Assume that there is already a green light

and traffic is moving in East-West ($V_{E\leftrightarrow W}$) bound. Let's consider the length of intersection is 400 ft. and has two lanes. East-West ($V_{E\leftrightarrow W}$) bound has greater number of vehicles i.e. 90 (70 vehicles east bound ($V_{\rightarrow E}$), where $LMax$(50) and 20 vehicles west bound ($V_{\rightarrow W}$), with the average group velocity of 45 mph i.e. (45×5280 = 237,600 ft/hr). Thus the TTP would be 400/237,600 = 6.0 s and the GLT would have been assigned for 300 s (50 x 6.0 s) for East-West ($V_{E\leftrightarrow W}$) bound. If there are any vehicles in North-South ($V_{N\leftrightarrow S}$) bound (say 4 vehicles North bound ($V_{\rightarrow N}$) and, zero vehicles on South ($V_{\rightarrow S}$), the algorithm will allow a maximum GLT to be 180 s(max. limit) to East-West($V_{E\leftrightarrow W}$) bound instead of 300s and follow the blocks C, D, E, F, G, H, I, and jump to K, L, M, N and turn GLT of 24s (4 x 6.0s) for North-South($V_{N\leftrightarrow S}$) bound and then continue with G, H, I, J, and back C.

3. *Traffic-light Duration Controller (TDC)*

The TDC receives the recently calculated GLT information from TDE (See Blocks I and M in Fig. 2). It sets the Green Light Time for *x* s based on real traffic.

Block O and P in the algorithm are to cater for the addition of new traffic lights, construction of new paved roadways, and new concrete/paved walkways. These updates are obtained from Google, Latlong.net or local administration to update the TSC.

IV. ANALYSIS RESULTS

Since our study is theoretical and prototype, the TSC presently is not connected to any base station (more specifically the DSP of the Smart Antenna). The TSC emulates the traffic generation for all directions through the static code we have developed in Java, where vehicles are created randomly and performs the tasks as per algorithm (Fig. 2). We have optimized our analysis by generating random traffic through simulator at multiple intersections (Fig. 3), while considering scenarios(1,2 and 3) mentioned above in section III for OTSAT compared to Conventional method (for 60s) for 15 iterations (i.e. a full cycle of traffic light for which signal light stays green or red for East-West and North-South).One may ask why we took 60 seconds of green for each direction in conventional traffic signals. Based on National Association of City Transportation Officials [xxii]. The major corridor receives almost four times as much green time (96 seconds) as the minor streets (24 seconds). So we have taken an average (96 + 24 = 120/2 = 60 seconds).

In the following paragraphs we analyze the scenarios to establish that the GLT is not fixed for OTSAT, but varies dynamically for each iteration (Fig. 5). The dynamic adjustment of GLT considering several factors (such as Number of vehicles traveling in a certain direction, their group velocity, the width of the intersection, and the most number of vehicles (*LMax*) etc.), plays a vital role in achieving the efficiencies we

claim over conventional method, where the traffic light remains unnecessarily green or red until the fixed duration timer expires. Whereas the green light time for conventional methods is considered as fixed for 60s.
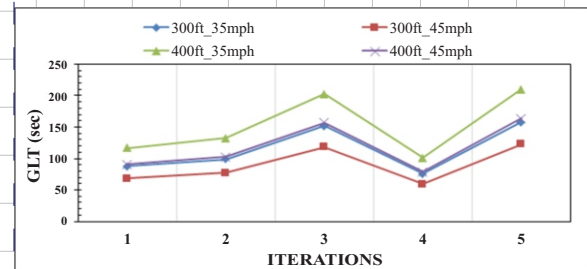

Fig. 5. Dynamic GLT calculation for OTSAT

Considering the light traffic volume Fig. 6, shows the GLT assigned for OTSAT versus conventional for East-West($V_{E\leftrightarrow W}$) and North-South($V_{N\leftrightarrow S}$) bound. Let's ponder on the first iteration for 20 and 21 cell-phones/Vehicles, where OTSAT calculates the GLT as 48.6 s, 27s, and 36 s for East-West ($V_{E\leftrightarrow W}$) bound and 56.7s, 0s, and 42s for North-South ($V_{N\leftrightarrow S}$) bound for Scenarios (1, 2 and 3) respectively to clear off the traffic, while the GLT for the conventional method is fixed for 60s. For the situation under discussion, the waste time (i.e. the time that vehicles waste in front of a red light, while the light is unnecessarily green on an alternate direction), OTSAT not only helps to avoid the waste time of an average is 48%, 85% and 62% for the above considered scenarios respectively but also reduce the queuing efficiency of 100% compared to conventional method.
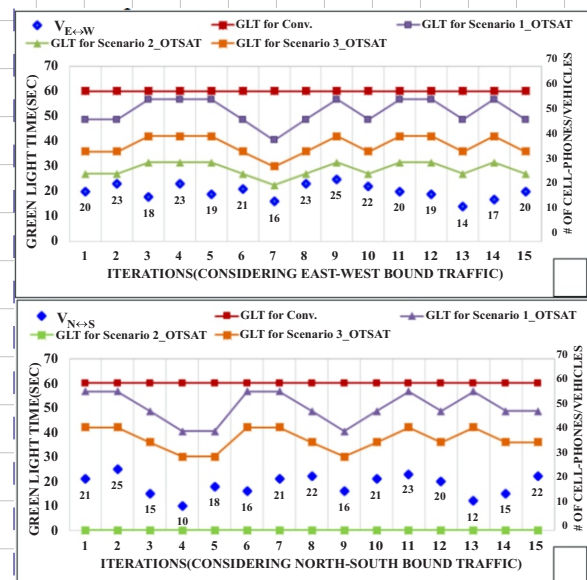

Fig. 6. GLT for Conventional and OTSAT for light traffic a) East-West and b) North-South bound

Considering moderate traffic volume (Fig. 7) show the GLT for East-West ($V_{E\leftrightarrow W}$)and North-

South($V_{N\leftrightarrow S}$) bound.

Let's ponder on the first iteration when there are 51 cell-phones/Vehicles in East-West ($V_{E\leftrightarrow W}$) and 48 in North-South ($V_{N\leftrightarrow S}$) bound. OTSAT calculates the GLT as 137.7 s, 76.5 s, and 102 s and 113.4 s, 0 s, and 84 s for 1st, 2nd, and 3rd scenarios to clear off the East-West ($V_{E\leftrightarrow W}$) bound and North-South ($V_{N\leftrightarrow S}$) bound traffic respectively, while the green light time for conventional methods remains fixed(60 s) every iteration. Likewise the GLT is been calculated for remaining iterations.

We have also evaluated all above scenarios for heavy traffic and observed that OTSAT compared to conventional method (60s), offers queue reduction efficiency of an average of 67% (refer to Table I).
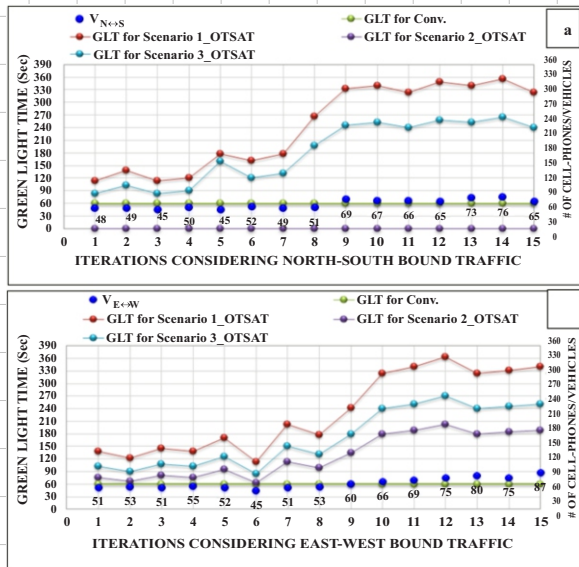

Fig.7. GLT for Conventional and OTSAT for moderate traffica) East-West and b) North-South bound

Fig. 8 shows the queue length of cell-phones/Vehicles for East-West ($V_{E\leftrightarrow W}$) bound and North-South ($V_{N\leftrightarrow S}$) bound. Fig. 8(a) shows that in iteration #1 for scenario 1 with TTP of 8.1s; where the *LMax* is 17 for East-West($V_{E\leftrightarrow W}$) bound. In the conventional method only 7 vehicles (8.1x7= 56.7s) can pass per lane in 60s and remaining 10 vehicles will be in queue, waiting for their turn until the next iteration. While OTSAT assigns GLT of 137.7s (17 × 8.1) for the same iteration with No queue for East-West ($V_{E\leftrightarrow W}$). Likewise for scenario 2 with TTP of 4.5 s, for the conventional method, there will be a queue of 4 cell-phones/Vehicles (since only 13 vehicles can pass during 60s), while there is no queue for the proposed method. Finally for scenario 3 with TTP of 6:0s, there will be queue of 7 cell-phones/Vehicles (since only 10 vehicles can pass during 60s) for conventional method, whereas there is no queue for OTSAT and likewise remaining iterations have been calculated. In Fig. 8(b)

shows the iteration #1 for scenario 1 with TTP of 8.1s; where the *LMax* is 14 for North-South ($V_{N\leftrightarrow S}$) bound, 7 vehicles will be in queue, while OTSAT calculates GLT of 84s for same iteration. Likewise for scenario 2 with TTP of 4.5 s, there is no vehicle at all on roadways for North-South ($V_{N\leftrightarrow S}$) bound to cross but signal light will still be green for 60s and finally for Scenario 3 with TTP 6.0 s, there will be a queue of 4 cell-phones/Vehicles for conventional method, whereas there is no queue for OTSAT and likewise remaining iterations have been calculated. At the end of each traffic light iteration, vehicles those could not pass the intersection contributes to the formation of a queue for the next iteration in conventional method. However for OTSAT, the queuing is reduced drastically.

Considering the results for moderate traffic type in Fig. 8, we can show an average numbers of cell-phones/Vehicles remained in queue per iteration for East-West($V_{E\leftrightarrow W}$) and North-South ($V_{N\leftrightarrow S}$) bound in Fig. 9. For Scenario 1, there is an average of 22/9 cell-phones/Vehicles for East-west ($V_{E\leftrightarrow W}$) and 23/10 for North-South ($V_{N\leftrightarrow S}$) bound remained in queue. For Scenario 2, there is an average of 16/1 cell-phones/Vehicles for East-west ($V_{E\leftrightarrow W}$) and 0/0 cell-phones/Vehicles for North-South ($V_{N\leftrightarrow S}$) bound and likewise for Scenario 3, there is an average of 19/5 cell-phones/Vehicles for East-West ($V_{E\leftrightarrow W}$) and 20/6 North-South ($V_{N\leftrightarrow S}$)bound remained in queue for the conventional method versus OTSAT.
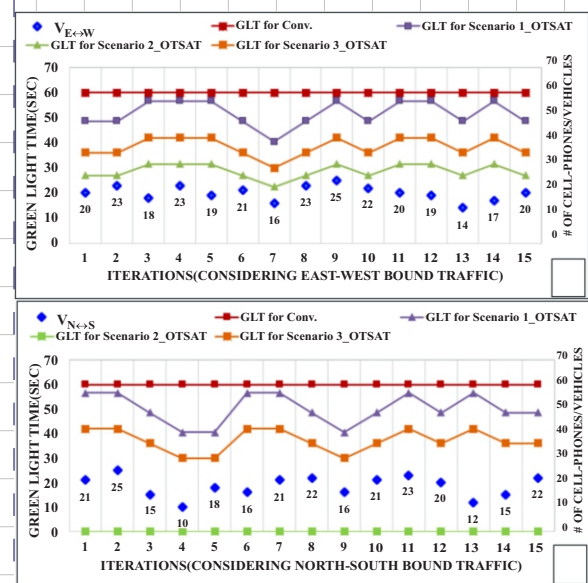

Fig. 8. Queue length of Conventional and OTSATfor moderate traffic a) East-Westand b) North-South bound

Considering the results in (Fig. 9 and10), an average queue of 668, 234 and 578 cell-phones/Vehicles for conventional method and 278, 10 and 155 cell-phones/Vehicles for OTSAT, for both East-West($V_{E\leftrightarrow W}$) and North-South ($V_{N\leftrightarrow S}$) traffic for 30

iterations, proofs that, OTSAT provides a significant reduction of queuing at an average of 77%, consequently would cause an equivalent idling time in queue for the East-West ($V_{E\leftrightarrow W}$) and North-South ($V_{N\leftrightarrow S}$) bound. According to the Air Quality Development Authority, the average vehicles consume about 0.156 gallons of fuel per hour while idling and emits 19.6 pounds of CO_2 for each gallon of fuel it burns .OTSAT reflects a reduction of 77% of fuel wasted and CO_2 emissions compared to the conventional method (Fig. 10 and 11).

One may argue here that green light time for the conventional method may be fixed to 120 s or 180 s, instead of only 60 s to eradicate the bottleneck effect. Refer Table I, where we have calculated the efficiencies for 60 s, 120 s, and 180 s for Light, Medium and Heavy traffic for Scenario 1,2 and 3 for conventional method and OTSAT and found that still our method offers queue reduction efficiency on an average of 100% for "Light", 57% for "Medium" and 52% for "Heavy" traffic over conventional method. It also reveals that even under "heavy traffic", the proposed algorithm has the potential to attain the queuing reduction efficiency, on an average from 22% to 100% for scenarios 1 and 2.
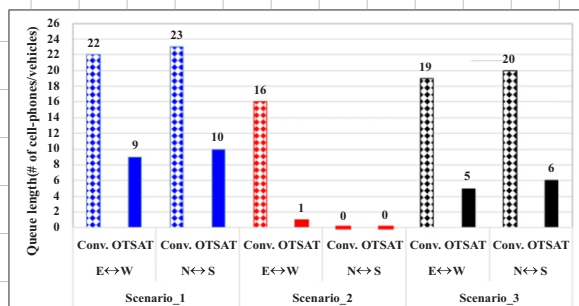

Fig. 9. An average Queue for East-West and North-South for moderate traffic
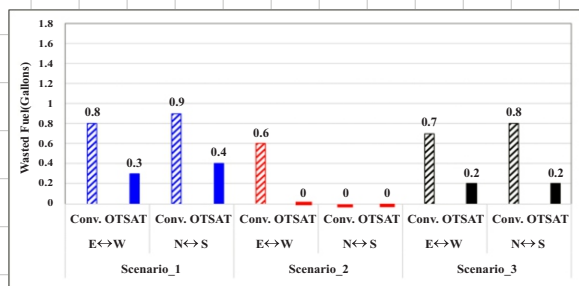

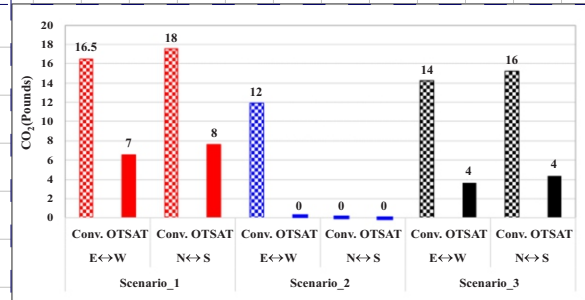Fig. 10. Wasted fuel (gallons) for East-West and North-South bound traffic

Fig. 11. Emitted CO_2 (pounds) for East-West and North-South bound traffic

TABLE I

Traffic Type	Scenario	Conv. Method GLT=60 Sec (%)	Conv. Method GLT=120 Sec (%)	Conv. Method GLT=180 Sec (%)	Average (%)
Light	1	100	100	100	100
	2	100	100	100	100
	3	100	100	100	100
Medium	1	58	35	0	31
	2	100	100	100	100
	3	73	51	0	41
Heavy	1	42	25	0	22
	2	100	100	100	100
	3	51	43	0	35

In the United States, the average commute time per commuter is 27.2 minutes [xxiv], which includes an average of 5 minutes waiting in front of traffic lights for each commute which means an average of 42 hours each commuter waste per year [xxv]. On the other hand, using our proposed OTSAT method, an individual commuter will not only avoid the time unnecessarily waiting on traffic lights but also fuel consumption and Pollution (CO_2) will drop significantly.

V. CONCLUSION

This paper proposes a solution for controlling traffic lights at intersections by exploiting the knowledge of location and Direction of Arrival from Smart Antenna used in the existing mobile communication systems. We presented system modeling and the analysis for different scenarios. From the extensive analysis performed, we observed that the proposed system has the potential to attain the queuing reduction efficiency from 22% to 100% with respect to traffic scenarios with different traffic patterns under consideration in this study. Consequently, such an approach reduces fuel consumption and CO_2 in the same ratios by avoiding queue and congestion (idling) on traffic lights.

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Security Threats and Measures in E-learning in Pakistan: A Review

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*Abstract-*Security has become one of the key research domains of Information and Communication Technology (ICT). Information security and privacy concerns in e-learning environment are crucial because multiple users are communicating via networking (Internet). On the other hand developers show negligible tilt in this regard while developing an e-learning system. Internet is the core mean of communication in e-learning which is inherently an insecure medium. Furthermore, Internet is available for all so it is also becoming the hub of various prohibited activities. Due to this interconnectivity, data or information is exposed to the large numbers of security threats and vulnerabilities. This study intends to explore the security challenges encountered by e-learning environment in Higher Education Institutions (HEIs) of Pakistan. A thorough review about security issue has been presented and concerns about local environment are emphasized. The remedies to the security threats have also been suggested to ensure the secure electronic learning environment.

*Keywords-*E-learning, E-security, Security Threats and Risks, Internet, Higher Education Institutions (HEIs).

I. INTRODUCTION

Advancements in Information and Communication Technology has formed e-learning in mainstream due to ease of training and learning, cost effectiveness, accessibility and flexibility of time and place[i-vi]. ICT has transformed the focus of education and training from traditional or distance education to electronic-based highly value-added and resourceful education. This new paradigm of learning has been referred in a number of ways in the literature such as Internet-based learning [v, vii], borderless learning [viii], technology-based learning, online learning, web-based learning, flexible learning, and e-learning[iv, ix-xiv]. This study has adopted "e-learning" terminology to refer the ICT-based education.

E-learning generally involves in the development of instructional/learning material [xv]. However, in Higher Education arena, it refers to the situation where learning is accomplished over Internet-based delivery of contents and programs [xvi]. Due to penetration of the Internet, the Web has been evolved into numerous applications like banking, gamming, e-commerce, e-learning etc. [xvii]. The web is an ideal platform for offering a lot of related information to the learners. As web, browsers have been adopted as a mean for the interaction with learners and other Information Systems (IS) such as e-learning. These systems facilitate learners, teachers and institutions by providing a collaborative and interactive environment to enhance learning and teaching activities[xviii].

E-learning environment (sometimes also recognized as e-learning tools) comprises of Learning Management System (LMS), Knowledge Management System (KMS), Content Management System (CMS) or contents authoring tools [xix-xxi]. E-learning environment is an Information System (IS) based on World Wide Web (WWW) [xxii]. According to IEEE Learning Technology Standard Committee, *"a learning technology system that uses Web-browsers as the primary means of interaction with learners, and the Internet or an intranet as the primary means of communication among its subsystems and with other systems"*[xxiii].

As the Internet is one of the primary means of implementing e-learning which faces numerous illegal activities and security threats. Hence, e-learning environment is unavoidably exposed to the wide variety of security threats, risks, attacks and vulnerabilities [xxiv-xxv]. E-learning is a multi user environment having shared information and most probably accessed through Internet which makes it security sensitive especially cyber security. Cyber security has become an integral part for various organizations dealing with communication systems, management systems, medical platforms, e-learning and etc.[xxvi]

Moreover, most of the state-of-the-art e-learning tools (LMS, CMS, KMS etc.) have information security mechanism up to some extent as authentication, authorization and access is granted only on the basis of users' unique login and protected password [xxvii]. Only use of login and password do not make e-learning enough secure and building confidence to the potential users of e-learning. Therefore, this study intends to elaborate the existing security issues encounter by e-learning systems in the context of HEIs. Moreover, this work also contributes in a fashion by suggesting possible remedies and measures to avoid security threats of e-learning system by ensuring the privacy, integrity and confidentiality of the learners' data.

The rest of the paper is organized as follows: the background of e-learning in the context of Pakistan has been presented in Section 2. Section 3 describes our research design. Section 4 delineates possible entry threats and their measures, whereas section 5 sums up efforts as the conclusion of this work.

II. BACKGROUND

The advancement in computer technology has made it feasible to reduce the price of computers in the range of ordinary people. On the other hand, availability of the Internet has connected the people and computers anywhere in the world. Due to this reason e-learning is becoming mainstream and its market growth rate is 35.6% globally [vi, xxviii]. Therefore, HEIs round the globe are switching to this digital learning approach in order to increase their revenue by diminishing the educational cost and having good quality. It is urged by Hassanzadeh, Kanaani [xviii] that 75 percent of the top 129 US universities have been switched to this learning paradigm. In addition, 1000 institutions in 50 countries are practicing e-learning [i]. This modern trend is slowly penetrating in developing countries such as Pakistan, especially since the last decade when the country started experiencing a rapid growth of ICT infrastructure [xxix]. Increasing popularity of e-learning boost the enrolment of students in this borderless paradigm due to its ease of accessibility, flexibility of time and cost [xxx, xxxi]. However, this growing adoption of e-learning has been raised security threats on the traffic produced by this paradigm i.e. educational material delivered to or from learners can be altered or controlled by "modern pirates". So there is the need to deeply explore the security threats faced by the e-learning paradigm.

The e-learning development focuses more on instructional design, development of learning objects, delivery of learning material and ignoring or giving confined attention to privacy and security issues of e-learning systems [xiii, xxxii-xxxiv]. Nevertheless, security is vital for the both development and execution of an e-learning system since it manages delivery of data among learners, instructors and administrators when accessed at the same time [xxxv]. Therefore, e-learning systems must be secured not at the administration end but also protects user's privacy at the learner's end [xiv]. In the case of e learning environment, administrator may require strong security measures like strong authentication for user's privacy [xxxi]. Therefore, the existing escalation in e-learning adoption round the globe demands for higher magnitude of confidentiality and privacy in e-learning environment. It is hard to secure and protect the contents and personal data among learners and systems. It is therefore crucial to take the advantage of ICT for learning and training practices in a secure manner. Due to advancement of ICT and Internet technology, security threats, attacks and other illegal activities like hacking, session hijacking are also getting common to the web based application systems like e-learning.

The significance of security for the integrated platform, which is a shared environment, is vital since it manages sensitive data that is accessed simultaneously by a variety of users. Users as a stakeholder have different roles and responsibilities according to their position and skills. The heterogeneity that characterizes those users raises the necessity of utilizing a Role Based Access Control (RBAC) mechanism to regulate user actions within the system [xxxvi]. These roles can guarantee that no user can perform ineligible acts. Keep in mind that e-learning systems are web-based applications, so that these inherit all vulnerabilities of web-based applications but still e-learning have some domain specific issues like teaching and learning activities and collaboration between students and teachers. Therefore, e-learning systems have various challenges other than traditional/conventional web based application systems.

A. E-Learning in Pakistan

With the prompt boost in the utilization of ICT, enormous universities around the world are shifting to this mode of learning by integrating ICT in education to enhance learning experience of learners [xxxvii]. This drift can easily be comprehended in Pakistan, as the country started experiencing a swift evolution of ICT Infrastructure since the last decade. Higher education facilities are progressively expanding for elevating the socio-economic condition of the people. The Government of Pakistan (GoP) has been profound in establishing IT infrastructure and enhancing digital learning in the country. For this purpose, in 2002, a university has been established with the name of the Virtual University (VU). Later in 2007, the National ICT R & D Fund for ICT-based learning and training

has been established [xxxviii, xxxix]. Moreover, the HEC administers all the HEIs in the country to gauge, enhance and encourage not only research activities but also higher education in the country as well. In the steady evolution of the adoption of e-learning, security issue has become vital for the HEIs offering e-learning. Several questions has been raised about the security of the e-learning systems e.g. how to secure the e-learning system? What measures should enforced for keeping system secure from unauthorized access? Answer to such questions can enhance the acceptability of e-learning in Pakistan among all communities.

Various studies as illustrated in Table I regarding adoption, promotion and implementation of e-learning systems have been conducted in Pakistan. However, these identified studies have confined to emphasize diverse issues like technological, infrastructural, user satisfaction, bandwidth etc. None of the identified study has addressed the security and privacy challenges encountered by e-learning systems and stakeholders. However, [xlv] addressed the security issues with other various challenges, no further work has been done by the authors. Therefore, an in-depth review has been conducted in this work regarding security threats and their remedies to the e-learning systems, which consequently lead the HEIs to take precautionary measures in order to facilitate learners with the secure learning environment.

TABLE I
IDENTIFIED STUDIES ADDRESSING VARIOUS ISSUES IN THE CONTEXT OF PAKISTAN

Identified Issues	Citation
Technological and institutional infrastructure, Computer literacy, English competency, lack of awareness, Teacher training and interaction between students and teachers	[xl]
Teacher training, Electric power, ICT infrastructure, Student assessment and insufficient funding	[xli]
User satisfaction, Lack of user training, Underestimation, Lack of awareness, Lack of technical and administrative end-user support and Resistance to change	[xlii]
Inertia of behavior of people, Like their resistance to changes, etc., Underestimation, Lack of awareness and Negative attitudes towards ICTs., Lack of systemic approach to implementation and lack of follow-up, High rates of system non-completion, Lack of user-training, Lack of administrative and technical end-user support, User dissatisfaction with new systems, Mismatches between technologies and the context, Culture and work practices.	[xliii]
User satisfaction	[xliv]
Computer literacy, Computer access, Security and privacy, Face-to-face interaction, English competency and Students' resistance to change	[xlv]
Lack of user perception, Ineffective user training, Borrowed e-learning models, Digital divide and lack of technical support	[xlvi]
Lack of knowledge about technology, Usage problems and Accessibility to e-learning tools	[xlvii]
Cost of mobile Internet, Practical arrangements for practical oriented courses, Literacy rate	[vi]
Lack of instructional designers, Lack of instructional design processes, Lack of software quality assurance processes, Bandwidth, Lack of formal implementation processes, Lack of faculty interest, Lack of ICT enabled teachers, Lack of ICT enabled students, Power failure, Lack of LOs in the local language, Socio-cultural norms, Lack of resources, Accessibility to Internet broadband, Access to the latest computers, Borrowed e-learning models, Lack of leadership, Change in university structure, E-learning environment, Software interface design, Support for students, Support for teachers, Role of teachers and students, Learning style, Cost of mobile Internet, Practical arrangements for practical oriented courses, Literacy rate	[xxix]

III. RESEARCH METHOD

Exploratory research model has been adopted to explore state of the art literature intensively. Exploratory method is useful where either the targeted issue has never been addressed or inadequate information is obtainable and researcher intends to probe the research area [xlviii, xlix]. Furthermore, an exploratory research begins constructing observations and penetrating for a pattern. The researcher puts forward idea about why this pattern occurs. This approach is sometimes known as the inductive method. Therefore, this mode of research provides an appropriate way to facilitate researcher with the basic work for later studies[xlviii, l].

IV. E-LEARNING SECURITY ISSUES

Security is one of the serious concerns in education sector where ICT is the way of transferring knowledge,

which is known as e-learning. Primarily, there are four main stakeholders of the e-learning system as illustrated in e-learning access model Fig. 1. These include developers, instructors, administrator and learners /students [xxix]. The developers design the instructions, also called Learning Objects (LOs), and upload on the servers in the form of web utilities. Learning Object can be defined as an entity in electronic form. It may be a text, an audio, a video, a power point presentation for online courses which may also be recognized as an e-learning product or a pedagogical entity [xxix, li]. Administrator maintains the material on server and controls the services. Learner access the LOs through network (Internet). Observing the e-learning access model one can say that two major security dimensions are network security and web security.
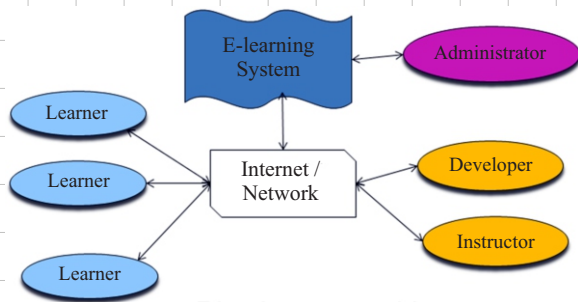

Fig. 1. E-learning access model

E-learning systems have multiple users and hence work in distributed environment connecting web and network resources. The distributed systems are more sensitive to security comparatively because of multiple users accessing from different locations. The primary security feature of e-learning paradigm is to facilitate the user with a secure transmission of information between learners and e-learning system [xxxiii]. Hence, security and privacy is one of the crucial concerns in educational context where e-learning enhancing the learning experience consequently enrolment of learners in online courses progressing rapidly [xxv]. Existing e-learning environments are production systems that demand to be secured [xiv]. Whereas, most of the e-learning systems are deficient to cope with the essential security requirements [lii]. Therefore, major issues of network security and web security like availability, confidentiality, integrity should be concentrated to achieve the effective level of e-security. Beside these there are some other factors, given below those contribute towards secure e-learning.

A. Privacy

Privacy also refers as confidentiality. It is prime concern of learners to feel the sense of privacy while working in an e-learning environment i.e. the transferring of information between learner and the e-system is secure and in the actual format in which it has been transferred. As learners send their data or assignment to the instructors/e-system over the Internet which expose to various threats and vulnerabilities of Internet [xxv, xxxiii]. This threat is concerned with the e-learning environment. Users will hesitate to adopt this new environment of learning until privacy is not ensured.

B. Authentication

It means who has created or sent the data. In other words, it is necessary to confirm the source of information for secure communication. Each user has unique identity that should be protected and checked before access and transmission of data. Protecting the identities of learners is crucial in cyberspace [xxxiii]. Rapid development in Internet technology makes it easy for the criminal to hack the users' identity. Hence, reliable identification of the learner is one of the essential factors of e-learning environment as it is the basis for access control[xiv]. Once the user is identified then it is required to verify that the learner is the same as the person is claiming to be [liii]. The learner's identity is in digital format in an online environment. Each identity in e-learning environment is unique due to specific characteristics and preferences. These characteristics may include login information, password, courses taken etc.

C. Authorization

Authorization states that legal users can access the information as per defined privileges. E-learning system lies under distributed system and multiple users are accessing it from scattered locations. It needs to identify the user with its identity. Therefore, there is a need of a secure authentication mechanism not only to recognize the user but also determines the users' access privileges on the e-learning system. Authorization services validates that whether the authenticated entity has privilege to access the demanded contents of e-system or not [liii, liv]. Only registered users are authorized with defined and limited facilities or level of learning content [xiv, lv]. All stakeholders like students, instructors, developers etc., are accessing e-learning system according to their responsibilities. Especially students, known as learners, are using e-learning environment from dispersed learning centres and require concrete assurance regarding identification of learners. Normally administrator of the system registers the users and assigns their access rights.

D. Diverse Location Access

There is the special characteristic of e-learning system that multiple users can access it simultaneously from diverse locations. Beside this, different users

belong to diverse fields as well as background. These factors make the security of e-learning system more complex. An e-system can have enormous users includes instructors, learners, administrators or managers, these might access e-learning systems[xxv] in order to perform their educational activities like downloading, uploading or to exchange distributed information over the network. Hence, there are multiple places for interaction inside e-learning system that may provide multiple opportunities to intruders as numerous users can access e-learning system simultaneously from disperse locations [lv]. This has increased the security risk to the e-learning data. The security risks can be reduced by limiting the entry point to the e-learning systems. On the other hand, implementation of e-learning systems loses its unique feature of access to large number of users from various geographical locations round the globe by reducing the entry point.

E. Confidentiality

The protection of the assets of e-system from unauthorized access is termed as confidentiality. Research indicates that privacy is the state of being secluded and confidentiality is the state of keeping data secure from unauthorized access and modification. Numerous security risks can arise in e learning that disrupt privacy and confidentiality of learners[lvi]. The learners need assurance that the data and information in e-system remain secure and private and never expose to unauthorized entities, devices or systems[xiv, xxxiii]. The access control to resources can helps to achieve the confidentiality of an e-system, that can enable secure contents delivery over the network and the storage of data [xxv]. The confidentiality is one of the prime concerns of the registered learners which means that their submitted assignments, papers, information will only be accessible by the relevant examiner or personal. The user should prevail access only to authorized contents and those persons who are not the legitimate users must not be able to gain access to the e-system.

F. Integrity

In network security, integrity means that data has not been altered. Data integrity defines the accessibility, reliability, correctness and high quality of stored data [lvii]. Integrity is the assurance that only authorized users or programs has right to modify data or executable programs. Hence, ensuring the integrity of the data and information is one of the major goals in relation to the security of an e-system [xxv]. Integrity depends on access control and requires to recognize all the users who try to access e-system[xxxiv]. Moreover, learners of e-system are required to assure that the intended personal (examiner, instructor, administrator

etc.) will receive their submitted contents/material (assignments, papers etc.) in its original and unedited state[xxxiii].

G. Availability

Availability can be explained as the degree to which a system is available and operational for use to the learners when it should be[xxxiv, lviii]. Moreover, availability of the system is also refers as the extent to which the system is available for learners whenever it is required[lix]. In addition, it refers to permanence, non-erasure and deals with Denial of Service (DoS) attacks and viruses that delete files. There are two main facets of availability includes Distributed Denial of Service (DDoS) and loss of data processing capabilities [lv], where DDoS attack is the root attack for data unavailability [lvii]. Hence, it is vital to confirm that information and communication resources are always available when demand is raised so that the authorize learners may submit their assignments, comments, notes or papers within the specified time. If the user is not able to access the required material or e-contents on time they may frustrate or lose their interest or even may fail at most to use e-learning system[lv, lx].

H. Non-Repudiation

Non-repudiation enforce legal users to not refuse the accomplished operation that they have done[xxv]. For example, if a learner submits his or her assignment he/she must not deny from submitting his material. Hence a systematic and formal mechanism is needed in order to enforce the registered users from denying the work or modifications that they have performed in the system[xxvii].

V. Security Measures for E-learning

E-learning users encounter various risks, attacks or threats while working in an e-learning environment as mentioned in previous section. As instructors, learners, administrator and data reside at various disperse physical and logical locations and the Internet is the only mean of their connectivity which makes difficult to implement the information security mechanism [xxv]. Therefore, there must be the mechanism to protect information to achieve the confidentiality, integrity and availability to attract the users to utilize the e-learning system. As an e-learning is open to many fold to multiple threats so it is required to consider and apply various measures especially to Pakistani universities in order to secure the e-system from prospective risks, attack or threats. These measures may include access control mechanism using firewall, digital signature and biometrics authentication. Cryptography and session authentication are also major network security

methodologies and have lot of applications for online communication and transmission of data. Beside these, using alert SMS (Short Message Service) of mobile devices can provide secure authentication and authorization to ensure the integrity and confidentiality of the e-system. The objective of this study is to focus that how mechanisms of security, mentioned above, can be applied to an e-learning system efficiently.

A. Access Control (Firewalls)

The simplest way to ensure access control is using firewalls. One of the possible techniques for improving security of the web applications is a firewall [lxi]. Firewall is firmware developed to secure the e-system from unauthorized access whether from outside or within the institution [lxii]. To enforce security, all traffic from inside to outside or vice versa must pass through it for screening, it acts as a protective layer. Therefore, all access to the system must be physically blocked and the authorize traffic should only allow to pass through it to make the e-learning system secure. A firewall creates a barrier between a trusted secure inside the network and the outside network, like the Internet, because it is supposed not to be protected or trusted. The goal of firewall is to protect the networks from threats and attacks. Firewalls can strengthen the network systems and protect systems from intruders. [lxiii]. Firewall blocks the unwanted and vulnerable communication between the networks. It is based on security policies that are predefined to secure the network from the threats [lxiv]. Firewalls are already available in the market and in use for communication over network (Internet). Therefore, it is proposed to incorporate firewalls to improve the security level of e-learning systems.

B. Biometrics Authentication

Various authentication techniques like passwords, smart card, digital certificate and digital signature are in practice. E learners can use smart cards for their authentication process because smartcard stores different parameters during registration phase and proves the authenticity of the user [lxv]. Moreover, apart from smart cards learners can use digital signatures and certificates for authentication process. Digital signatures are encrypted electronic stamp and to create a digital signature, signing certificates are needed that proves the identity [lxvi]. Even then no body cannot guarantee that the users will not provide their password [lxii] at the time of downloading, uploading of e-contents, submission of assignment, receiving/attempting the question papers and etc. Using password is an old and widely used mechanism and has good results in many cases incurring minimum cost. Still there is a chance of stealing or forging the password. Attacker can forcefully get the sensitive data like passwords through pre-functioned software[lxvii].

Biometrics authentication is a best choice to replace password matching. Therefore, biometric authentication mechanism can provide a comparatively better and secure environment as user can never misplace their biometrics and the biometric signal is difficult to steal or forge [lv]. HEIs of Pakistani can restrict the enrolled students to provide their one or more biological characteristics like face, handwriting, fingerprints, blinking of eyes or voice, which is stored in the database in order to authenticate the respective user. Keep in mind that this technique requires biometric device that incurs some cost. Recently these devices, like fingertips recognition device, are easily available in the market within affordable price. These facts prove that biometrics authentication is a feasible solution for e-learning system in Pakistan.

C. SMS Authentication

In Pakistan like other countries, use of mobile phone is increasing day by day as a mean of communication regardless of the age and educational level. Increase of cellular phone subscribers as compared to the computer users is very rapid. With such growth of telecom and mobile industry these mobiles phones are more than a simple phone. These have now become smart phone[vi]. These smart phones have potential advantage to the HEIs offering e-learning system and can be used for authentication purposes. It is proposed to use SMS for secure access of e-learning system. Possible procedure may be divided into two steps. In first step, a student submits the user ID and password through his/her cellular phone. In response to this e-learning system generates a special code and sends it to the registered phone of the user by SMS, which is actually the key for the current session. In second step, student enters this code in order to authenticate his identity and access the e-learning system safely. The complete possible login scenario with two steps login and verification is shown in Fig. 2. Such mechanism is already used for web accessing by some applications but not for e-learning systems. It is proposed to HEIs of Pakistan for adopting this two steps login and verification scheme. This simply can be done by adding a cryptographic algorithm that takes username and password as input and provide output in the form of random/unique pass code. This code is sent to user's registered mobile phone not only to identify but also to authenticate and authorize the all kinds of users with pre-granted privileges.
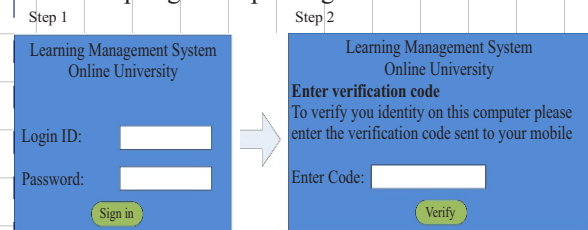

Fig. 2. Login scenario for two step verification

D.   Cryptography

Cryptography is one of the essentially recommended techniques implemented to enforce the security in Internet based transmission of information. It has two parts encryptions, hide the data at sender end, and decryption or retrieve original data from hidden form. Cryptography is useful for protecting data from theft or alteration during transmission as well as in storage and can perform the user authentication too. According to [lxviii] cryptographic algorithms can be categorized into three major types: secret-key (symmetric) algorithm, public-key (asymmetric) algorithm and hash functions. Public-key crypto-systems use two keys. The purpose of first key is to encrypt the information on sender end while role of second key is in the decryption process of the delivered data or message. In contrast to public key, secret-key cryptography uses a single key for both encryption and decryption [lxii]. Where as in hash algorithms, hash value is appended to the data/message at the source at a time when the message is assumed or known to be correct. Then encrypt the appended message and send to the destination. The receiver authenticates that message by re-computing the hash value. Hash algorithms are used to provide a digital fingerprint of a file's contents for confirmation that an intruder has not modified data. Many operating systems utilize the hash functions to encrypt passwords [lxviii]. If any intruder, make system compromised then hashing algorithms [lxix] and cryptographic techniques [lxx] can keep the information safe.

E.   Session Authentication

Session hijacking or cookie hijacking is the way to misuse the legal computer session. Attacker can hijack the session to have unauthorized access in your computer system. [lxxi]. Authentication methods are not reliable and secure; the challenge is to design such an e-system which authenticate a true user during the class session or at specified time intervals [xiv, xxv]. Two-step authentication method is more secure than the single authentication method [lxxii]. First it is required to login using ID and passwords and after that it is required to authenticate sending an email or by short message using hand held device [lxxiii]. This type of re-authentication have successfully been implemented by various secure web application systems like e-banking etc.

F.   Secure Socket Layer (SSL)

Secure Sockets Layer is a standard protocol used for secure information on Internet. In e system SSL is used between the server and the user [lxxiv]. The (HTTPS) secure hypertext transfers protocol is designed to transfer encrypted information on Internet. HTTPS is simple http that uses the SSL. A SSL is encryption protocol that uses HTTPS invoked on a Web server [lxxv].

G.   Physical Security Device

Learners can register a security key to their account so that next time they login after enabling approvals with that USB security device. Security can be tackled with the help of their USB device. With this physical security device phishing can be handled as user do not required to enter a code by themselves. If user uses a security key with their computer for logging in, it will be as simple as a tap on the key after your insert your password.

VI. Conclusion

Various security threats, risks and attacks have been explored encountered by e-learning environment of HEIs within Pakistan. Privacy of the user and his personal identity is most crucial issue in a shared e-system. Moreover, the methods of authentication, authorization and delivery of e-content to the users require secure mechanism. Beside authentication and authorization, non-availability of the system or e-contents to the learner at the required span of time is one of the major threats to the e-system. If the e-system is not available, it is totally useless for the learners and also cause the frustration and demoralization from the e-learning. Moreover, various methods of authentication like login, password etc. are discussed and are not found to be secure and reliable. Authentication of the learner is quiet difficult as anyone can get access on behalf of the registered user. Hence, in order to cope with such authentication concerns, biometric authentication using finger impression, eye or face recognition can be implemented. Hence, the e-system is required to deploy security services such as access control, encryption, authentication, managing users and their privileges. Few remedies such as pass code login scenario or biometric based authentication have been suggested in this study. It is recommended that existing e-learning environments adopted by HEIs of Pakistan should embed the security measures described in above section to enhance the security. Moreover, the data transfer between the system and administrators or content operators or learners should employ the encryption. A secure learning platform should not only incorporate all the aspects of security but also make most of the processes transparent and easier to the teacher and the student so that it becomes attractive for all stakeholders.

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Adaptive Error Control Mechanism for Near Threshold Computing based on Network-on-Chip

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Abstract-In this paper, we present a switching model to increase reliability of Network on Chip (NoC)which is compromised due to Near-threshold computing (NTC) faults. The Proposed method provides three modes of switching to tolerate some diverse faults occurring in the network. In low noise conditions, our model operates on End to End mode to achieve better reliability and low latency. In more significant noise conditions it is shifted towards slope and Hoe to Hop mode to tolerate accmulated faults in the network. The proposed model achieves a better trade-off conditions in term of reliability and latency as compared to BCH and CADEC codes and attain energy efficiency with the help of NTC model and provide reliability by switching between different modes to realizes a better fault correction capability.

Keywords-NoC, NTC, Fault Tolerance

I. INTRODUCTION

The decreasing size of a transistor has [i-ii] enables the designers to integrate billions of transistors on a single chip. This abundant availability of the transistors has led to the concepts of chip multiple processors(CMP). For handling the communication needs between these CMPs has led towards the concepts of the network on chip(NoC) [iii-iv].The communication in the network on chip required minimum latency and high reliability [v]. This decreasing size of the transistor has also give rise to increased power consumptions for the NoC. It revels in research conducted in the US that in 2006, datacenters consumed about 1.5 percent of the total electricity [vi]. This dangerous condition has focused towards optimizing the power consumptions for future computer systems based on NoC. Different alternatives are available to reduce power consumption caused by cores. One possible solution is dark silicon where transistors are underutilized due to low power budget [vii]. One of the best alternatives to the dark silicon is Near-Threshold Computing (NTC) [viii] which operates the transistor at a low voltage level and lead to in a better tradeoff conditions between power and latency in comparison to subthreshold circuits [ix]. NTC has now been in used in NoC to overcome the energy and power constraints of the NoC. However, due to process variations, this power efficiency costs performance loss [x]. The benefit of NTC is that it consequences in increased power efficiency for traditional architectures which were designed for operating on specific voltage [xi].

Due to increase of transistors on a single chip according to Moor's law, NoC architecture tends to achieve better performance and reliability. According to the concept of the NTC, as the operating voltage of the transistor is reduced it results in better energy efficiency [xii] at the cost of performance loss. This performance loss occurred due to increase in the crosstalk, Single-event upsets(SEU) and aging problems which may lead to transient, intermittent or permanent faults [xiii-xiv] which may fail the system [xi].Thus, there is a high need to tolerate the faults occurring due to NTC. The Error Control Coding (ECC) protection can be used to provide desired reliability for NoC.

The previous research has adopted ECC at the datalink layer [xv-xvii]. Hop-to-Hop (H2H) ECC can tackle higher noise but resulted in higher energy consumption if number of faults in the network are lower. Another alternative to the H2H coding scheme is to adopt network-layer ECC protection scheme named the End-to-end (H2H) which correct the error in a packet only when it reaches the destination router [xvii-xx].

These techniques have pros and cons. We propose a framework that can combine the merits ofH2H, E2E and Slope technique to improves the reliability and energy efficiency of the system while maintaining performance.

The proposed framework is designed to address both Logic Voltage Induced (LVI), and Timing Voltage Induced (TVI) based Single Event Upset (SEU) faults. The rest of the paper includes literature review, proposed three-layer model description and performance analysis of the proposed method with state-of-art techniques available.

II. LITERATURE REVIEW

E2E protection schemes are operated on the Network Interface. The encoding and decoding process is only performed when it reached the destination router as shown in the Fig.1. H2H protections schemes are performed at the datalink layer and operated on each hop, as shown in Fig.2. Every router input port has its own encoder and decoder. For low noise regions Hybrid Automatic Repeat request [xxi] recovers the faulty flits without incurring latency overhead. In case of low noise, the additional encoding and decoding waste energy. Rossi et al. [xvii] propose a model that use different ECC schemes. To reduce the energy waste, Li et al. [xv] have utilized the error detection capability to the solve the transient faults. Wang, J., et al.[xxii] has conducted a comprehensive study to tolerate the faults caused by NTC and dark silicon. Different coding schemes Hamming, boundary shift code (BSC) and modified dual rail code (MDR) has solved the single error. E2E coding schemes resolve the transient faults only at the NI. The receiver sends an acknowledge signal to the sender if packet is correct. In this work, we take advantage from H2H, E2E and Slope methods to covers the faults caused by the NTC in NoC. E2E is performed only when the number of corrupted packets are less than to a pre-defined threshold value T1. If the number of corrupted bits increased from that threshold value T1, the ECC mode is switched to the second layer which is Slope as shown in Fig.3. In case of more corrupted packets exceeding threshold value T2, the ECC mode is switched to the third layer which is H2H protection. The flit corruption record is saved in history flit which keeps tracks of corrupted flits and helps the control unit to accommodate that switching.

The detailed descriptions of this model are described in the next sections.

III. PROPOSED SWITCHING SCHEME

The Switching protocol work by the amount transient faults occurring in the network. In case of a variable number of transient faults, switching between multiple layers results in improved performance and reliability of the system. We propose an ECC mode switching protocol which shifts between different layers during runtime operation of the system. In case of a small number of transient faults, E2E ECC protection is performed to maintain the integrity of the packet. In case number of faults occurring in the network exceeds a specific threshold value T1, Slope approach is utilized to tackle the faults. Slope utilized optimize locations to place the ECC protection. When the number of faults exceeds the threshold value T2, then H2H ECC protection is used to solve the faults. The state machine diagram is shown in the Fig. 4. There are three state transition along with some intermediate states which are used for synchronization purpose. The intermediate states named as Pre-E2E,Pre-Slope,andPre-H2Hare used for sending the instruction to the network for the mode switching to maintain synchronization. The E2E protection is used in the network if NoC is in the E2E state or Pre-E2E, Slope is used to when the network is in Pre-Slope and Slope state, and H2H protection is used when the network is in the Pre-H2H and theH2H state. When the network starts, it goes in E2E state to reduce the energy consumption and providing better reliability. The network monitors some faults in the network after every T count cycles and compares it with threshold values T1 and T2. If the number of faults exceeds from value T1 then the associated node request to switch the mode to Pre-Slope and if it exceeds from value T2, it sends a request to shift mode to Pre-H2H. This switching information is also delivered to others nodes in the network to inform them there is a mode switch in the network. This information is sent to all nodes of the network to maintain synchronization in the network. The switching request is transmitted to the network in first T propcycles of each T period. During that cycle.

Fig. 1. E2E Protection in Baseline Fig. 2H2H Protection in the Baseline
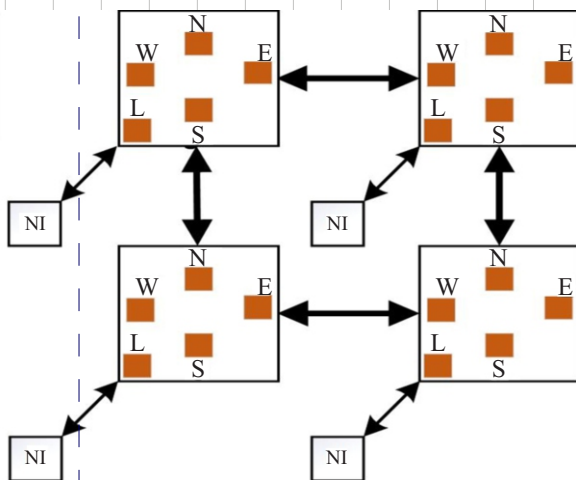
After that time the nodes switch to operate on E2E, Slope and H2H protection modes. The maximum propagation time for delivering this message to all the node is given by (1).

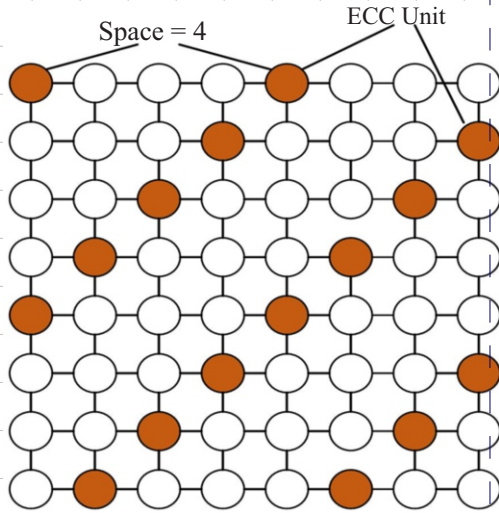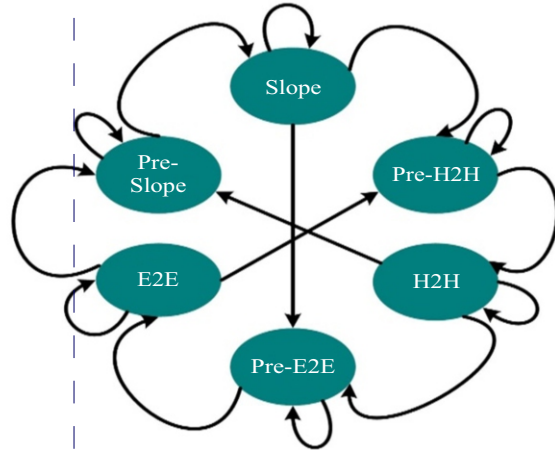$$T_{prop} = 3(\sqrt{n} - 1) \qquad (1)$$
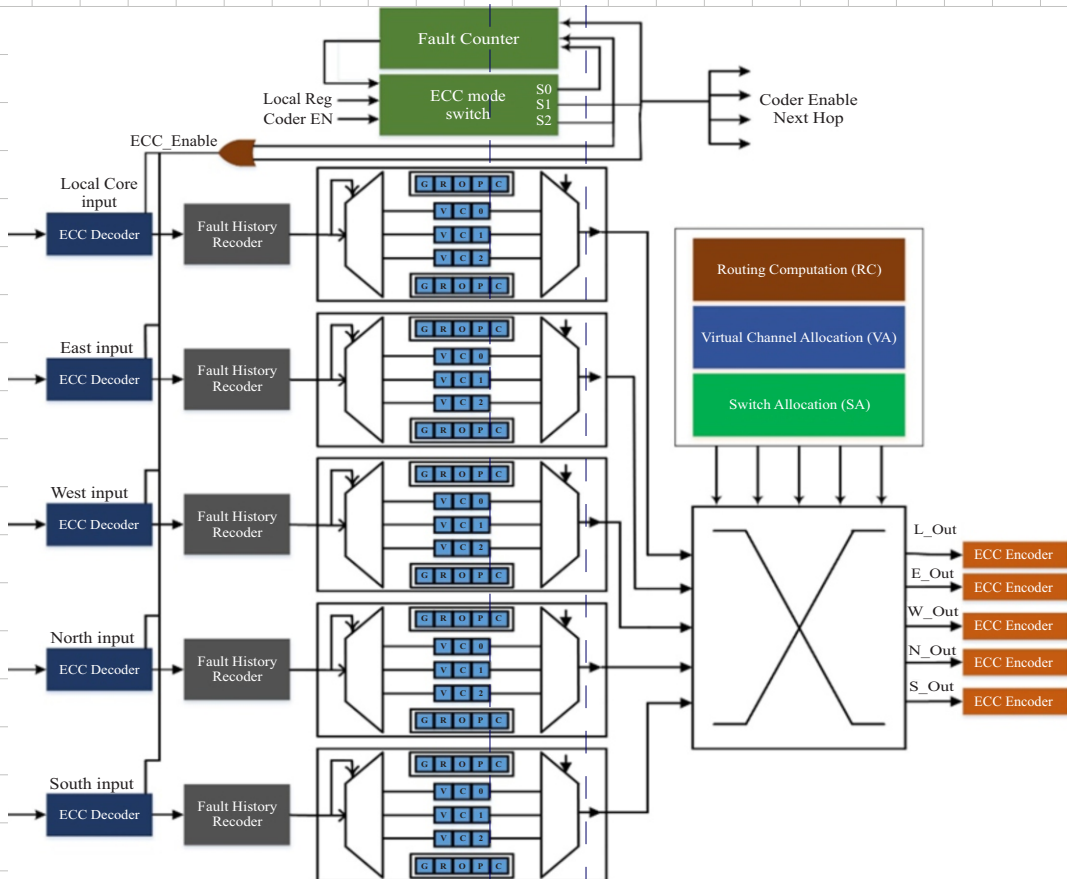
Where, n is the number of nodes in the network. To prevent mode oscillation in the network, it monitors the requests coming from the network. The only request coming from the local node and neighbor nodes resulted in a state transition. This mode switching is activated only when the number of errors during T count exceeds the specific threshold value.

Fig. 3. ECC Protection using Slope

Fig. 4. ECC Mode Switching Protocol

Fig. 5. Router Architecture

For a given traffic load α and error rate p_e after leaving the *h* hops the packet containing errors are expressed by (2).

$$Total\ corrupted\ packet = T_{count} \times \alpha \times p_e \qquad (2)$$

In which

$$p_e = 1 - (1-\varepsilon)^{\omega\rho} \times h \qquad (3)$$

The term p_e is used to represent the fault model, ωρ is the number of corrupted bits and ε represent total error rate. T_{count} can be obtained by rearranging (2) and by putting (3).

$$T_{count} = \frac{Total\ corrupted\ packets}{\alpha \times (1-(1-\varepsilon)^{\omega\rho} \times h)} \qquad (4)$$

A modular counting timing T_{count} is attached to each router. The T_{count} can also be set by (5)

$$T_{count} = \frac{Total\ corrupted\ packets}{\alpha_{avg} \times (1-(1-\varepsilon)^{\omega\rho} \times h_{avg})} \qquad (5)$$

In this equation avg α_{avg} is used to represent average load h_{avg} is the average hop counts.

The network interface and router architecture are modifiedto implement the proposed switching methodology in NoC. The network interface is responsible for measuring the number of corrupted flits in the network. If the node is in the E2E state and number of corrupted packets exceeds from threshold value T1 then it will make a transition to Pre-Slope. In case of value exceeding the threshold value T2, it will request a transition to the Pre-H2H state. This is accomplished by keeping track of error history flit maintaining at each router.

The flit starts with a unique Id which determines the router Id. The rest of the flit contains information of error detection or not. If an error is detected at a hop, it is written as "1" otherwise "0" is written in the flit. The counter is incremented if this field contains "1" and counter resets after every T_{count}.

IV. Fault Tolerant Router

The router architecture also needs some modifications to handle this three-layer switching protocol. The proposed router architecture is shown in the Fig.5. A router in NoC consists of five input ports and five output ports named as East, West, North, South and Local. The main addition to the conventional router architecture design is Fault History Recorder, Fault Counter, and ECC mode Switch. It is the responsibility of the Routing Computation Unit (RC) to obtain the destination information. The switch allocator controls the connection between input and an output port with the help of crossbar unit. For facilitating the error

control mechanism NACK signal is used. The switching mechanism is represented with the state diagram in the Fig.4. There are six state transitions in the network. For E2E switching in the network the S1=0 to maintain E2E switching overall in the network. For Slope its value is S=1 and for H2H switching its value is S=2.The Fault counter sends the propagation finish signal which indicates mode switching is completed in the network.

If the network is operated on the H2H switching, then the output of the EEC decoder is saved. This flit contains unique bit pattern which is sent to Fault History Recorder, and last bit is used with hop EEC decoder to represent the number of the errors. The other error history bits of the different hops are pushed forward to the next hop. For a 32-bitflit, it can hold records of 24 hops error history.

The switching between different modes depends upon the exchange of the information between different protocol. When the network is operated on E2E switching protocol, the global history is used for switching. When the network is operated on the Slope, and H2H switching protocol, both local and global history are used to determine the total errors in the network and determine if there is a need to mode switch. The total number of errors in the network plays an essential role in switching between these modes. Different switching modes are activated based on the number of faults in the network.

V. Results and Discussions

In this section, we analyzed our proposed scheme by simulating 8x8 mesh using Gem5 [xxiii] and Garnet 2.0[xxiv]. We make use of synthetic and benchmark traffic to evaluate the proposed design. We evaluated our proposed model with Fixed EEC decoder applied in the [xxv] to evaluate the efficiency of the proposed model. We have evaluated different error control mechanism to observe and compare the reliability and performance evaluation of our proposed model on benchmark and synthetic traffic patterns.
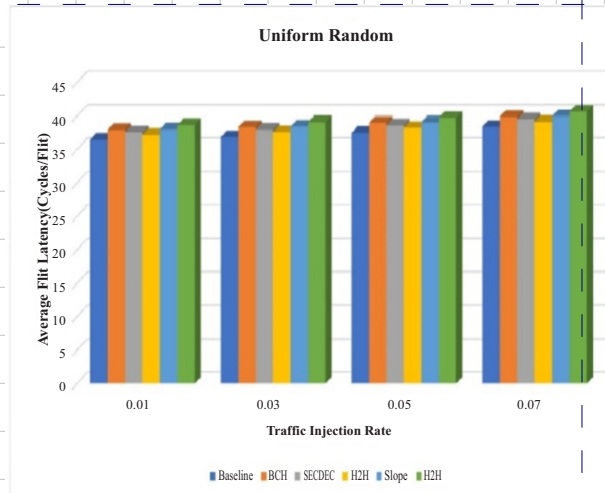
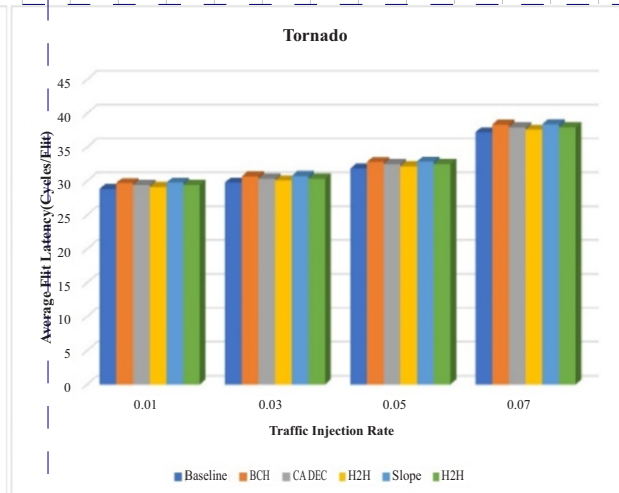Fig. 6. Comparison on the basis of Uniform Random Traffic

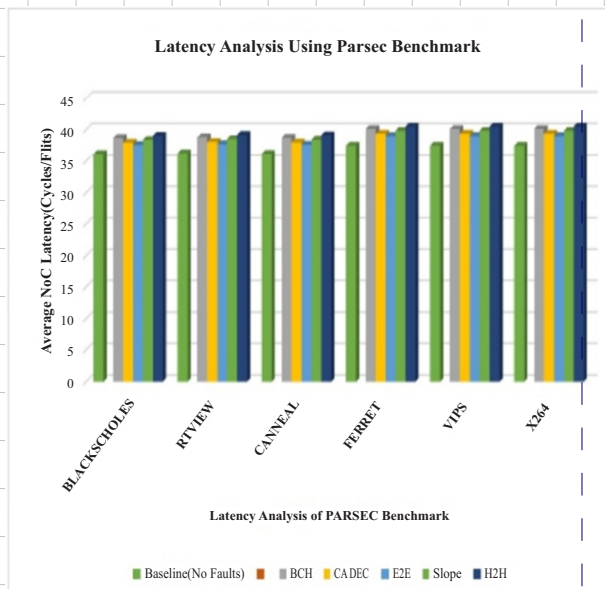Fig. 7. Comparison on the basis of Tornado Traffic

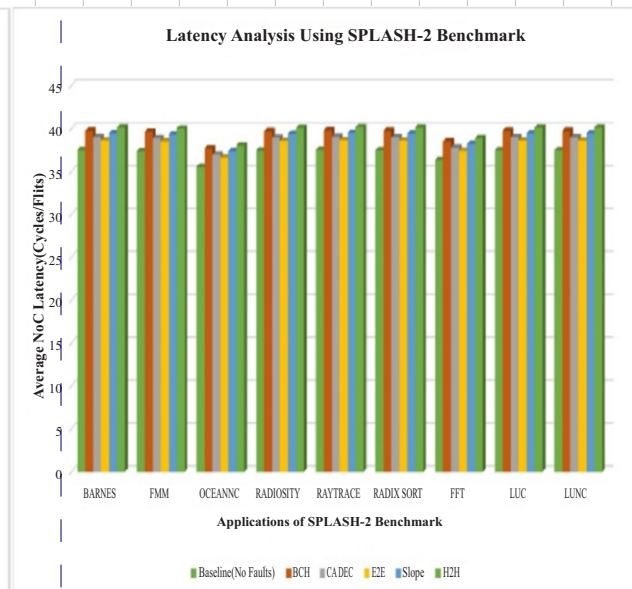Fig. 8. Comparison on the basis of PARSEC Benchmark

Fig. 9. Comparison on the basis of SPLASH-2 Benchmark

We simulated the desired configuration for the synthetic traffic patterns and observed the effect on latency with increase injected packets. We injected increasing number of randomly generated faults in at the varying inject rate and compared their correction capability and impact on the latency. For uniform random and Tornado traffic pattern, it is observed that as the number of injected faults increased the fault correction capability of the proposed slope is equal to BCH with a minor overhead of latency. The fault correction capability of CADEC is higher as compared to the proposed E2E mode, and E2E is not capable of correcting accumulated faults. To overcome this situation our proposed switching model, change a transition to H2H state which corrects the more considerable number faults with some minor increased

overhead of latency as shown in Fig.6 and Fig7.The proposed model is also evaluated for real-time benchmark traffic pattern. The impact on latency with an increased number of injected faults is shown in Fig.8 and Fig.9. Our proposed model has the advantage of shifting different modes to tackle a different number of faults.

The Error correction scheme E2E BCH has error correction capability 3 errors at the destination router. If more than 3 number of errors occurred, then this technique failed to solve that problem. For CADEC, it can solve maximum 2 errors occurred during its path traversal.

In our proposed scheme there are three types of switching modes for tackling a different number of faults. We have utilized adaptive routing in the network

to increase the error resiliency of the proposed method. For a fair comparison, we have utilized both schemes for adaptive routing and observed the number of uncorrected flits by these schemes. Our method shows better resiliency to tolerate more faults in the network. For less than 3 number of faults in the network can be tolerated by E2E switching protocol. The correction schemes BCH and CADEC tolerate these faults. The number of uncorrected flits is being monitored if the flits remain uncorrected with BCH and CADEC it means they fail to correct these faults. The proposed model request for transition to a Pre-Slope state where ECC protection is applied to the optimized locations. The slope handles a more substantial number of faults by utilizing the adaptive routing with the help of optimized ECC locations. If the number of uncorrected flits exceeds then, it will switch to H2H switching mode which now can tolerate single fault at each hop. In this way the error resiliency of the proposed model's increases.

VI. CONCLUSION

In this work, adaptive error control mechanism is efficiently utilized and extended to operate in three mode including End to End, slope, and Hop to Hop protection. In this work, we combined NTC with NoC and used switching model to tolerate the faults occurring in the network due to NTC. The error detection outcome and analysis show that this switching results in better reliability and improved performance in term of energy. Simulation results show that the proposed model achieves better error correction capability and improved network performance.

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