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Sustainable Transport Measures: Acceptance Rate in Lahore

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Abstract-Sustainability defined as development meeting needs of the present without compromising on the ability of future generations to meet their own needs, has become a wide area of study in Civil Engineering. It has particularly become important in the transportation sector as a result of non-renewable fuel depletion, energy insecurity, traffic congestion, air pollution, global climate change and so many other negative issues. Sustainable transportation aims to tackle all these issues while providing other advantages. Furthermore sustainability is steadily gaining more footholds in the construction industry and is now one of the main expected competencies in a Civil Engineer. This paper focuses on the economical implications of sustainable transport measures. Furthermore it focuses on user rating and acceptance of these measures and how that affects their economical repercussions. In this research, A questionnaire was come up with aim to monitor user acceptance and rating of sustainable transport measures in the city of Lahore. It was found that public transportation has a very high rating and user acceptance whereas car sharing has low user acceptance in Lahore region. The research uses the data on user acceptance and rating to evaluate the economical impacts of sustainable transport measures. From the user acceptance and rating, it can be concluded that congestion charging would have a positive economical impact if it was employed in the area. However it has to be reiterated that the survey only reflected the views and opinions of only a small percentage of the population. Sustainable transport measures have both positive and negative impacts, which are social, economical and environmental. However the positive impacts, as seen in this research outweighs the negative ones especially in terms of economical impacts.

Keywords-Sustainability, Economy, Congestion, Public Transport, Car Sharing

I. INTRODUCTION

Sustainability has become a wide area of study in Civil Engineering and the transportation sector so that it is being incorporated into almost every design project [i]. Sustainability is defined as development that meets the needs of present without compromising on the needs of future generations. Hence the objective of sustainable development is to enable people to satisfy their basic needs and enjoy a better quality of life without compromising on quality of life of future generations [ii]. Furthermore, sustainability has become one of the most important and expected competencies of a civil engineer. In the world, it is necessary to embed sustainability into every construction project as it is one of those subjects that cannot be ignored any longer [iii].

A good transportation system enhances quality of life through increased access to health care, employment, education, recreation and a wide range of consumer goods [iv]. However the current transportation system has some negative impacts as well. The challenge of a sustainable transport development lies in minimising these negative impacts while offering strong transportation benefits at the same time [v].

Considerable amount of research has been done to study the affect of different parameters on sustainability of transport. Shaheen et.al; did a study in Canada and found out that between 15 to 29% of car sharing participants sold a vehicle after joining a car sharing program while 25 to 61% had delayed or forgone a car purchase [vi]. Similar sort of study in Netherlands showed that car sharing has brought about a 39% decrease in private vehicle ownership among its members [vi]. However it should be noted that car sharing activities are more limited in Asia. Although car sharing has a relatively high profile, it has had little influence on traffic. This can be seen clearly in Switzerland where even the successful effort being put into place generates only a few thousand trips a day. This accounts for less than 0.1% of the total trips made by the 7 million residents of Switzerland [viii]. It is certain is that the concept of car sharing has to be optimised and perfected if it is to be used in reducing congestion. Studies have shown that one shared car equals reduces about four to eight cars on the road as a result of the measure. Secondly there is reduced

parking pressure as a result of car sharing [ix].

Congestion charging as a sustainable transport measure was studied in London. It was found out that this measure improved traffic during coarse of day rather than just peak hours [x]. Traffic speed increased by almost 20% whereas congestion reduced by 30.5%. Analysis have shown that due to reduced congestion and improved traffic flow by the implementation of sustainable transport measures, Ambient pollution also reduced considerably and inevitably reducing the health hazards associated [xi].

Use of Public transport as a sustainable transport measure was implemented in Germany. As a result of increasing problems to sustainability, the German government sought to rejuvenate the public transport sector. This helped increase the quality of public transport in Germany and hence attracted more customers while increasing productivity, reducing costs and cutting subsidies [xii]. Another study showed that use of public transport instead of personal cars not only reduced travelling cost per person but also reduced traffic congestion due to reduced traffic load on roads [xiii].

II. Problems in Transportation

A. Congestion

Congestion plays an important role in providing sustainable transportation measures. This is so because congestion worsens motorised mobility. Increase in traffic congestion in city of Lahore is due to the lack of adequate and reliable transportation funding in addition to increased personal and freight movement. Especially in recent years, repair works on roads with proper detours, have worsened traffic flows. Congestion is a major issue if not tackled it can leave next generations without an adequate means of mobility. Therefore congestion plays an important role in terms of sustainable transportation and this congestion must be kept in mind while designing any transportation network time.

B. Local Air Quality

Local air pollution has steadily gone worst as a result of motorized vehicles' contribution. Almost 80% of vehicles in Lahore do not comply with Euro 4 Emission standards. These air pollutants, especially toxic ones, have various negative health impacts, which may include cancer, cardiovascular, respiratory or neurological diseases. The emission of nitrogen dioxide (NO_2) from transportation sources increases the risks of respiratory problems and may even reduce lung function. Also some of the gases emitted can help causing acid rain. Sulphur dioxide (SO_2) and nitrogen oxides (Nox), when released, form various acidic compounds in the atmosphere, which when mixed in cloud water form acid rain. Furthermore acid rain has various negative impacts on the environment as it reduces agricultural crop yield and causes forest decline [xiv].

C. Fatalities and injuries

A high number of fatalities and injuries is a problem currently being faced in the transportation sector [xv]. According to a news report, 328 people died and more than 46000 suffered injuries in traffic accidents in Lahore [xvi]. Not only Lahore but this problem with fatalities and injuries is taken to be a global phenomenon so that authorities in countries all of over the world are concerned about it. From the reports “Global Burden of Disease” [xvii] and “World Health Reports- Making a Difference” [xviii], road crashes and accidents were placed at ninth place, out of a total of over 100, among the causes of death in 1990. Furthermore, the problem is getting worse as forecasts have suggested it will move up to sixth place by 2020 and “in terms of life years lost and disability-adjusted life years” will be in second and third places respectively if proper measures are not taken.

D. Ecosystem damage

Government policies in Pakistan have not considered adverse affects on ecosystem since the beginning. Lahore being the second largest city in the country and so is the traffic density in the city. It should be kept in mind that transportation activities can harm biological resources [xix] and generate a number of adverse environmental effects. These effects can be direct, indirect or cumulative. Studies have shown that the indirect effects may have grater impacts than the direct ones, but are not generally well understood [xx]. The effects can range from the death of a single animal to a complete loss of habitat. Hence it can be seen that some impacts are localised while others are more profound and widespread.

III. Methodology

This research focuses on congestion charging, public transportation, car sharing and car pooling as sustainable transport measures. In order to answer the questions being asked, a questionnaire was come up with. The aim of the questionnaire was to monitor user acceptance and rating of the aforementioned sustainable transport measures. Furthermore the information gathered will help to develop a study on their economical impacts.

The questions that the questionnaire aims to answer are as follows:

- How does the public perceive these sustainable transport measures?
- Would they be accepted if they are encouraged?
- What are the barriers preventing these measures from being adopted?

The questionnaire was used to gather this information instead of other means. The questionnaire

used was aimed at the general public; therefore it provides information on how the general public view and use sustainable transport measures. Furthermore it gives information on the acceptance level of sustainable transport measures and what needs to be done for there to be accepted if encouraged. The study comprised of a total of 100 questionnaires, out of which 60 were selected for data analysis as they were completely filled. Out of these 60, 36 were males and 24 were females.

The questionnaire was set to satisfy some of the indicators that were mentioned above. Firstly looking at the social aspects, it aimed to find out the user rating of sustainable transport measures. As was stated earlier this involves the overall user satisfaction of transport systems by disadvantaged users. Furthermore it was stated earlier that this data is limited and may require special collection, which the questionnaire aims to do.

However, some may question why user rating and acceptance of sustainable transport measures is important in regards to their economical evaluation. This is so because even if these sustainable transport measures are implemented, they need to be accepted by the public before they can make any headway. An example of this can be seen in congestion charging where the highway agency collects revenue from users, which is then used to compensate them with better infrastructure and the likes. On the other hand, if a lot of users change their means of transportation as a result of this measure being implemented, then enough revenue will not be collected. As a result the survey aims to collect the user rating and acceptance level of sustainable transport measures, which will then give an insight on their economical impacts if implemented.

It is also set to find out the commute time and employment accessibility of the general public. It is noteworthy that, as stated earlier, employment accessibility data is limited and requires special collection. They include transport diversity, mode split, travel costs, and affordability. Table I gives information about the indicators and their direction whereas Table II demonstrates the breakdown of sustainable transportation impacts.

TABLE I
ECONOMICAL INDICATORS OF SUSTAINABLE TRANSPORT MEASURES

Indicator	Direction
User rating	More is better
Commute time	Less is better
Employment accessibility	More is better
Land use mix	More is better
Electronic communication	More is better
Vehicle travel	Less is better
Transport diversity	More is better
Mode split	More is better
Congestion delay	Less is better
Travel costs	Less is better
Transport cost efficiency	Less is better
Facility costs	Less is better
Cost efficiency	More is better
Freight efficiency	More is better
Delivery services	More is better
Commercial transport	Higher is better
Crash costs	Less is better
Planning quality	More is better
Mobility management	More is better
Pricing reforms	More is better
Land use planning	More is better

TABLE II
SUSTAINABLE TRANSPORTATION IMPACTS

Economical	Social	Environmental
Traffic congestion	Social equity	Air and water pollution
Mobility barriers	Impacts on mobility disadvantaged	Climate change
Accidental damages	Human health impacts	Noise impact
Facility costs	Community cohesion	Habitat loss
Consumer costs	Community livability	Hydrologic impacts
Depletion of non-renewable resources	Aesthetics	Depletion of non-renewable resources

The questionnaire was given at bus stops as it is an area where a person might find a lot of people that use sustainable transport measures. It was short and concise so that people would not feel daunted to fill it up. The survey could have been made longer to reflect more data but it was made shorter so that it will not take too much of people's time. Attempt was also made to capture participants having personal cars but most of them were not interested in filling the questionnaires saying that local transport in Lahore is unreliable.

IV. RESULTS AND DISCUSSION

The three measures that were looked in this research for analysing of user acceptance of sustainable transport are congestion charging, car sharing and public transportation.

A. Congestion charging

In relation to congestion charging, most people who drive cars as their usual means of mobility gave reliability, speed and comfort as their main reasons. A question that needed to be asked them was whether congestion charging would be accepted by these drivers if it was implemented.

Even though it was stated that most people would

accept congestion charging if it was implemented, it is important to gather information on those that wouldn't as well. From the data collected it was known that most of the car drivers never shared a car on a regular basis. However a lot of them made it clear that they would use public transportation on a regular basis if some improvements were made. As a result, it can be assumed that most car drivers who get dissatisfied with their current means of transportation would change to public transport. This is very beneficial since public transportation is also classified as a sustainable transport measure.

B. Car sharing

In relation to car sharing, most of the people that filled in the survey did not car share. As a result, it was important to find out why they didn't. Most of them did not do it because it would reduce their flexibility and independence. Furthermore it was asked to them, what would mostly encourage them to car share. A surprisingly high number of people said that nothing would encourage them to car share. This brought about a dilemma in the encouragement of car sharing as a sustainable transport measure.

Car sharing clubs provide employment and business opportunities, which are positive economical impacts of car sharing. Furthermore, most members do not end up buying a car as a result of the cost savings, which such clubs provide. Therefore car sharing as a sustainable transport measure provides positive economical impacts on both a personal and public scale. Studies show that each car sharing vehicle replaces at least four to eight personal vehicles [xxi].

However, all these positive economical impacts are meaningless if the public do not accept car sharing and give it a high-rating [xxii]. As a result of this negative perception towards car sharing, it would have a negative overall economical impact even if it was employed.

On the other hand, most people would be willing to share a car as passengers. Nevertheless this would not make much difference since you need car drivers before you can car share. The following pie charts show the responses of people asked about car sharing. When asked about why they use car as their mode of transport, the response was mixed as shown in Fig. 1.

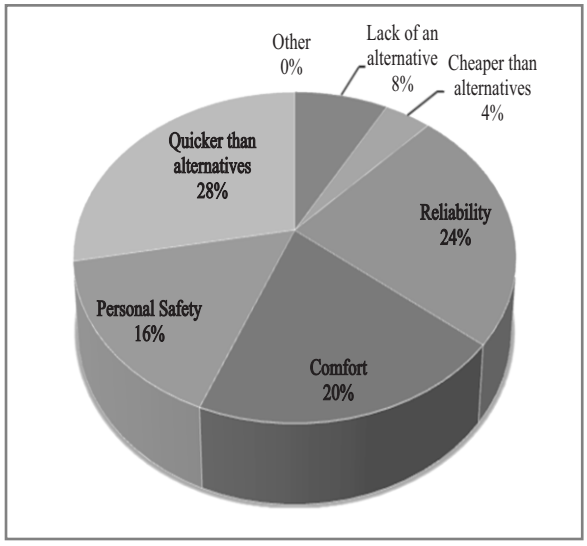

Fig. 1. Reason for using car as a method of transport

Next pie charts show the dispersion of opinions when asked about car sharing.

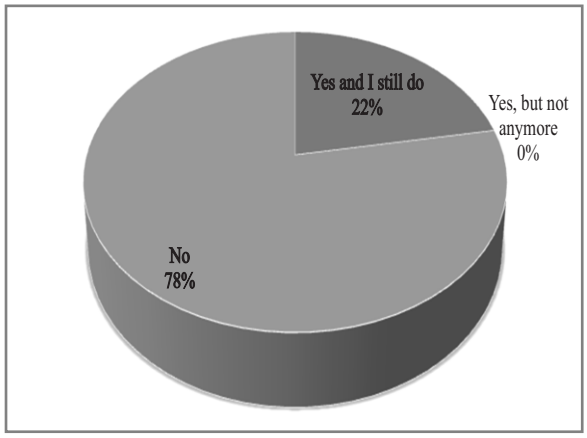

Fig. 2. Car sharing

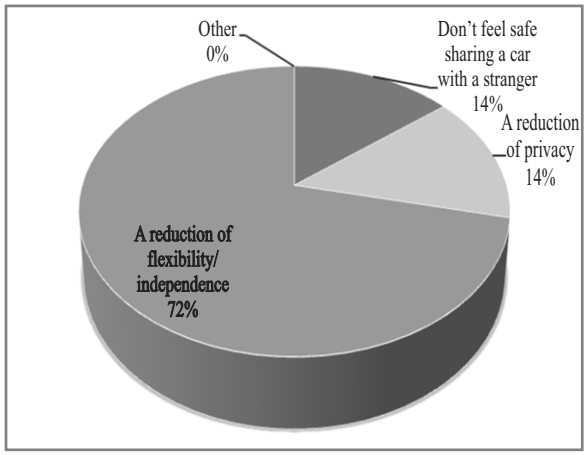

Fig. 3. Reason for not sharing car

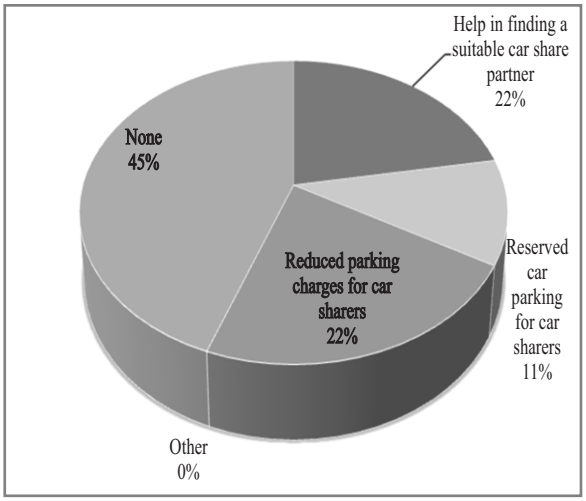

Fig. 4. Encouragements to car share

C. *Public transportation*

From the data collected in the survey, public transportation proved to be the most popular and common means of mobility. Most of the people who use public transportation do so because it's cheaper than other alternatives while a very high number do so because they do not have other alternatives. It was important to monitor the satisfaction level of public transport users. In relation to adherence to schedule times of public transport, most of the users were neutral. However, a surprisingly high number was satisfied with this. In relation to safety, most of the users were either neutral or satisfied. The next few Figures demonstrate the public response when asked about public transportation.

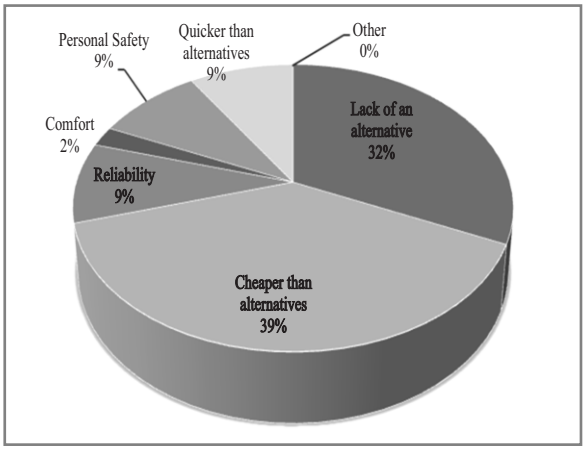

Fig. 5. Reason for using Public transport

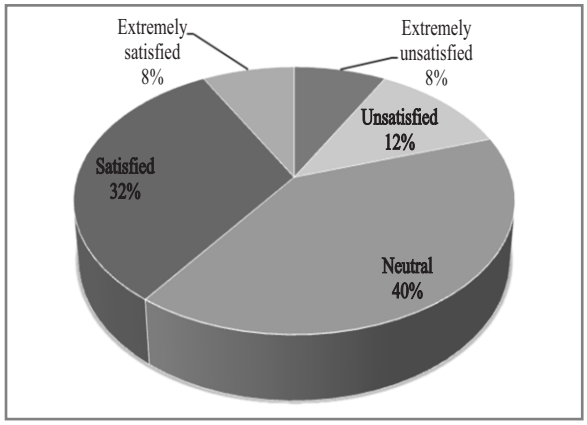

Fig. 6. Satisfaction with adherence to scheduled times by public transport

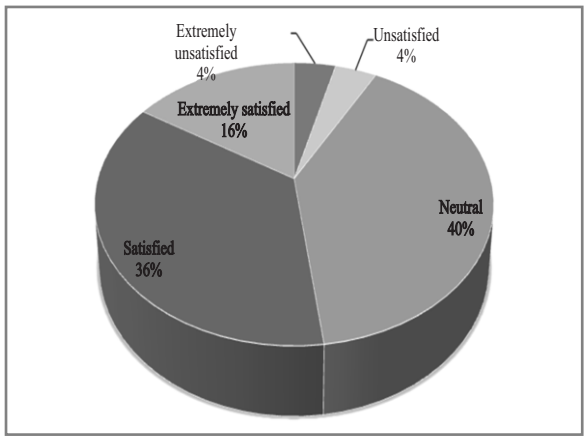

Fig. 7. Satisfaction regarding safety by public transport

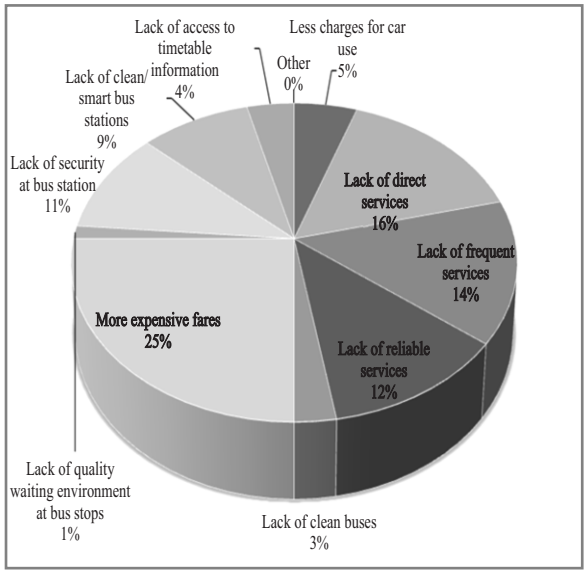

Fig. 8. Most discouraging factor about public transport

From the above impacts and effects, it can be seen that public transportation has a lot of positive economical impacts. Furthermore, as it is widely accepted, these positive economical impacts are optimised as it is encouraged. However, the survey provided information on factors that would mostly discourage people to use public transportation. From the public answers, the main factors are the more expensive fares and lack of direct services. At the end, it can be said that public transportation has an overall positive economical impact. Furthermore, since it has a high user rating and acceptance, it stands to reason that more people would flock to it, which in turn will maximise these positive economical impacts.

V. CONCLUSION

- The research has measured the user acceptance and rating of some of the most general sustainable transport measures in Lahore. It was found that public transportation has a very high rating and user acceptance whereas car sharing has low user acceptance in Lahore region.
- From the user acceptance and rating, it was concluded that congestion charging would have a positive economical impact if it was employed in the area. However it has to be reiterated that the survey only reflected the views and opinions of only a small percentage of the population.
- It was also found out that public transportation is the most popular and common means of mobility.
- Sustainable transport measures have both positive and negative impacts, which are social, economical and environmental. However the positive impacts, as seen in this dissertation, outweigh the negative ones especially in terms of economical impacts.

VI. RECOMMENDATIONS

As a result of the survey, several recommendations to improve in sustainable transportation were came given as follows:

- Encourage car sharing and to educate the general public more on it as there is a low user acceptance and rating of this sustainable transport measure.
- Provide help in finding a suitable car share partner as the public cited this as barrier for car sharing.
- Provide reduced car parking charges for car sharers.
- Provide reserved car parking for car sharers.
- Provide more direct services for public transportation.
- Provide annual season ticket loan for public transportation.
- Provide more frequent services for public transportation.
- Provide adequate security at bus stops.
- Evaluation of economical impact of user acceptance of sustainable transport measures

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Intentions of Car and Motorcycle Oriented Groups towards Public Transport In Lahore

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***Abstract*-**The rapid increase in private vehicle usage tends to increase the demand for the road infrastructure and related facilities. Like other cities in the world, Lahore city is also facing with the dilemma of auto-dependency and transit insufficiency. It is very important for local government to develop and promote state-of-art public transport. To develop such polices, it is essential to explore the potential factors at the planning stage that can affect the intended use of improved transit facilities. Therefore, this study attempts to explore the significant influencing factors on the use of public transport using results of a questionnaire survey. In this study, a questionnaire was designed which included socio-demographics and trip characteristics of respondents, statements on travel attitudes and intentions to use public transport under specific conditions. This survey was conducted in Lahore city and 428 usable samples were obtained. An exploratory factor analysis was conducted and two factors were extracted i.e. auto-oriented and transit-oriented. Structural equation modeling technique was used to evaluate the influence of extracted factors on people's intentions to use public transport. The results depict that the intentions to use public transportation are affected negatively by auto-oriented attitudes whereas positively by transit-oriented attitudes. The study findings implicate that auto-oriented attitude of travelers need to address properly in planning and designing public transport improvement policies for Lahore city. The findings would be helpful for local planners and policy makers in developing a transport system for Lahore system that should be sustainable, equitable and affordable for the community.

***Keywords*-**Public Transport, Travel Behavior, Attitudes, Intentions, Car, Motorcycle

I. INTRODUCTION

The rapid increase in private vehicle usage tends to increase the demand for the road infrastructure and related facilities. Actually the growth of urban population, increase in vehicle ownership and its usage as well as the pace of globalization have affected the travel demand in most of the countries and subsequently have altered the travel pattern in different ways [i]. The lack of good quality and efficient public transport system generates more travel demand for private vehicle and people especially in middle-high income class become auto-dependent. In addition to insufficient and/or inefficient public transport system, availability of cheaper parking facilities is another major contributing factor in promoting the use of private vehicle. The increased traffic jams tend to increase social costs in-terms of increase in energy consumption, travel time and cost, environmental pollution and traffic accidents. To ensure the sustainable development of the cities, it is very important for local governments in developing world to develop and promote state-of-art public transport facilities. To develop polices for public transport improvement, it is very essential to explore the potential factors at the planning stage that can affect the intended use of improved public transport facilities.

The important features need to be considered in policymaking concerning transport is the current and changing nature of society and lifestyle patterns that generate diversified travel demand [ii]. Other instrumental factors seem to play an important role such as feelings of power, freedom, status and superiority [iii]. Commuters in developing regions are mainly dependent on affordable transportation options like walking, cycling, and transit. This implies that travel demand management (TDM) measures that facilitate cheaper travel options will be more effective for a major portion of residents in developing countries [iv]. It is believed that lifestyles, social status traits and travel attitudes are important elements in changing travel behavior and travel pattern [ii, iii, v-vii]. Cao and Mokhtarian [viii-ix] stated that travel related measures are likely to be affected by individual's travel attitudes, personality, and lifestyles. As many Asian people tend to believe that owning an automobile is a social status symbol, and drive not only for mobility needs but also as a status symbol. Therefore, it has been hypothesized that travel attitudes and lifestyle preferences are likely to affect individual's behavioral intentions to TDM measures such as improvements in public transport system. However, different lifestyles and attitudes may affect the consideration of each strategy differently [vi,

x]. Javid *et al.* [xi] believe that public transport improvements strategies are affected by individuate travel pattern, mobility restrictions and incentives on use of public transport. Some recent studies report the different factors that influence the user's intentions towards public transport such as access and accessibility, negative experience by others, individual socio-demographic, attitudes towards travelling, and service quality attributes of public transport [xii-xv]. Most of the previous studies on evaluation of specific TDM measures in relation to user's attitudes and intentions are related to the context of developed countries. Only few studies in the developing world provide the evidence of significant factors influencing the consideration of specific TDM policy [ii, vi, viii-x, xi]. These studies mainly include the factors related to socio-demographic aspects of the travelers. There is still need to explore the relationship of lifestyles and attitudes of specific users with the improvement of public transport facilities. In addition, consideration of local social and cultural factors of a particular region is very important in order to ensure the success of developed transportation policies. Therefore, this study attempts to explore the significant influencing factors on the use of public transportation considering the results of a questionnaire survey. In this study, only attitudes and intentions of private vehicle users are considered. It is supposed that to make significant modal shift from private vehicle to public transportation it is vital to understand attitudes of private vehicle users i.e. car and motorcycle users. This paper is organized in the following manner. Section 2 describes the characteristics of study area and section 3 elaborates the data collection methods. Section 4 presents the results of questionnaire survey and analysis. Last section summarizes the key findings and their implications.

II. Study Area Characteristics

Lahore is the capital and most advance district of Punjab province and almost 81.7% of its population is urban [xvi]. Current population of Lahore is almost 8.65 million and increasing at a growth rate of almost 3% per annum. The vehicle growth rate has reached to 17% per year between 2004 and 2008 [xvii].Now a days, Lahore citizens are showing a high trend of motorcycle ownership and usage, which has tremendously increased by 483% during the last decade. Motorcycle almost accounts 45 % of road traffic [xviii] and 22.4 % of modal share [xvii]. The share of motorcycle is almost two times of public transport in modal share and even sometime uses as a family mode. Rapid increase in motorcycle usage has also threatened the safety of pedestrians and bicycle users. The main reasons of increase in automobile ownership and its usage are the banking leasing policy of government to own a car and the absence of an efficient public transport system.

Currently, public transport is under-developed, highly fragmented, and inefficient. More than 800,000 passengers are using public transport in Lahore where only 800 high occupancy buses are operating along with Para-transit service [xvii]. Public transport modes include high occupancy bus, wagon or minibus, motorcycle rickshaw, auto-rickshaw and taxi. There are almost 53 planned routes for buses and 48 routes for wagons along with concentration of motorcycle rickshaws on some routes. The public transport modes constitute almost 20.1% of modal share (bus and wagon: 12.5%; rickshaws, taxi, etc. 7.6%) [xvii]. High occupancy bus routes operate by many private operators such as Daewoo, Niazi, Malik, Baloch, etc. Auto-rickshaw and taxi are on demand modes, their schedule and routes are not fixed. Motorcycle rickshaws have fixed routes but some of rickshaws are running on un-authorized routes due to lack of enforcement and monitoring. Motorcycle rickshaw is very common in high density and low profile areas. Initially, provincial government was responsible to own and operate public transport. However, from last decade government has encouraged private operators to enter in market and run buses. Therefore, a large number of small private operators permitted to fill gap between passenger demand and capacity in a fragmented way. The incomplete routes, high fares, fewer buses, gender discrimination, and even absence of buses on some routes are common. Efficiency is acceptable on certain routes but reliability is poor, because there is no schedule at all. Public transport has now become the privilege of private sector in the absence of human resources, and financial capacity of public sector. Recently, local government has established Lahore Transport Company (LTC) to regulate public transportation system. Government of Punjab has taken various steps at different occasions to provide efficient and affordable public transport for the public. In 1991, JICA proposed rail mass transit including the construction of light rail transit. This project has four lines i.e. green line, blue line, orange and purple line [xix]. So far, this project did not implement due to financial and political issues. In last 2-3 years, various private operators started operation on different designated routes with CNG buses. In February 2013, operation of 27.8 km BRT track was started. Despite of all these public transport improvement efforts there is still big gap between demand and supply. It is required to explore the public transport improvement potential under the influence of attitudes and intentions of different modes users especially non-users. Therefore, this study selects only car and motorcycle users and evaluates their intentions towards public transport.

III. Data Collection Methods

This study finding derived from the results of a questionnaire survey and structural equation modelling. Fig. 1 presents a schematic flow diagram of research methods used in this study. A questionnaire was designed consisting of following three parts: (1) personal information; (2) trip information; and (3) attitudes and intentions. The questionnaire was designed to know attitudes and intentions of car and motorcycle users only. The questionnaire survey was conducted in Lahore city with the help of university undergraduate students. Thirteen locations were selected in Lahore city. The selected students were trained for the purpose and methods of survey in order to ensure the reliability of data. Initially, one-day pilot survey was conducted to check the concreteness of questionnaire items. After pilot survey, questionnaire was revised for better understanding and easiness of the respondents. Self-completion and interview approaches were used to conduct this survey. It was assured to interview those respondents whose literacy level was low in order to ensure the reliability of data.

A total of 428usable samples were obtained. Sample strata represent a good mix of different occupations. The female respondents are less because they do not drive motorcycle, and do not work in commercial sectors (business, shops, etc.). Table I shows that 64.6% respondents have education bachelor or above, which is higher from actual literacy rate in Lahore. This is because majority of car and motorcycle users belong to medium andhigh-income category in this study and education level increases with the increase of income in Lahore. The distribution of other SEDs is given in Table I.

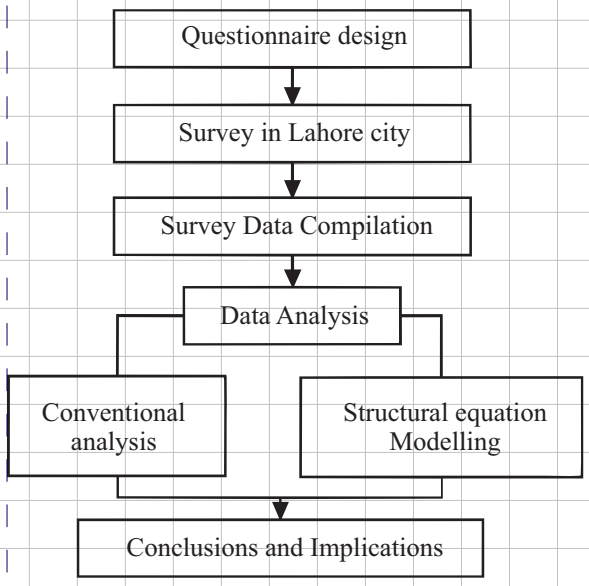

Fig. 1. Research methodology framework

TABLE I
Descriptive Statistic of Respondent's Socio-Economic Characteristics

Characteristics	Distribution (%)
Gender	male (70.6), female (29.4)
Marital status	single (62.7), married (37.3)
Age (years)	< 20 (14.4), 21-30 (56.3), 31-40 (20), 41-50 (6.97), above 50 (2.36)
Education	below high school (8.9),high school (8.9),higher secondary (11.9), diploma (5.7), bachelor and above (64.6)
Occupation	students (23.6),government employees (20.8),private employees (29),business (15.7), others (11.0)
Personal income per month (PKR)	< 10,000 (37.3), 10,000-20,000 (23.1), 21,000-30,000 (16), 31,000-40,000 (10.9), 41,000-70,000 (7.3),> 70,000 (5.4)

IV. Results and Analysis

A. *Average Response on Attitudes and Intentions*

In Table II, average response of respondents is presented on attitudes and intentions. They place a high score on attitude of '*using car or motorcycle increases their work efficiency'*. It is, because they can reach timely at work place and these modes provide more flexibility in travelling and accessibility to different destinations. The intentions to use public transport are little lower for short trips and destinations with limited parking space. It means that some people prefer to use their private vehicle to destinations with short distance and limited parking facilities. Similarly, high parking charges may not have any impact on less usage of private vehicles. This might be true for auto-dependent people. Similarly, situational constraints and climatic condition have some impact on people intentions to use public transport or private vehicle. Most of the respondents have willingness to use better mode of public transport such as rapid rail mass transit or bus rapid transit as indicated from question 11 in Table II.

TABLE II
AVERAGE RESPONDENT'S RESPONSE

Sr. #	Description of statements	Average
1.	Using car/motorcycle increases my work efficiency	3.36
2.	I do not mind to share my personal vehicle with friends or colleagues going to work/study/business trip	3.00
3.	It is acceptable for me to use public transport for short trips like 3-5 km	2.57
4.	It is acceptable for me to use public transport, if parking facility is not available at destination or work place	2.72
5.	It is preferable for me to use public transport, if parking charges are very high	2.58
6.	I prefer to use air-conditioned bus whenever I need to use public transport	3.08
7.	It is not possible for me to use public transport during rain or hot weather	2.85
8.	I will prefer to use personal vehicle even if other modes offer shorter travel time	2.66
9.	It is not possible for me to use public transprort when I have trip other than work/ study	2.89
10.	In any case, I try to avoid to use public trasnport	2.58
11.	I would use public transport if there is better mode like rapid rail mass transit/ bus lanes	3.20
12.	Even if I have or will own a car, I do/would use public transport sometimes	2.60

B. Factor Analysis of Attitudes and Intentions

For analysis purpose, an exploratory factor analysis was conducted to categorize the attitudes and intentions into appropriate groups. Two factors were extracted for overall sample size. These two extracted factors were named considering the nature of their related indicators or observed variables i.e. auto-oriented and transit oriented. Auto-oriented factor mainly includes user's attitudes having concern with travel using private car or auto. Transit oriented factor consists of observed attitudes having nature of public transport travel.

Sample was classified into two groups i.e. car users and motorcycle users considering most frequent travel mode. The sample size for car users and motorcycle users was 204 and 224, respectively. Factor loadings were estimated for the indicators of extracted factors for both groups. Structural equation modeling (SEM) technique was used to evaluate the influence of extracted factors on people's intentions towards public transport.

C. Structural Equation Modeling of Respondent's Intentions toward Public Transport

The results of structural equation modeling (SEM) in Fig. 1 depict that extracted auto-oriented and transit oriented attitudes have significant relationship with users intentions towards a better mode of public transport in the form of rail mass transit or rapid bus transit. Overall structural model in Fig. 1(a) shows that the user's intentions to use public transport are affected negatively by auto-oriented attitudes whereas positively by transit-oriented attitudes. These results imply that people who have strong belief on auto-oriented attitudes would have less potential to use improved public transport. The users with strongtransit-oriented attitudes have more potential to use public transport modes in the future. The structural relationships were also estimated for car users and motorcycle users groups separately. The modeling results of car user's model in Fig. 1(b) are same as overall model i.e. both structural relationships are significant and have it signs as overall model. The results of motorcycle users model are little different from overall and car users model. The auto-oriented attitudes of motorcycle users have insignificant relationship; however, transit-oriented attitudes have positive and significant relationship with the intentions to use public transport. The other factors presented in previous studies affecting the traveler's intentions towards public transport include specific situational constraints, attitudes towards auto and transit modes, individual's lifestyle pattern, and social and personal constraints of the people [ii, vii-ix, xi-xiii]. Okamura *et al*. study revealed similar factors that influence user's intentions towards public transport modes [xx]. This comparison implicates that motorcycle users have more potential to be attracted by a better mode of public transport in comparison to car users. The motorcycle users usually belong to low and middle income category and would have more propensity to use a public transport mode that can provide a better service with reasonable cost in comparison to motorcycle. It would be difficult to attract car users towards public transport as they generally belong to high-income category and feel comfortable, freedom and flexibility in travelling with car. They also own different lifestyles, social status and attitudes, and use of car is the status symbol for them in the society.

Various parameters are used to assess the reliability of structural model such as chi-sq/DF, CFI, GFI, AGFI, RMR and RMSEA. Researchers in the

field of statistics have suggested critical values of these parameters. For example, $\chi 2$/DF less than 5 indicates a reasonable fit of model [xxi], GFI, AGFI, and CFI greater than 0.90 indicate good fit [xxii-xxiii], RMSEA less than 0.08 shows a good fit [xxiv], RMR less than .08 is acceptable [xxv]. The indices of goodness-of-fit parameters for all models show that these developed models have good estimation of respondent's intentions towards public transport under the actions of their attitudes. These results imply that we need to encourage or promote positive transit oriented attitudes among private vehicle users in order to reduce use of private vehicle and promote use of public transport with the introduction of a better quality transit mode. However, public transport facilities first need to develop and improve considering the specific attitudes, intentions and preferences of targeted groups.

TABLE III
ROTATED FACTOR LOADINGS FOR ATTITUDES AND INTENTIONS

Attitudes and intentions	Overall (N: 428)		Car users (N: 204)		Motorcycle users (N:224)	
	Auto Oriented	Transit Oriented	Auto Oriented	Transit Oriented	Auto Oriented	Transit Oriented
It is not possible for me to use public transport when I have trip other than work/study	0.771		0.696		0.713	
In any case, I try to avoid to use public transport	0.706		0.474		0.556	
I will prefer to use personal vehicle even if other modes offer shorter travel time	0.698		0.513		0.482	
Using car/motorcycle increases my work efficiency	0.655		0.520		0.293	
It is not possible for me to use public transport during rain or hot weather	0.645		0.653		0.405	
It is acceptable for me to use public transport, if parking facility is not available at destination or work place		0.778		0.714		0.531
It is preferable for me to use public transport, if parking charges are very high		0.753		0.644		0.654
It is acceptable for me to use public transport for short trips like 3-5 km		0.716		0.692		0.630
I do not mind to share my personal vehicle with friends or colleagues going to work/study/business trip		0.561		0.372		0.371

Note: 'N' number of samples for each group

TABLE IV
INDICES OF GOODNESS-OF-FIT PARAMETERS OF EACH MODEL

Model	Chi-sq/ DF	CFI	GFI	AGFI	RMR	RMSEA
Overall	2.413	0.919	0.964	0.940	0.065	0.058
Car users	1.706	0.932	0.951	0.919	0.077	0.059
Motorcycle users	1.608	0.913	0.954	0.924	0.068	0.052

Note: Chi-sq/degree of freedom, CFI: Comparative fit index, GFI: goodness of fit index, AGFI: adjusted goodness of fit index, RMR: root mean square residual, and RMSEA: root mean square error adjusted.

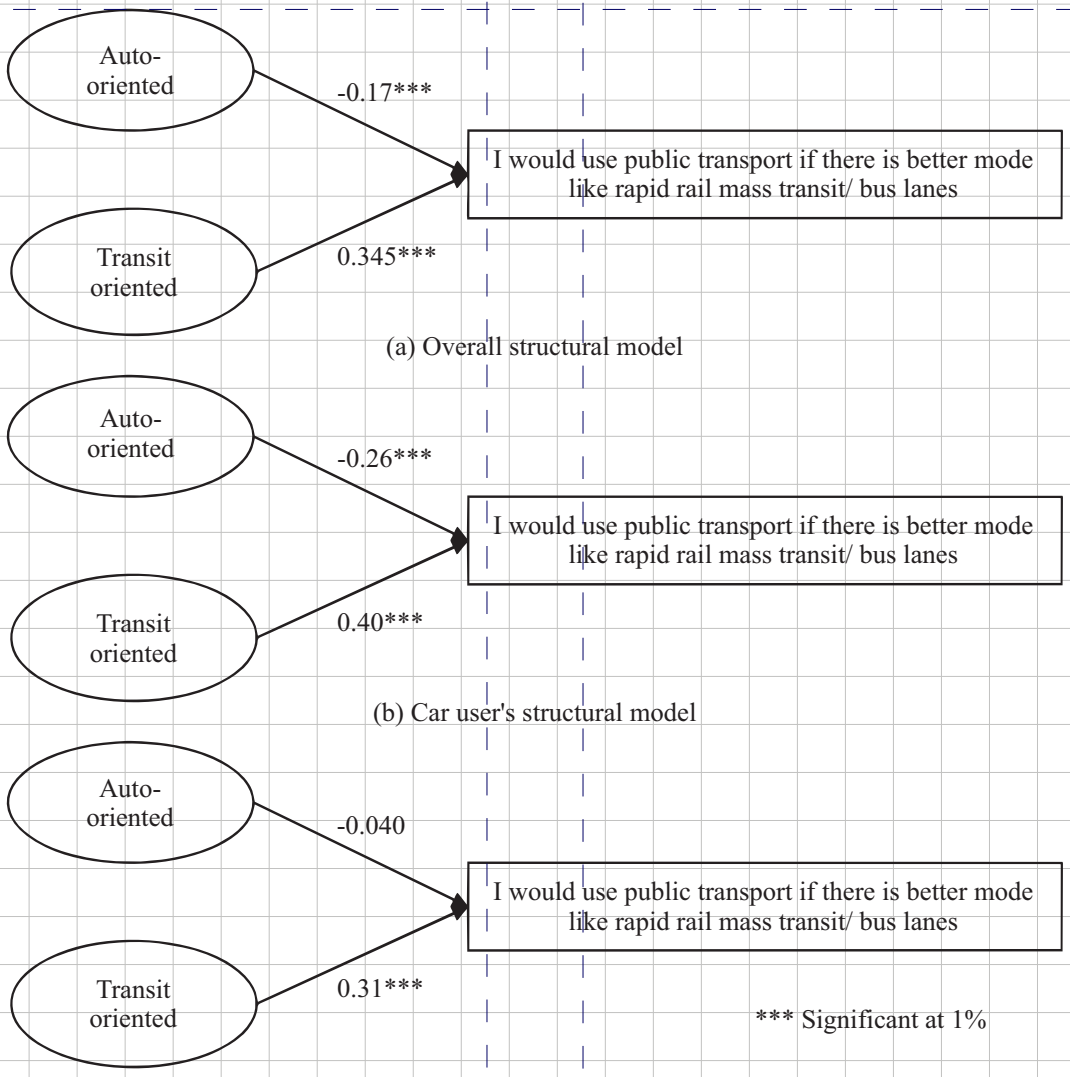

Fig. 2. Structural models of user's intentions toward public transport

V. Conclusions and Suggestions

The survey and analysis results reveal that auto- and transit specific attitudes are significant factors in defining the user's intentions towards public transport. The findings implicate that auto-oriented attitude of travelers need to address appropriately in planning and designing public transport improvement policies for Lahore city. It means that proper attention should be given to provide convenient, reliable, time saving and comfortable transport service. Concurrently, transit-oriented attitudes need to develop and promote among users of all private modes especially motorcycle users for proper modal shift. For this purpose, some physical polices need to adopt that should make sure the development of positive attitudes among people towards public transport. These physical policies should include improvement in service quality attributes of existing public transport modes and development of new mass transit modes. These measures would help to meet the increased travel demand and needs of existing users as well as to handle traffic congestions by making proper modal shift from private transport to transit modes. Soft policies should be considered for the promotion of developed facilities and change of public attitudes towards public transport.Moreover, public transport improvement polices need to be integrated with hard TDM measures concerning use of private vehicle. These policies may include restriction on parking facilities and imposition of parking feein areas served by public transportation modes.Implementation of such hard policies would help in making transit improvement efforts successful. The findings of this study would be helpful for local planners and policy makers in developing a transport system for Lahore system that should be sustainable, equitable and affordable for the community.

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Prediction of CBR Value from Index Properties of different Soils

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Abstract-A Prediction is a vital tool in engineering used to take right decisions. Therefore, it is very important for engineers to quickly predict the behavior of geo-materials used in the infrastructures. California Bearing Ratio (CBR) test is a common laboratory test, performed to evaluate the shear strength and stiffness modulus of sub grade for the design of pavement. CBR test is a laborious test, therefore, it is vital to develop the models for quick assessment of CBR value. This study is an attempt to develop valid models to determine the CBR value from index properties of soil which are quicker to estimate from their standard method of testing. In this study authors developed predictive models using 59 set of soil samples containing both fine grained and coarse grained soil samples. Three models were developed and validity of these models was checked on 25 set of soil samples tested separately. Authors developed separate models for coarse grained soil and fine grained soils. These models were developed, based on liquid limit and plasticity index for fine grained soil, the coefficient of uniformity and maximum dry density for coarse grained soil.

Keywords-Prediction,California Bearing Ratio, Fine Grained Soil, Coarse Grained Soil, Liquid limit, Plasticity index, Coefficient of Uniformity, Maximum Dry Density

I. Introduction

Geotechnical engineers should play a vital role in planning and designing of infrastructures. A prediction is an important tool in engineering used to take right decisions. Therefore, it is very important for Geotechnical engineers to quickly predict the behavior of geo-materials used in the infrastructure. CBR is an important parameter used in designing a pavement. To determine the shear strength and stiffness modulus of subgrade to be used in design of pavement, California Bearing Ratio (CBR) is performed on subgrade material. CBR value can be directly assessed by California Bearing Ratio test. CBR test is laborious and tedious. It usually takes four days to complete a test. So for quick assessment of CBR value, it is required to correlate the CBR value with the quickly assessable properties of soils. Different researchers have worked in this context. Various studies i.e. Black in 1962, Graft-Johnson & Bhatia in 1969, Agarwal and Ghanekar in 1970 and NCHRP in 2001 [i-iv] have focused the effect of geotechnical characteristics of soils and soil types on CBR values. Many researchers have made attempts to develop effective correlations for prediction of California Bearing Ratio (CBR) from index properties of soils. Black in 1962aimed to develop an approximate method to quickly predict the CBR value. He established predictive models to predict CBR value based on Plasticity index [i]. Agarwal and Ghanekar in 1970 established a relation between CBR value and different index properties of soil [iii]. Following prediction model was proposed using liquid limit and optimum moisture content.

$$CBR = 2 - 16\log(OMC) + 0.07LL \quad (1)$$

Yildirim & Gunaydin (2011) proposed following correlation for CBR soaked value with index properties of fine grained soils [iv].

$$CBR=0.62OMC+58.9MDD+0.11LL+0.53PL-126.18 \quad (2)$$

TABLE I
SUMMARY OF THE LITERATURE MODELS CORRELATING CBR AND INDEX PROPERTIES OF SOILS

Equation	No. of Materials	R^2	Remarks	Country	Reference
CBR_u=17.009-0.0696(PI)-0.296(MDD) +0.0648(OMC)	12	Error = -2.5%	Fine Grained Soils	South Gujarat, India	[vi]
CBR=-18.78(MDD)+43.907-0.093(PI) - 0.3081(OMC)		Error = -2.5%	Fine Grained Soils		

$CBR = 4.5\,[(20-GI)/18]^2$	NA	NA	Fine grained, cohesive soils with CBR ≤ 20%	Australia	[vii]
$CBR=96.3–17.8Log[(LSP)(P425)^{0.7}]\ 28.7Log(P200)$	NA	0.69	NA	South Africa	[vii]
$CBR=97.7–17.1Log[(PI)(P425)^{0.5}]–30.7Log(P200)$		0.66			
$CBR=90– 47.4Log\ (P200)$		0.59			
$CBR = 13.56+1.04\ (PL)$ $CBR = 28.87+0.22\ (LL)$ $CBR = -70.22+50.28\ (MMD)$ $CBR = 10.91+9.42\ (SG)$ $CBR_u = 65.31+0.8\ (PL)$ $CBR_u = 83.19+0.031(LL)$ $CBR_u = 65.88+8.66\ (MMD)$ $CBR_u = 56.19+10.43\ (SG)$	08	NA	lateritic soil (A-2-4)	Osogbo, Nigeria	[viii]
$Log10(CBR) = 0.29(GM) - 0.024(PI) +1.23$	NA	NA	Base course material	NA	[ix]
$CBR=0.064(F)+0.082(S)+0.033(G)-0.069(LL) + 0.157(PL)-1.810\ (MDD)-0.061(OMC)$	25	0.92	Fine Grained Soil	India	[x]
$CBR=(1.44-4.23PI)[Fs+264PI^2-56PI-5]$ $CBR_u=(8.44-16.1PI)[Fi+488PI^2-314PI+45]$	24	NA	Fine Grained Soils (Silty Clay)	Sudan	[xi]
$CBR=-0.889(WLM)+45.616$ $where,\ WLM= LL\ (1 – P425/100)$	NA	0.979	NA	NA	[xii]

Where: CBR = California Bearing Ratio (soaked), %; wPI = Weighted Plasticity index; MDD=Maximum dry density; OMC=Optimum Moisture Content; GI=group index; CBRu = unsoaked CBR; LL = Liquid limit; PL = Plastic limit; PI=Plasticity index; SG = Specific gravity; LSP = Linear shrinkage P200 = passing No. 200 U.S. sieve, %; GM = grading modulus; P425 = passing sieve size 0.425 mm; F=Fines, %; S=Sand, %; G=Gravel, %; Fi=initial state factor; Fi=soaking state factor.

Nugroho et.al (2012) compared value of CBR given byun-soaked and soaked test and proposed following linear correlation of un-soaked and soaked CBR value with Index properties of soils [v].

$$\Delta CBR = 25 + C_1 - C_2 LL - C_3 PI + 3.5 OMC \qquad (3)$$

Where C1,C2, C3,are coefficients depend upon the clay fraction.

Prediction models for CBR value documented in the National Cooperative Highway Research Program (2001) of United States of America through the "Guide for Mechanical-Empirical Design of New and Rehabilitated Pavement Structures" are the most cited models [ii]. Prediction model based on plasticity index is quoted for fine grained soil and for coarse grained soil ($wPI = 0$)$D60$,diameter at 60% passing from grain size distribution is used as predictor.

$$CBR = \frac{75}{1 + 0.728 wPI} \qquad (4)$$

$$CBR = 28.09 D_{60}^{0.358} \qquad (5)$$

Some other prediction models for CBR value from literature is presented in Table I [vi-xii]. Literature review emphasizes the importance of development of prediction models [xiii-xviii]. All these prediction models have their own limitations. Hence, while adopting any prediction model, calibration of the models based on local materials is essential. Otherwise a new model should be developed based on the actual data. No such attempt is made to develop prediction models for CBR value using locally available geo-materials in Pakistan. The aim of this study is to develop valid prediction models using locally available geo-materials in Pakistan.

II. METHODOLOGY

To achieve the objectives of the research study, soil samples of varying geotechnical characteristics were collected from different parts of Pakistan as shown in Fig. 1. Total 84 number of soil samples were collected from different projects among which 43 samples were of fine grained soil and 41 were of coarse grained soil. Fig. 2 shows testing program for the present study.

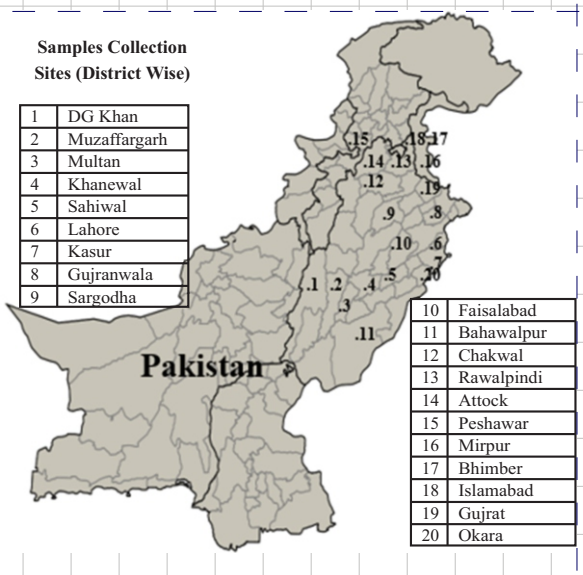

Fig. 1. Location of Collected Soil Samples

Among 84 tested samples, 59 samples test results were utilized for the development of correlations and 25 were utilized to check the validity of developed correlations. Correlations were developed separately for fine grained soils and coarse grain soils.

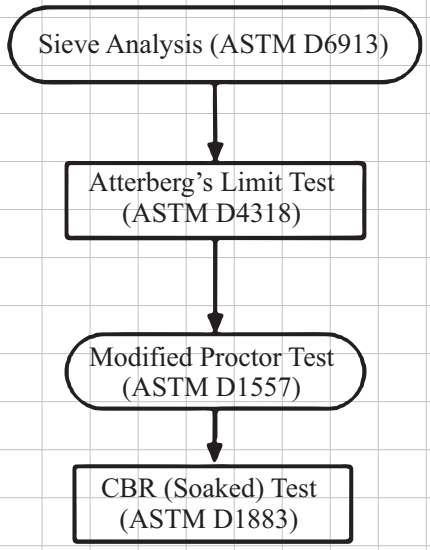

Fig. 2. Laboratory Testing Program [xix-xxii]

III. Test Results

All the soil samples were tested as per ASTM standards [xix-xxii]. 59 samples of soil were tested for the establishment of correlations. Summary of all test results is given in Table II.

Sieve Analysis of soil samples showed that soil samples can be classified among coarse grained soil samples and fine grained soil samples. Among fine grained soil samples percentage of gravel was ranging from 0-28%, sand 1-46% and fines(F200)51-99%, where among coarse grained soil samples percentage of gravel was ranging from 0-26%, sand 51-99% and fines(F200)1-41%.Atterberg's limit test results of soil samples showed that liquid limit is in a range of 0- 41%, The plastic limit is in a range of 0-21% and plasticity Index is in a range of 0-19%. Soil samples were classified as per Unified Soil Classification System. Samples wereclassified as CL, ML, CL-ML,SP, SC, SM and SP-SM. From modified compaction test results it was observed that OMC was ranging from 8-15% and maximum dry density 103-130 pcf.Soaked CBR test results revealed that overall CBR value was ranging from 3.8-35 [xviii]. For Fine grained soil samples this range was 3.8-15 and for coarse grained soil samples this range was 7-35.

IV. Soil Test Result Analysis

Based on soil test results, different relationships were established. The strength of these relationships was checked from R2 value based on criteria proposed by Pellinen, and shown in Table II. Soil samples were classified majorly as fine grained soil samples having F200 greater than or equal to 50% and coarse grained soil samples having F200 less than 50%. It was observed that with an increase in fines the CBR value tends to decrease but strength of this relationship is very poor as shown in Fig. 2.

The relationship was also established between CBRsoaked value, optimum moisture content and maximum dry density. It was observed there is a linear relationship between CBRsoaked value and optimum moisture content for both fine grained and coarse grained soil as shown in Fig. 3. With an increase in optimum moisture content of soil CBRsoaked tends to decrease. Similarly, a linear relationship was observed between CBRsoaked value and maximum dry density as shown in Fig. 4. CBRsoaked tends to increase with the increase in maximum dry density of soil.

Liquid limit and plasticity index are two very important index properties of fine grained soils. In the present study it was observed that with an increase in liquid limit and plasticity index, CBRsoaked Value tends to decrease for fine grained soil as shown in Fig. 5 and 6. The value of R2 is very high for both relationships 0.8482 and 0.8949 indicating very less scatter and good correlations.

TABLE II
LABORATORY TEST RESULT DATA

Classification Symbol	Number	LL	PI	Grain Size Distribution			Compaction Characteristics		Soaked CBR Value
(USCS)		(%)	(%)	Gravel (%)	Sand (%)	Fines, F_{200} (%)	OMC (%)	$\gamma_{d\ max}$ (lb/ft^3)	CBR_s (%)
CL	16	23-41	9-19	1-28	3-34	66-99	12-15	114.5-123	3.8-9.5
ML	5	17-22	5-19	1-9	15-34	53-84	9-11	117-124	10.5-15
CL-ML	8	19-25	4-7	0-6.0	8-38	51-89	9-11	112.5-130	9-14
SP	6	0-0	0-0	0-2	91-99	1.0-9	12-15	103-120	7.5-11
SC	3	23-30	9-14	0-4	59-80	20-41	8-8.5	128-130	10-21
SM	19	0-21	0-0	0-26	52-84	12-40	8.5-11	108-121.5	8.1-35
SP-SM	2	18-19	0-0	0-0	92-94	6-8	8-11	103-131	7-21
Overall	59	0-41	0-19	0-26	3-99	1-99	8-15	103-130	3.8-35

For coarse grained soil sample relationship was established between CBRsoaked Value and D60 as shown in Fig. 7. The value of R2 is very low (R2 = 0.019) indicating high scatter in data and very poor relationship. Relationship between CBRsoaked Value and coefficient of uniformity Cu was also established as shown in Figure 8. It was observed that with increase in the value of coefficient of uniformity Cu, CBRsoaked Value tends to increase. A high value of R2 was observed (R2 = 0.810) indicating less scatter in data and good strength of correlation between Cu and CBRsoaked value.

V. DEVELOPMENT OF PREDICTION MODELS

In order to develop valid prediction models correlating CBRsoaked Value (%) and index properties of soils, different relationships were drawn between CBRsoaked Value (%) and index properties of soils as discussed in previous section. The scatter diagrams of the soaked CBR and each of the index soil properties was drawn and presented in Fig. 3 through 9. For fine grained soil Fig. 6, 7 show relatively stronger correlations. The strength of these correlations is also indicated by R2 0.8482 and 0.8949 respectively. Similarly, for coarse grained soil Fig. 3, 9show relatively stronger correlations. The strength of these correlations is also indicated by R2 0.639 and 0.810 respectively. A multiple regression modeling was then tried using the solver tool within SPSS and the goodness of fit statistics checked according to the the conceptual criteria proposed by Pellinen, and shown in Table III was used to select the best model [xxiii]. Linear Regression estimates the coefficients of the linear equation, involving one or more independent variables that best predict the value of the dependent variable. Regression analysis gives the different equations by correlating CBR values with different groups of soil properties.

TABLE III
CRITERIA FOR GOODNESS OF FIT STATISTICAL PARAMETERS [XXIII]

Criteria	R^2
Excellent	> 0.9
Good	0.7-0.89
Fair	0.4-0.69
Poor	0.2-0.39
Very Poor	< 0.2

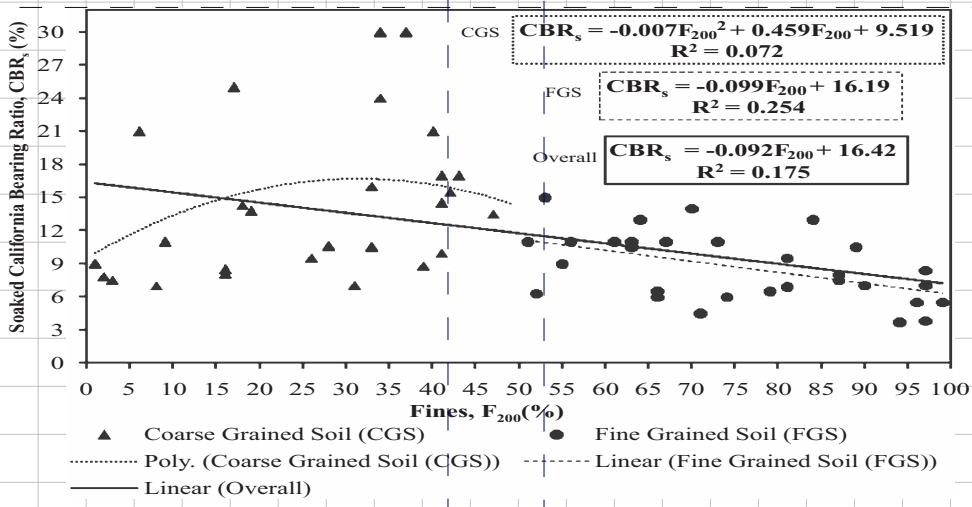

Fig. 3. Relationship between CBRsoaked Value (%) and Percentage Fines (%)

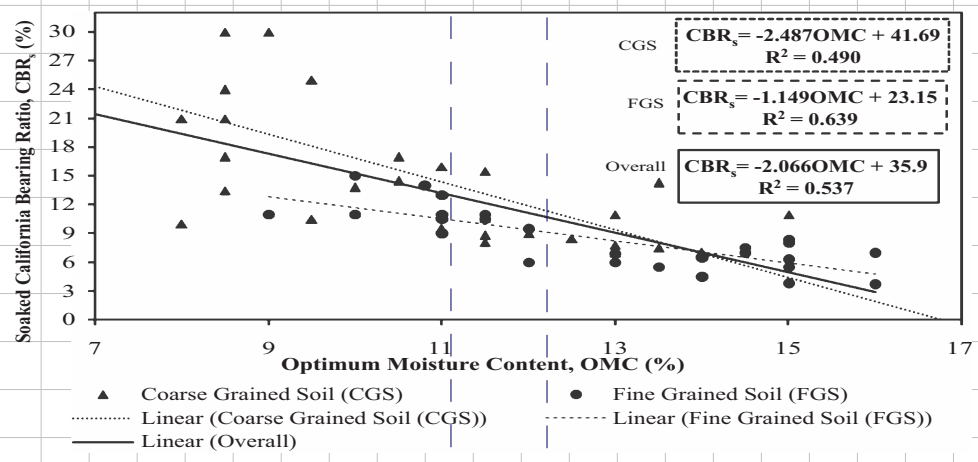

Fig. 4. Relationship between CBR_{soaked} Value (%) and Optimum moisture content (%)

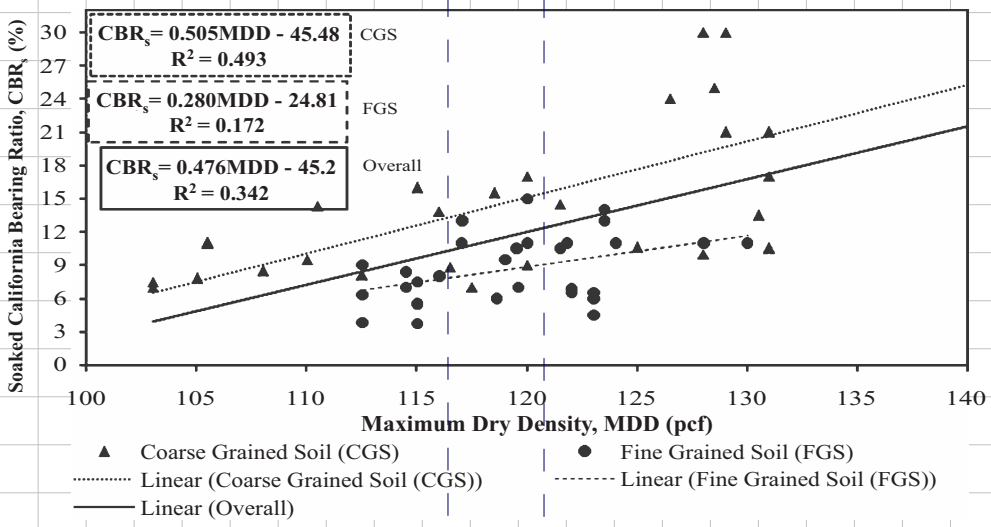

Fig. 5. Relationship between CBR_{soaked} Value (%) and Maximum dry density (pcf)

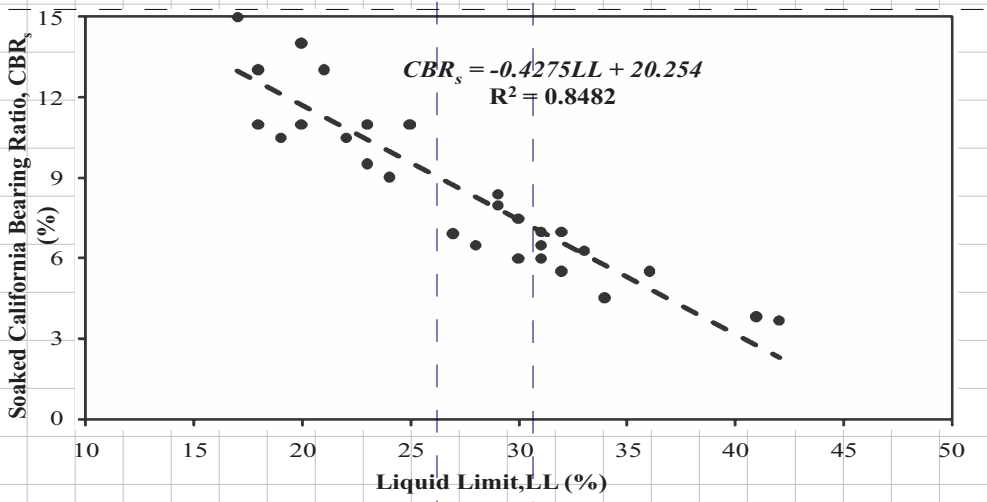

Fig. 6. Relationship between CBR_{soaked} Value (%) and Liquid limit (%)

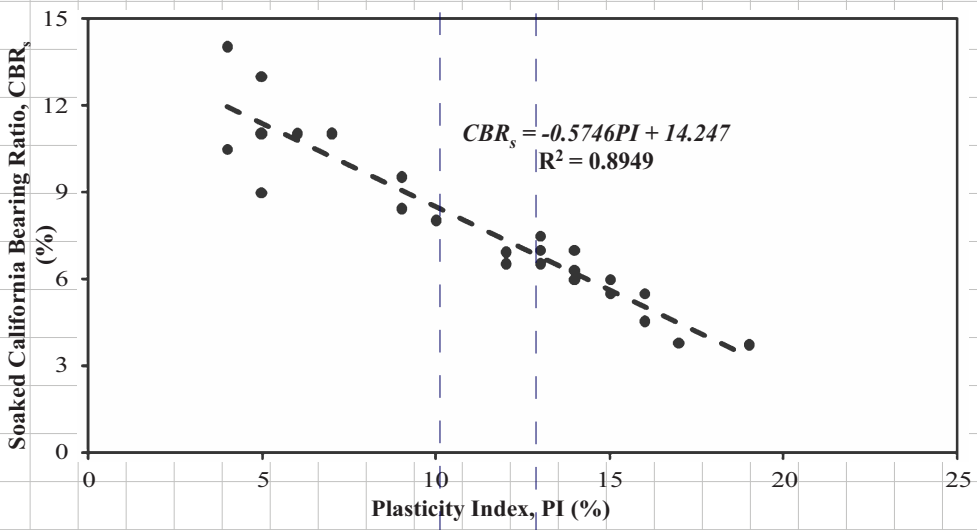

Fig. 7. Relationship between CBR_{soaked} Value (%) and Plasticity Index (%)

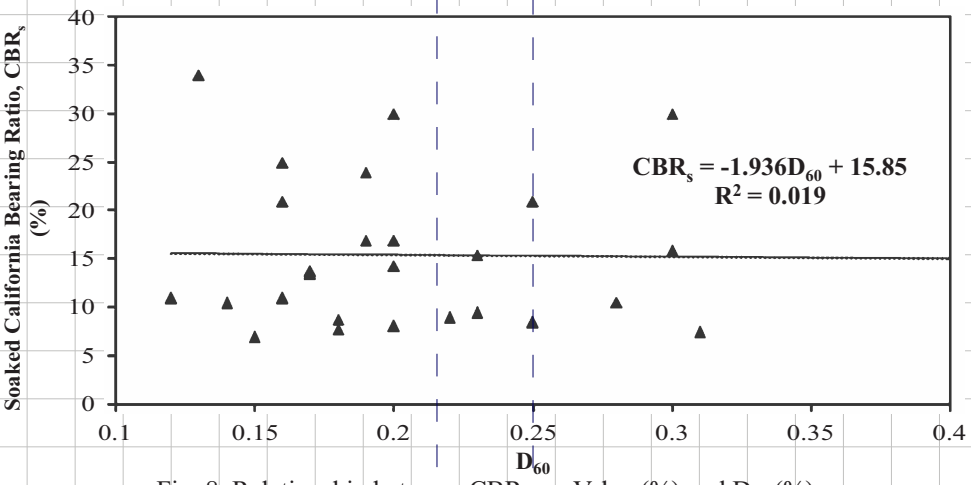

Fig. 8. Relationship between CBR_{soaked} Value (%) and D_{60} (%)

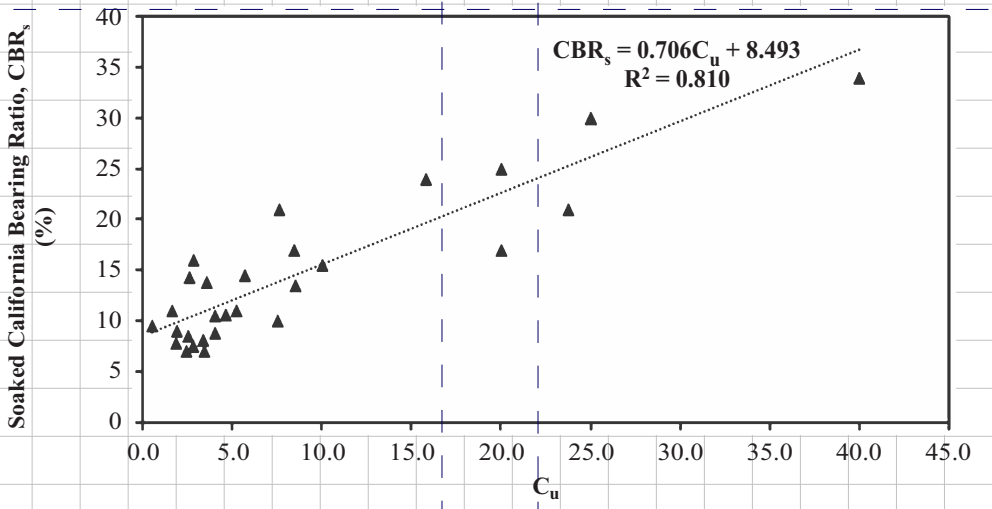

Fig. 9. Relationship between CBR_{soaked} Value (%) and C_u

Following correlations were developed for fine grained soils having F200≥50%;

$$CBR_s = -0.43LL + 20.52 \ (R^2=0.85) \quad (6)$$
$$CBR_s = 0.58PI + 14.25 \ (R^2=0.85) \quad (7)$$
$$CBR_s = -0.10LL - 0.425PI + 15.73 \ (R^2=0.9) \quad (8)$$

Where for coarse grained soil having F_{200}<50%;

$$CBR_s = 0.7C_u + 8.5 \ (R^2=0.8) \quad (9)$$
$$CBR_s = 0.7C_u + 0.045MDD + 3.4 \ (R^2=0.8) \quad (10)$$

Where;
CBR_s is soaked value of California Bearing Ratio (%)
LL is Liquid Limit (%)
PI is Plastic Limit (%)
C_u is Coefficient of Uniformity
MDD is Maximum Dry Density (pcf)

VI. Validity of Developed Models

To check the validity of developed models a separate set of soil samples were tested. Test result summary of these samples are presented in Tables IV and V. Experimental values of CBR_S (%) are then plotted against predicted values of these CBR_S (%) by developed equations. Percentage error from 45^0-line (equality line) was calculated by given formula in equation 11;

$$PercentageError = \frac{100\%}{n}\sum_{t=1}^{n}\left(\frac{A_t - P_t}{A_t}\right) \quad (11)$$

Where;
A_t=Actual value
P_t=Predicted value
n= Number of values

Validity was checked for all models (Eq. 6 to Eq. 10) developed in present study based on criteria described above. It was observed that among all the developed models equation 6 and equation 7 showed high degree of scatter around equality line. While equations 8, 9 and 10 showed less scatter around equality line as shown in Fig. 8, 9 and 10.

Based on the above discussion three models are proposed for the prediction of soaked CBR Value. The first model is for fine grained soils having F_{200}≥50%, Whereas, the next two models are for coarse grained soil having F_{200}<50%.

Predictive Model	R^2	Percentage Error
$CBR_s = -0.10LL - 0.425PI + 1$	0.9	± 8%
$CBR_s = 0.7C_u + 8.5$	0.8	± 9%
$CBR_s = 0.7C_u + 0.045MDD + 3.4$	0.8	± 7%

Where;
CBR_s is soaked value of California Bearing Ratio (%)
LL is Liquid Limit (%)
PI is Plastic Limit (%)
C_u is Coefficient of Uniformity
MDD is Maximum Dry Density (pcf)

Validity of correlation from literature is also checked for the same set of soil samples and compared with the models developed in present study. Different correlations for the prediction of CBR_s value for fine grained soil in the literature (NCHRP, 2001 and Yildirim & Gunaydin, 2011) are also plotted in Fig. 9 for comparison with predictive model developed in present study for fine grained soil. It was observed that both of these correlations from the literature showed more deviation from equality line than the predictive model of the preset study, as shown in Fig. 8. Similarly, correlations for the prediction of CBR_s value for coarse grained soil in the literature (NCHRP, 2001) is also

plotted in Fig. 11 for comparison with the predictive model developed in the present study for fine grained soil. It appears that the model developed in the present study shows less percentage error than other model in literature, as shown in Fig. 11.

TABLE IV
VALIDITY DATA FOR FINE GRAINED SOILS

Soil Type	No. of Samples	Gravel (%)	Sand (%)	Fines, F_{200} (%)	LL	PI	CBR_s (%)
CL	8	0-14	3.0-37	61-89	27-34	12-18	4-7
ML	2	0-2	13-16	84-85	18-21	3-3	13.5-16.5
CL-ML	2	2-10	33-33	57-65	21-27	7-7	8.5-9.3

TABLE V
VALIDITY DATA FOR COARSE GRAINED SOILS

Soil Type	No. of Samples	Gravel (%)	Sand (%)	Fines, F_{200} (%)	C_u	MDD (lb/ft^3)	CBR_s (%)
SP	2	0	91-99	1-9	2-5	110-112	10.6-11
SM	8	0-27	42-91	1-43	0.5-40	110-137	9-34
SC	2	12-21	42-45	42-45	8.4-25	120-140	15-30

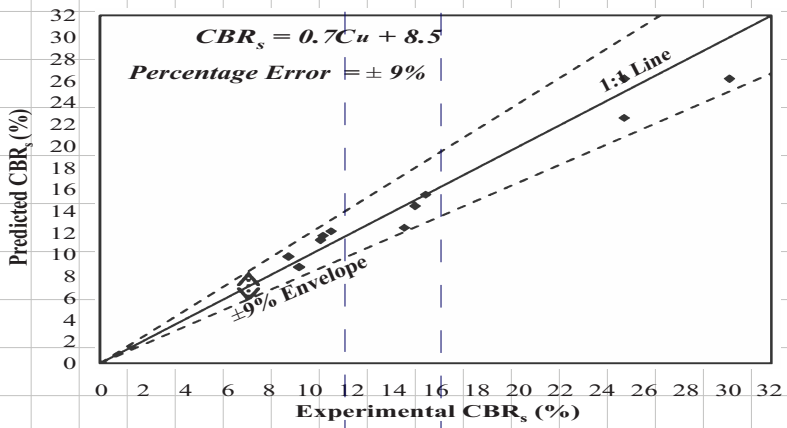

Fig. 10. Validity check for Eq. 9

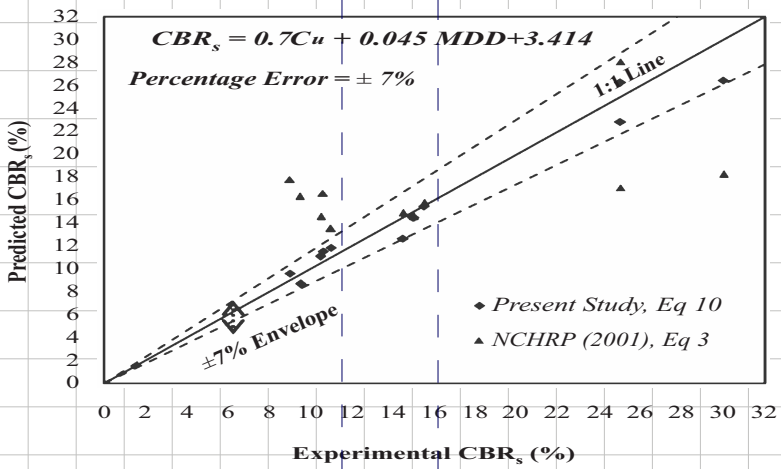

Fig. 11. Validity check for Eq. 1

VII. Model Implication

Because of the involvement of more than one variable in the predictive models the accurate prediction of the values of soaked CBR (%) becomes generally difficult. However, the predictive model presented in the present study are simple and can be effectively used for the prediction of the CBR_s values for fine grained as well as coarse grained soils with reasonable accuracy. These models would be very useful in the quick evaluation of shear strength and stiffness modulus of sub grade at the site without performing the laboratory CBR tests. The prediction of shear strength and stiffness modulus of sub grade material will help in the selection of suitable subgrade material. Predictive curves are the graphical calculating chart, a 2D diagram designed to perform the approximate graphical computation of a mathematical model or function, used for the quicker estimation. For quick and easy computation, predictive curves are presented based on the models developed for fine grained and coarse grained soils, as shown in Fig. 12 and 13.

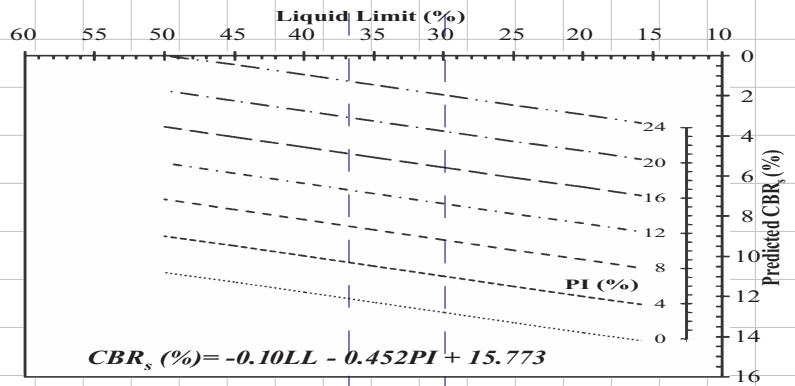

Fig. 12. Predictive Curve for Fine grained soils (Eq. 8)

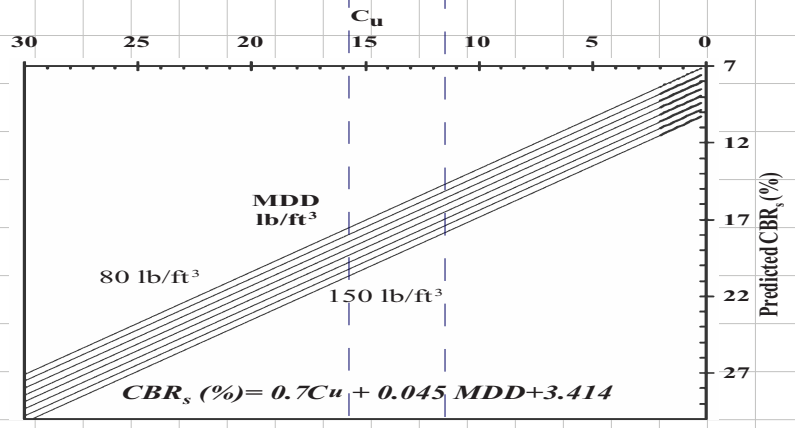

Fig. 13. Predictive Curve for Coarse grained soils (Eq. 10)

VIII. Conclusion

A number of soil samples are collected from different regions of Pakistan to develop predictive models for locally available soils. Models are developed for the prediction of CBR Soaked value for both fine grained and coarse grained soils. One model is developed for fine grained soil and two models are developed for coarse grained soil as follow. These models are proposed after checking their strength based on R^2value and validity on real scale data. Simplified predictive curves are also presented to determine the CBR_{soaked}values for fine grained and coarse grained soil from multiple regression models proposed in the present study.Models presented in the present study can be effectively used for preliminary prediction of CBR_s value for locally available soils in Pakistan. However, such models can't be the replacement of actual tests.

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Flexible Pavement Design Evaluation Using Mechanistic-Empirical Approaches

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Abstract-This study presents an evaluation of different pavement design sections using a software developed by AASHTO Pavement Design Guide and a mechanistic software known as "Kenlayer". The basic aim was to ascertain the effect of different parameters like pavement thickness, asphalt layer thickness, material properties of each layer on pavement performance indices likerut depth, international roughness index and stress-strain response. Present study further predicts the sensitivity of different parameters involved in a pavement design. Study reveals that the asphalt thickness component contributes significantly towards reducing the pavement rut value, and international roughness index, as compared to aggregate base course thickness. Subgrade material properties overall contributed in affecting the IRI. This study also reveals that the poisson ratio affects the performance pavement performance indices. An increase in the poisson ratio of each layer, increases the pavement rut resistance. The study provides a comprehensive approach to evaluate the materials requirement under a given pavement design conditions. The findings of the study directly applies on similar kind of pavements. It provides a guideline to the pavement designer how to evaluate the role of different layers and their properties to reduce the premature failures.

Keywords-Pavement, Mechanistic-Empirical Pavement Design, Poisson Ratio, Rutting, IRI

I. Introduction

Sargodha city is famous about crushed aggregate supplies in central Punjab, Pakistan. Sargodha quarry is one of the major Quarries in Pakistan. The city has hot weather in summer and moderate cold in the winters. The maximum temperature reaches up to50 °C in the summer. Sargodha is connected to the M-2 by different interchanges at different locations. A large number of loaded and unloaded trucks move through Sargodha interchanges daily carrying Sargodha crush, causing damage to the pavement. Premature pavement failure as a result of abnormal loading was the consequences. Pavement agencies are using different pavement analysis methodologies like Road note 31 and AASHTO design guide to improve the pavement design. Present study focused on Makhdoom interchange (M-2) to Sargodha provincial highway with a length of 39.2 kilometers. The study suggests the design improvement technique to reduce the rutting failure and riding quality issues.

Pavement evaluation mainly involved ride quality, surface distresses like rutting, cracking etc., surface friction and surface deflection. Asphalt pavement undergoes different type of distresses under heavy load and varying traffic spectrum. One of the major distresses that affect the pavement structural performance is rutting. Ruttingcan be controlled by changing thicknesses and material properties of different pavement layers. High temperature stability of intermediate course of asphalt pavement was one of the major element developing rutting [i].Rutting is prominent in higher summer temperatures and under heavy loads. The pavement rut value increases linearly with the gradual passage of vehicularload up to certain limit then it grows. Therate of rut development depends on the ambient temperature [ii]. Middle layer of asphalt pavement generate 60% of total rutting and remaining 40% came from other surface layers. Laboratory testing showed that shear stress in the middle layer of asphalt pavement was the highest in magnitude [iii].

In addition to rutting, ride quality and other surface distresses contribute effectively in a pavement performance. Those distresses also increase the rate of deterioration of pavement structures. Overall serviceability of a pavement section can also be representative by a distress called as roughness, which defines the rid quality of a pavement. Pavement performance has become the focus point of pavement designs. Pavement ride quality has also an impact on traffic safety. International Roughness Index (IRI) has been a well-known tool for evaluating pavement riding quality. Road agencies have been using IRI for evaluation of newly constructed asphalt pavements [iv]. Crash rates for a pavement have been linked with the pavement roughness. Elghriany et al.(2015) concluded that with the increasing IRI value, pavement looks more susceptible to higher crash rates and pavement having less IRI was safer for travelling [v].

A stream of traffic may include both light and heavy vehicles, which may have different loading impact. Heavy vehicles; typically the trucks damage the pavement depending upon the axle type, axle load and their speed. This also accompanied variation of traffic volume. Given the complex nature of variations, pavement material response is also a complicated phenomenon. Advances in computational mechanics and with the applications of statistics the ability to predict pavement response to load and climate effects can now be possible to certain extent. For a pavement design, mechanistic or empirical design methodologies can be adopted. Pavement designed either by a mechanistic or empirical approach alone may lead to a poor performance.

A. Mechanistic-Empirical Pavement Design Guide (MEPDG)

In 1996, the National Cooperative Highway Research Program (NCHRP) launched Project 1-37A to develop a new design guide for pavement structures. The design guide was based on mechanistic-empirical (M-E) principles. The MEPDG is a mechanistic-empirical (M-E) method for designing and evaluating pavement structures. In MEPDG structural responses (stresses, strains and deflections) are mechanistically calculated based on material properties, environmental conditions and loading characteristics [vi]. MEPDG involved application of the dynamic modulus technique for asphalt concrete and the resilient modulus for unbound materials. Improved material characterization and constitutive models made it possible to incorporate nonlinearities, rate effects, and other realistic features of material behavior [vii]. Following models for rutting prediction in asphalt pavement has been incorporated by MEPDG:

$$RD_{AC} = \sum_{i=1}^{N} (\varepsilon_p)_i \cdot \Delta h_i \quad (1)$$

Where; RD_{AC} = asphalt concrete layerrut depth, N = shows number of sublayers in a pavement, $(\varepsilon_p)_i$ = vertical plastic strain at mid-thickness of ith asphalt layer, Δh_i = = ith sublayer thickness. Any increment in surface distress increased the rate of surface roughness that directly affect the pavement ride quality (NCHRP, 2004).MEPDG incorporated roughness prediction model for the international roughness index (IRI). Aguiar et al. (2011) evaluated the pavement performance by incorporating the long-term pavement performance data (LTPP) into M-E-IRI model and concluded that M-E-IRI model was one of the best model for evaluating the pavement performance [viii]. Following relationship shows the roughness model for a certain age of conventional flexible pavements with granular base;

$$IRI = IRI_0 + 0.0463FC\left(e^{\frac{age}{20}} - 1\right) + 0.00119TC_L + 0.1834COV_{RD} + 0.00736BC + 0.00115LC \quad (3)$$

Where; TC_L = total length of transverse cracks in m/km, FC_T = total area of pavement fatigue cracking and equals to the percent of total lane area in a pavement, BC_T = total area of block cracking and equal to percent of total lane area, LC = length of sealed longitudinal cracks measured in m/km outside the wheel path. Several improvements have been proposed in the current MEPDG, which incubates several problematic and sensitive pavement regarding issues. However, MEPDG considers the similar input parameters that have been used previously in different design aids [ix]. Different research studies reported the importance of MEPDG in a pavement design and evaluation. Chehab and Daniel, (2006) implemented the MEPDG for design of flexible pavement and AC overlays for New England and New York states. A comprehensive sensitivity analysis were carried out. Different levels were utilized to assess distresses and the computed values were related with the field-measured values [x].Pavement structural performance is the function of pavement subgrade performance. Wang et al. (2010) used the heavy vehicle simulators on AASHTO class A-2-4, A-4 soils and concluded that pavement subgrade performance was fully dependent on soil type. Actual measurements under the HVS (heavy vehicle simulator) loading was further analyzed by developing mechanistic-empirical pavement design guide (MEPDG) subgrade rutting model [xi]. Chen et al. (2004) developed mechanistic-empirical model to assess rutting resistance of a pavement. According to this study the accumulated value of rut mainly depends on material property and traffic loading. The study revealed that MEPDG effectively assess pavement performance [xii].MEPDG not only used for evaluation of pavements but also has its applicability as basic pavement design tool. Goh and You, (2009) implemented MEPDG for rutting prediction of asphalt mixtures with varying design traffic levels and concluded that asphalt mixtures with lower design traffic levels showed less rutting as compare to other mixtures [xiii].

B. Kenlayer

The Kenlayer is a part of the KENPAVE package. This software can be used to assess both the rigid and flexible pavement. Kenlayer software was used to evaluate the structural condition of a pavement by measuring the critical strains [xiv]. Kenlayer software is based on an elastic multilayer pavement system analyzed under a circular loaded area. Asphalt layer was assumed to be linearly elastic. For non-linear analysis, unbound layers; base and subgrade has been treated as stress dependent layers [xv]. Following relationship has been used for the design repetitions model in Kenlayer.

$$N_f = 0.0796(\varepsilon_t)^{-3.291}(E_1)^{-0.854} \quad (3)$$

Where N_f = number of load repetitions before failure, ε_t = amount of tensile strain as a result of load repetitions measured at the bottom of asphalt layer, E_1 = elastic modulus of asphalt layer. (Mirza et al, 2011) evaluated the design thicknesses of two empirical design methodologies Road Note 31 and AASHTO design guide with ME program Kenlayer and concluded that the differences in approaches results were function of pavement material properties and traffic level [xvi].

For a pavement design, empirical design methodology based on either theoretical or practical approaches were used in the past. Those approaches led most of the pavements toward poor performance. The distresses developed in a pavement is significantly influenced by variation in thicknesses and material properties of different asphalt layers. Present study utilized the MEPDG to analyze the effect of varying thickness and poisson's ratio of AC layer on pavement performance indices (rutting and IRI). Poisson's ratio indicates the strain development in the material as a result of a stress tensor produced with in the material when force is applied. This ratio has a significance till the stress is within the elastic range. Studies in the past prove that poisson's ratio has significant relationship with the dynamic modulus of the asphalt materials. MEPDG recommends dynamic modulus as a good parameter for asphalt material performance. MEPDG provides us a deep insight about the material performance under traffic loading. MEPDG along with the mechanistic approaches such as kenlayers provides better understanding about the material behavior under the traffic loading. This study further used Kenlayer to ascertain the strain behavior and service life of best performing pavement section under MEPDG analysis.

II. Objectives

The main objectives of research study were:-

- Comparing the results of MEPDG analysis with the Kenlayer output and assessing the difference among the performance parameters.
- Assessing the effect of different parameters like pavement thickness and material properties of different layers on pavement performance.
- To study the contribution of chosen variables in the improvement of pavement design.

III. Experimental Program

The representative pavement sections were developed with varying asphalt concrete and base course layer thicknesses. The developed sections were analyzed using MEPDG for pavement rutting performance and riding quality. The varying parameters used in MEPDG were layer thickness and poisson's ratio. The best performing sections under MEPDG analysis were further analyzed using Kenlayer for strain behavior and design repetitions under standard loads. A three phase study was designed to accomplish the study objectives. Fig. 1 summarizes the scope of work.

Phase-I was comprised of, collection of traffic data and development of representative pavement sections with varying pavement layer thicknesses. The collected traffic data was truck traffic data of Sargodha interchange.

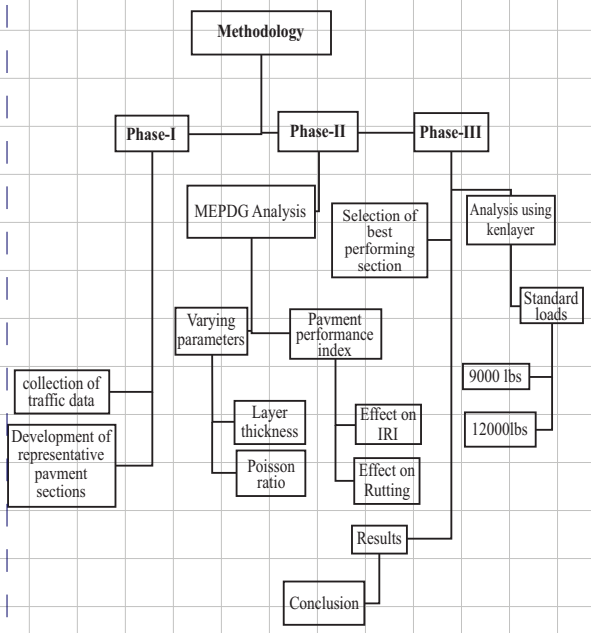

Fig. 1. Scope of work

The developed sections in phase-I were analyzed in Phase-II, using MEPDG. The phase-II comprised into two parts. In part-1, different parameters namely layer thickness and poisson's ratio were selected. In part-2, the effect of selected variables was analyzed on pavement performance indices (rutting and IRI). In phase-III, the selection of best performing pavement sections were analyzed under different standard loads using a Kenlayer software.

IV. Material and Methods

Nine representative pavement sections were developed with varying thicknesses of asphalt concrete and base course layers. The basic purpose was to cover the effect of wheel damage on pavement structure. A large number of loaded and unloaded trucks passed through Sargodha interchange daily carrying Sargodha crush, causing a considerable amount of damage to the pavement. The present study aims to improve pavement design of road section by minimizing

distresses and improving the riding quality. MEPDG characterizes the vehicular load ranges with respect to classes and configuration and each axle type has different load regimes. Vehicle class distribution, daily traffic volume and axle load distributions define the number of repetitions of each axle load group at each load level. All types of trucks with respect to their classes and axle can be accommodated in this software. It allows adding axle type and group combinations along with loads. One can use real time field loading conditions through this software and predicts the pavement performance. The Sargodha interchange traffic was used in the analysis. The specific traffic inputs in addition to operational speed also includes annual average daily truck traffic, lanes and trucks (%) in the design direction along with their percent in the design lanes. Nine pavement sections with typical range of thicknesses of asphalt concrete and granular layers are shown in Fig. 2.

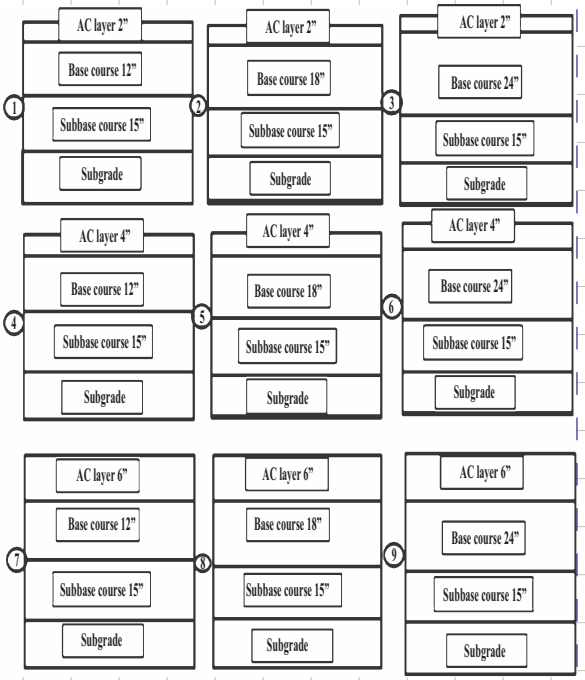

Fig. 2. Initially developed pavement sections

It may be noted from Fig. 2 that each pavement section was varied in asphalt concrete and base course layer thicknesses. Analysis of each developed pavement section was carried out against pavement performance indices (rutting and IRI) using MEPDG. The best performing section (with minimum rutting and required IRI level) out of all 9 sections was further analyzed using MEPDG to ascertain the effect of poisson ratio and subgrade soil type on pavement performance indices as shown in Fig. 3.

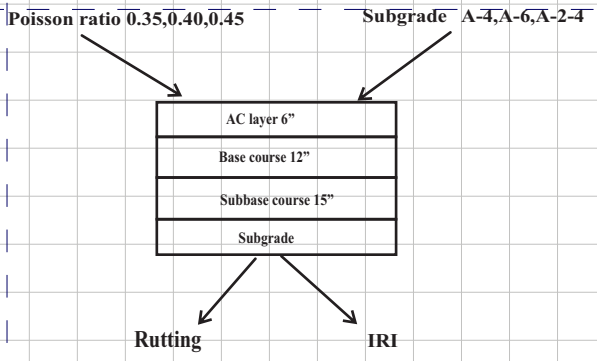

Fig. 3. Parameters for analysis against pavement performance index

It may be noted from Fig. 3 that well performing pavement section selected on the bases of MEPDG analysis results was further analyzed with varying subgrade soils (A_4, A_6, and $A_{2\text{-}4}$) and Poisson ratio (0.35,0.40,0.45) and its effect on pavement performance indice was studied. The best performing section was further analyzed using Kenlayer software for strain analysis and pavement life prediction. Kenlayer includes the effect of varying subbase thickness on pavement performance. Two pavement sections were developed with varying subbase course thickness. The thickness of asphalt concrete layer was also varied to ascertain the sensitivity of AC layer on strain development as shown in Fig. 4.

It may be noted from Fig 4 that best performing section under MEPDG analysis was further analyzed using Kenlayer software.

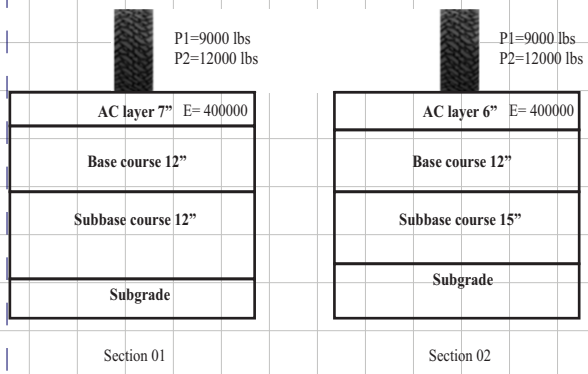

Fig. 4. Pavement sections analyzed under Kenlayer software

To assess the sensitivity of asphalt concrete and subbase layer. Another pavement section was developed by decreasing the subbase layer thickness and increasing the asphalt concrete layer thickness. Two Standard axle loads of magnitude 18 kip (8.16ton) and 24 kip (10.9ton) were selected for analysis of selected pavement sections. The pavement sections were analyzed using same asphalt concrete layer modulus of 400,000 psi (2757.9 MPa). Tire pressure of 100 Psi (0.7 MPa) was maintained during analysis.

Subgrade material consisted of A_4 soil, normally available soil in study region.

V. Results and Discussion

Nine representative pavement sections were developed with varying thicknesses of asphalt concrete and base course layers. Rutting performance and ride quality of each pavement section was analyzed for a period of 20 years using MEPDG as shown in Table I.

It may be noted from Table I that pavement sections 7, 8 and 9 showed minimum rutting and good ride quality as compared to other sections, but the structural number of the pavement increases effectively.

There was no significant effect of granular base course layer thickness on rutting and IRI. Out of above three mentioned pavement sections, pavement section # 7 has minimum thickness of granular base course layer with respect to remaining two sections as shown in Fig. 5.

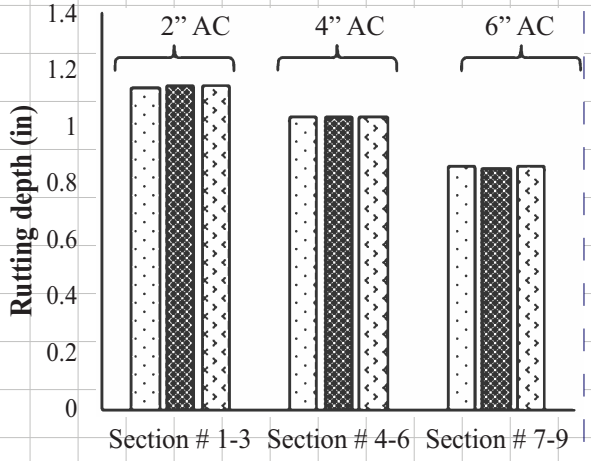

Fig. 5a. Influence of pavement thickness on rutting depth

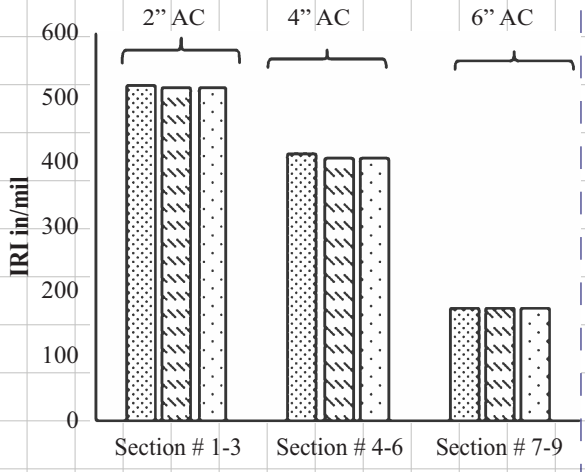

Fig. 5b. Influence of pavement thickness on IRI

It may be noted from Fig. 5 that granular base course layer thickness has insignificant effect on rutting depth and IRI of asphalt concrete pavement. One of the major reasons behind was the basic philosophy of design procedure. MEPDG protect subgrade by thickness of asphalt layer, rather than granular layer. An increase in the thickness of AC layer covers the effect of loading rather an increase in granular layer thickness.

TABLE I
Rutting Depth and IRI of Developed Pavement Sections for 20 Years of Pavement Life

Sect.	1	2	3	4	5	6	7	8	9
Total rut (mm)	29	29	29	26	26	26	23	23	23
IRI (m/km)	33	33	33	26	26	26	11	11	11
SN	2.6	3.4	4.3	3.5	4.3	5.1	4.4	5.2	6

The effect of Poisson's ratio on ride quality was also assessed by using the well performing pavement section as shown in Fig. 6.

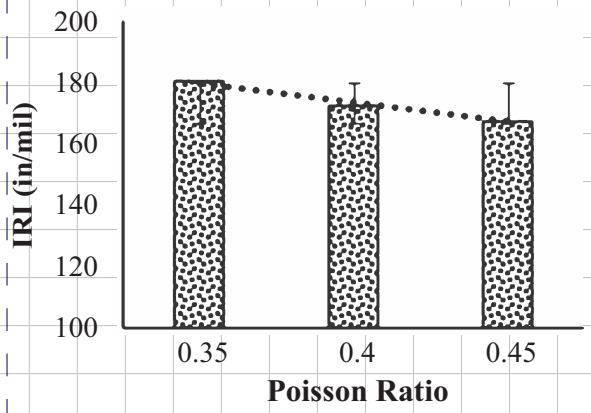

Fig. 6. Influence of poisson's ratio on and IRI

It may be noted from Fig. 6 that IRI of pavement section decreases with an increase in Poisson ratio of AC layer. It is because the material shows more ductile properties which increases its propensity to offer more IRI and relatively higher rate of deterioration.

The selected pavement section was also analyzed for horizontal tensile strain and vertical compressive strain against 18kip (8.16 ton) to 24kip (10.9 ton) load. To assess the effect of variation in subbase layer thickness on strain behavior of pavement, another pavement section was developed as shown in Fig. 4. Horizontal tensile strain at the bottom of the asphalt layer (ε_t) has been presented in Fig. 7.

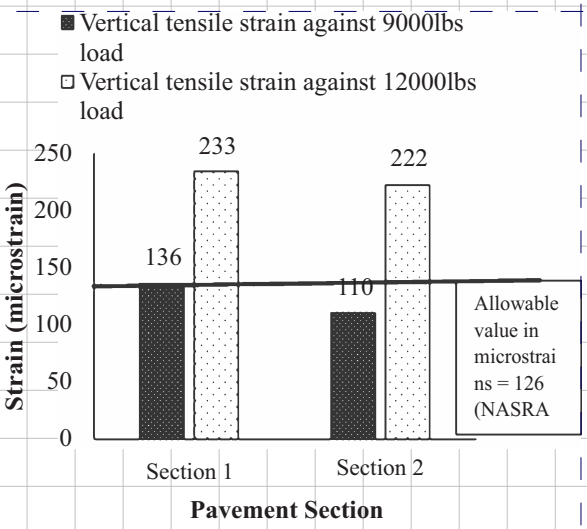

Fig. 7. Axle load versus tensile strain in a pavement

It may be noted from Fig. 7 that by increasing standard load from 18kip (8.16 ton)to 24kip (10.9 ton), tensile strain development in the pavement section increases to prominently high value for both representative pavement sections. But as the thickness of granular layer increases by lowering the asphalt layer thickness, the developed strain decreases for both 18kip (8.16 ton)and 24kip (10.9 ton)loads.Thicker aggregate layer reduces the strain value by spreading the load to a wider area. Vertical compressive strain at the top of subgrade (ε_c) was also analyzed as shown in Fig. 8.

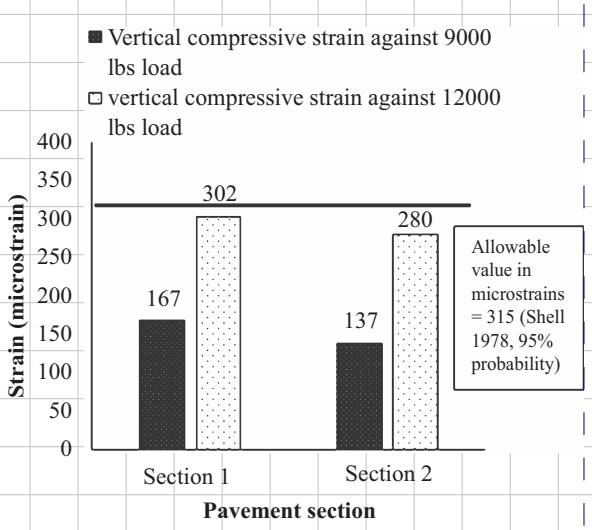

Fig. 8. Axle load versus compressive strain in a pavement

It may be noted from Fig. 8 that by increasing standard load from 18kip (8.16 ton) to 24kip (10.9 ton), compressive strain developed in pavement section increases to significantly in both the representative pavement sections. At the same time as the thickness of granular layer increases by lowering the asphalt layer thickness, the developed strain decreases for both 18kip (8.16 ton) to 24kip (10.9 ton) loads. Fig. 9 shows that as the load increases from 9 kips(4.08 ton) to 12 kips (5.44 ton), the number of repetitions also decreases.

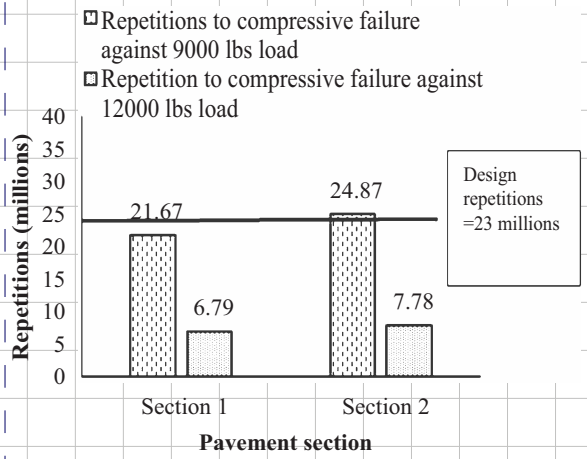

Fig. 9. Axle load versus repetition for pavement life

It may be noted from Fig. 9 that adopting laid methodology, selection of a pavement section for a given condition can be made. The pavement designer can select a section for any given set of load and material conditions. Adopting AASHTO 1993 pavement design for structural design of a pavement can further be analyzed for its adequacy of performance by following analysis with MEPDG and Kenlayer software. This would develop a confidence to designer for probable performance in the field.

VI. Conclusion

Present study investigates the effect of different parameters on a pavement structural capacity and the ability of different software to ascertain stress response in a pavement. Following conclusions have been drawn from this study:

- Rut resistance and riding quality of a pavement section increases with an increase inthe asphalt layer thickness. MEPDG protects the subgrade by increasing the thickness of asphalt layer, whereas Kenlayer software protects the subgrade by increasing the thickness of granular layer and keeping the thickness of asphalt layer constant.
- Rut resistance of asphalt pavement increases with an increase in Poisson's ratio of AC layer. With the increment in poisson ratio of AC layer, the pavement shows good riding quality.
- Tensile strain at the bottom of AC layer and Compressive strain at the top of subgrade increases significantly as standard load on pavement increases from 18kip (8.16 ton) to 24kip (10.9 ton) . At the same time thickness of granular

layer decreases the developed strain for both 18kip (8.16 ton) to 24kip (10.9 ton) loads and design repetitions increases no matter the AC layer thickness decreases.

- Pavement performance parameters like international roughness index can be predicted through MEPDG software, while Kenlayer calculates the stress, strains and repetitions to failure in the pavement. Adopting AASHTO 1993 pavement design for structural design of a pavement can further be analyzed for its adequacy of performance by following analysis with MEPDG and Kenlayer software.
- Based on the findings of present study it is recommended that different design methodologies including mechanistic and mechanistic-empirical pavement design aids may be utilized to review stress response of a designed pavement.

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Section B

ELECTRICAL AND ELECTRONICS ENGINEERING

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Dual-Band Frequency Reconfigurable Microstrip Patch Antenna on Wearable Substrate for Wi-Fi and Wi-MAX Applications

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Abstract-In this paper the design of wearable dual band frequency reconfigurable microstrip patch antenna is presented for wireless communication services (i.e. Wi-Fi at 2.44 GHz and WiMAX at 3.54 GHz). For body-worn and wearable applications, the antenna is employing 1 mm thick Denim Jeans textile material as a substrate with dielectric constant of 1.7 and loss tangent of 0.0001. The proposed microstrip patch antenna with volume of 105.38×90×1 mm^3 has been reconfigured using optical switches to operate at two different frequencies depending upon the switching mode. The antenna operates at single band mode at 2.44 and 3.54 GHz frequency bands, when the switches the switches are ON and OFF, respectively. The proposed structure has an operational bandwidth of 2% (50 MHz) and 1.13% (40 MHz) at the resonant frequencies of 2.44 and 3.54 GHz, respectively. Better impedance matching characteristics with input impedance in acceptable range of 51-52.5 Ω and VSWR nearly equal to 1.05 has been provided by the proposed antenna. Directional gains of 5.73 and 9.17 dB are achieved at 2.44 and 3.54 GHz frequencies, respectively with maximum efficiency of 94.6%. Proposed wearable frequency reconfigurable dual band microstrip patch antenna has the capability to be used in wearable, medical, safety, rescue, body-worn, security and military applications. The proposed microstrip antenna is designed, simulated and analysed in Computer Simulating Technology Microwave Studio employing Finite Integration Method.

Keywords-Dual-band, Wearable, WiFi, WiMAX, Microstrip, Jeans, Patch, Low Profile, Reconfigurable.

I. Introduction

Modern wireless communication technology provides flexibility to the users of electronic portable devices. The innovation in technology have gained a peak value in demand graph that humans should be able to wear electronic devices for communication purposes in body area networks, personal area networks and other fixed/mobile networks. For effective communication between different wearable devices in wireless communication networks, a wearable component made from textile materials known as wearable antenna is required. Wearable antennas employed on textile materials have the capability to radiate electromagnetic waves of specific wavelengths. For this reason, these antennas are used in various applications including medical, sports and military [i].

Wearable and body-worn antennas, made up from textile materials [ii-iii], can be worn directly as button antennas [iv] or can be integrated into clothing [v]. In literature, the authors have discussed wearable whip antenna for the first use in military applications [vi]. Similarly, Telemedicine devices are observed utilizing the wearable antenna technology for medical applications [vii-viii]. In [ix-x], it is reported that the wearable antennas are introduced as flexible metallic strips on textile materials as substrates. The authors have presented the design of wearable dual band antenna in [xi]. However, the above described antennas are radiating electromagnetic waves at different frequency bands irrespective of the user need. To consider particular communication services required by the user, the best solution is to use frequency reconfigurable antennas.

Reconfigurable antennas have the capability to reconfigure its characteristics such as resonant frequency, far-field radiation pattern and electric field polarization, depending upon the integrated mechanisms. The resonance of frequency reconfigurable monopole, dipole, loop, microstrip patch and slot is controlled by the effective length of the radiating structures in these antennas. In frequency reconfigurable antennas, the resonant frequency is switched from one band to another band by incorporating electronic switches within the antenna including PIN diodes, RF MEMS and optics. In [xii], the authors have designed dual-band frequency-reconfigurable textile antenna for wearable applications using PIN diode switching. In [xiii], the antenna is reconfigured using RF MEM switches. The authors have discussed the design of dual band frequency reconfigurable microstrip antenna using

varactor diode switching in [xiv].

In this paper, a wearable frequency reconfigurable dual band microstrip patch antenna is designed on a 1mm thicker textile material, the Denim Jeans. The proposed wearable antenna is configured to transmit and receive electromagnetic waves at Wi-Fi and WiMAX frequency bands by using optical switches. The commutation of optical switches for simulation purposes has been realized in such a way that the resistance is kept as low as 5 Ω and as high as 1 GΩ for switch ON- and OFF-state, respectively. Rest of the research efforts are organized and arranged section-wise in the following manner: In section II, the geometrical structure and design methodology of wearable Dual band frequency reconfigurable microstrip patch antenna is discussed. Section III presents the performance, simulation results of the antenna. Finally, the article is concluded in Section IV.

II. Geometry and Design Methodology

The dimensions of proposed wearable microstrip patch antenna for Wi-Fi (2.44 GHz) and WiMAX (3.54 GHz) applications are shown in Fig. 1. Normally, -10dB band-width of microstrip patch antenna is narrow because of the fact that it provides a single resonant frequency for operation. Thus, to lead in multiband performance characteristics it is required to design a reconfigurable microstrip radiating structure that has the ability to radiate electromagnetic waves at two or more than two frequencies. For this reason, this design structure is adopted to achieve reconfigurability and dual-band frequency mode in the antenna, with good input impedance matching characteristics in the respective operating frequency

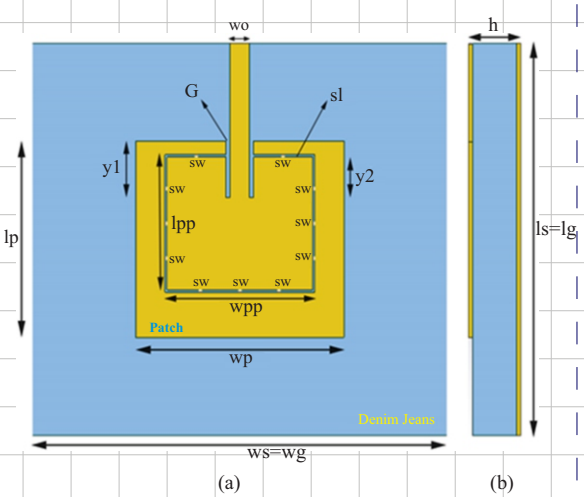


Fig. 1. Structural Dimensions of Wearable Microstrip Patch Antenna, (a) Top View (b) Right Side View

In this design, the basis of the radiator is a microstrip rectangular patch with the dimensional lengths and widths (i.e. lp×wp, for lower resonance; and lpp×wpp, for higher resonant frequency). To make the antenna capable for body-worn and wearable applications, the patch is employed on 1 mm thick textile material, Denim Jeans as a substrate with dielectric constant of 1.7 and loss tangent of 0.0001 [xv]. The proposed wearable antenna is fed via 50Ω microstrip line with width of wo= 5mm. The microstrip line feeding method is easy to fabricate, simple to model and input impedance is matched efficiently by adjusting the inset position of the line [xvi].

To achieve reconfigurability, the two rectangular patches are separated by a rectangular slot of 0.5mm for the integration of eleven switches, as depicted in Fig. 1. The spacing between the patches is adjusted in such a way that the outer patch resonates at lower frequency band (i.e. Wi-Fi @2.44 GHz) whereas the inner patch provides resonance at higher frequency band (i.e. WiMAX @3.54 GHz). The effective lengths and widths of wearable microstrip patch are calculated using well-known transmission-line model theory in [xvii]. Resonant lengths of the two concentric patches in terms of guided wavelengths (i.e. $\lambda_{2.44}$ and $\lambda_{3.54}$) are calculated using the equations given as:

$$L_{2.44} = lp = \frac{\lambda_{2.44}}{2} - 2\Delta L_{2.44} \quad (1)$$

$$L_{3.54} = lpp = \frac{\lambda_{3.54}}{2} - 2\Delta L_{3.54} \quad (2)$$

Where λ_{fr} is a guided wavelength which can be found for a particular frequency f_r in a following equation as:

$$\lambda_{fr} = \frac{c}{f_r \sqrt{\varepsilon e}} \quad (3)$$

In the above equation, c represents the velocity of light and the parameter ε_e is known as effective dielectric constant, given in the equation as:

$$\varepsilon_e = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[1 + 12\frac{h}{W_{fr}}\right]^{-1/2} \quad (4)$$

Where W_{fr} is the width of rectangular patch at frequency f_r, h is the thickness of substrate material used (i. e. Denim Jeans in this case) and ε_r is known as effective relative permittivity. The widths of both the inner and outer patches at their respective frequencies are calculated using the equations written as:

$$W_{2.44} = wp = \frac{\lambda_{2.44}}{2}\sqrt{\frac{2}{\varepsilon r+1}} \quad (5)$$

$$W_{3.54} = wpp = \frac{\lambda_{3.54}}{2}\sqrt{\frac{2}{\varepsilon r+1}} \quad (6)$$

The extension in length of the patches ΔL_{fr} mentioned in above two equations (i.e. eq-1 and -2) is found as:

$$\Delta L_{fr} = 0.412h\frac{(\varepsilon_e + 0.3)(\frac{W_{fr}}{h} + 0.264)}{(\varepsilon_e - 0.258)(\frac{W_{fr}}{h} + 0.8)} \quad (7)$$

The lengths, widths and feed-line depths calculated using above mentioned equations are adjusted in simulation for the desired frequencies at 2.44 and 3.54 GHz. The proposed wearable microstrip antenna has an over-all dimensional volume of *105.38*x*90*x*1mm*^{3}. Table I summarizes the dimensions of proposed wearable reconfigurable microstrip patch antenna.

TABLE I
SUMMARY OF DIMENSIONS OF WEARABLE MICROSTRIP

Symbol	Quantity	Values (in terms of guided wavelength, λ=94.3 mm)
ls =lg	Length of substrate	0.95 λ
Ws=wg	Width of substrate	1.12 λ
lp	Length of patch	0.5 λ
wg	Width of ground	0.56 λ
Lpp	Length of inside patch	0.33 λ
y1	Outer patch difference	0.14 λ
wpp	Width of inside patch	0.4 λ
y2	Inner patch difference	0.1 λ
G	Gap	0.011 λ
SI	Slot length	0.005 λ
Wo	Width of feed line	0.053 λ
h	Height	0.011 λ

III. SIMULATION AND RESULTS

The proposed wearable microstrip patch antenna, employing denim jeans as a substrate, is designed, simulated and analysed using Computer Simulation Technology Microwave Studio (CST MWS. In this software environment, denim jeans substrate was defined by adding new material with permittivity of 1.7 and loss tangent of 0.0001. The radiating element and ground plane uses copper metal as a conducting material. To analyze the results of the antenna, open-add-space boundary conditions and the transient solver was used in simulation. The frequency range was set in the range from 2 to 4 GHz, as the antenna is designed for 2.44 and 3.54 GHz bands. Excitation of the patch antenna is accomplished by assigning a wave-guide port to the face of 50Ω microstrip transmission feed-line. The antenna parameters such as Magnetic- and Electric-field Gain, -10dB Return Loss, Scattering parameter, Surface E-fields and Voltage Standing Waves Ratio (VSWR), 3D Far-field radiation patterns are evaluated and investigated for performance analysis and are presented below in this section.

Switches in the radiating element of the patch are inserted in the positions represented as *sw*. When all the switches are ON, the antenna operates at 2.44 GHz. Similarly, the patch antenna achieves resonance at 3.54 GHz when all the switches are OFF. Table II explains the switching mechanism and resonant frequency modes.

TABLE II
SWITCHING MECHANISM OF WEARABLE AND RECONFIGURABLE MICROSTRIP PATCH ANTENNA

S. No	Switch Condition	Frequency
1	ON	2.44 GHz
2	OFF	3.54 GHz

Microstrip patch antenna gives -10 dB reflection coefficient (S_{11}) of -29.49 dB at 2.44 GHz and -32.2 dB at 3.54 GHz, when all the switches are ON and OFF, respectively. The bandwidths in the respective lower and high frequency bands are 2% (50 MHz) and 1.13% (40 MHz). The plot of frequency versus S_{11} of patch antenna is given in Fig. 2. It can be observed from the graph that the antenna provides minimum reflections at 2.44 and 3.54 GHz frequencies. Additionally, the patch gives resonance at 3.376 GHz with S_{11} of -20 dB. However, at this additional band the antenna is not matched.

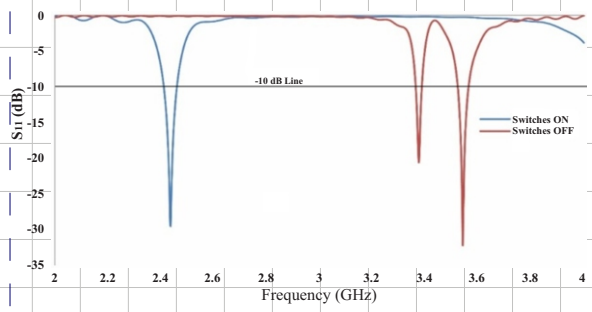


Fig. 2. Reflection coefficient (S_{11}) of Wearable and Reconfigurable Microstrip Patch Antenna in both switching modes

In Fig. 3, VSWR values of the antenna are plotted against frequencies, which clearly illustrate the fact that the antenna is satisfactorily matched with VSWR values of 1.069 at 2.44 GHz and 1.05 at 3.54 GHz frequency bands. Input impedance realized by the antenna structure is 51.5 ohms at 2.44 GHz and 52.46 ohms at 3.54 Ghz.

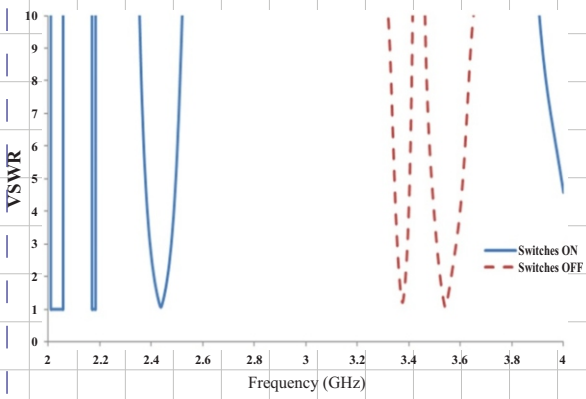
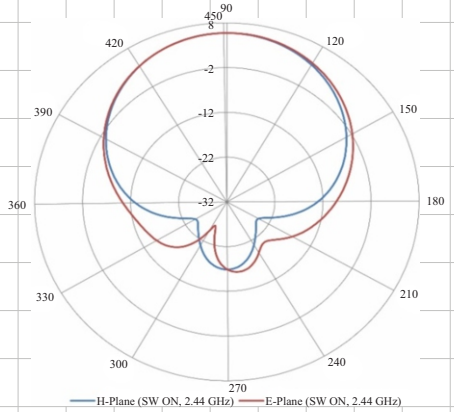


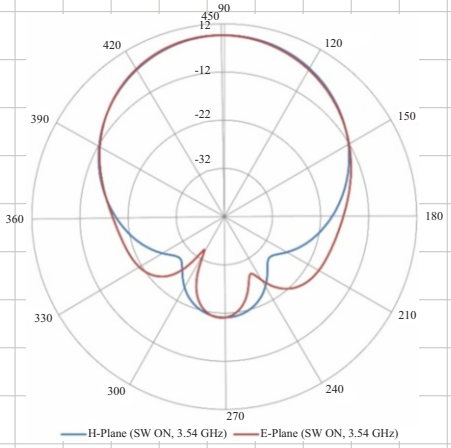
Fig. 3. VSWR values of Wearable and Reconfigurable Microstrip Patch Antenna in both Switching Modes.

E/H-plane gain patterns in both switching modes are depicted in Fig. 4 a and b. Gain of the antenna in ON-switch state is 5.728dB at 2.44 GHz. When all the switches are OFF, gain value of 9.167dB is achieved by the patch at 3.54 Ghz.

In Fig. 5 a and b, the surface electric fields can be observed at 2.44 and 3.54 GHz. From these figures, it has been observed that the inner patch is responsible for radiations at 3.54 GHz, whereas the outer patch radiates electromagnetic waves at 2.44 GHz. In other words the density of E-field is maximum at the edges of the outer patch which helps in generating the lower frequency band (2.44 GHz). This E-field density is maximum at the edges of the inner patch which contribute in generating the upper frequency band (3.54 GHz). The E-field density is minimum at the center of the patch. The proposed wearable antenna attains the maximum efficiency values of 51% (lower due to insertion losses) at 2.44 GHz and 94.6% at 3.54 GHz frequencies. Table III summarizes performance of the proposed wearable dual band patch antenna. The antenna gives sufficient gain (> 5 dB), directivity (>8 dBi) and bandwidth (1-2%) in both frequency bands.

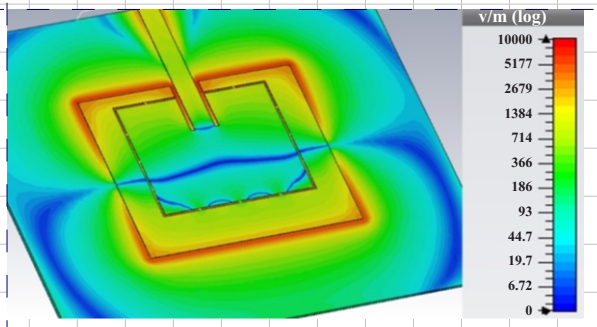


(a)

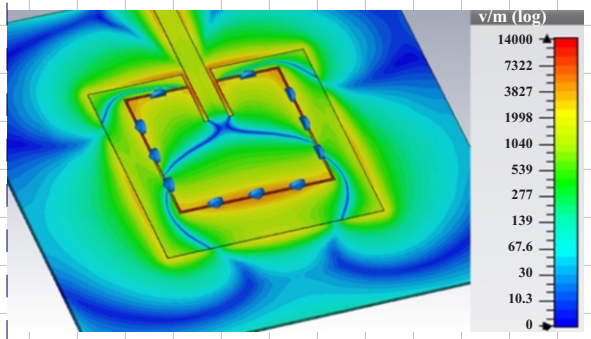


(b)

Fig. 4. Gain Pattern of Wearable and Reconfigurable Patch Antenna at (a) 2.44 GHz (All SWs ON) (b) 3.54 GHz (All SWs OFF)



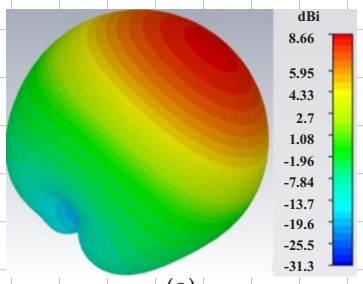
(a)



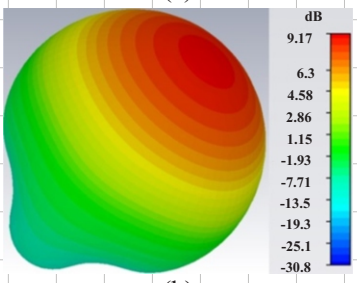
(b)

Fig. 5. Surface E-field of Wearable and Reconfigurable Microstrip Patch Antenna at (a) 2.44 GHz (b) 3.54 Ghz

The patch antenna, employed on wearable material like denim jeans, gives the directivity values of 8.66 and 9.41 dBi at the resonant frequencies of 2.44 and 3.54 GHz. Fig. 6 a and b shows the 3D far-field radiation plots at 2.44 and 3.54 GHz bands which reports that the antenna has directional far-field pattern.



(a)



(b)

Fig. 6. 3D Directivity of Wearable and Reconfigurable Microstrip Patch Antenna at (a) 2.44 GHz (b) 3.54 GHz

TABLE III
SUMMARIZED RESULTS

Parameters	Switch On	Switch OFF
Frequency	2.44 GHz	3.54 GHz
Directivity	8.66 dBi	9.41 dBi
Gain	5.73 dB	9.17 dB
VSWR	1.069	1.05
S_{11}	-29.5 dB	-32.2 dB
Efficiency	51 %	94.6 %
Impedance	51.5 Ω	52.4 Ω
Bandwidth	2 %	1.13 %

IV. CONCLUSIONS

In this paper, the design of wearable dual band frequency reconfigurable microstrip patch antenna has been presented. The proposed antenna can be used for body- worn and wearable applications at Wi-Fi (2.44 GHz) and WiMAX (3.54 GHz) frequency bands. This wearable has the key advantage that it can be reconfigured for operation at two different frequency bands depending upon the need and switching mode. The efficiency values achieved by the microstrip patch have been observed to be 51 and 94.6% at 2.44 and 3.54 GHz frequencies. It has been reported that the antenna provides -10dB band-widths of 2% (500 MHz) and 1.13% (40 MHz) at 2.44 and 3.54 GHz bands, respectively. The proposed wearable microstrip patch antenna has a directional 3D far-field radiation pattern with matched input impedance and has achieved the E/H-plane gain values of 5.73 dB at 2.44 GHz and 9.17dB at 3.54 GHz. The proposed wearable frequency reconfigurable dual band microstrip patch antenna has the attractive potentials to be used in wearable, medical, safety, rescue, body-worn, security and military applications.

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Design of a Novel UWB Hexagonal Patch Antenna having Three Notched Band Features

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Abstract-A UWB hexagonal patch antenna with three band-stop features is suggested in this article having a hexagonal shaped radiator fed with microstrip line with "I", "C" and Inverted "U" shaped slots to attain the band notch characteristics. The dimensions of the suggested antenna are 30mm×28mm×1.6mm. The design is printed on FR4 substrate of permittivity 4.6 and loss tangent 0.02. The antenna reports a substantial bandwidth from 2.65 GHz to 11.3 GHz. Out of this 8.65 GHz range, the VSWR is less than 2 except at three notch bands for WiMax system (3.3 to 3.7 GHz), WLAN system (5.15 to 5.85 GHz) and ITU (7.95 to 8.4 GHz). The proffered antenna has a stable gain in the entire range of 8.65 GHz except the notch bands. The radiation pattern of this antenna is nearly omni-directional.

Keywords-Ultra-Wide Band, ITU Frequency Band, WLAN, VSWR, WiMAX, HFSS.

I. Introduction

Ultra wideband (UWB) is a rapidly emerging technology with enhanced features for example low power utilization, high data rate, minimal effort and enhanced resolution of multipath [I]. This is a peerless and unrivalled technology for implementation in high speed and short range transmission. It is highly recommended for its utilization in the field of medical such as high precision cancer detection [ii]. High resolution ground penetrating radar also uses UWB technology. In 2002, the Federal Communication Commission (FCC) in America completely transformed and revolutionized it by approving the unlicensed utilization of UWB range from 3.1 to 10.6 GHz [iii]. Since then, an elevated and enlarged number of research labs, academic institutions and governmental agencies have been trying to amplify the latent potentials of this technology and actualize it into reality. Its maximum power is restricted to -41dBm/MHz. UWB implies time shifting mechanism to broadcast binary data having rate in million pulses per second. In this 7.5 GHz bandwidth, several narrow band systems pre-exist. Interference problems emanate from these narrow band systems. UWB system is affected by WiMax(3.3 to 3.7 GHz), WLAN (5.15 to 5.35 GHz and 5.72 to 5.8 GHz) and ITU (7.95 to 8.4 GHz).One solution, to get rid of interference problem, is to use filter but it may add up to the expenditure and increase the multifaceted nature and sophistication of the system [iv]; a simpler technique which could be implied is the use of antenna in order to overcome this conundrum. There are varied methods and techniques employed with a specific end goal to accomplish the objective of band notching. One being the use of parasitic element in order to stop the undesired range of frequencies [v-vi]. Another method being the introduction of fractal geometry in the designing of antenna which notches specific frequencies and thus enlists itself in the category of notching techniques [vii]. Yet another method could be acquired where band notch UWB antenna is outlined by utilizing split-ring resonator. The dimensions of the rings determine notch frequency [viii]. Additionally, open loop, closed loop, open-circuited and short-circuited coplanar waveguide resonators are used to design band notch UWB antenna [ix-x]. Apart from the above mentioned procedure, yet again, Computer auto-design technique is one of the procedures in which optimization process is used to design band stop antenna [xi-xii]. Last but not the least, Cuts or slots of various geometrical shapes are driven in the radiator to achieve band notch characteristics. Current flows mainly on the surface of patch feeding line and ground plane and thus, cuts in these portions trap the current. The dimensions of the cuts are proportional to the notch frequency and its bandwidth [xiii-xiv]. This paper is based on slot technique of band notching which uses CST Microwave Studio Suite for simulation. Triple stop band characteristic has been achieved by introducing 'I' shaped and 'C' shaped slots and an inverted 'U' shaped cut in the radiating element. The excitation given here is microstrip line in nature.

II. Antenna Design

UWB monopole antennas employ various geometrical shapes but in our propounded design, hexagonal geometrical structure has been brought into service. The desired antenna is formulated on FR-4 substrate. Its thickness (h) is taken to be 1.6 mm so as to achieve the relative permittivity (ε_r) of 4.6. The dimensions of the substrate are 30 x 28*mm*. The

dimensions of the ground plane are 8 x 28*mm*. It also has a slot in the top mid of ground which has a length of 3.5mm and width of 3.3mm. The desired antenna is provided with a 50 Ω micro strip feed which has a length of 8mm and width of 3mm. The length of each side of the hexagon is 10 mm. The resonating range of this antenna varies from 2.65 to 11.3 GHz. Different slots are exploited to stop various bands to side-step interference. WiMax band (3.3 *to* 3.7 *GHz*) is thwarted by 'I' shaped slot of dimension 12.5 *mm* x 0.3*mm*. 'C' shaped slot having length 18.7 mm and width 0.5mm is made use of to stop the band in the range of 5.15 *to* 5.8 *GHz* used for WLAN application. The ITU frequency band (7.95 *to* 8.4 *GHz*) has been stopped by inverted 'U' shaped slot of dimension 12.28 *mm* x .60*mm* in feeder line and lower portion of the patch. Notch frequency and substrate permittivity determine dimensions of the slots. At notch frequencies, length of the slots is quarter wavelength or half wavelength. The following postulates define length of the slots (*Ls*) [15].

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

or

$$Ls = c/(2f_n\varepsilon_c) \quad (2)$$

Whereas

$\varepsilon_c = \sqrt{(\varepsilon_r + 1)/2}$.

ε_c is the relative dielectric constant of FR-4 substrate

Ls is length of slot in mm,

C is the speed of light and its value is 3 x 10^8 *m/s*and

f_n is notch frequency in Ghz.

The above equations are used to determine the dimensions of the design. By careful analysis and parametric study of the proposed model, the final structure of the antenna is obtained which is displayed in illustration 1. The length of 'I' shaped slot is 12.5mm and its width is 0.3mm. The length of 'C' shaped slot is 18.7 mm and its width is 0.5mm. The inverted 'U' shaped slot is 12.28 mm long and its width is 0.6mm. The other parameters are recorded in Table 1.

TABLE I
DIMENSIONS OF THE VARIOUS PARAMETER OF THE NOVEL ANTENNA DESIGN

Parameters	Value(mm)	Parameters	Value(mm)
L	30	L_1	1
W	28	L_2	7
H_1	6	L_3	1
H_2	10	L_4	12.5
H_3	5.5	L_f	3
H_4	6		
H_5	5.5	L_g	3.5
H_6	8	W_g	3.3

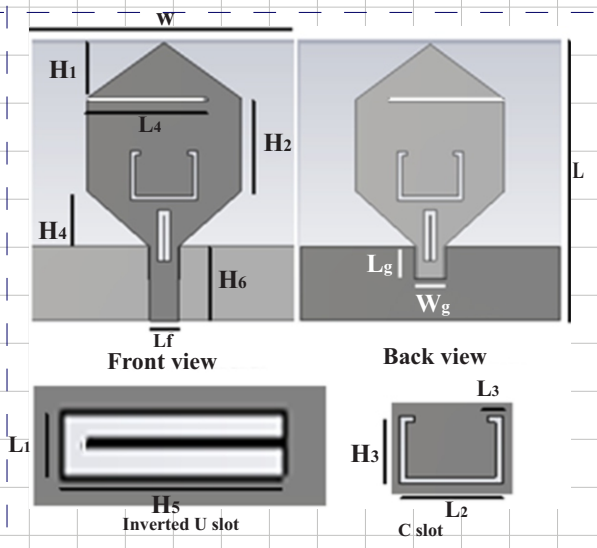


Fig. 1. Design of Novel Hexagonal Antenna

III. DISCOURSE/DEBATE ON FINDINGS

In this portion, the findings of UWB monopole antenna with triple notch bands are put forward. The S_{11} (*dB*) characteristic of the suggested antenna is displayed in Fig. 2. This graph reveals the wideband behavior of the antenna in which 2.65 to 11.3 GHz portion of S_{11} (*dB*) is less than -10dB which stands perfectly in line with the criterion set by FCC.

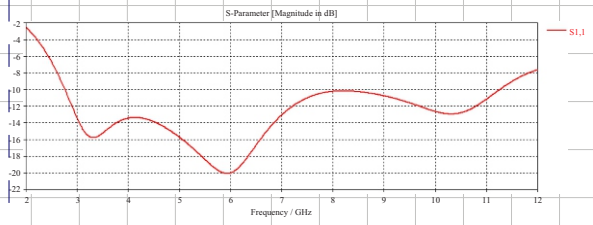


Fig. 2. S_{11}(dB) of the novel Antenna covering the whole UWB Band

Fig. 3 shows the VSWR plot without notched characteristics.

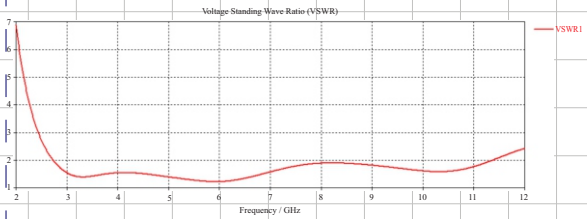


Fig. 3. VSWR plot of the novel antenna

Fig. 4 shows the notched characteristics of the antenna at three different communications bands and from VSWR plot it is clear that the three bands centered at 3.48, 5.52 and 8.15 GHz have been halted by the antenna.

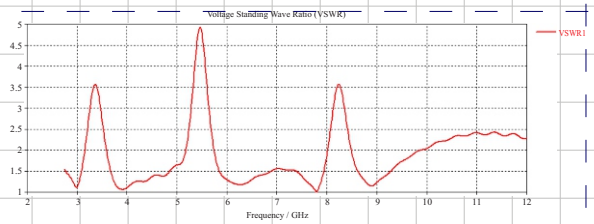


Fig. 4. VSWR plot of the antenna with triple stop band features

In the entire 8.65 GHz bandwidth $VSWR \leq 2$ except at notch bands.

Fig. 5, Fig. 6 and Fig. 7 represents the stepwise return loss of the proposed antenna with three notch bands. Fig. 8 is showing all the results in one plot.

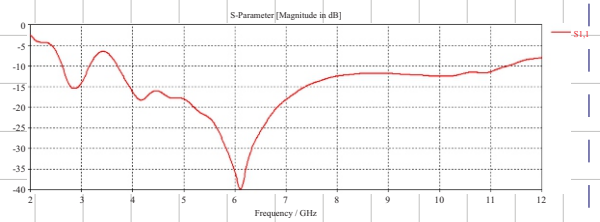


Fig. 5. S_{11}(dB) of the antenna with first notch of WiMAX band.

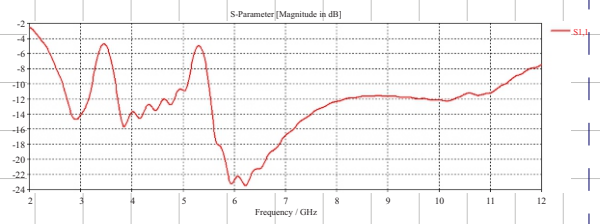


Fig. 6. S_{11}(dB) of the antenna with first and second notch of WiMAX and ISM bands.

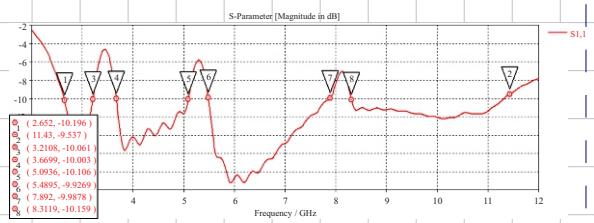


Fig. 7. S_{11}(dB) of the antenna with first, second and third notch of WiMAX, ISM and ITU bands.

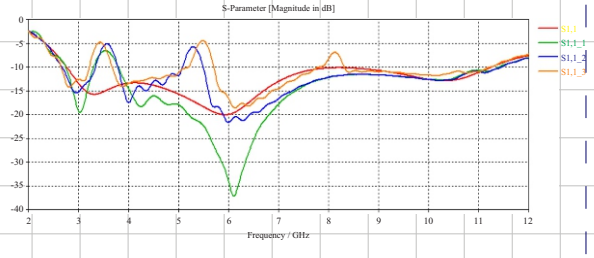
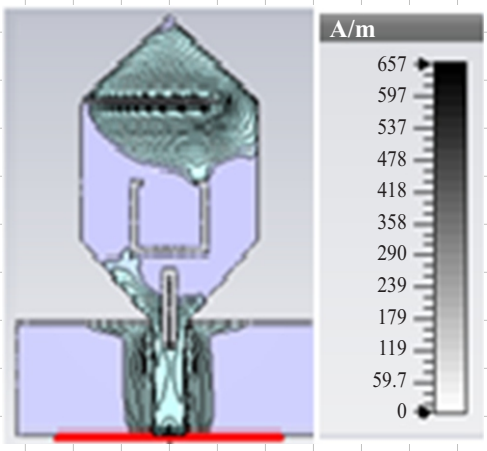
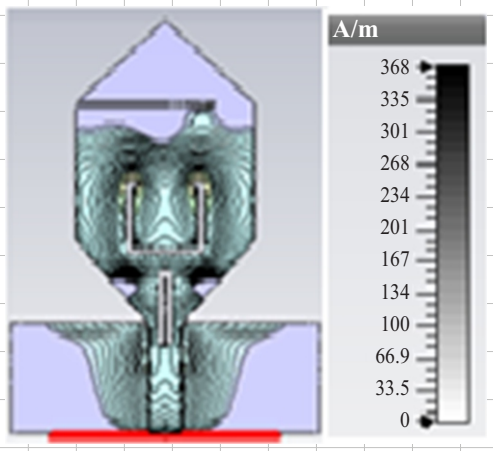


Fig. 8. Progressive S_{11}(dB)of the proposed antenna with all three notches.

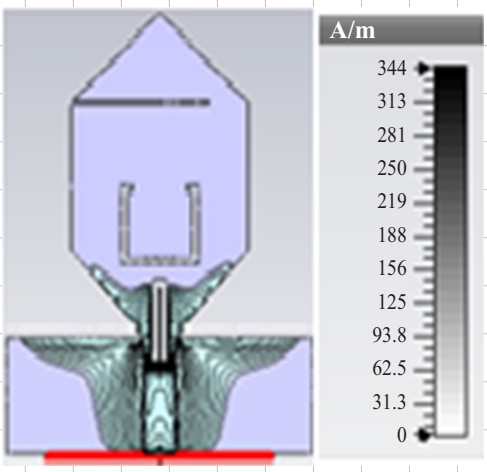
To discuss notching characteristics of the simulated antenna, the surface current circulations at various bands are depicted in Fig. 9(a), (b) and (c).



(a)



(b)

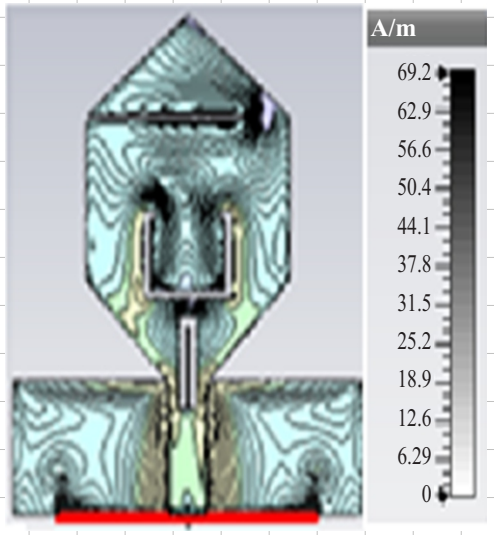


(c)

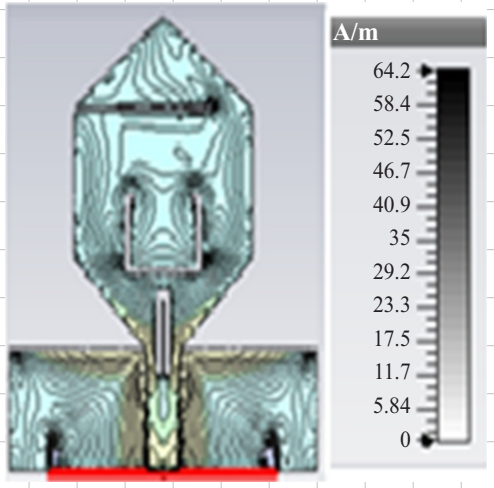
Fig. 9. Current circulations at stop bands of (a) 3.48GHz, (b) 5.52GHz and (c) 8.15GHz

While Fig. 10 (a) and (b) highlights the current circulations at 4.5 GHz and 7 GHz which are considered as present in pass bands.

The results presented in Illustration 9 and 10 signify that energy is concentrated around the slot and does not radiate into the space. At stop band, the current circulation is dominant in the area encapsulating the slots which enhances near field radiation counteracted and thus enhanced power is bounced back to the incoming terminal. This way the band notching characteristics of antenna can be achieved [xvi]. While current distribution at pass bands show that slots have negligible effect on the radiations.



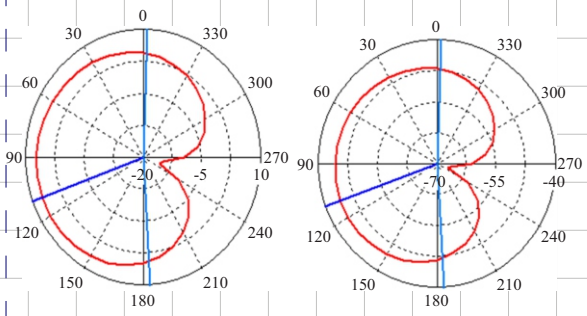
(a)



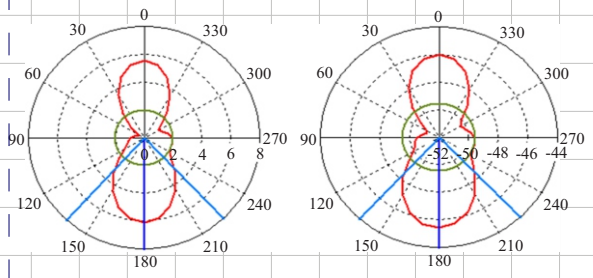
(b)

Fig. 10. Current circulations at pass bands of (a) 4.5GHz and (b)7GHz

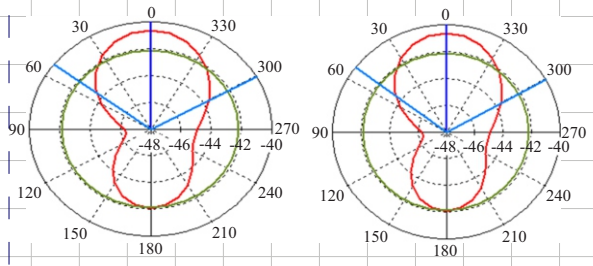
The radiation pathways at varied frequencies are displayed in Fig. 11. Fig. 12 describes the gain of the antenna. The gain increases with increase in frequency. However, there is a sharp decrease in gain at notch bands. The 3-dimensional (Directivity) radiation pattern of the propounded antenna is displayed in Fig. 13 with 6.8dBi at 9 GHz of directivity.



(a) E & H plane at 3.48 Ghz



(b) E & H plane at 5.52 Ghz



(c) E & H plane at 7 Ghz

Fig. 11. Radiation pattern (E and H-plan) at (a) 3.48GHz, (b) 5.52 GHz and (c) 7GHz

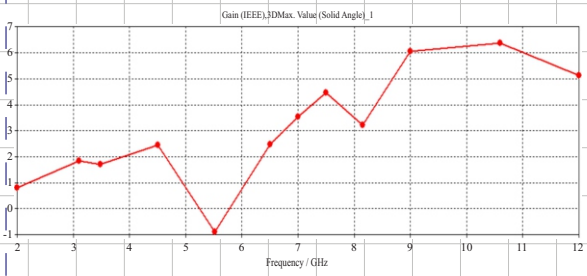


Fig. 12. Gain versus Frequency plot

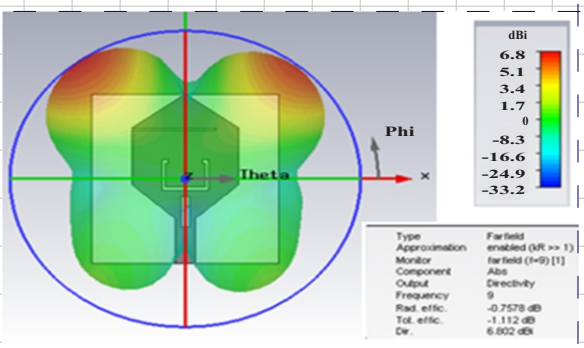


Fig. 13. The 3-dimensional (directivity) radiation pattern

IV. Conclusion

A monopole antenna with triple stop bands features for UWB application has been propounded. This 30 x 28 mm^2 antenna operates in the whole UWB range barring three stop bands. These three stop bands at 3.48 GHz, 5.52 GHz and 8.15 GHz have been actualized by the introduction of slots in radiator and micro-strip feeding line. 'I' shaped slot in radiator stops WiMax band. 'C' shaped cut in the radiator notches WLAN. Inverted 'U' shaped cut in radiator and feeding line blocks the ITU band. The length of cuts is half or quarter of guided wavelength of central frequency of notch bands. The simulated findings confirm the suitability of proposed antenna for UWB communication system to evade interference with above mentioned three narrow bands.

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Device to Device (D2D) Communication: Interference Management Perspective

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Abstract-Evolution of devices has lead mobile generations into revolution. User's demands like gaming, advertisement, content sharing, and downloading speed insist cellular operators to move on new research paradigm that can fulfil these requirements. These demands of users have put cellular operators to pacify the demands in cellular traffic over coming years. Hence, to cope with mentioned problems researchers left with reduction of cell size. The most reasonable method is via Pico cells which demands installation of new base stations. To preclude this overhead cost cellular offloading of data becomes a solution. In such a scenario, Device-to-device (D2D) communication gained its popularity which is offloading of cellular traffic whenever the users are in proximity. Moreover, advantages like spectral efficiency, Quality of Service and cell edge performance have attracted the man more. In this paper, we briefly describe the concept of D2D and different scenario's in which D2D can work. Then, we move towards its hurdles and challenges which are interference management, resource utilization, power control, and mode selection. However, most of the paper is contributed towards interference types, management issues and techniques used by different researchers.

Keywords-Device-to-device Communication, Cellular Users, Interference Management, Spectrum Efficiency, Power Control, Mode Selection

I. INTRODUCTION

Telecom gives birth to old wired telephone system when voice transfer is the only demand. Interference, call drop and poor quality of service (QOS) are the accepting challenges. The above-mentioned data is first generation (1G) then we move towards sending short messages which is fruitful effect of second generation (2G). Addition of features on daily basis comes up with integrated internet service which becomes third generation (3G). Then, high capacity multimedia and World Wide Web access demand lead us to fourth generation (4G) and fifth generation (5G). Fig. 1 shows evolution towards 5G.

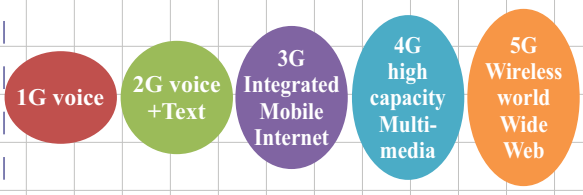

Fig. 1. Evolution towards 5G

These escalating demands of users have moved telecom operators from old telephony systems to today's technologies of third generation partnership project (3GPP) [i],Long term evolution advance (LTE-A) and 5G [ii] but data demands of users are still not pacified because expansion of 5G has provided the need of high connectivity speed with existing mobile networking standards. In such environment researchers found many ways to solve problem like installation of Pico cells which require additional Capital expenditures(CAPEX), operating expenses(OPEX) and base stations. It increases overhead cost. Second method is Green communications. It is a vital technology which implements virtualization, upgrades older system and provide high efficiency. It lies with still one of major disadvantage i.e. system design. Then, researchers go to a new versatile technique i.e. device to device (D2D) communication. On the other hand, increased momentum towards effective design approaches proves that modern age demands are cost effective and need high connectivity traitsas shown in Table I [iii].

TABLE I
YEARLY INCREASED NUMBER OF USERS

Year	World population	Connected Devices	Connected Devices per Person
2003	6.3 billion	500 million	0.08
2010	6.8 billion	12.5 billion	1.84
2015	7.2 billion	25 billion	3.47
2020	7.6 billion	50 billion	6.58

Numbers of users in 2003 were 6.3 billion but connected devices per user were 0.08 which are increased to 3.47 in 2015 i.e. almost four times above. In such a scenario, D2D has paved its way. The revolutionary concept of D2D can be delineated as direct communication between two devices without infrastructure. The concept of base station (BS) will be declined as it will only be a supplier to some users then they will serve to other devices. A BS will give a signal to user then user will connect to other devices. For example on small scale we can understand it by Wi-Fi-direct [iv]while on large scale; In 5G all data is offloaded to D2D pairs without passing through central controller. Hence, comfortably deal with proximity problem.

TABLE II
COMPARISON OF WIRELESS TECHNOLOGIES IN INDUSTRIAL APPLICATIONS

Featured Technology	Standard	Spectrum range	Max. transmission range	Max. data rate	Uniformity of service provision	Application	Backhaul	cost
D2D	3GPP LTE-A	Licensed band	1,000m	1 Gbbps	Yes	Offload traffic	No	No
Wi-Fi direct	802.11	2.4 GHZ	200 m	250 Mbps	No	Context sharing, group gaming	No	No
NFC	ISO 13157	13.56 MHZ	0.2m	424 kpbs	No	Bluetooth, Wi-Fi connection	No	No
ZigBee	802.1504	868/915 MHZ, 2.4 GHZ	10-100m	250 kpbs	No	Home entertainment And control environment monitoring	No	No
Bluetooth	Bluetooth SIG	2.4 GHZ	10-100m	24 Mbps	No	Object exchange peripherals connection	No	No
UWB	802.1503a	3.1-10.6 GHZ	10m	480 Mbps	No	Wireless USB etc.	No	No
Multi-Cell	3GPP (release 9,10,11)	Licensed band for LTE-A	1-2 Km	100-500 Mbps	No	Better coverage	Central controller require	High cost

A. D2D versus Ad Hoc Network

Recently, IEEE 802.11 standard based technologies such as Wi-Fi, Wi-Fi direct [iv]which are wireless local area network technologies (WLAN) and Bluetooth, Ultra-Wide band (UWB), etc. are wireless personal area network (WPAN) technologies which have gained popularity because of its fastest speed and low cost. They use unlicensed band i.e. industrial, scientific, and medical (ISM) radio bands. These technologies are limited to small range because a small interference between devices can break the connection. Further, they are using unlicensed part of band where interference issues are not managed by the cellular user. Hence, interference management is a great hurdle to overcome the advantages of their usage because there is no proper cellular network to control all activities. However, in licensed band interference issues are more complicated but can be managed. Multi-cells technologies are part of licensed band.

Following is the summary of the technologies.

a) Wi-Fi and Bluetooth work in unlicensed part of band. So, a small interference can deteriorate the whole communication.
b) Global synchronization is a major issue in Wi-Fi Direct.
c) Multi-cells technology is backhauled based technology that needs cost and time.

When we review all technologies, we come to an effective result of D2D technology where range, efficiency and cost issue can be minimized. The comparison of the mentioned technologies [v] is given in Table II.

The organization of this paper is as follow: Section II deals with classification of D2D communication. Section III describes implementation of D2D communication.

Section IV analyzes interference management which is the main focus of paper. Challenges and issues are discussed in Section V while Section VI is dedicated to conclusion.

II. Classification of D2D Communication

D2D technique has been classified into two categories as shown in Fig. 2. In-band and out-band. In-band remains inside cellular spectrum while out-band remain outside [vi]. Following is the detailed discussion about it.

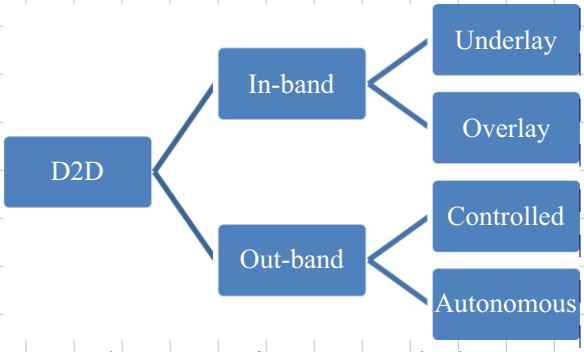

Fig. 2. Types of D2D communication

1) In-Band

It deals with licensed part of band. More work is done on this type of communication [xxv-xxvi] as it is easy to manage interference because it is highly controlled cellular link. Moreover, QOS and spectral efficiency [vii] are highly guaranteed here. In-band D2D is further categorized into two types i.e. underlay [viii] and overlay [ix-x]. In underlay [xi] both cellular users (CU) and D2D users use same spectrum resources while in overlay [ix], [xii-xiii], dedicated resources are used for D2D and cellular users as shown in Fig. 3. Here comes a disadvantage of resource wastage but still due to interference management it is an attracting concept.

2) Out-Band

It deals with unlicensed part of band. Here, it seems easy to handle interference between D2D and cellular spectrum as D2D uses unlicensed part of band [xiv]. Exploitation of the unlicensed band needs another interface to communicate. Bluetooth, ZigBee and Wi-Fi direct etc. are suitable examples of it. Researchers have categorized that out-band falls into two categories i.e. controlled [xv], [xxii] and autonomous [xvii]. In former, researchers prefer to give control to cellular networks [xviii], [xxiii], [xxiv] while in latter D2D communication usage is left on users [v]. Fig. 3 depicts a schematic diagram of D2D types.

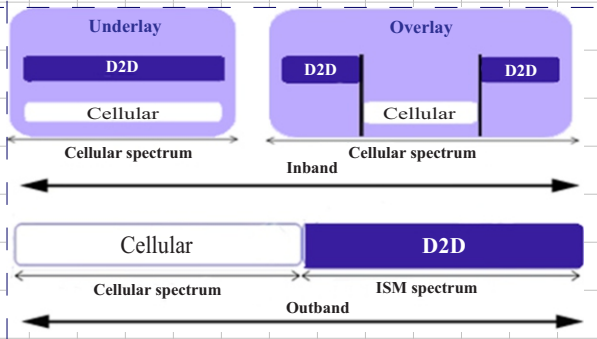

Fig. 3. Schematic diagram of D2D types

Researchers come to decision that core network is required where low data rates applications (short message service and voice calls) are implemented but people are moving towards high data rate demands such as live video streaming, gaming, content distribution, broadcasting and advertisement [xix]. Hence, D2D is a cost cutting and infrastructure less technology and becomes a reasonable solution to increasing demands of users. Moreover, D2D not only increases spectrum efficiency but also increases resource utilization [xx], system throughput [xxi], QOS [vii] and degree of freedom [xxii]. A lot of work has been done in the field of D2D such as machine to machine communication [xxiii], peer-to-peer communication [x], relative positioning system [xxiv], cellular offloading [xix], catastrophic conditions [xxv] and many more as shown in Table III.

III. Implementation of D2D Communication

The need and Implementation of D2D is required as it is well suited in proximity condition [i]. Fig. 4 shows four scenarios' in which D2D can be implemented and is advantageous to implement.

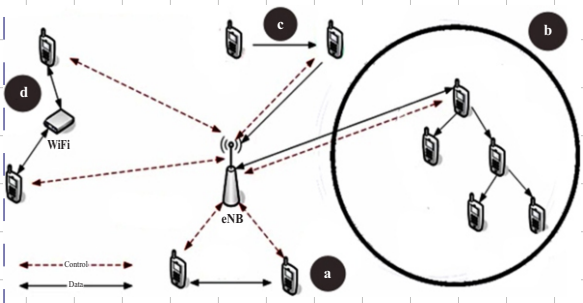

Fig. 4. Different scenario's where D2D can be used

Scenario (a) shows two devices which are in proximity to each other. They are controlled by eNB but data can be easily shared between two without interruption from controller. Issues like latency, load and data sharing can be easily handledby it but limited by range. Scenario (b) shows a broadcasting or advertisement case in which single device is controlled

by eNB. This device broadcasts the information to every other user e. g. we want to send an advertisement to people in a stadium. Scenario (c) represents a case in which device is not in range of controller, here device is connected to eNBand can act as a relay to un-ranged device. Scenario (d) represents a data offloading case to Wi-Fi (an opposite scenario to (a)). D2D is still facing many challenges to overcome such as optimum power consumption, interference and resource utilization. Most of the work in D2D is concentrated on interference management but question is whether the connection is in-band or out-band. Majority of the work is contributed to underlay (type of in-band) i.e. cellular spectrum and D2D uses same resources than overlay (type of in-band) in which D2D is allocated a separate spectrum which results in resource wastage [xl], [ix]. Some researchers are interested to work without-band because here D2D works on entirely different radio resource which is assumed unlicensed part of band (e.g. Bluetooth, Wireless fidelity (Wi-Fi) direct but it has its own limitations of power expenditure.

IV. Interference Management

The Synchronization between D2D pair and cellular user cause serious interference issues to cellular user. Cellular networks are always on priority and hence these issues should be addressed to take advantage of D2D.

Interference results in efficiency degradation. Hence, efficiency of system is an important parameter in D2D communication. It can be achieved by interference management which in return can be controlled by resource allocation, power control and mode selection techniques. It is better to describe the well-known types of interference which are categorized based on network and frequency reuse. Based on network, they are classified into two types: homogenous and heterogeneous interference while based on frequency reuse they are classified into types: Uplink and downlink as depicted in Fig. 5. Further, they fall in four scenarios' which we will describe later in this paper.

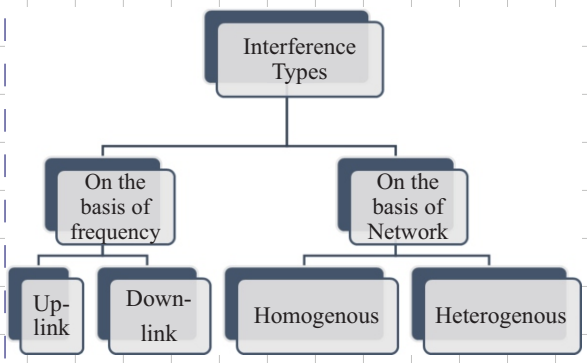

Fig. 5. Types of interference hierarchy

TABLE III
Literature Overview of Objectives Achieved by D2D

Objective	Analytical techniques	Direction		Evaluation	Achieved gain
		Uplink	Downlink		
Spectrum efficiency [22],[26],[27], [28],[29]	-Time division scheme. -channel based grouping algorithm and distance based grouping algorithm. -Massive MIMO. -coalition formulation game and algorithm. -Graph-coloring based algorithm	✓ ✓ ✓ ✓ ✓	✓	-Numerical simulation -system level simulation	-A gain of 31.8% is shown to be attainable at a reasonable transmit signal power -Increases system sumrate by 20%-65% with maintaining resource sharing
Improving QOS[30], [31],[32],[33]	-Rate calculation -clustering algorithm -CILP greedy algorithm -Radio Resource allocation method -joint mode selection and resource allocation scheme -QOS driven optimal power allocation scheme	✓ ✓	✓	-Simulations -Monte-Carlo Simulation -Numerical and simulation analysis	-Increased number of D2D by 50%
Improving system throughput [34],[35]	-Interference Aware Graph Based Resource Alloqation -Time Division Scheduling Algorithm	✓	✓	-Simulations	
Improving security [36],[37]	-security embedded scheme -symbol error probability analysis -stochastic geometry			-Simulations	
Cell Edge Performance [38],[39]	-D2D communication assisted interference alignment (DIA) -Interference suppression area	✓	✓	-Simulations	

A. Classification based on Network

a) Homogenous Interference: It is between two D2D or CU [xli] with in a cell. D2D in a cell can disturb other D2D in the same cell. Moreover, it can disturb other CU present within range as shown in Fig. 6.

b) Heterogeneous Interference: It is between two different D2D or CU from different cells [xlii-xliii] as depicted in Figure 6.D2D from one cell can cause interference to D2D in another cell or CU of another cell.

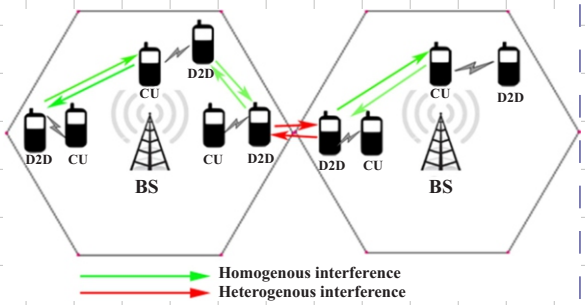

Fig. 6. Network Based interference types

B. Classification based on Frequency

Frequency reuse is additional challenge between D2D and CU for both uplink and downlink. It comes up with four scenarios when D2D is used. Scenario (I) represents the case when frequencies in the uplink are re-allocated to D2D user in the cell, BS receives interference from the D2D user transmitter. Moreover, scenario (II) represents the case in which D2D receiver receives interference signal from the cellular user transmitter. When frequencies in downlink as shown in scenario (III) are re-allocated to D2D user, cellular user receiver receives interference from D2D user transmitter and D2D user receiver receives interference from the BS transmitter is represented by scenario (IV). Here, it is important to ponder that downlink resources are user requirement because of high data demands. More traffic is present on downlink which causes congestion and in return becomes a stumbling block. Further, interference can be understood through its scheme and control level.

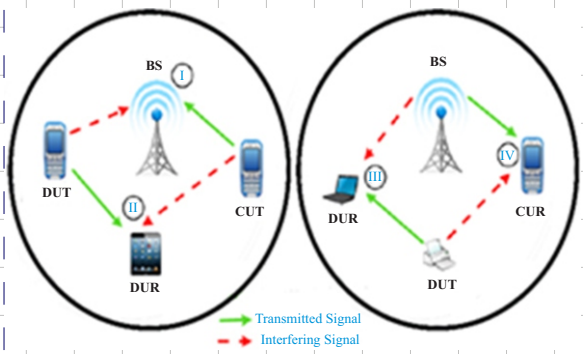

Fig. 7. Frequency based interference types

C. Interference Control Level

Interference control level fall into two categories i.e. centralized and distributed:

Centralized: In the centralized scheme [xliv], a central controller is present which manages channel state information, feedback, quality of service and noise management for individual user in the network. Necessary actions like resource allocation and power control are controlled by it [xlv]. However, it has a disadvantage, as it deals with everyone separately so it requires an extra overhead cost.

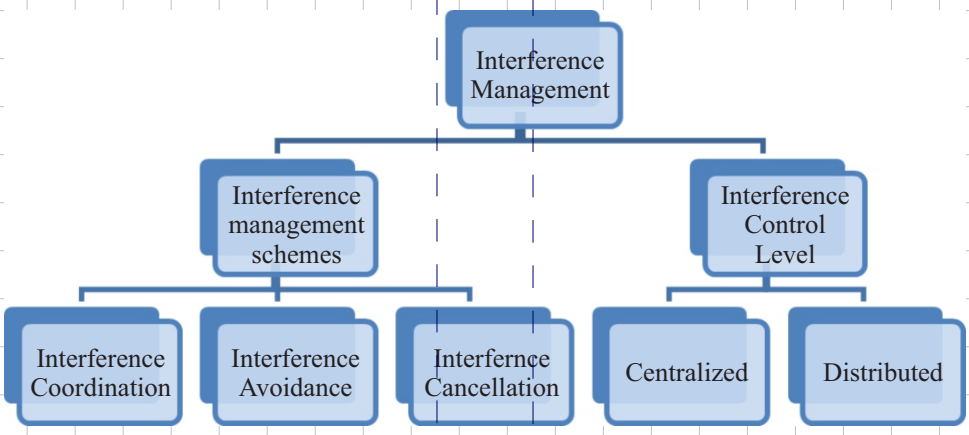

Fig. 8. Interference schemes and control level in D2D communication

Distributed: This type has no central control as every D2D is independent in making its decision [xxxiv]. Hence, it reduces over computational cost [xlvi] and used for large D2D networks.

D. Interference management Schemes

Three interference management schemes are mostly used i.e. Coordination, Cancellation and Avoidance. Authors deal with interference through different strategies as discussed in [xxxix-xl],[lii] in order to increase spectrum efficiency. In [lii] authors have managed interference without having knowing the exact location of the D2D and CU from BS but the distance is known. On the technique, special attention is given to D2D or CU which is allocated, not to use the same resource when it is used by other CU and D2D. Authors of [liii] have discussed two types of interference alignment scheme. First is interference free (IF) scheme and second is interference limiting (IL) scheme. In former, few sub channels of eNB are free and orthogonal space is created while in latter threshold level is designed. Results and simulation have proved that IL is best where large numbers of D2D are present. In [ix] interference-aware interference mitigation algorithm is used. This algorithm controls the interference through network assistance.

Author of [lv] have used the concept of peak and average interference. In first type, signaling overhead increases due to location information while in second type without knowing location D2D users use uplink resources. In[lvi] a limit is set on power transmission so that D2D near base station can communicate directly through it which decreases interference. In [xxxix] interference-suppression-area method is used.The given area is divided into two regions i.e. peak interference region and low interference region. Then, peak interference in DL and UL is controlled through the mentioned technique. Authors of [v] have revealed a new idea of interference temperature. Game theory approach is used to achieve its performance in which BS (leader) sells its interference to D2D while D2D (follower) to increase its payoff; purchase it. Further, two pricing schemes have used i.e. uniform and differentiated. Former deals with small information while latter deals with large information. In [xi] authors have done the work efficiently in an inter-tier environment i.e. user and BS. Dynamic programming is used to control user traffic demands. This technique has proved through numerical evaluation.

A. Resource Allocation

Interference issue can be resolved by another parameter of spectrum efficiency technique i.e. Resource Allocation. Resource allocation is efficient use of resources in term off requency, power and bandwidth. Many techniques like spatial reuse gain, game theory and graph theory are used for better efficiency, good sum rate and better outage probability. In spatial reuse gain concept; if frequency is dedicated to D2D then it cannot be used by any other CU [lx] which is wastage of resource. The techniques we are going to discuss in this paper are graph theory and game theory.

***Game theory**: A* well-known technique has added its attribute to D2D and mitigate hurdle of interference. Price auction [ii], [iii] method is a type of game theory in which most resources are sold to bidders. Authors of [lxi] have discussed bandwidth (BW) allocation through broker, supplier and demander. They are reusing the bandwidth used by users and BS. They offer a price auction scheme to overcome inter and intra-tier interferences. Resource utilization is increased through orthogonal and non-orthogonal sharing mode (NOS). In low interference environment D2D and CU can use same resources through NOS mechanism while in high interference environment orthogonal frequency mechanism is used. It is achieved through Nash equilibrium. Adding to this another price auction technique is Sequential Second Price Auction method in which the block is sold to highest price bidder and pay the price of second highest bidder [lxii]. Author of [lxiii] also deal BS as player and competitor for supplying demand to D2D. Coalition game strategy in [lxiv] is used to achieve maximum utility function on large scale. Authors in [lxv] use Bayesian technique to overcome resource utilization by introducing three market concepts. A matching system is designed to market so that core of the game will not remain empty. Simulation results have proved its performance and achieved sum rate of 20%-65%. Authors of [lxvi] have used the game theory to resolve the problem of energy efficiency and interference by maintaining a coalition between them.

Graph theory: In contrast to game theory, Graph theory is one of the popular methods in showing relationship between networks and different parameters. Authors of [lxvii] and [lxviii] have worked through graph theory in order to achieve optimal performance. They have resolved problem in term of three attributes: cluster, link and resource. Cellular communication and D2D are taken as parameters to draw a relationship and show the interference between them. Another category of graph theory is graph coloring scheme [xxix], same resources are allocated to different D2D pairs. In this scheme, firstly a feedback system is introduced then resources are allocated. Based on defined work, the sum rate and outage probability is improved. A combine work of game and graph theory is presented in [lxix],where a single network and multi D2D users are assumed. Their spectrum efficiency and equilibrium is achieved through both techniques.

B. Power Control

Power control is another technique of resource utilization to mitigate the effect of interference.

TABLE IV
LITERATURE OVERVIEW OF INTERFERENCE MANAGEMENT

Objective	Used Network	Analytical Method	Direction	
			Up-link	Down-link
Interference Coordination[15],[41], [47],[48]		Graph theory -Almost blank sub frames -Power Control Strategy -Self optimization		
Interference Cancellation[49],[50]		-Optimization Algorithm -Greedy algorithm successive interference cancellation		
Interference Avoidance[29],[51]		-Graph Coloring Algorithm -Resource allocation and power control		
Interference management [41],[58], [15],[49],[59],[60],[56], [34],	**-LTE -LTE-A -LTE advance -OFDMA**	-Dynamic Programming Model and Algorithm -Almost blank sub-frames -Graph theory & pseudo-code algorithm -Iterative algorithm -Radio Resource Allocation policy -Low Complexity Heuristic Algorithm -interference aware graph based resource allocation,	✓ ✓ ✓	✓

Different researches are done in uplink and downlink to control the problem of resources utilization. Auction game approach is used in [lxxiv] to control power problem same as [ii-iii]. While, the authors of [xl] have increased network utility through iterative algorithm and scheduling which are interference cancellation (IC) schemes. IC receivers are used for multi D2D and one CU. As every time resources, must be allocated so a scheduling approach is used. Further to solve the scheduling problem, as every time, it is not possible for it to allocate resource. So, iterative algorithm is introduced to resolve the problem. Authors of [lxxv] have considered D2D and CDMA where both are using same resources through iterative algorithm. Stackelberg game [lxxvi-lxxvii] theory approach is used to maximize the number of D2D underlay user with BS and CU. Game procedure takes place in two steps to approach equilibrium. As age is moving towards LTE and 5G, multi-tier system is the increasing demand of present age. Author of [lxxviii] have faced a three-tier interference. To overcome this problem, Network-assisted Device-decided (NDD) methodology is used in heterogeneous environment. This technique involves broadcasting of resources of macro eNB to users. Then, favorite channel is selected. NDD is compared with fixed and network assisted schemes and proves its performance. Throughput is another factor forwhich a lot of struggle is done.

Authors of [xliv] have increased throughput with distributed algorithm. A two-layerapproach is used in which one layer deals with inter call updates and other layer deals with intra cell updates. Leading to throughput, localization and network life time are other tasks need to be controlled in D2D issues. Authors in [lxxix] have added its attributes in D2D through cooperative wireless network localization. The authors have divided the problem of optimization into two stages, infrastructure and cooperation phases.

Distributed power allocation scheme is used to achieve the accuracy of localization and optimal power usage. The author in [lxxx] also works for wireless network but for duplex networks. Ergodic capacity is achieved in this paper. Nonlinear programming method [lxxxi] is used to improve quality of service (QOS) through power control. Authors in [vii] have also dealt wireless network localization but in a different manner. They think that most of the research is far from reality so they work in smaller and divided manner i.e. they have divided the resources in small blocks. Then, buffer is focus in whole paper. Its size is reduced and then scheduling is done as it is previously done by [xxxix]. To prove his results and QOS, OPNET is used for verification. Particle Swarm optimization technique [lxxxii] is used for QOS through gradual remove mechanism for channel assignment and power control.

C. *Mode Selection*

Relays are widely used in D2D communication for interference mitigation, spectrum efficiency and power constraints. They are widely used because interference is a big hurdle in D2D communication. It can be used in overlay and underlay both mode [lxxxv]. Mostly three cases are selected reuse mode, dedicated mode and cellular mode. The authors of [lxxxv] have considered a multi cell scenario with both shared and no relays. It has observed that reuse mode has higher optimal power. Relays help in reducing transmission power. Authors have considered the distance and location of devices and CU. Adding to this, [lxxxvi] have used primal-dual technique to reduce the computational problem while maintaining QOS. The authors of [lxxxvii] have divided the whole area into two regions i.e. inner and outer region. Inner region is specified for CU and outer region is defined for D2D. Graph theory is used here for resource allocation so easily area can be divided into sub areas. Major focus of this work is on average UL edge users and resource allocation to manage interference. It is not always necessary that slots are available for D2D communication so in [lxxxviii] a

TABLE V
LITERATURE OVERVIEW OF RESOURCE ALLOCATION, POWER CONTROL AND MODE SELECTION

objective	Analytical Technique	Direction		Evaluation
		Up-link	Down-link	
Resource Allocation [69],[65], [71],[72],[73]	**-Greedy algorithm & dynamic programming algorithm -QOS resource allocation scheme -Discovery resource allocation scheme -NP hard resource allocation algorithm & iterative algorithm**	✓ ✓	✓	**-simulation -Numerical simulation**
Power Control [83], [84],[44]	**-Fractional Power control -Two layer power control algorithm -Binary Power Control Scheme -Centralized and distributed power control algorithm -Quantum particle swarm optimization -Modeling**	✓ ✓ ✓	✓	**-Simulation -Numerical simulation -Simulation -Numerical**
Mode selection [85],[86], [89],[90]	**-Modeling -deterministic and heuristic algorithm -Distributive iterative algorithm -Guard-zone mode**	✓	✓	**-Network throughput has increased 5.9-6.3 times.**

scheme or technique should be defined to handle such scenario's. Bursty Traffic Model is used when all the resources are occupied by CU. Here D2D has a choice to communicate through via BS or CU. Distributive iterative algorithm [lxxxix] is found to be fruitful solution in multi-antenna condition. Most of the literature in D2D is dedicated towards Single input single output system (SISO) while Multiple Input Multiple Output (MIMO) is used in four antenna environments. Here, to reduce complexity pre-coding scheme is required at each node. Moreover, authors of [xc] have done it through guard-zone based mode selection scheme. It works on the principle of guard radius which makes a zone around users. This method is verified through stochastic technique. The work in [xci] is an area of interest of study as number of users are increasing and our study is mostly related to small areas. The authors have dealt with game theory approach to catch the large distribution of mobile users. Queue state information is used to analyze the threshold level of BS because large number of users can decrease the efficiency of availing services.

V. Challenges and Open Issues

D2D implementation is still far from real world as it is facing many challenges like interference management, power control, resource allocation, modulation format, channel information, energy consumption and many more. One of the biggest challenge of D2D implementation i.e. interference management which already has been discussed in this paper but still some issues are left for future purpose. For example, Cell densification which results from increased number of users. In this concept, pico and femto cells are deployed which decreases transmission power as distance between sender and receiver decreases. It also decreases interference because of reduced transmission energy but increases back haul cost. However, interference becomes challenge when this small cell technology is implemented with underlay (in-band type). Throughout the literature we have focused on single-tier system while interference becomes uncontrollable in multi-tier system. Multi-tier system also depends on threshold noise level which is different in different scenarios. Still some issues need to be addressed after interference as we named before. First, we are going to address modulation format which is the most negligible issue but the most challenging one. It needs to be addressed because it deals with the compatibility of D2D with existing infrastructure. In existing structure of LTE, on downlink side CUs require OFDMA receiver while on uplink side a single carrier FDMA transmitter. So, same receiver and transmitter would be required when we use D2D. Second, channel information which makes an extra overhead cost is big challenge to address. Channel information on uplink and downlink between D2D pairs, D2D and CU, and CUT and D2R gives overhead to system because in conventional cellular uplink channel information is dealt through BS. Third is battery life time which is user's priority and is a post implementation challenge. Whenever CU wake up for connection request it consumes energy of CU. In future, interference from multi cells and multi-antenna concept at BS will be discussed. Moreover, D2D in more complex environment will be addressed.

VI. Conclusion

In this paper, we have done an extensive survey on D2D communication with major focus on interference management either it is in-band or out-band.Interference is a big obstacle in implementation of D2D because it causes severe disturbances to CU which results in performance degradation of CU. To understand D2D, we have discussed basic concepts of D2D. We gave its comparison with adhoc technologies

and why we preferred D2D over adhoc with its advantages. Then, we discussed interference types whether it is based on frequency or network. Moreover, controlling techniques in opinion of other authors is also discussed. In the last section, we have elaborated interference management in term of resource allocation, power control and mode selection.

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Power Optimization using Low-Transition Rate based LFSR Pattern Generator

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***Abstract*-**Dynamic power dissipation has been increased exponentially with the excessive switching of nodes inside the digital electronic circuits. Power dissipation on these circuits are highly input pattern dependent. This work exploits the generation of efficient input patterns with the ability to reduce maximum switching activity in the circuit by using linear feedback shift register (LFSR) technique. This approach is further modified by the insertion of the low-transition density with highly correlated signals in the LFSR-based patterns. The transition between different patterns reduces the substantial amount of switching activity in the circuit. Reduction in transition results the low dynamic power consumption. Power consumption have been estimated by using standard ISCAS 85 and 89 benchmark circuits. The experimental results demonstrate that power can be significantly optimized using this approach.

***Keywords*-**Switching Activity, Digital Patterns Generator, Power Optimization, Benchmark Circuits

I. Introduction

Power analysis of electronic circuit design is a major challenging task due to the accurately analyzing power without the direct information of the design details. With the wide utilization of portable systems, low-power chip design is becoming an increasingly important focus of modern research. Therefore, a suitable power optimization (reduction) approach is very much important in both testing mode and functional to design high-performance circuits, so that reliability and satisfactory performance can be efficiently achieved. In power estimation methods, input patterns play a significant role. Low -power dissipation can be achieved only by focusing on input stream. Digital patterns can be generated from pattern generator such as linear feedback shift register (LFSR), for which different parameters can be observed to produce maximum power reduction without affecting the performance of the circuit. Input pattern generator can be carefully designed to meet all requirements for power reduction.

Several researchers have been proposed to optimize power by reducing the toggle rate of input patterns. A well-known technique was introduced in [i], [ii] to select the LFSR seed for energy reduction. It was analyzed the impact of LFSR's polynomial and seed selection on the core-under-test switching activity. Another approach was proposed for the design of low-transition test pattern generator [iii]. Two LFSRs with different number of registers have been used to control inputs with high transition densities. Based on cellular automata, a low-power pattern generator was proposed in [iv] to reduce the testing power of the circuit-under-test. In [v] the authors used clock gating technique in which odd and even vectors in the scan chain has been controlled by two non-overlapping clocks reducing power by factor of two. Single-input change sequence was generated in [vi] by using ring generator which can effectively reduce the test power. In [vii], the efficient selection of the most suitable subset of scan cells for gating along with their gating values were studied. The authors in [viii], reduced the number of input patterns to obtain the target fault coverage to minimize the testing power. The non-detecting patterns have been filter out by using gate-based logics, however, the experimental result produces with high delay. The power reduction is achieved by increasing the correlation between consecutive test patterns by reducing the switching activity in [ix]. Furthermore, the insertion of intermediate patterns was used by combining two pattern generation schemes in LFSR-based patterns. The LFSR was modified for low-energy consumption by adding weights to tune the pseudo random vectors for different probabilities.

Previously we proposed an accurate power macro-modeling techniques in [x], [xi], [xii], [xiii] that implemented on IP-based digital test systems. In this work, we further continue this research and developed efficient pattern generator for low-power dissipation in electronic circuits. This paper exploits the generation of input patterns with the ability to reduce maximum transition activity in the digital circuits by using LFSR technique. Our approach proposed the insertion technique of low-transition density with high correlated signals in the LFSR-based patterns. Power consumption have been estimated by using standard ISCAS 85 and 89 benchmark circuits. The experimental results demonstrate that power can be significantly optimized using this approach.

The paper is organized as follows. The traditional linear feedback shift register and proposed low-transition rate based LFSR pattern generator is discussed in Section II, and III respectively. In Section IV, the experimental results and discussion is given. The Section V summarizes the work.

II. Linear Feedback Shift Register

A conventional architecture of linear-feedback shift register is used as a pattern generation. It is a shift register whose input bit is driven by XOR gate and it is a linear function of its previous state as shown in figure 1. When LFSR receives clock signals, it advances the signal within the register from one bit to the next most-significant bit. Some outputs of the register are used in XOR configuration to make a feedback input to the registers.

The shift register length is determined by the highest polynomial degree. The locations of the feedback taps of the register corresponds the exponents in the polynomial. The bit values at different taps are added by XOR operation or by modulus 2. The result is a feedback to the input of the register. On every clock signal a new bit appears at the input of the register, while in every flip-flop a bit generates to the next flip-flop.

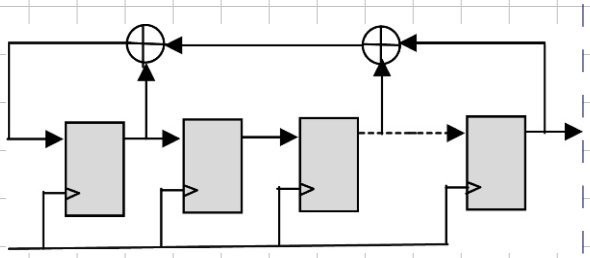


Fig. 1. Conventional Linear feedback shift register

III. LFSR Pattern Generator

In this section, we propose a low-transition rate based modified LFSR technique. This approach elaborates the digital pattern generation scheme by using LFSR into low-transition patterns making them applicable for low-power applications without affecting performance of the circuits. The technique applied on generated patterns with low-transition density between selected pairs of the pattern. Generated pattern stream is then applied to the input of ISCAS 85 and 89 benchmarks of combinational and sequential circuits.

The low-transition rate LFSR pattern generator has n number of flip-flops (A_0, A_1 ..., A_{n-1}) with each time step A_i takes the value of A_{i-1} for $i > 1$. A_0 updates the value to the feedback function f: $\{0,1\}^n \rightarrow \{0,1\}$ and A_{n-1} is the output of the LFSR as shown in Fig. 2. A sequence $(x_i)_{i\in\mathbb{N}}$ is generated by a shift register satisfying the n-term recursion $x_{i+n} = f(x_i, ..., x_{i+n-1})$.

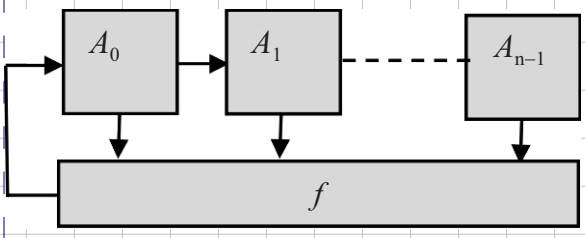


Fig. 2. Feedback shift register

A. Word-wise sequence generation

LFSR is used as a pattern generator consists of several of D Flip-flops, XOR gates in the feedback path and is initialized with a seed value as shown in Fig. 2. Number of bits in the pattern is given by the polynomial which is equal to the number of primary inputs of a combinational or sequential circuit. Patterns are generated by LFSR by using pseudo random in nature with high toggle rate and high transition density. If n is the maximum length of LFSR then it produces an n-sequences, since the XOR of zeros will remain zero and state cannot be changed.

The transition rate LFSR pattern generator used an array of words (b_0, b_1 ,..., b_n) indicates the internal state of the register. The shift operation is implemented by calling the rotation instructions and shift of the value as shown in Fig. 3.

```
Pattern generator sequence of input
pattern ()
   num_gen = 0;
   Generation of randomly signals;
Rshift b_{n-1} ;    -- right-shift by 1
for m← n-1 to n-1 do
rcr b_k ;          -- right roll by 1 with
the use of carry-flag
end for;
```

Fig. 3. Flow of the pattern generator

In case of polynomial of feedback has non-zero coefficients, then the feedback value can be determined by $f_b = a(f_{b0}) + a(f_{b1}) + ... + a(f_{bk})$. There are several non-zeros coefficients of the feedback polynomial stored in f_b. We compute coefficient a and feedback f_b, then count the non-zero bits in a and f_b modulo 2.

Let w is the word size and we assumed $w = 2^n$. The length l of LFSR is divisible by w and $l = w\hat{l}$. The LFSR may be defines a linear mapping procedure from its initial state $(x_0, x_1,..., x_{n-1})$ to output sequence $(x_i)_{i\in\mathbb{N}}$ in (1):

$$V: (x_0, x_1,..., x_{n-1}) \rightarrow (x_0, x_1,..., x_{N-1}) \quad (1)$$

The pattern generator parity check matrix can be expressed in (2):

$$B = \begin{bmatrix} v_0 & \cdots & v_{n-1} & -1 & 0 & \cdots & 0 \\ \vdots & \ddots & & \vdots & & & \\ 0 & \cdots & 0 & v_0 & \cdots & v_{n-1} & -1 \end{bmatrix} \quad (2)$$

According to the coding theory based on LFSR sequences [xiv], the code V can have generator matrix in (3):

$$I = \left(\begin{array}{cc|ccc} 1 & 0 & v_{n,0} & \cdots & v_{N-1,0} \\ & \ldots & & \cdots & \\ 0 & 1 & v_{n,n-1} & \cdots & v_{N-1,n-1} \end{array} \right) \quad (3)$$

We have $(x_0, x_1, \ldots, x_{N-1})\,(x_0, x_1, \ldots, x_{n-1}).I$, i.e.

$$x_c = \sum_{i=0}^{n-1} v_{c,i} x_i \quad (4)$$

The linear representation of the related component x_c in (4) is related to the initial state.

The arrangement of taps for feedback in LFSR can be expressed in arithmetic as a polynomial mod 2. This means the coefficients of the polynomial must be either 1 or 0. In Fig. 2, the feedback polynomial $x^{16}+x^{14}+x^{13}+x^{11}+1$ is taken. In case of primitive polynomial of low-transition rate LFSR has becomes a maximal length. Following conditions are necessary to meet the criteria of feedback polynomial:

- The number of taps should be even.
- The set of taps, taken all together, not pairwise (i.e. as pairs of elements) must be relatively prime. In other words, there must be no divisor other than 1 and common to all taps.

LFSRs can never have the zero value, since every shift of a zeroed LFSR remain as zero. The low-transition rate LFSR must be initialized, i.e., seeded, to a non-zero value. When the LFSR holds 1 and is shifted once, its value always be the value of the polynomial mask. When the register contains all zeros except the most significant bit, then the next several shifts gives the high-bit shift to the low-bit with zero fill. For example, any 8-bit shift register with a primitive polynomial can eventually generate the sequence 0x80, 0x40, 0x20, 0x10, 8, 4, 2, 1 and then the polynomial mask.

B. *Insertion of low-transition density pattern*

In this approach, we introduce a switching mechanism to insert low-transition density signals in the LFSR-based patterns. The Fig. 4 demonstrates this mechanism. Any two consecutive patterns of LFSR are compared with each other to reduces the number of switching activity in the patterns. At any bit location, when transition occurs between two input signals, a pattern generator insert either 0 or 1 (random bit) at the specific position. While for remaining locations, bits remain same as of the previous pattern. In the Fig, the selection of random bit b is made on the base of transition density (TD). Patterns generated with random bit 1 and random bit 0 are stored in the memory.

The selection of pattern is decided by evaluating the value of TD for each newly generated intermediate pattern. A pattern with low-transition density is sent to output and gives new patterns between original pattern pairs. The new pattern is generated from the insertion of random bit at a place of transitions so it eliminates the consecutive switching. Due to this signal insertion mechanism, the improved correlated patterns are generated for the circuit. Mathematically, this mechanism can be expressed in the following example.

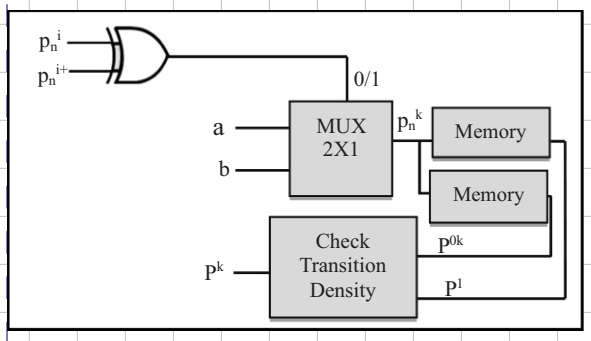


Fig. 4. Schematic diagram for first modification

Assume we have two patterns generated by LFSR as:

$$P^i = (p_0^i, p_1^i, \ldots, p_{n-1}^i, p_n^i) \quad (5)$$

$$P^{i+1} = (p_0^{i+1}, p_1^{i+1}, \ldots, p_{n-1}^{i+1}, p_n^{i+1}) \quad (6)$$

where n represents the number of bits in the input pattern, which is equal to the number of primary inputs of the circuit. All bits are compared with each other from both patterns taking one bit at a time (see Fig 4). b is the random bit which takes value of 0 and 1 in generating P^{0k} and P^{1k} patterns respectively. Transition densities for both new patterns are calculated. Pattern with low-transition density gives output pattern P^k as given in (7) and (8):

$$for\ p_j^i \oplus p_j^{i+1} = 0, \quad p_j^k = p_j^i \quad (7)$$

$$for\ p_j^i \oplus p_j^{i+1} = 1, \quad p_j^k = b \quad (8)$$

Where $1 \le j \le n,\ 1 \le i \le 2^n$ in (11) and (12):

$$P^{0k} = (p_0^{0k}, p_1^{0k}, \ldots, p_{n-1}^{0k}, p_n^{0k})\ \ with\ b = 0 \quad (9)$$

$$P^{1k} = (p_0^{1k}, p_1^{1k}, \ldots, p_{n-1}^{1k}, p_n^{1k})\ \ with\ b = 1 \quad (10)$$

If $TD(P^{0k}) < TD(P^{1k})$ in (11):

$$P^k = P^{0k}\ else\ P^k = P^{1k} \quad (11)$$

where TD is the transition density and it is the ratio of transitions to the number of unit intervals in a serial data stream. For unit interval T with $N(t)$ number of transitions, we have transition density as $TD=N(t)/T$.

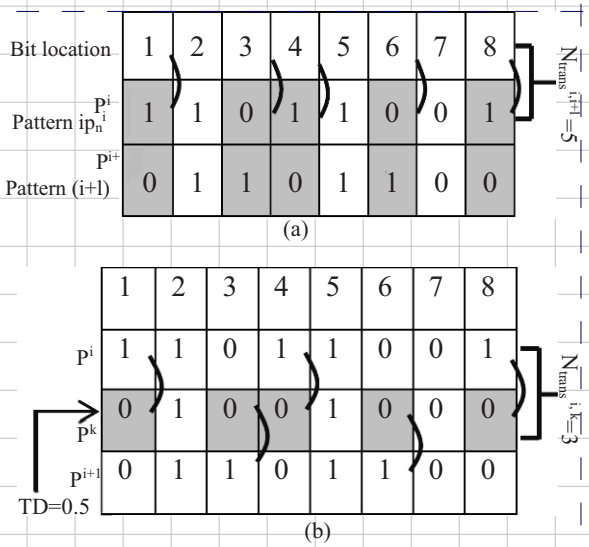


Fig. 5. Example of low-transition densities (a) Placement of bits (b) with 0.5 transition density

In case of switching activity occurs, the XOR output produces 1 and the random bit is inserted at this specific location. When both patterns are generated i.e. pattern with random bit 1 and random bit 0, the transition density is calculated and low- transition density pattern is send to the output. In case of no switching activity occurs, the XOR of the two selected bits give us 0 values. Hence, the newly generated bit remains same as of the previous bit.

IV. Experimental Results

Previously, we have proposed power estimation techniques for system-on-chip (SoC) based systems in [x], [xi], [xii], [xiii]. In this section, the experimental work in evaluated on ISCAS 85 and 89 benchmark circuits. In experiments, power analysis is obtained for these benchmarks circuits. The power is analyzed for these patterns i.e. patterns generated by conventional LFSR and the patterns generated by low-transition pattern generator. Furthermore, the fault coverage is calculated by using parallel fault simulation method. The following summarized steps are used in the power analysis and fault coverage.

1. First patterns are generated using LFSR on Matlab.
2. ISCAS 85 and 89 benchmarks are implemented on Xilinx software using random input patterns generated in step 1.
3. The switching activity is recorded from VCD file in Xilinx. Power is analyzed on Xpower analyzer through generated VCD file.
4. Fault coverage is calculated on Xilinx and faults are inserted in benchmark circuits and parallel fault simulation method is used for detecting the faults.
5. The modified low-transition patterns are generated using same seed as used for general LFSR using Matlab tool.
6. Step 2 and 3 are repeated to get power and fault coverage results for modified patterns.
7. Power is analyzed for ISCAS 85 and 89 benchmark circuits as well as fault coverage is obtained using fsim fault simulator.

The dynamic power is compared with general LFSR and modified LFSR based pattern generators using (12):

$$P_{dyn} = \frac{P_{dyn\_LFSR\_gen} - P_{dyn\_LFSR\_mod}}{P_{dyn\_LFSR\_gen}} \times 100 \quad (12)$$

The fault coverage for ISCAS benchmark circuits are estimated using (13):

$$Fault\ Coverage = \frac{Detected\ Faults}{Total\ Faults} \times 100$$

Table 1 demonstrate the results of power comparison between general LFSR and modified low-transition rate LFSR based pattern generators. The list

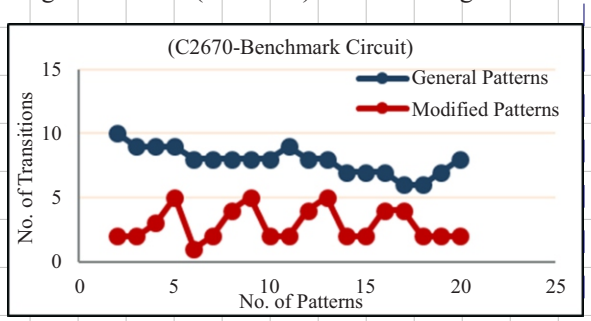
TABLE I
Power Analysis Results for ISCAS 85/89 Benchmarks

Sr. #	Circuit	General LFSR	Modified LFSR	%age Power reduction ΔPdyn
		Dy. Power (mW)	Dy. Power (mW)	
1	C17	0.023	0.014	39.131
2	C432	0.130	0.060	53.842
3	C499	0.210	0.125	40.470
4	C880	0.322	0.214	33.540
5	C1908	0.619	0.419	32.311
6	C2670	0.788	0.612	22.332
7	C3540	0.899	0.521	42.043
8	S27	0.013	0.009	30.762
9	S208	0.110	0.089	19.094
10	S298	0.210	0.116	44.764
11	S344	0.343	0.239	30.320
12	S349	0.398	0.220	44.721
13	S382	0.432	0.310	28.241
Average		0.346	0.227	35.503

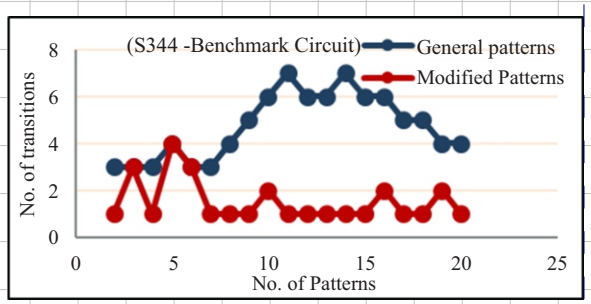
of the ISCAS 85 and 89 benchmark circuits are shown in the second column of Table I. The ISCAS-85 benchmark represents the combinational circuits and ISCAS-89 are the sequential circuits. The dynamic power dissipation of both generators are shown in third and fourth columns. The average power consumed by the general and modified LFSR based pattern generators are 0.346mW and 0.227mW respectively. The percentage of dynamic power reduction is

shown in fifth column of the Table. It is evident from Table I, that the results of our modified pattern generator reduce the average dynamic power till 35.50%. A substantial power reduction has been achieved by using our approach.

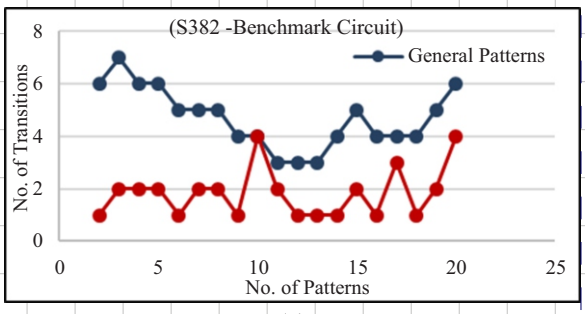
Patterns generator is also utilized for the fault coverage analysis in both digital combinational and sequential benchmark circuits. The results demonstrate that both general and modified LFSRs give 99% fault coverage. However, patterns used for detecting faults are less for modified LFSR pattern generator. The error range varies from (-3.1-+2.8) between both generators.



(a)



(b)



(c)

Fig. 6. Comparison of general patterns and modified low-transition patterns of ISCAS benchmarks (a) C2670 (b) S344 (c) S383

Low-power pattern stream significantly reduces the number of transitions among different patterns. Figure 6 (a),(b),(c) demonstrates the number of transitions occurs by using both pattern generators of different combinational and sequential benchmark circuits. Sample of 20 patterns are randomly chosen and transitions are calculated by taking pair-wise patterns. The general patterns generator has large number of transitions. While by inserting the intermediate patterns, transition between two different patterns reduces the substantial amount of switching activity in the circuit. Reduction in transition results the low dynamic power consumption.

V. Conclusion

This paper presents the generation of input patterns with the ability to reduce maximum switching activity in the circuit by using linear feedback shift register technique. This approach is modified by the insertion of the low-transition density with high correlated signals in the LFSR-based patterns. Furthermore, dynamic power is analyzed with our inserted low-transition density based LFSR technique. Power consumption and fault coverage have been estimated by using standard ISCAS 85 and 89 benchmark circuits. The experimental results demonstrate that power and fault coverage can be significantly optimized using this approach. Currently, we are implementing this approach on more complex circuits.

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Section C

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

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Effect of Varying Nickel Addition on Shape Memory, Mechanical and Corrosion Behaviors of Copper-Aluminum-Niobium Alloys

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Abstract-Shape memory alloys find their applications in automotive and aircraft structures as micro-actuators. In present study, shape memory and mechanical behaviors of Cu-Al-Nb shape memory alloys are investigated with varying Ni addition (0, 1, 2 and 3 w/w %) by bend and tension experiments. It is observed that Ni addition has resulted in gradual improvement of mechanical and shape memory properties. Microstructure observation and xrd analysis reveals that this improvement in properties is because of increased amount of monoclinic 18R type thermo-elastic martensite. Ni containing Cu-Al-Nb shape memory alloy has also shown better corrosion resistance.

Keywords-Shape Memory Alloy, Microstructure, Mechanical behavior, X-ray Diffraction, Corrosion

I. Introduction

Shape memory alloys (SMAs) have a variety of applications. These applications fall in two broad categories, namely, medical (implants) and non-medical [i, ii]. Recent interests are focused to improve the shape memory strain, thermal stability and creep resistance of these materials. SMAs when employed in engineering components in automotive and aerospace industries can improve their performance. The maximum operating temperature of binary Ni-Ti SMAs is limited to 100-120°C [iii, iv]. This has motivated scientists to develop shape memory alloys that are capable of sustaining working temperatures above 100°C to meet the future aircraft design and performance requirements [v]. Ni-Ti-(Pd/Pt) and Ni-Ti-(Hf/Zr) SMAs show some potential for such applications but these alloys also have some shortcomings [vi]: (1) difficult to process, (2) expensive due to constituent elements, also (3) abrupt decrease in the shape memory recovery when the operating temperature exceeds 300°C [vii, viii].

Compared with Ni-Ti-based SMAs, Cu-based SMAs, as the second family of SMAs, are low cost and easy to process. Cu-Al-Ni shape memory alloys have some disadvantages, namely microstructure instability and less ductility [vii, ix, x]. Cu-Al-Nb shape memory alloys, another class of Cu-based SMAs, have good thermal stability, ductility and high shape memory effect [xi]. Martensitic transformation temperature of these alloys is above 200°C which makes them appropriate candidate for actuation purposes [xii]. It is recently shown that the shape memory strain of these alloys shows dependency on annealing temperature and duration of time [xiii]. Different methods have been employed to manufacture Cu-Al-Nb SMAs, among which mechanical alloying is evaluated as a suitable method but no data has been reported about the mechanical properties or shape memory properties [xiv]. Effect of various alloying elements in Cu-Al-Nb system has also been studied along with grain refiners (like B and Ti) [xv]. No quantitative data has been presented about the shape memory recovery of these alloys.

Furthermore, effect of fourth element addition (e.g, Ni) in Cu-based SMAs is found to decrease the plasticity [xi]. However, very little quantitative information exists in literature about these alloys. This lack of key information demands more studies to be carried out to optimize the properties of Cu-based SMAs [xvi]. This work aims to study the effect of varying Ni content on the shape memory and mechanical behaviors of Cu-Al-Nb SMAs. Corrosion behavior of the prepared alloys is also studied.

II. Experimental

A. Alloy Preparation

Four compositions of Cu-Al-Nb SMAs were prepared from high purity element metals by electric arc-melting (locally manufactured arc furnace) in argon atmosphere. The alloy buttons were re-melted

five times to achieve the desired composition. After processed, homogenization was carried out for 6 hrs at 950°C under shielding argon atmosphere in Carbolite Tube Furnace. Chemical composition of these alloys, given in Table 1, was determined by energy dispersive spectroscopy (EDS) analysis.

TABLE I
EXPERIMENTAL ALLOYS, CHEMICAL COMPOSITION MEASURED BY EDS

Alloy	Nominal composition, w/w%			
	Cu	Al	Nb	Ni
Alloy 1	85.9	11.6	2.5	-
Alloy 2	86.2	10.2	2.4	1.1
Alloy 3	84.0	11.8	2.2	1.9
Alloy 4	83.4	11.1	2.4	3.0

B. Hot rolling and Heat Treatment

Alloy buttons were rolled at 900°C into sheets by gradually reducing their thickness from 10mm to about 0.85-0.90mm. These sheets were further cut by diamond saw to prepare samples for bend test and tension test. Samples were solution treated at 850°C for 20 minutes in argon atmosphere and quenched into iced-salt water.

C. Microstructure Evaluation

For microstructure examination, samples were polished using Struers Polishing Machine and etched with a solution of 50ml NH_4OH, 50ml H_2O_2 (3wt%) and 50ml H_2O. Microstructure of samples was observed under an optical microscope (OLYMPUS B061). Grain size was measured by following an ASTM standard E112-10 using lineal intercept method. SEM micrographs were obtained using XL30 (Philips Japan) scanning electron microscope. For phase determination x-ray diffraction (XRD) experiment was carried out in the range of 2θ from 20° to 80° with PANalytical X'Pert PRO diffractometer. Ni filtered Cu-K_α radiations were used for this purpose.

D. Mechanical Properties Evaluation

Hardness experiment was performed using SEIKI DVK-2 (MATSUZAWA Japan) Vickers' hardness tester. Readings were obtained while setting following parameters: load of 1kgf, loading speed of 50μm/sec and dwell time of 10seconds. Samples for bend test had following dimensions: $40\times3\times0.9mm^3$. Annealing treatment, for shape recovery determination, was performed at 400°C for 20 minutes in argon atmosphere. Tension tests were carried out on a100kN universal testing machine (Instron-8501) at a strain rate of 5×10^{-5}/s. Tension test samples had the dimensions shown in Fig.1.

E. Shape Memory Evaluation

Shape memory effect was measured by pre-straining the samples followed by annealing. Pre-strain (ε) value of 3.5% was calculated by using the formula in Eqn. (1):

$$\varepsilon = \frac{t}{(t+2R)} \quad (1)$$

Where t is sample thickness, R is radius of curvature. Recovery (η), representative of shape memory behavior, was calculated by the formula [xii]:

$$\eta = \frac{\theta_s - \theta_t}{\theta_s} \times 100\% \quad (2)$$

Where θ_s is the spring back position, θ_t the heating position.

F. Corrosion resistance evaluation

Corrosion resistance of Alloy 1 (0 w/w% Ni) and Alloy 4 (3w/w% Ni) was investigated in a solution of 0.5M H_2SO_4 by Tafel scan. Corrosion current (I_{corr}) was determined from Tafel plot by Butler-Volmer equation fitting. Then corrosion rate was determined in mills per year (mpy).

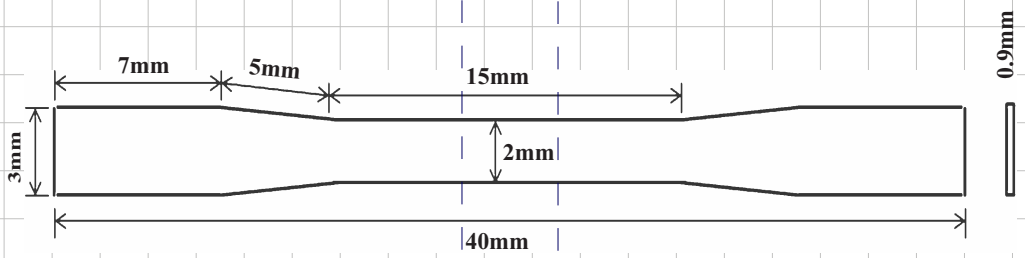

Fig.1. Dimensions of the samples for tensile testing

III. RESULTS AND DISCUSSION

A. Microstructure and Phases

X-ray diffraction (XRD) patterns of Alloys 1-4 are shown in Fig. 2, suggesting the presence of monoclinic 18R martensite (peaks at 2 of 40°~50°) in the studied alloys no matter how much amount of Ni is present. It is clear that in Alloy 1 few peaks are present between 40°~50°. In alloys with 1-3w/w% Ni addition more peaks of monoclinic 18R martensite appear in this range and further intensify. In Alloy 4 with maximum

amount of Ni (i.e. 3w/w%), these peaks of monoclinic 18R martensite are intensified to a great extent. Optical micrographs of Alloys 1-4 in Fig. 3 indicate that Ni addition seems to have little influence on grain size (G). For Alloys 1-4, the grain size is in the range of 151µm-180µm. The presence of martensite can be seen in the optical images. The SEM images of Alloys 1 and 4 in Fig. 4 show twinned martensitic structure in the prepared alloys which is the characteristic of shape memory alloys.

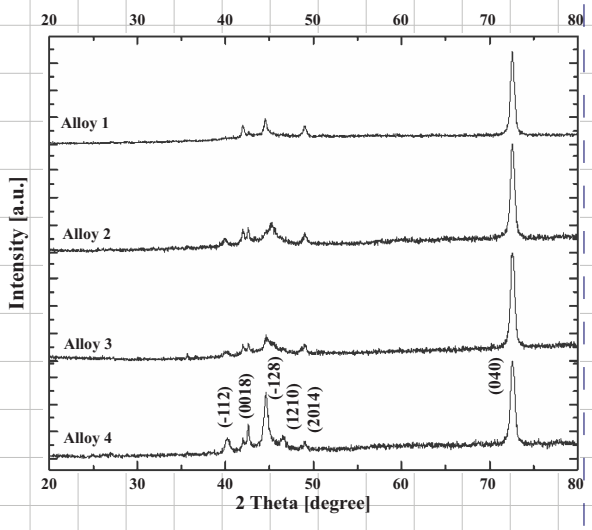

Fig. 2. X-ray diffraction patterns of Alloys 1-4

B. Shape Memory Behavior

Fig. 5 shows variation of shape memory recovery (SMR) in Cu-Al-Nb SMAs with Ni addition. For Alloy 1, the value of SMR for 3.5% pre-strain is 38.2% and it is considerably increased with Ni addition. However, when the amount of Ni is beyond 2w/w%, increase in SMR is slightly dropped. The maximum SMR is 91% for Alloy 4. This improvement in SMR is due to increase in critical stress and increased amount of monoclinic 18R martensite with Ni addition. This thermos-elastic martensite is responsible for shape memory effect [xiii-xiv].

When a shape memory alloy is deformed in solution treated condition stress-induced martensite is formed which demonstrates shape recovery upon annealing. Otsuka and Ren [xvii] has suggested that solid solution strengthening from alloying addition plays a very important role in improving the shape memory properties. In our study, addition of Ni in the Cu-Al-Nb SMAs has resulted in considerable improvement of shape memory recovery.

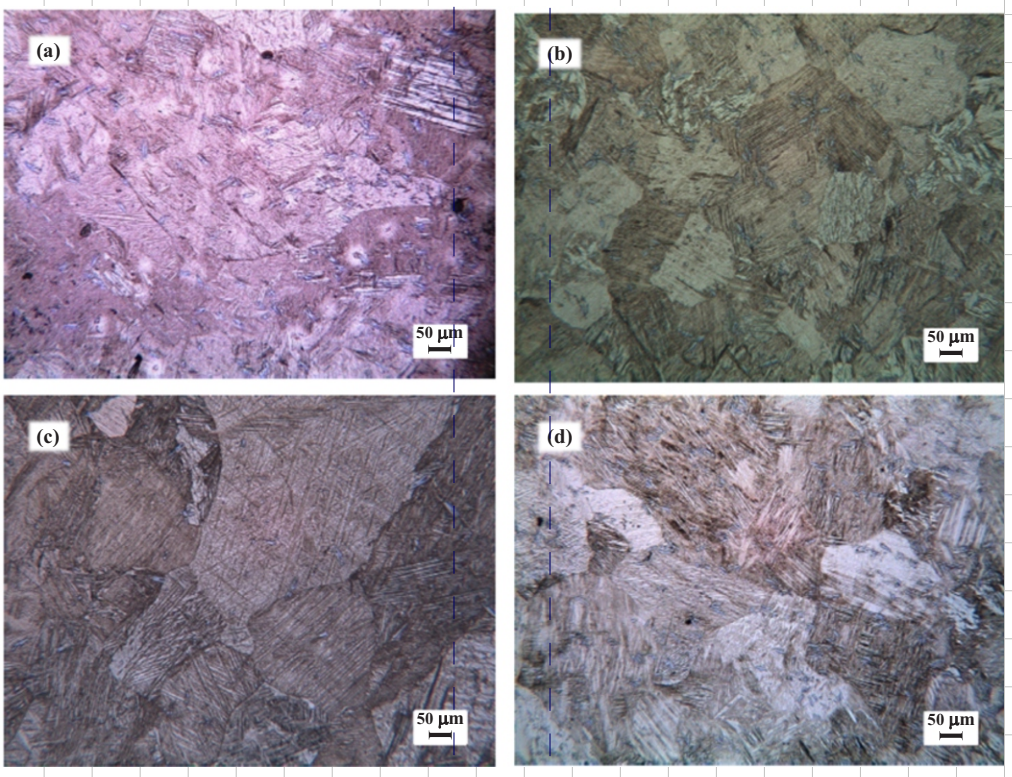

Fig. 3. Optical microscopy images showing martensitic structure, (a) Alloy1, (b) Alloy 2, (c) Alloy 3, (d) Alloy 4

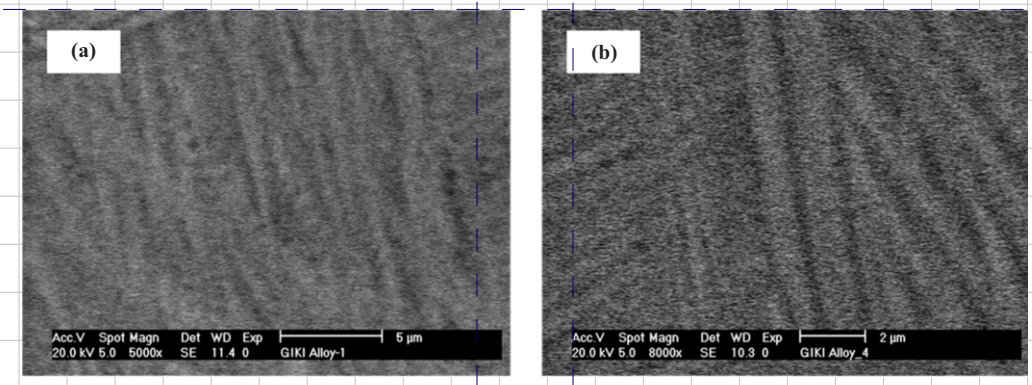

Fig. 4. Scanning electron microscopy images of the studied alloys showing twinned martensitic structure, Alloy 1 (a) and Alloy 4 (b)

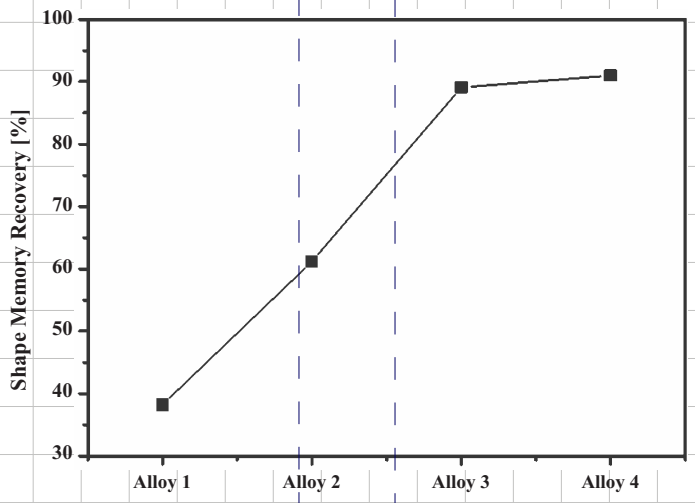

Fig. 5. Variation in shape memory recovery of Alloys 1-4, showing improvement in shape memory recovery with Ni addition

C. Mechanical Properties

Fig. 6 (a) shows engineering stress-strain plots for Alloys 1-4. It shows that yield strength of the prepared alloys is increased from 206MPa to 436MPa with Ni addition. Ultimate tensile strength (UTS) is also improved from 532MPa to 722MPa, while fracture elongation is decreased from 12.1% to 6.1%, as seen in Fig. 6 (b). For Alloy 1, UTS is 532MPa and fracture elongation is 12.1% quite close to the value of 12.7%reported in the literature [xii]. Maximum UTS of 722MPa is obtained in Alloy 4 while the fracture elongation drops down to 6.1%. The increase in strength is related with the solid solution strengthening from Ni addition. These results are in good agreement with the literature [xvii, xviii].

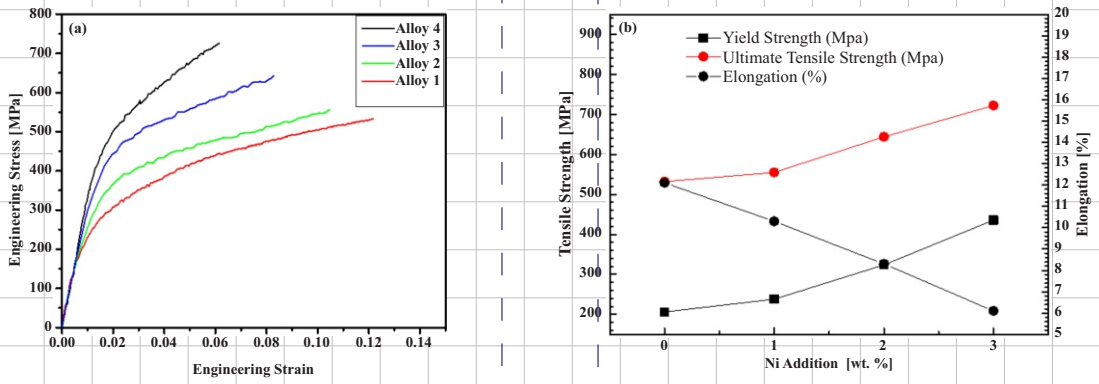

Fig. 6. Stress-strain curves of Alloys 1-4 (a), and variation in ultimate tensile strength and fracture elongation with Ni addition(b)

Hardness experiment results are shown in Fig. 7. Value of hardness for Alloy 1 is determined to be 207HV which is very close to reported value of 213HV in literature [xii]. With Ni addition, it is considerably increased and a maximum value of 238HV is reached for Alloy 4. It has been suggested in literature [xi] that addition of fourth element in shape memory alloys can result in strengthening of these alloys (in our case Ni).

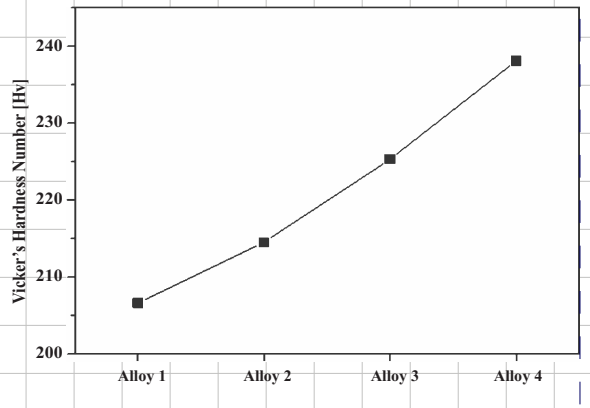

Fig. 7. Variation in Vicker's hardness number for Alloy 1-4, showing effect of Ni addition on hardness

D. Corrosion behavior

Two alloys Alloy 1 and Alloy 4 (with 0w/w%Ni and 3w/w%Ni) were selected to study the corrosion behavior. Corrosion experiments were performed in 0.5M H_2SO_4 solution by Tafel scan and the results are shown in Fig. 8. It is reported that Al content plays a key role in the corrosion protection of Cu-Al based alloys in 0.5M H_2SO_4 [xix]. In present investigation Al content was same in all the four alloys. For corrosion rate determination, first corrosion current (I_{corr}) was calculation by fitting Butler-Volmer equation on Tafel plot. It yielded values of 4.38mA and 2.45mA for Alloy 1 and Alloy 4, respectively. By using ASTM standard G102, the corrosion penetration rate (CPR) for Alloys 1 and 4 were determined to be 54.72×10^3mpy and 21.33×10^3mpy, respectively. These results are also summarized in Table II. So, Alloy 4 is more corrosion resistant than Alloy 1, namely, addition of Ni has enhanced the corrosion resistance.

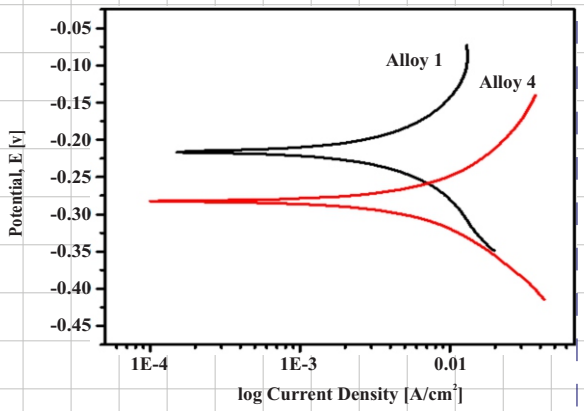

Fig. 8. Tafel scans of Alloy 1 and Alloy 4

TABLE II
CORROSION TESTING RESULTS OF ALLOY 1 AND ALLOY 4

	I_{corr} [mA]	E_{corr} [mV]	Corrosion Rate [mpy]
Alloy 1	4.380	-216.00	54.72×10^3
Alloy 4	2.450	-283.00	21.33×10^3

IV. CONCLUSIONS

Ni addition in Cu-Al-Nb shape memory alloys results in considerable increase in yield strength and ultimate tensile strength. Due to increased yield strength more stress-induced martensite is formed during plastic deformation and demonstrates improved shape memory recovery upon annealing. At the same time, Ni addition improves the corrosion resistance of Cu-Al-Nb shape memory alloys.

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Design, Fabrication and Manufacturing of 100 Ton Hydraulic Press to Perform Equal Channel Angular Pressing (ECAP)

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Abstract-There are different mechanical presses used to deform or press the material through dies to convert into useful product by applying different conditions like temperature, pressure, speed of ram etc. These material deformation techniques not only used to produce finished products but also to increase the strength of the material by introducing severe plastic deformation. Equal channel angular pressing (ECAP) is a technique used to increase the strength of materials by introducing severe plastic deformation through grains refinement. The ECAP die consisting of two channels intersecting at 90 degree was designed and manufactured to perform angular extrusion. The load was calculated through mathematical modelling. A hydraulic press equipped with conventional temperature control furnace, sensor based limit switches, pressure controlled mechanism and with variable speed control was designed, fabricated and manufactured at UET Taxila. The material used for the fabrication purposes is mild steel. The major designing parameters included stroke length, maximum load, pressure, cylinder bore, sealing mechanism and volume flow rate of working fluid. The main parts of the hydraulic press consist of piston and cylinder arrangement, structure or frame, press stand and hydraulic circuit. The press was tested initially for its leakage and then test was performed on Teflon and Nylon materials at 2 tons of pressure. Later on the aerospace grade aluminum alloy 6061 was pressed through ECAP die at a speed of 9mm/sec.

Keywords-Hydraulic Press, Pump, Pressure, Cylinder Bore, Speeds of Ram, Hydraulic Circuit.

I. INTRODUCTION

In the history of science and engineering, the development of engineering equipment is progressing and better machines are being developed with high measures of safety and precautions. To push, pull, rotate or to thrust the material through the dies more efficient and suitable presses have been developed and manufactured [i].

There are different materials deforming techniques (rolling, forging, extrusion, forming, wire drawing etc.) used to produce different kinds of products, extrusion is one of these. Extrusion process is very simple in which specimen is pressed through a die with the help of punch to produce a continuous length with constant or variable cross-section depending upon the shape and size of the die. As pressing of material through presses seem very simple and because of that highly engineering presses were not designed in the past [ii]. Due to the importance of angular extrusion to introduce severe plastic deformation for grain refinement new, better and electronically controlled presses were developed [iii]. Presses are the pressure exerting mechanical machines used for different purposes [iv, v]. The presses can be categorized into following three main types as:

- Hydraulic presses actuates on the principles of hydrostatic pressure.
- Screw presses actuate due to power screws to transmit power and
- Mechanical presses in kinematic elements linkage is used to transmit power [vi-viii].

In hydraulic press fluid is used under pressure to generate force, amplification and transmission. The liquid system shows good characteristics of solid and offers rigid and positive power transmission and amplification. The amplification took place when a small piston transfers fluid to a large piston under high pressure in a simple application. The large amount of energy can be easily transferred practically by amplification also it has a very low inertia effect.

Hydraulic press comprises a pump which generates power for the fluid and this power of fluid is transferred through hydraulic pipes, control valves, connectors and finally to the hydraulic motor which transforms hydraulic energy into mechanical energy or work at the point of interest[ix, x].

Hydraulic presses provide more positive actuation against the input pressure, over other types of presses,

used to accurately control the force and pressure that is available during the whole working stroke of the ram [xi]. The hydraulic presses are very useful and effective when very large magnitude of force is required to process the material[xii, xiii].

The hydraulic press is much appreciated device in laboratories and workshops particularly for material deformation, testing and press fitting operations. To carry out equal channel angular pressing experimentation, it was decided to design, fabricate, and manufacture a hydraulic press with a capacity of 100 tons using locally available material. It not only saved the money, if imported from abroad, but enhanced technical knowledge about press manufacturing, designing and fabrication[xiv].

II. Design Methodology

Hydraulic power systems were designed according to the requirements of ECAP. The main issue of designing such system was to rearranging the required performance parameters of the system into hydraulic pressure system, volume flow rate and then comparing these performance parameters to the system to endure operation. The principal designing parameters included the piston stroke, maximum load, cylinder bore, volume flow rate of the working fluid and system pressure. The important designing components included hydraulic cylinder, hydraulic circuit and main structure of the system known as frame.

III. Designing of Component

A. Hydraulic cylinder

The shape of hydraulic cylinder is of tube-shaped in which piston slides due to the hydraulic fluid pumped into it with hydraulic pump. The design requirements of hydraulic cylinder included end cover plate, minimum wall thickness of the cylinder, thickness of flange and specification, sizes and number of bolts[xv].

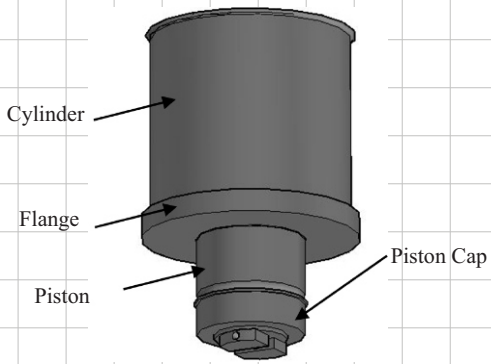

Fig. 1. Isometric view of cylinder and piston

The determination of cylinder area, minimum wall thickness and cylinder bore depend upon required output force of hydraulic cylinder and available hydraulic pressure.

Wall thickness 't' of hydraulic cylinder was computed using equation 1 which was equal to 22.8 mm.

$$t = r_i\left[\sqrt{\frac{\sigma_t}{(\sigma_t - 2P)}} - 1\right] \quad (1)$$

where

r_i = Internal radius of cylinder =0.7 m
P = Internal fluid pressure = 50 Mpa
σ_t = Tangential stress =480x10^6 Mpa

B. End-Cover Plate of Cylinder

Equation 2 was used to determine thickness 'T' in mm of the end cover plate which is fixed at the top of the cylinder and was subjected by a uniformly distributed internal pressure.

$$T = KD\sqrt{\frac{P}{\sigma_t}} \quad (2)$$

Where:
D = Diameter of end cover plate (m)
K = Coefficient depending upon the material of plate
P = Internal fluid pressure (Mpa)
σ_t = Design stress of the cover plate (480 Mpa)

The thickness 'T' of the end cover plate was found to be,
T = 40.5 mm

C. Cylinder Flange

The cylinder flange may fail due to pressure exerting at it in tensile nature [xvi, xvii]. In designing the cylinder flange, its minimum thickness 't_f' is to be determined using bending theory. Cylinder flange was an essential part to place at the top of cylinder for tightening purpose. Two types of forces were very important for designing point of view; one was the pressure of fluid and second was its tendency to detach the flange due to sealing and it was restricted by the stress induced in the bolts [xviii]. This force can be determined by Equation 3 and its value is 6.5x10^4 N.

$$F = \frac{\pi D_s^2}{4}P \quad (3)$$

where:
D_s = outside diameter of seal =175 mm

D. Determination of Flange Thickness

Applying bending theory, the thickness of flange was obtained along the weakest section A-A as shown

inFig. 2.

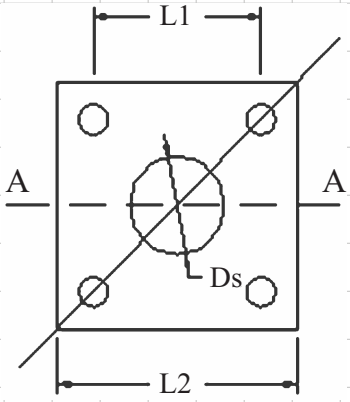

Fig. 2. Sketch of square flange

L1 is the distance between holes centers and L2 is the overall length of cover plate. The bending is developed due to fluid pressure inside the cylinder and the forces in the bolts. The equation 4 was used to determine the flange thickness which was found equal to 60 mm.

$$T_f = t_f = \frac{6M}{b\tau} \quad (4)$$

where:
b=Width off langeat section A-A 40 mm.
τ= Shear stress of flange material 480 Mpa.
M= Resultant bending moment 6512.5 N-m.

E. Design of piston and rod

The piston rod was influenced by a number of factors such as the force acted upon due to compression, fixing condition of cylinder itself, the stroke length over which the load was to be applied and strength of piston rod. So the column size and dimensions of the piston rod should sustain these loading conditions. The piston rod is also aligned with the center line of the cylinder bore.

Keeping in view the above mentioned parameters, the piston rod was selected 95 mm in diameter.

F. Selection of Seals

In hydraulic system sealing is a very critical issue. The fluid in hydraulic system is compressed at very high pressure, the sealing plays a vital role and is very important. Under different operating conditions of speed and pressure, seals are used to avoid any kind of leakages in the system. Different sealing mechanisms are used in hydraulic system for static seal, the groove and ring principle is used to make sealing affective. The groove dimension is based on the compression of the O-ring in one direction and expansion to the other direction when compressed. Under this principle, the O-ring is compressed 15 -30% in one direction and equal to 70-80% of the free cross-sectional diameter. For this purpose the groove dimension of 6 mm x 5 mm was identified for the sealing purpose.

G. Frame Design

The frame provides a rigid support for the hydraulic unit placed over it. The units and all other related parts were mounted on it during all working environments and conditions [viii]. The column of the frame is directly under the condition of tensile loading. So columns are designed using column theory. The base plate of the system on which sample is placed and pressed is under the action of pure bending. The lower and upper plates provide a direct point of contact with the sample being compressed. Due to equal and opposite couple in the same plane, these are under pure bending stress. So the design of these plates is based for the determination of maximum bending moment (M) and the larges value of shear force (V) applying beam theory. The value of maximum bending moment was determined equal to 7.5×10^4N-m and largest value of shear force was found equal to 32×10^4N.

H. Section Modulus

The section modulus of the plates was determined using values of shear force (V*)* and bending moment (M). The minimum thickness (t) of the plates was determined to be 40 mm using following equation.

$$t = \sqrt{\frac{(6M)}{\sigma b}} \quad (5)$$

Where;
M= Maximum bending moment, 7.5×10^4N-m;
$b = 600\times10^{-3}$m;
σ = 480×10^6PMa

IV. Pump

The maximum fluid discharge including a factor of frictional loss was determined equal to 59.5×10^6 N/m^2. A four stage solenoid actuator was attached with the pumping system, The pressure can be changed with the help of this solenoid actuator.

V. Detail Manufacturing Procedure

Two MS plates 435 x 435 x 40 mm^3 were purchased; machined and converted into final required dimensions. Four MS rods 60mm diameter and length of 1000 mm were purchased, machined and fixed with the lower and upper plates. The frame for the system was fabricated with MS angle iron of 50 x 50 x 4 mm. MS pipe of Φ160 mm with Φ100 mm internal diameter was purchased, bored and lapped to Φ120 mm on the Lathe machine.

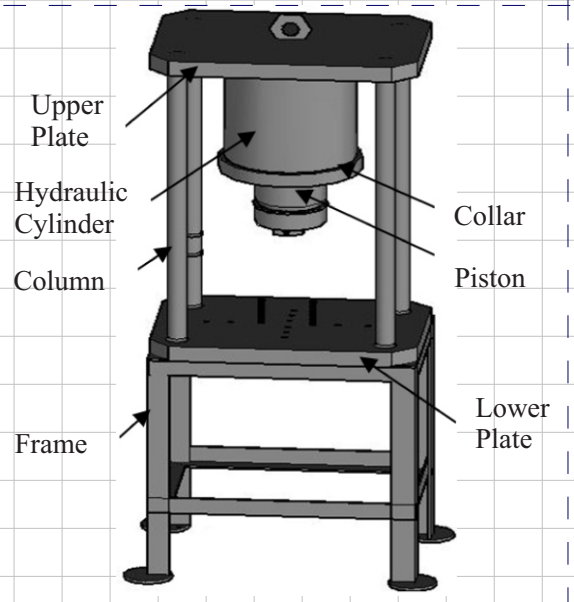

Fig. 3. Isometric view of Hydraulic press with bed

The piston and cylinder were assembled and welded with the top plate. Two limits switches were also fixed with one of the vertical columns to control the motion. Two house pipes were also fitted with the cylinder for the flow of liquid. The complete assembly of the hydraulic is shown inFig. 3.

VII. Testing Performance

The testing of engineering components/system is a normal routine after their manufacturing. Also it is part of the design procedure to test the components or system for their performance. Different kinds of tests were performed to check strength, leakage, quality, repeatability, to see that it satisfied its functional requirements. The leakage test is very important for hydraulic presses. The test was started by priming the pump and then fluid was pumped without any load for at least three hours. The hydraulic press then was tested by applying a load of 15 kN on two open coiled helical springs having spring rate 10 N/mm. The springs were arranged in parallel between plunger and base plate. The springs were compressed axially for a length of 70 mm. The load was applied for two hours to test leakage and no leakage was observed.

VIII. Calibration

The accurate and correct working of equipment depends upon its fine tuning and calibration performed according to some standard. There are two different techniques used for the calibration of hydraulic presses; one is hollow load cell and second is thread bar. This hydraulic press is calibrated using thread bar method according to the ISO standard 7500-1. With the help of thread bar method, different accessories and their influence on uncertainty of calibration were analyzed. A load cell of 100 tons was used for calibration. The calibration was performed with loading force capacity up to 200 MPa and the uncertainty was found only 0.2% of the load applied.

IX. Conclusion

A 100-ton hydraulic press was designed, fabricated, manufactured, and calibrated. The press was tested to ensure adaptability and conformability. The hydraulic press was found to be satisfactory at a test load of 40ton. The press was also tested at different pressures starting from 20 Mpa to 200 Mpa. Any leakage or drawback for not found during operation. This hydraulic press is now available in Fracture Mechanics lab of the mechanical engineering department and is being used by different research groups.

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Comparison and Effects of Longitudinal and Transverse Cracks on the Mode Shapes and Natural Frequencies of Y-Junction Pipes

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***Abstract*-**Plants and Industries are needed to give continuous output without any disruptions. Pipes are integral part of plants, specially of Process industries for the purpose of transporting fluid. This fluid flow causes vibrations and may trigger resonance which will damage the pipes. However, If the frequencies of vibrations and the shapes of the pipes are continuously monitored and compared with the natural frequencies and mode shapes of the pipes respectively, then such damages can be detected at early stages and can be prevented from becoming catastrophic. In this work, longitudinal and transverse cracks are introduced, in 3 cases of Y-Junction Pipe having different junction angles between two inlets, using fatigue/hairline crack technique in ANSYS, APDL® and their effects on the natural frequencies and mode shapes are studied. It is concluded that mode shapes do not show significant change under the effect of cracks, however change of natural frequency is more in longitudinal cracks as compared to the transverse cracks.

***Keywords*-**ANSYS, Y-Junction pipes, Natural Frequencies, Mode Shapes, Crack.

I. Introduction

Investigation of the effects of cracks on dynamic characteristics of systems/pipes has been studied in [i-xvi]. During manufacturing of pipes, the finishing processes and the uneven distribution of material causes the mistuning in piping systems. The modal characteristic which is function of dynamic parameters is very sensitive to such changes [i-v]. Modal characteristics are directly related to structural and material properties of any structure [vi-viii]. Because, whenever material is removed or is unevenly added, the modal characteristics changes [ix-xi]. These changes can directly be related to tacking of damage growth in any operating structure [xii-xvi]. So in this research work, different pattern of mistuning is applied on structures and along with that crack at different depths and locations have also been modeled. The damage is then detected using change in natural frequencies and the mode shapes.

III. Modal Analysis of Y-Junction Pipes

Modal Analysis details can be found in [xvii] and included here for the sake of completeness. [i] For a discrete dynamic system, the general equation of motion can be given as:

$$[M]\{\ddot{U}\} + [C]\{\dot{U}\} + [K]\{U\} = \{F(t)\} \quad (1)$$

Where:

$[M]$ = Structure mass matrix,
$\{\ddot{U}\}$ = Acceleration vector,
$[C]$ = Structure damping matrix,
$\{\dot{U}\}$ = Velocity vector,
$[K]$ = Structure stiffness matrix,
$\{U\}$ = Displacement vector,
$\{F(t)\}$ = Forcing function.

Assuming free vibration and ignoring damping,

$$[M]\{\ddot{U}\} + [K]\{U\} = 0 \quad (2)$$

For a linear system, free vibrations will be harmonic of the form:

$$\{U\} = \{\phi_i\}\cos(\omega_i t) \quad (3)$$

where:

$\{\phi_i\}$ = Eigenvector representing the mode shape of the i^{th} natural frequency,
$\omega_i = i^{th}$ natural circular frequency (radians per unit time),
t = Time.

For harmonic vibrations, Equation 3 becomes

$$\{\phi_i\}[-\omega_i^2[M] + [K]] = \{0\} \quad (4)$$

Equation 2 is satisfied if either $\{\phi_i\} = 0$, or $-\omega_i^2[M] + [K] = 0$. Ignoring $\{\phi_i\} = 0$, the second option gives:

$$|-\omega_i^2[M] + [K]| = 0 \quad (5)$$

The solution to Equation 3.3 can be found in terms of eigenvalues (ω_i^2) and eigenvectors ($\{\phi_i\}$) [xvii].

IV. Modelling

Three Y-junction models were developed having different angles between the inlets.

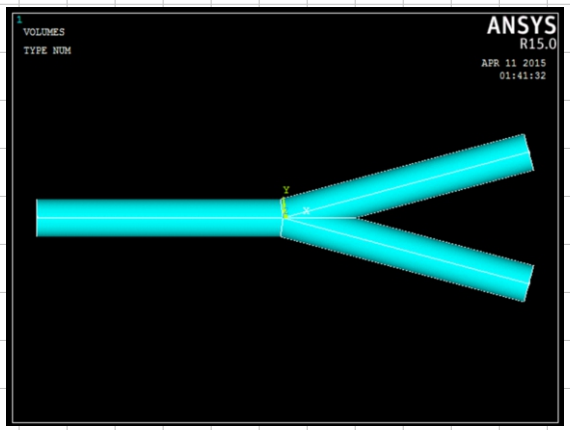


Fig. 1. Case 1, 30° junction angle between inlets

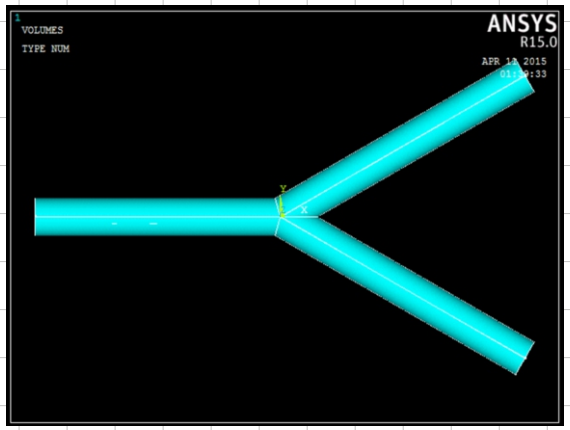


Fig. 2. Case 2, 60° junction angle between inlets

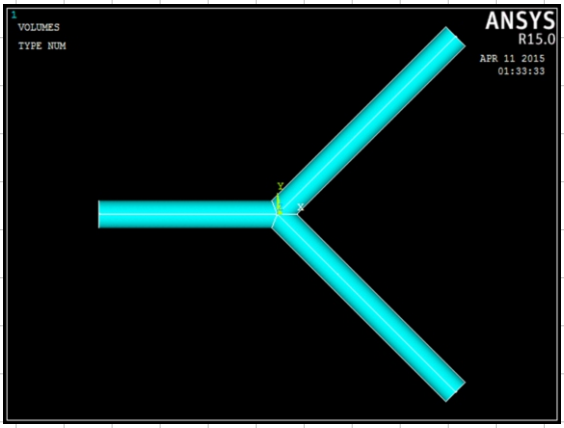


Fig. 3. Case 3, 90° junction angle between inlets

Purpose of this research is to investigate the effects of the crack on the natural frequency of the pipes. Crack free model will be taken as reference and then models with cracks will be compared from reference. Longitudinal type crack will be propagated on the junction of the pipes for the analysis. There are several techniques of crack modelling being taken up by the researchers, some of which are as follows:

a: Fatigue or Hair Line Crack
b: Material Removal Crack
c: Smeared Crack
d: Lumped Mass Crack

Fatigue or Hair line Crack method is used here for crack modelling. In this technique, model is design in such a way that we get several volumes having their own separate nodes. These separate nodes are all merged together except for some which behave as crack during the analysis phase.

There are two types of cracks under consideration.

- Transverse Cracks
- Longitudinal Cracks

Transverse Cracks which are perpendicular to the pipe axis are called transverse cracks. Longitudinal Cracks which are parallel to the pipe axis are called longitudinal cracks.

V. Simulation Iterations

Simulations are designed to be done only on specific locations to get accurate results. Locations of all the experiments are mentioned in the table below.

TABLE I
Design of Experiments

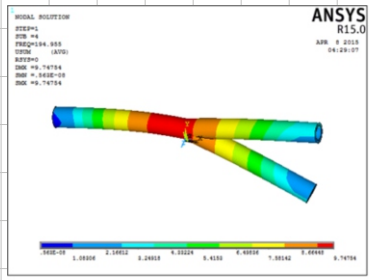
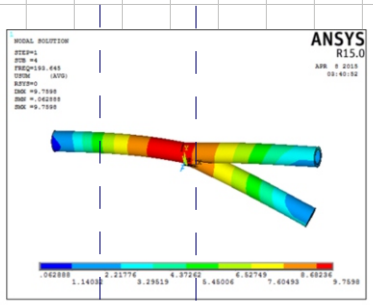
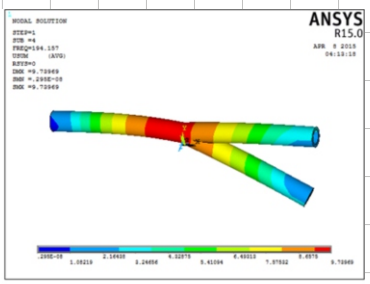
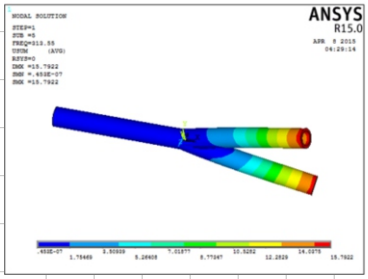
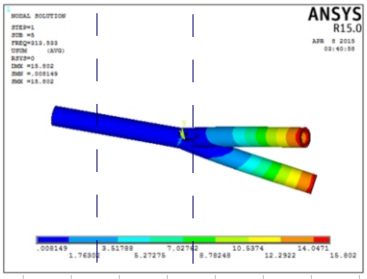
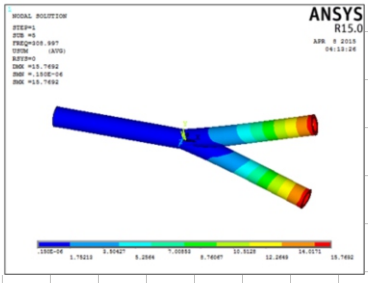
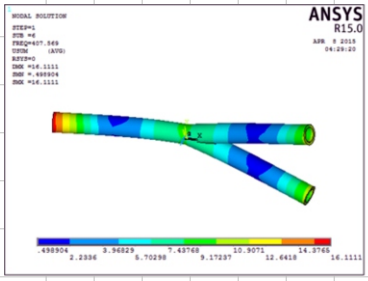
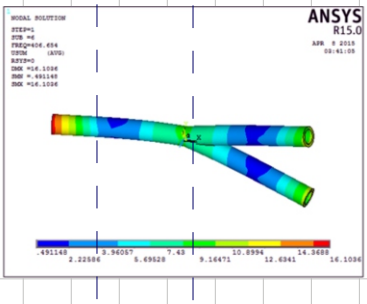
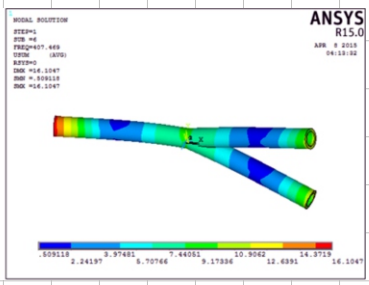
EXPERIMENT NO.	CASE	CRACK TYPE	CRACK DEPTH (A/D)
1.	CASE 1 (30 DEGREE JUNCTION)	TRANSVERSE TYPE	0.0
2.			0.2
3.			0.4
4.			0.6
5.			0.8
6.			1.0
7.		LONGITUDINAL TYPE	0.0
8.			0.2
9.			0.4
10.			0.6
11.			0.8
12.			1.0
13.	CASE 1 (60 DEGREE JUNCTION)	TRANSVERSE TYPE	0.0
14.			0.2
15.			0.4
16.			0.6
17.			0.8

18.			1.0
19.		LONGITUDINAL TYPE	0.0
20.			0.2
21.			0.4
22.			0.6
23.			0.8
24.			1.0
25.	CASE 1 (90 DEGREE JUNCTION)	TRANSVERSE TYPE	0.0
26.			0.2
27.			0.4
28.			0.6
29.			0.8
30.			1.0
31.		LONGITUDINAL TYPE	0.0
32.			0.2
33.			0.4
34.			0.6
35.			0.8
36.			1.0

VI. Results & Discussion

Modal analysis of the pipe is done in ANSYS, APDL and mode shapes along with the data related to frequencies is gathered from there. It can be seen after through comparison that crack propagation does not affect the mode shapes of the pipe junction.

TABLE II
MODE SHAPE COMPARISON OF CASE 1

Mode Shapes No.	Reference Model	Transverse Crack	Longitudinal Crack
IV			
V			
VI			

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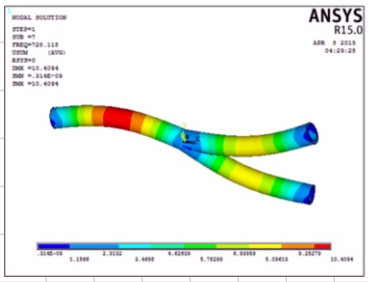

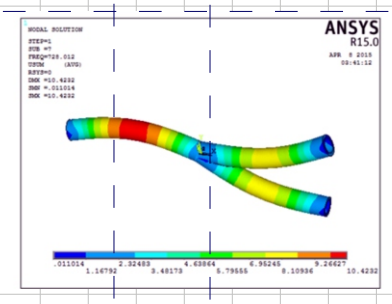

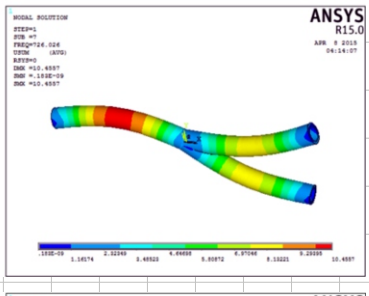

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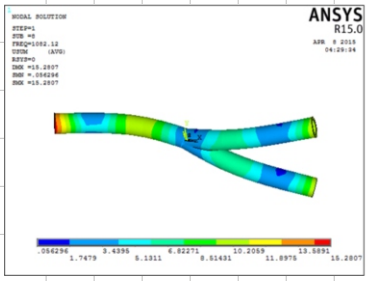

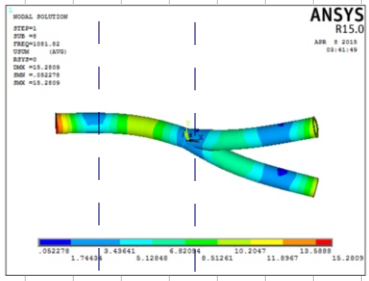

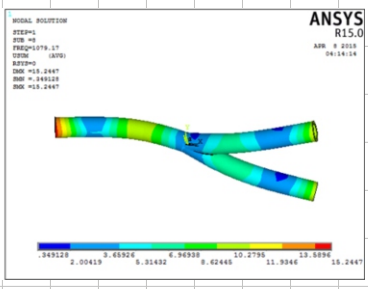

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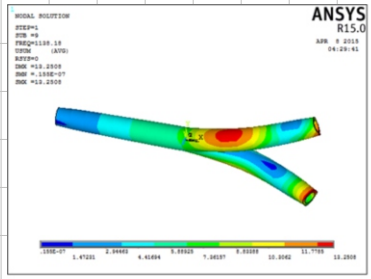

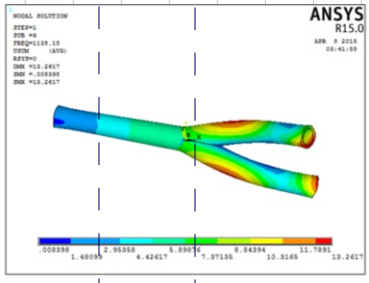

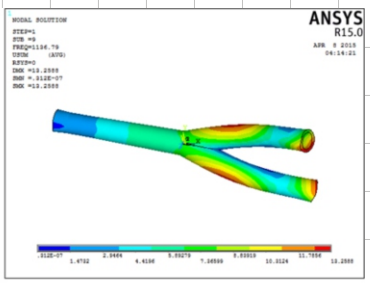

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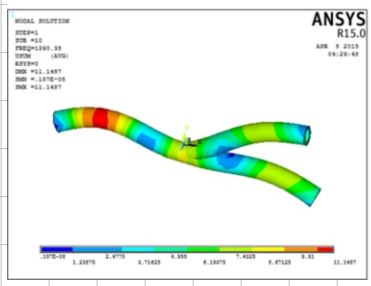

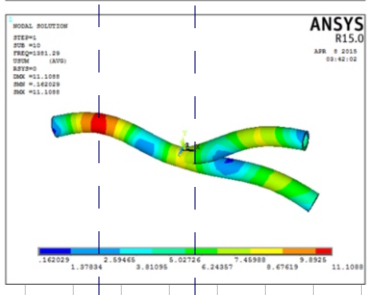

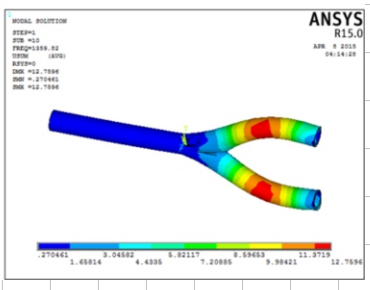

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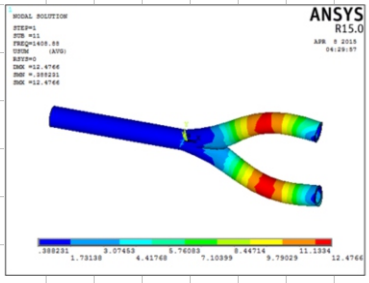
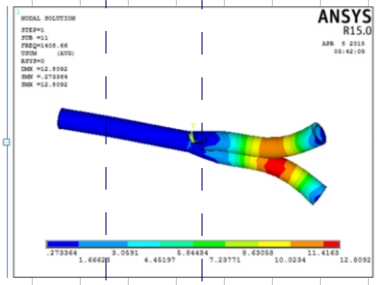
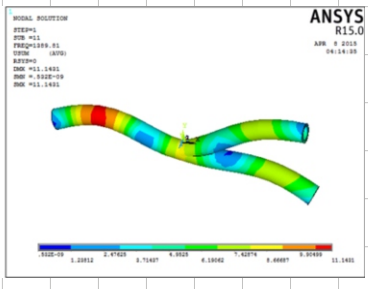
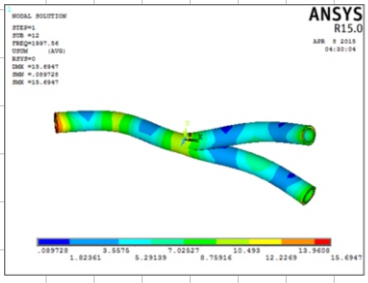
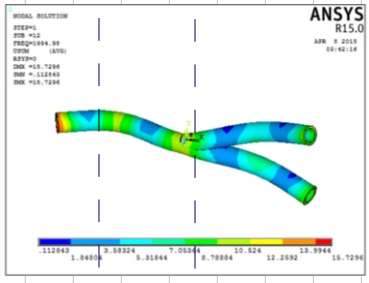


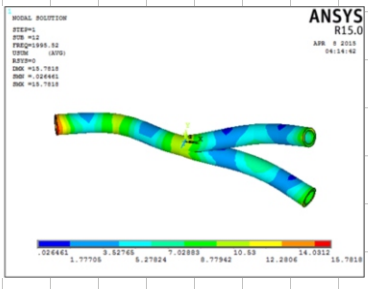




XII







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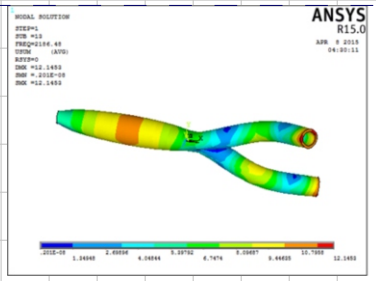

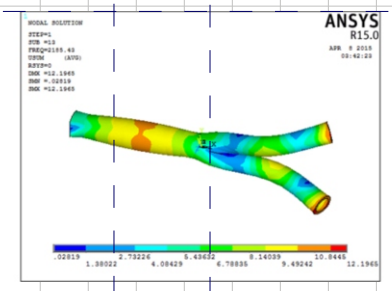

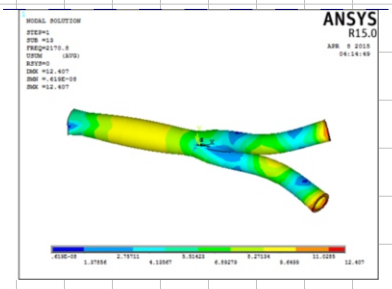

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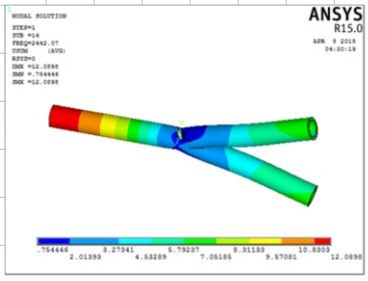

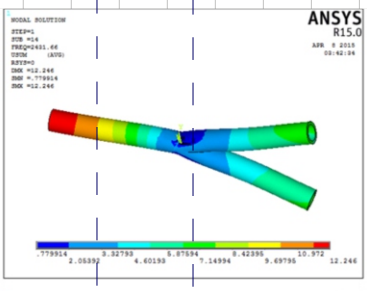

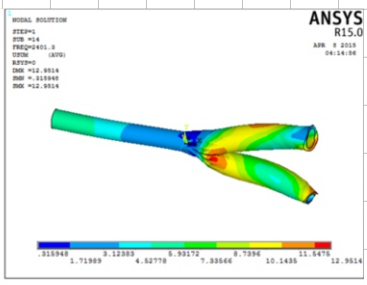

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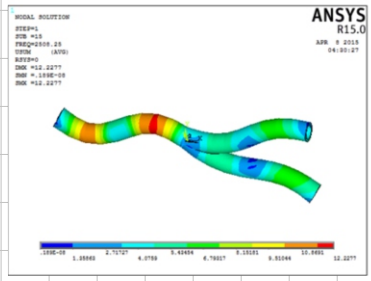

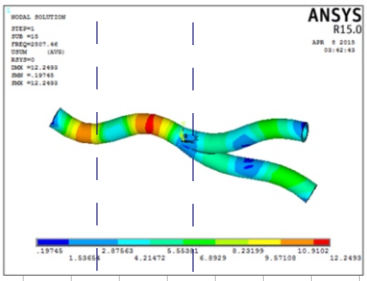

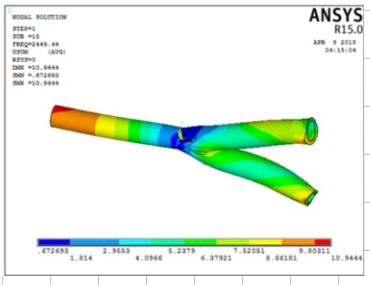

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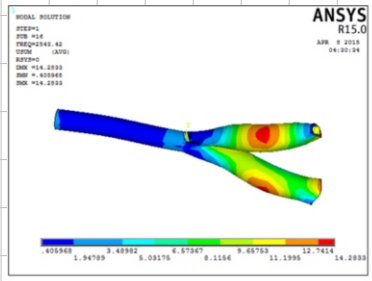

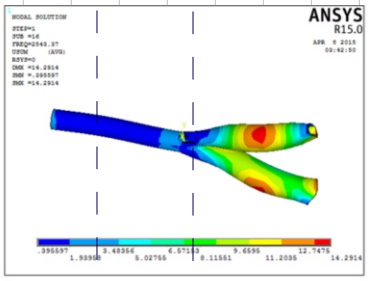

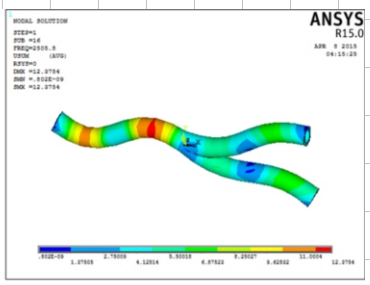

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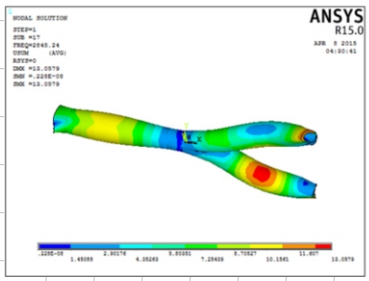

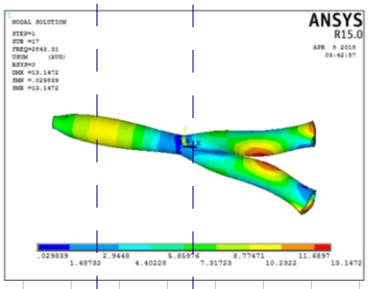

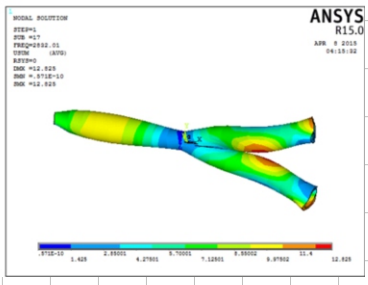

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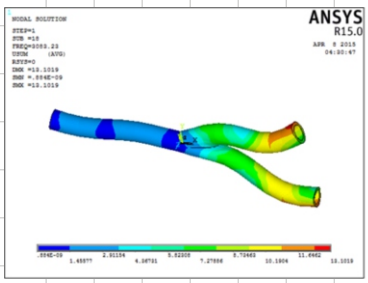

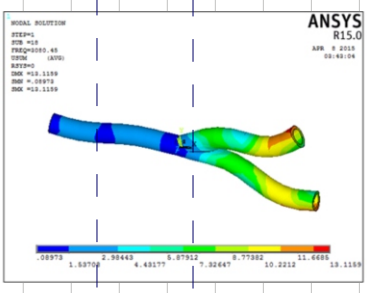

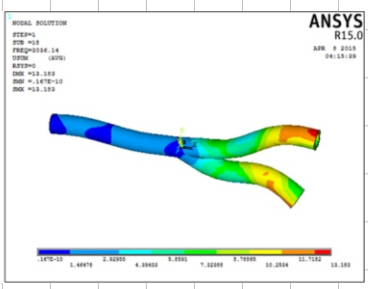

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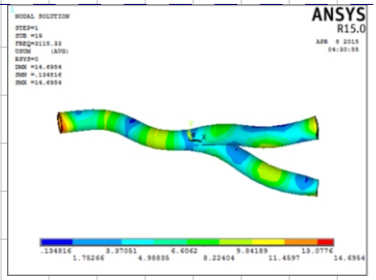

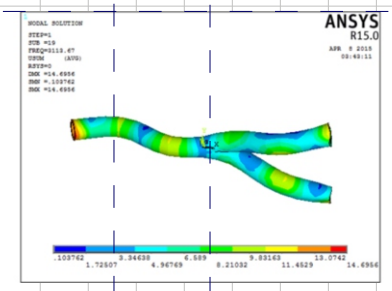

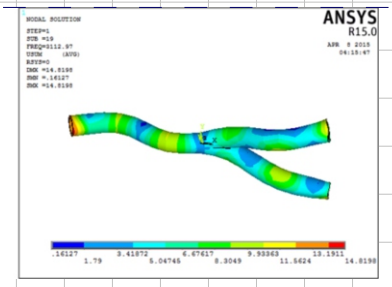

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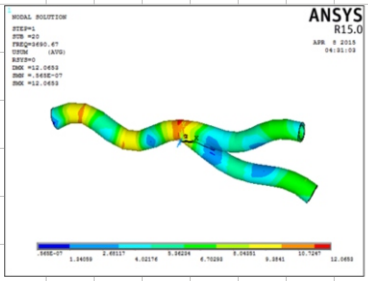
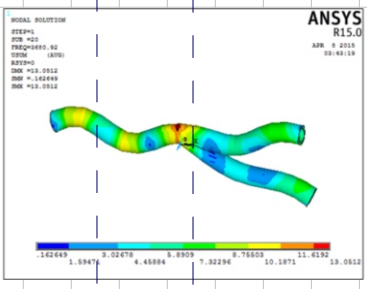
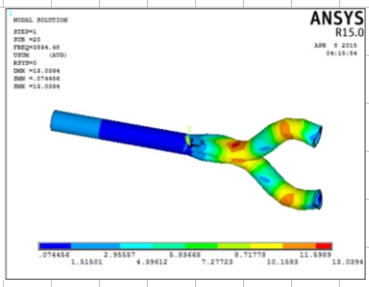






Natural frequencies of 30-degree pipe junction under a **Transverse crack** at various crack depths are shown below in Table III.

TABLE III
NATURAL FREQUENCIES OF CASE 1 UNDER TRANSVERSE CRACKS.

Mode Numbers	a/d= 0	a/d= 0.2	a/d= 0.4	a/d= 0.6	a/d= 0.8	a/d= 1.0
1	9.49E-03	1.07E-02	9.15E-03	1.07E-02	9.77E-03	7.63E-03
2	1.35E-02	1.43E-02	1.34E-02	1.41E-02	1.01E-02	1.03E-02
3	2.49E-02	2.96E-02	2.47E-02	3.31E-02	3.59E-02	2.86E-02
4	194.95	194.76	194.24	193.64	193.08	192.61
5	313.55	313.55	313.54	313.53	313.53	313.53
6	407.57	407.42	407.07	406.65	406.29	406
7	728.12	728.08	728.05	728.01	727.97	727.92
8	1082.1	1082.1	1082	1081.8	1081.6	1081.3
9	1138.2	1138.2	1138.2	1138.1	1138.1	1138.1
10	1390.4	1388.8	1385.5	1381.3	1377.7	1374.6
11	1408.9	1408.8	1408.7	1408.7	1408.6	1408.6
12	1997.6	1997.1	1996.1	1995	1994	1993.2
13	2186.5	2186.3	2185.8	2185.4	2185.1	2184.8
14	2442.1	2440.4	2436.5	2431.7	2427.4	2423.7
15	2508.3	2508.1	2507.8	2507.5	2507.1	2506.6
16	2543.4	2543.4	2543.4	2543.4	2543.3	2543.3
17	2845.2	2844.9	2844.2	2843.3	2842.3	2840.8
18	3083.2	3082.8	3081.7	3080.4	3079.3	3078.3
19	3115.3	3115.1	3114.5	3113.7	3112.6	3110.7
20	3690.7	3689.1	3685.3	3680.9	3677.2	3674.5

Natural frequencies of 30-degree pipe junction under a **Transverse crack** at various crack depths are plotted in Fig. 4.

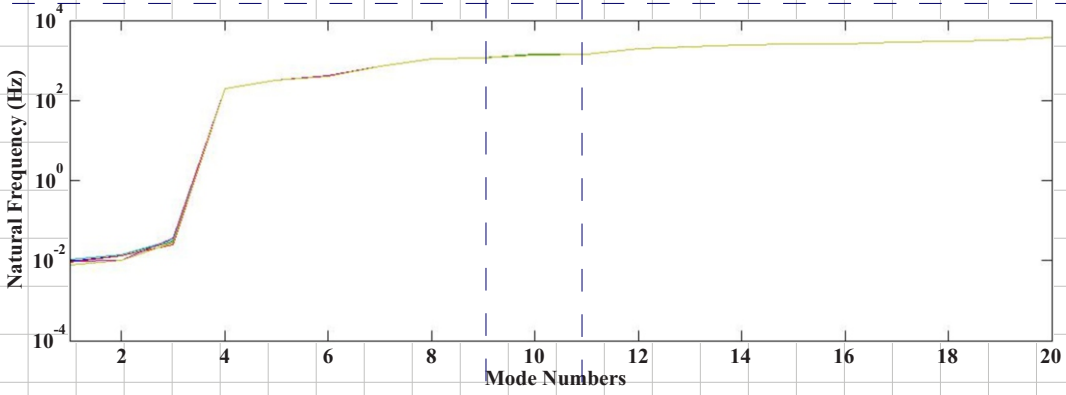


Fig. 4. Natural Frequency Trend for 30-degree pipe junction under a transverse crack

Natural frequencies of 30-degree pipe junction under a **longitudinal crack** at various crack depths are listed in Table IV.

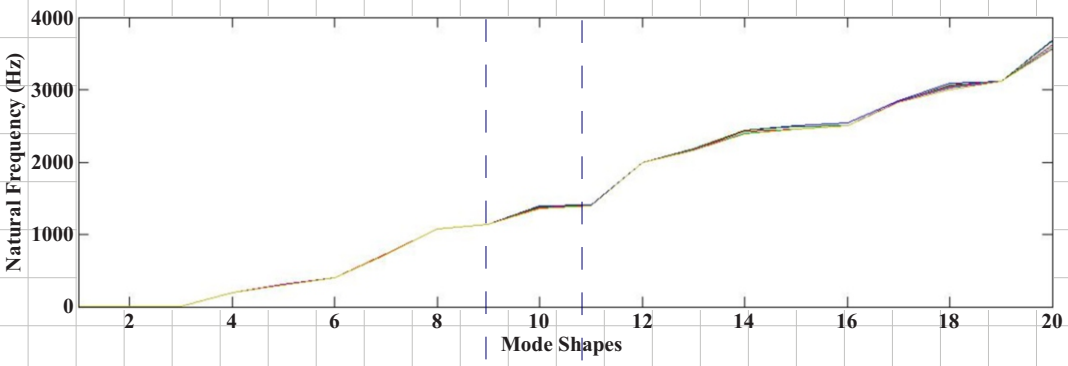
TABLE IV
NATURAL FREQUENCIES OF CASE 1 UNDER LONGITUDINAL CRACKS.

Mode Numbers	a/d= 0	a/d= 0.2	a/d= 0.4	a/d= 0.6	a/d= 0.8	a/d= 1.0
1	9.49E-03	9.87E-03	8.73E-03	8.44E-03	9.11E-03	7.75E-03
2	1.35E-02	1.06E-02	1.00E-02	9.70E-03	1.81E-02	1.20E-02
3	2.49E-02	3.50E-02	3.53E-02	2.95E-02	2.96E-02	3.10E-02
4	194.95	194.72	194.44	194.16	193.87	193.2800
5	313.55	311.59	310.11	309	307.91	305.55
6	407.57	407.54	407.5	407.47	407.44	407.42
7	728.12	727.35	726.61	726.03	725.58	724.94
8	1082.1	1081.1	1079.9	1079.2	1079	1078.8
9	1138.2	1137.8	1137.2	1136.8	1136.4	1135.5
10	1390.4	1386	1369.7	1359.8	1355.1	1353.4
11	1408.9	1390.3	1390.1	1389.8	1389.5	1388.6
12	1997.6	1996.7	1995.9	1995.5	1995.5	1994.6
13	2186.5	2179.9	2174.7	2170.8	2167.1	2158.6
14	2442.1	2439	2423.5	2401.3	2394.9	2389.4
15	2508.3	2491.7	2454.9	2449.4	2449	2446
16	2543.4	2507.3	2506.4	2505.8	2505.4	2504.9
17	2845.2	2838.7	2834.6	2832	2829.5	2822.9
18	3083.2	3068	3051.4	3036.1	3020.9	2993.7
19	3115.3	3114.3	3113.4	3113	3112.9	3112.7
20	3690.7	3670.1	3624.8	3594.5	3576.6	3565.7

Natural frequencies of 60-degree pipe junction under a **Transverse crack** at various crack depths are listed in Table V.

TABLE V
NATURAL FREQUENCIES OF CASE 2 UNDER TRANSVERSE CRACKS.

Mode Numbers	a/d= 0	a/d= 0.2	a/d= 0.4	a/d= 0.6	a/d= 0.8	a/d= 1.0
1	0.0085396	1.12E-02	8.69E-03	1.17E-02	1.08E-02	1.03E-02
2	0.0088036	1.48E-02	9.43E-03	1.18E-02	1.11E-02	1.29E-02
3	0.032321	2.22E-02	2.99E-02	3.50E-02	3.08E-02	2.16E-02
4	176.5	176.46	176.38	176.33	176.31	176.29
5	189.49	189.13	188.55	188.03	187.61	187.37
6	377.7	377.46	377.04	376.64	376.36	376.2
7	633.53	633.25	633.19	633.1	633.04	632.97
8	844.36	844.34	844.3	844.25	844.19	844.1
9	964.28	963.56	963.15	962.68	962.38	962.09
10	1010.3	1010.2	1010.1	1009.9	1009.7	1009.4
11	1129.3	1126.9	1123	1119.1	1116.5	1114.7
12	1752.6	1752.3	1751.7	1751.1	1750.6	1750.1
13	1963	1962.3	1961.5	1960.9	1960.7	1960.6
14	2084	2083.4	2082.6	2081.9	2081.5	2081.3
15	2217.2	2215.9	2213.9	2212	2210.7	2210.1
16	2241.3	2240.7	2240.1	2239.6	2239.1	2238.7
17	2512.7	2512.4	2511.9	2511.4	2510.8	2510
18	2626.5	2624	2619.3	2614.7	2611	2608.9
19	2681.3	2679.6	2676.7	2674.3	2672.7	2671.5
20	2863.3	2862.8	2861.9	2860.9	2860	2858.7



Natural frequencies of 60-degree pipe junction under a **longitudinal crack** at various crack depths.

TABLE VI
NATURAL FREQUENCIES OF CASE 2 UNDER LONGITUDINAL CRACKS.

Mode Numbers	a/d= 0	a/d= 0.2	a/d= 0.4	a/d= 0.6	a/d= 0.8	a/d= 1.0
1	0.0085396	7.73E-03	7.92E-03	1.15E-02	8.00E-03	8.45E-03
2	0.0088036	1.12E-02	1.26E-02	1.48E-02	8.65E-03	1.07E-02
3	0.032321	2.75E-02	2.81E-02	2.21E-02	3.24E-02	3.13E-02

4	176.5	176.2	175.89	175.65	175.47	175.2
5	189.49	189.36	189.18	189	188.81	188.55
6	377.7	377.65	377.58	377.53	377.48	377.45
7	633.53	633.45	633.33	633.2	633.04	632.84
8	844.36	844.26	844.16	844.08	844.01	843.96
9	964.28	954.35	946.26	941.7	939.7	938.9
10	1010.3	1010.2	1010.2	1010.2	1010.2	1010.1
11	1129.3	1129	1128.6	1128.1	1127.7	1127
12	1752.6	1746.7	1741.5	1739.3	1738.9	1737.8
13	1963	1960.8	1958.5	1956.9	1955.8	1954.2
14	2084	2075.6	2068.8	2066.4	2066.1	2062.6
15	2217.2	2206.2	2197.9	2192.9	2190	2188.7
16	2241.3	2240.5	2239.4	2238	2236.6	2234.6
17	2512.7	2507.8	2502.9	2499	2495.7	2492
18	2626.5	2617.4	2610.3	2606.1	2603.6	2602.7
19	2681.3	2679.8	2677.5	2674.9	2672.2	2668.2
20	2863.3	2861.8	2860.4	2859.5	2859	2858.6

Natural frequencies of 90-degree pipe junction under a **Transverse crack** at various crack depths are listed in Table VII.

TABLE VII
NATURAL FREQUENCIES OF CASE 3 UNDER TRANSVERSE CRACKS.

Mode Numbers	**a/d= 0**	**a/d= 0.2**	**a/d= 0.4**	**a/d= 0.6**	**a/d= 0.8**	**a/d= 1.0**
1	1.28E-02	1.18E-02	1.24E-02	1.19E-02	1.15E-02	1.06E-02
2	1.37E-02	1.35E-02	1.28E-02	1.55E-02	1.34E-02	1.16E-02
3	2.91E-02	2.17E-02	2.76E-02	2.66E-02	2.07E-02	2.58E-02
4	106.86	106.82	106.77	106.74	106.73	106.72
5	164.16	163.7	163.1	162.61	162.28	162.14
6	317.9	317.65	317.3	317.02	316.86	316.8
7	488.56	487.77	487.5	487.24	487.11	486.97
8	580.17	580.14	580.09	580.03	579.97	579.88
9	745.29	743.91	743.26	742.67	742.35	742.08
10	871.87	871.71	871.48	871.25	871.07	870.9
11	961.21	958.94	956.21	953.93	952.59	951.87
12	1265	1264.9	1264.8	1264.7	1264.5	1264.2
13	1554.2	1553.8	1553.8	1553.7	1553.7	1553.7
14	1710.2	1709.3	1707.8	1706.2	1705.2	1704.7
15	1718.7	1716.6	1714.5	1713.3	1712.4	1711.8
16	1750.5	1750.4	1750.3	1750.2	1750.2	1750.1

17	1788.3	1787.3	1786.3	1785.7	1785.4	1785.3
18	2191.7	2187.8	2182.3	2178.1	2175.6	2174.6
19	2448.2	2447.1	2445.7	2444.5	2443.8	2443.2
20	2488.4	2488	2487.3	2486.6	2486.1	2485.7

Natural frequencies of 90-degree pipe junction under a **longitudinal crack** at various crack depths are listed in Table VIII.

TABLE VIII
NATURAL FREQUENCIES OF CASE 3 UNDER LONGITUDINAL CRACKS.

Mode Numbers	**a/d= 0**	**a/d= 0.2**	**a/d= 0.4**	**a/d= 0.6**	**a/d= 0.8**	**a/d= 1.0**
1	0.012785	0.011099	0.012669	0.012487	0.0092025	0.0095517
2	0.013656	0.012225	0.016009	0.013787	0.010329	0.013253
3	0.029145	0.033942	0.026877	0.036924	0.031442	0.02923
4	106.86	106.82	106.78	106.74	106.73	106.72
5	164.16	164.09	164.01	163.92	163.84	163.77
6	317.9	317.86	317.8	317.73	317.67	317.64
7	488.56	488.56	488.56	488.55	488.53	488.52
8	580.17	580.17	580.16	580.14	580.13	580.11
9	745.29	740.94	736.84	733.86	732.4	732.5
10	871.87	871.71	871.56	871.41	871.35	871.38
11	961.21	961.01	960.71	960.4	960.14	959.85
12	1265	1262.2	1260	1258.4	1258.2	1258.2
13	1554.2	1545.7	1538	1532.1	1529.4	1530
14	1710.2	1709.9	1709.5	1709.3	1709.1	1709.1
15	1718.7	1718.7	1718.6	1718.5	1718.4	1718.1
16	1750.5	1748.8	1746.8	1744.9	1743.3	1741.8
17	1788.3	1787.7	1787.3	1787.1	1787	1786.3
18	2191.7	2191.1	2190.6	2190.3	2190	2189.8
19	2448.2	2447.6	2446.8	2445.6	2444.3	2442.8
20	2488.4	2486.6	2484.9	2483.5	2483.2	2483.7

VII. VALIDATION

Mode shapes obtained after above mentioned iterations indicated consistency in their order and there was no mode swapping occurred. This is an indication of validity of the modal analysis process which was adopted to obtain modal characteristics.

VIII. CONCLUSIONS

After thorough investigation it can be seen that the both of the longitudinal and transverse cracks change some of the mode shapes of the pipes however natural frequencies, other than the first three (Because of very low value), comparatively showed more decrement in case longitudinal cracks. So it is concluded that,with the decrease in material due to crack propagation in longitudinal direction, the natural frequencies will decrease more than in the case of transverse crack propagation.

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Section D

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Significant Risks of Oursourced IT Projects

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Abstract-The volume of IT outsourcing is continuously growing due to benefits of outsourcing and various constraints of the organizations. However, there are certain risks linked with IT outsourcing. Manifestation of such risks adversely affects the successful completion of outsourced projects and may cause project failure. This study's objective is to explore and rank the significant risks for IT outsourcing. A literature-based list of IT outsourcing risks has been employed for this purpose. Two questionnaire surveys have been conducted to perform Delphi method. After the first round, significant risks for IT outsourcing have been identified. The significant risks have been ranked during the second round. The study also highlights top 10 risks for IT outsourcing. Keeping in view identified and ranked IT outsourcing risks, designing a proactive strategy can address the risks and hence anticipated benefits of IT outsourcing can be achieved.

Keywords-IT Outsourcing, Outsourced Projects, Risk Identification, Risk Management, Outsourcing risks.

I. Introduction

During the IT outsourcing, services of another organizations are attained to accomplish software development and associated activities [i]. The income of the Information Technology Outsourcing (ITO) market has augmented from $228.7 billion in 2010 to $246.6 billion in 2011 with rate of growth of 7.8% according to a report published in 2012 [ii].

According to Barry Boehm [iii], cost reduction is the main reason of outsourcing. There are multiple reasons of outsourcing that can be categorized into: 1) benefits of outsourcing and 2) certain limitations of companies. The possible benefits include obtainability of high-class competencies, cost lessening, amplified revenue, effective processes, emancipating inner resources, and outsourcing non-core activities. The possible limitations are shortage of resources, privation of suitable services, and complications in handling IT functions. Outsourcing concept is making progress by leaps and bounds due to such benefits and limitations [iv].

IT Outsourced projects can be classified into four types:

I) Contractor and outsourcing organization are co-located.
ii) Contractor is located in another country (off shore development).
iii) Contractor and outsourcing organizations are located in the same country but at significant distance.
iv) Group of contractors and/or subcontractors (Global Software Development) [v].

Risk is the likelihood of happening an event that may lead to unwanted consequences [vi]. Many software development projects are failed in spite of a lot of efforts and engaging huge resources, and one of the main failure causes is poor requirements definition [vii].

When project stakeholders are not co-located as is the case of outsourced projects, the following possible reasons lead to inadequate requirements definition:

- Ineffective communication.
- Different working hours (time zones).
- Intermittent face to face meetings.
- Multiple communication languages.
- Disparities in stakeholders' culture, political environment and intellectual property rights.
- Dissimilar working practices.

Similarly, some other risks for IT Outsourcing are change reluctant attitude, high employee staff turnover, scope slinking, service repudiation from contractor, undetected costs, litigation matters, utilization of superseded technologies by vendor, and high tax tariffs at out source destination [viii]. These risks also yield impediments when business processes are outsourced [ix]. Therefore, the significant risks for outsourcing must be identified, prior to the effective handling, to gain the pay backs of outsourcing [x]. In this context, this study intends to answer the following research questions:

RQ1:What are significant risks in case of IT outsourcing?
Rq2: What is the ranking of the significant risks in case of IT outsourcing?

II. Related Work

IT outsourcing has been discussed in literature from various aspects. According to Ravi, outsourcing risks limit the business process outsourcing and risk management improvement has dramatically increased the sourcing [ix]. A framework for IT outsourcing risk

management has been presented in [vi]. For illustration, five case studies have also been discussed to show risk management. Literature-based IT offshoring risks have been identified in the study [viii] through content analysis. Another study presents risks, benefits and challenges of global IT outsourcing. The study confers two case studies to validate previous research [xi]. Risks related to information system outsourcing have been presented in [xii, xiii] by reviewing relevant literature and performing survey with 5000firms. In order to manage the risks in case of information system outsourcing, an approach has been presented in [xiv] to analyze outsourcing risks. Offshore outsourcing risks, challenges and possible solutions have been discussed in [xv]. Kim and Tim explore empirically how process standardization can reduce the risks related to outsourcing [xvi]. A systematic approach has been proposed in [xvii] to prioritize the outsourcing risks. Another study presents taxonomy of IT outsourcing risks to identify and quantify the risks [xviii]. Achievements and risks in case of information system outsourcing have been presented in [xix]. A framework for risk assessment in case of offshore IT outsourcing has been provided in [xx]. By applying grounded theory principles, offshore IT outsourcing risks have been analyzed in [xxi] from the service provider perspective. Three phase life cycle for information system outsourcing, has been identified in [xxii]. The study also analyses risk factors associated with each phase.

Several studies focus on IT outsourcing risks [ix][x][vi][viii][xi][xii][xvii] but to the best of our knowledge no study provides a list of significant risks for IT outsourcing. The objective of this research is to provide a comprehensive list of significant IT outsourcing risks and rank such risks. The next section explains research methodology followed in this research.

III. Research Methodology

Selection of appropriate research methodology is vital to achieve the research goals. Survey research method has been adopted in order to identify and rank the significant risk for outsourced IT projects. This method is considered as one of the appropriate techniques that work with both qualitative and quantitative data [xxiii]. Various methods can be used to collect the data such as written materials, observations, interviews, data sampling, documentations and survey questionnaires. Moreover, combination of different data gathering techniques or any specific method can be adopted for survey research method [xxiv].Therefore, semi-supervised surveys [xxv] have been deployed to gather required data. Before conducting the survey the respondents were demonstrated the survey goals, format of survey and different sections were explained to respondents specifically how to respond to the questions selecting appropriate option, utilizing *Computer-Assisted Telephone Interviewing* (CATI) technique. CATI is used to facilitate the surveys and guide respondents. *Automated Computer Telephone Interviewing* is advanced form of CATI which is used to record the answers given by respondents.

We have extracted a list of risks for IT outsourcing projects from [x][vi][viii][xi][xii][xiii][xvii]. The risks have been denoted by R_1, R_2, R_3…R_{32} and have been shown in 2nd column of Appendix A. Several studies are based on lists extracted from literature [xxvi, xxvii]. For further research we have employed Delphi method briefed in the next subsection.

A. Delphi Method

This study involves two rounds of Delphi method. Delphi method is a repetitive process that is used to build the consensus or to converge the opinion of experts on certain issue(s). A group of experts, from a particular area, is employed for two or three rounds of study (or even more). After each round, every expert is provided with a summary of results of that round and his or her response in that round. The experts are suggested to modify their responses given during last round if they feel it appropriate keeping in view the combined responses of other experts in that round. This process is continued till the achievement of a pre-decided criterion like number of rounds or consensus on a specific achievement [xxviii, xxix]. In this research Delphi method was used to identify the RE practices for software development outsourcing that are significant according to the agreed-upon opinion of experts.

For completion of two rounds of Delphi method, two online questionnaire surveys were conducted. Before starting surveys, two rounds of pilot study were carried out for improvement of questionnaires' layout, for estimation of time required for questionnaires' filling and for assessing comprehension of language. We accommodated the suggestions given during first round of pilot study. Second round was conducted to ensure that the recommendations of first round were followed for modifications.

Two online questionnaires were presented to IT outsourcing practitioners belonging to Malaysian and Pakistani software development companies. The respondents were system analysts, senior managers, project managers, requirements engineers, technical managers having at least 10 years of IT outsourcing experience as basic criterion. Prior to conducting study, 200 relevant practitioners were identified who satisfied the basic criterion. Out of 200, only 45 responded to the request for participating in the study. However only 36

(T) respondents completed both rounds and thus were considered for the rest of the analysis.

B. First Questionnaire Survey

Questionnaire used during first round was divided into two parts. The first part was intended to gather information regarding the job nature of respondent, his experience and respective company as well. The succeeding part was for finding significant risks for IT outsourcing. By providing a literature-based list of 32 IT outsourcing risk, respondents were solicited to rank the given risks according to impact of those risks on outsourcing. Based on 10-point scale, four categories of impact as suggested by [xxvi, xxx] are as follows:

a. Catastrophic (C_i) (10): if an issue is most relevant and has direct impact on an IT outsourcing project.
b. Serious (S_i) (7): if an issue is relevant and has significant impact on an IT outsourcing project.
c. Tolerable (T_i) (4): if an issue is insignificantly relevant and has a little impact on an IT outsourcing project.
d. Insignificant (I_i) (1): if an issue is non-relevant and has no measurable impact on an IT outsourcing project.

i) Criterion for Selection of Significant risks for IT Outsourcing

If according to 50% of participants, the perceived effect of a risk falls in 'Catastrophic' and 'Serious' categories, then that is regarded as significant for outsourced IT projects. In preceding studies a similar methodology has been deployed very efficiently, in which decisions were made by taking into consideration the views of 50 percent or above respondents [xxxi, xxxii, xxxiii]. A similar measure was also used by Hall and Rainer [xxxi] for identifying key factors of software process improvement by considering that if 50 percent of respondents agree on strong impact of a factor, then that factor will be considered as important The term 'significant' here means 'important to be worthy of attention' or 'important enough to have an effect' as also described by [xxxiv, xxxv]. To identify the significant risks for IT outsourcing 'Catastrophic' and the 'Serious' impact categories have been taken into account only [xxxvi]. The rationale for this decision is that a risk belonging to 'Catastrophic' category is the most relevant and has direct impact on outsourced projects. Hence such risks must be considered for IT outsourcing projects. Likewise a risk from 'Serious' category is relevant and has significant impact on IT outsourcing project. Thus such risks cannot be ignored. For each risk, The percentages of responses in 'Serious' and 'Catastrophic' categories are represented here by prominence level (PL). It is calculated as follows

$$PL = \frac{[(Ci + Si)]}{T} * 100 \quad (1)$$

Where C_i = No. of responses in 'Catastrophic' category (in case of an IT outsourcing risk),

S_i = No. of responses in 'Serious' category (in case of an IT Outsourcing risk), and

T = Total number of responses considered for analysis.

C. Second Questionnaire Survey

Questionnaire utilized during the second round also contained two parts. The first part was to collect demographic information about the professionals. The second part was to rank the significant risks for IT outsourcing.

During the first survey, we have sent online questionnaire to the 45 IT outsourcing practitioners. We have received back 40 responses. During the second survey, online questionnaires have been sent to the 40 IT outsourcing professionals who responded in the first round. For the second round, we have been successful in receiving back 36 responses. For the data analysis, we have considered responses from 36 professionals based on their participation in both rounds of Delphi method. The overall research methodology is shown via Fig. 1 below.

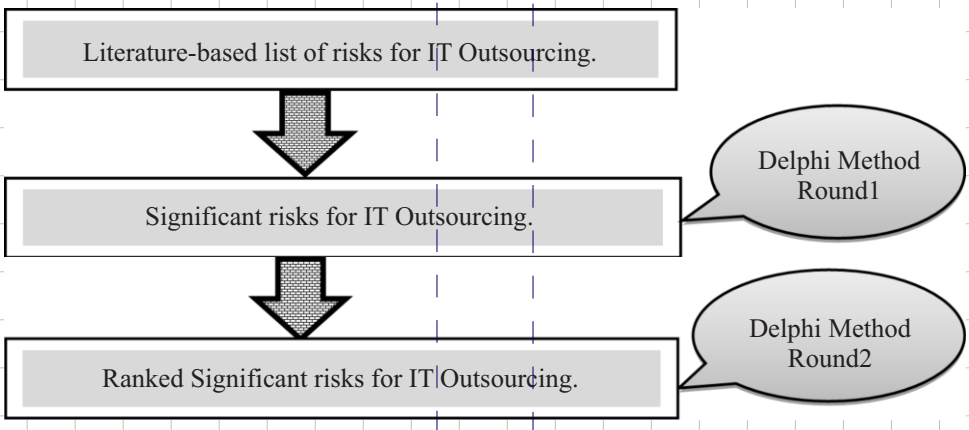

Fig. 1. Steps to identify significant risks for IT outsourcing.

IV. Results and Discussions

Results obtained can be divided into two main categories:

a. Identification of significant risks for IT outsourcing.
b. Ranking of significant risks for IT outsourcing.

A. Identification of significant risks for IT outsourcing

The significant risks for IT outsourcing have been identified through the first round of Delphi method.

i) First Round **:** By providing a literature-based list of 32 risks for IT outsourcing, we requested the IT outsourcing practitioners for ranking the given risks weighing their impact in case of outsourcing. The four categories of the ranks of impact, by incorporating 10-point scale are: Catastrophic (10), Serious (7), Tolerable (4) and Insignificant (1). By applying criterion for significance, we have identified 31 significant risks for IT outsourcing.

The results of first round of Delphi method are shown in column 3 and 4 of Appendix A. The column 3 shows number of responses for Catastrophic, Serious, Tolerable and Insignificant categories, and column 4 displays PL in case of each outsourcing risk. A PL of 50 or above proves that corresponding risk is significant for IT outsourcing. On observing 4th column of Appendix A, it is evident that in case of only one risk (R_{31}) value of PL is less than 50. This means that according to IT outsourcing practitioners' perception, $\mathbf{R_{31}}$is not significant for IT outsourcing. The R_{31}isregarding dissimilar languages at the client and vendor locations. In case of all the remaining IT outsourcing risks, the value of PL is above 50. All of the remaining 31 IT outsourcing risks are, therefore, significant according to defined criterion. This reveals that according to the perception of IT outsourcing professionals, these 31 risks substantially affect IT outsourcing projects, therefore, must be addressed through proactive strategy. The significant risks for IT outsourcing are R_1, R_2, R_3…..R_{29}, R_{30}, and R_{32}. These risks have been shown in 2nd column of Appendix A which also provides answer to research question 1 (RQ1) of this study. In the next phase for ranking, these 31 significant risks will be used as an input.

B. Ranking of the significant risks for IT outsourcing

Significant risks for IT outsourcing have been ranked during the second round of Delphi method based on the results of first round.

ii) Second Round : Before starting the second round of Delphi method, average rankings and standard deviations were calculated in case of each significant risk. In the second round, for each significant risk, IT outsourcing practitioners were provided with their respective individual round 1 ranking and average ranking. The practitioners were solicited to reassess their respective individual rankings, for each significant IT outsourcing risk, keeping in view the average rankings if necessary. The average rankings and standard deviations, for each significant risk, were calculated again after second round.

The average rankings and standard deviations calculated, for each significant risk, after first and second round have been shown in Appendix B. The average rankings calculated after second round have been shown in Table I in descending order**.** This order determines the overall ranks of significant IT outsourcing risks. This provides answer to research question 2 (RQ 2) of this study.

TABLE I
AVERAGE RANKINGS OF THE IMPACTS OF RISKS (IN DESCENDING ORDER) CALCULATED AFTER ROUND 2 OF DELPHI METHOD

Final Ranks	Significant Risk for IT Outsourcing	Round 2 Average Rankings of the Impacts of Risks	Final Ranks	Significant Risk for IT Outsourcing	Round 2 Average Rankings of the Impacts of Risks
1	**R_{24}**	9.58	17	R_{14}	8.42
2	**R_{21}**	9.50	18	R_{30}	8.42
3	**R_{23}**	9.50	19	R_{4}	8.33
4	**R_{25}**	9.42	20	R_{12}	8.33
5	**R_{16}**	9.33	21	R_{26}	8.33
6	**R_{29}**	9.08	22	R_{2}	8.08
7	**R_{17}**	9.00	23	R_{9}	8.08
8	**R_{28}**	9.00	24	R_{22}	8.00
9	**R_{11}**	8.92	25	R_{5}	7.92

10	**R_{18}**	8.92	26	R_{10}	7.92
11	R_{19}	8.83	27	R_{8}	7.83
12	R_{32}	8.75	28	R_{15}	7.83
13	R_{1}	8.67	29	R_{3}	7.67
14	R_{20}	8.67	30	R_{7}	7.58
15	R_{13}	8.58	31	R_{6}	6.17
16	R_{27}	8.50			

This is evident from the Appendix B that average standard deviation is reduced from 1.87 in round 1 to 1.83 in round 2. Also practitioners were not available to participate in the third round, therefore, we decided to conclude the study after two rounds.

a. Top 10 significant risks for IT outsourcing

Based on the average rankings of the impacts of risks, given in the Table 1, we confirm that the top ten significant IT outsourcing risks are:

1) Poor communication facilities or communication lack between vendor and client.
2) Inconsistency between outsourcing organization expectations and their deliverables.
3) No protection of Intellectual property rights.
4) Vendor's lack of expertise in related domain.
5) Confidentiality of information.
6) Resource shortage of outsourced location.
7) Legal issues.
8) Lack of trust.
9) The size of project and its complexity.
10) Unpredicted or high staff turnover of vendor.

V. Conclusion

The idea of IT outsourcing is gaining popularity rapidly owing to advantages like reduction of cost, optimal resource utilization and the state realization of art capabilities. But because of the occurrence of the risks like lack of communication between vendor and client, insufficient expertise of vendor and disparity between expectations and deliverables, the outsourcing benefits are not attained. Therefore, possible risks for IT outsourcing must be anticipated and handledin advance. In this study, significant risks for IT outsourcing have been identified and ranked by employing Delphi method. Two rounds of Delphi method have been conducted by involving 36 IT outsourcing practitioners having at least 10 year experience of IT outsourcing. By providing a literature-based list of 32 IT outsourcing risks, the respondentshave been solicited to rank the given risks according to the impact of the risks on IT outsourcing projects. Based on 10-point scale, four categories of a risk impact are: Catastrophic (10), Serious(7), Tolerable (4) and Insignificant (1). During the first round of Delphi method, 31 risks have been identified which are significant for IT outsourcing projects whereas the second round helps us to rank the identified significant risks. The top 10 significant risks have also been presented. The study suggests that for successful completion of outsourced IT projects and to attain foreseen benefits of IT outsourcing, strategy must be designed to avoid or address the identified significant risks for IT outsourcing.

Although this research work identifies significant risks for IT outsourcing but it lacks a framework to address the identified risks. Another limitation is that the study does not compare two contexts. We have addressed the external validity by selecting the opinion of 36 respondents from two different countries. All the relevant practitioners belonging to the two countries may not fully agree with the results, but we believe that this sample is a true representative of population. One limitation of the study is that it has small sample size. However, such small sample sizes are common in studies involving experts from the field because of the lack of time on their part.

One of the important aspects that could be enhanced from this work is to propose a framework for dealing with the identified risks.

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Appendix A: Results of Delphi method round 1

Risk IDs	Risks for IT outsourcing	Assessed Ranks				PL
		C_i	S_i	T_i	I_i	
R_1	High staff turnover of the outsourcing organization.	22	8	6	0	83.33
R_2	Outsourcing organization employees' low morale.	18	13	5	0	86.11
R_3	Resistance to alteration.	15	14	7	0	80.56
R_4	Less awareness about the contractor competence.	20	12	4	0	88.89
R_5	Inadequate or incomplete drafting of the outsourcing contract.	16	15	5	0	86.11
R_6	Augmented switching cost or start- up cost or transaction cost.	10	12	8	6	61.11
R_7	Outsourcing of wrong kind of service.	14	15	7	0	80.56
R_8	Unseen costs (e.g. due to unexpected changes to contract).	15	16	5	0	86.11
R_9	Ambiguous requirements.	17	15	4	0	88.89
R_{10}	Scope creeping.	16	15	5	0	86.11
R_{11}	Project complexity and size.	23	13	0	0	100.00
R_{12}	Risk of business failure.	20	12	4	0	88.89
R_{13}	Degradation or denial of service from contractor.	21	13	2	0	94.44
R_{14}	Vendor does not comply with the contract or fails to deliver.	20	13	3	0	91.67
R_{15}	Usage of obsolete technologies and products by vendor.	18	10	8	0	77.78
R_{16}	Confidentiality of information.	25	11	0	0	100.00
R_{17}	Legal issues.	24	12	0	0	100.00
R_{18}	Unexpected or high staff turnover of vendor.	23	13	0	0	100.00
R_{19}	Long learning curve of contractor's employees.	22	14	0	0	100.00
R_{20}	Disasters at off shored destination.	20	16	0	0	100.00
R_{21}	Disparity between outsourcing organization expectations and deliverables.	28	8	0	0	100.00
R_{22}	High tariff or tax rates at contractor destination.	20	8	8	0	77.78
R_{23}	No protection of Intellectual property rights.	29	7	0	0	100.00
R_{24}	Poor communication facilities or lacking of communication between vendor and client.	28	8	0	0	100.00
R_{25}	Insufficient expertise of vendor in relevant domain.	29	7	0	0	100.00
R_{26}	Synchronization and communication hazards due to different time zones.	21	10	5	0	86.11
R_{27}	Cultural diversities.	20	14	2	0	94.44
R_{28}	Lack of trust.	24	12	0	0	100.00
R_{29}	Shortage of resources on outsourced location.	25	11	0	0	100.00
R_{30}	Delayed delivery.	20	13	3	0	91.67
R_{31}	Dissimilar Languages.	6	8	15	7	38.89
R_{32}	Poor quality	19	13	4	0	88.89

Appendix B: Average Rankings of perceived impacts and Standard Deviations calculated after round I & round 2 of Delphi method.

Sr. #	IDs of the Significant Risks for IT outsourcing	Round 1		Round 2	
		Average	St. Dev	Average	St. Dev
1.	R_1	8.33	2.32	8.67	2.08
2.	R_2	8.08	2.17	8.08	2.17
3.	R_3	7.67	2.28	7.67	2.28
4.	R_4	8.33	2.08	8.33	2.08
5.	R_5	7.92	2.13	7.92	2.13
6.	R_6	6.17	3.18	6.17	3.18
7.	R_7	7.58	2.25	7.58	2.25
8.	R_8	7.83	2.10	7.83	2.10
9.	R_9	8.08	2.05	8.08	2.05
10.	R_{10}	7.92	2.13	7.92	2.13
11.	R_{11}	8.92	1.46	8.92	1.46
12.	R_{12}	8.33	2.08	8.33	2.08
13.	R_{13}	8.58	1.83	8.58	1.83
14.	R_{14}	8.42	1.96	8.42	1.96
15.	R_{15}	7.83	2.44	7.83	2.44
16.	R_{16}	9.08	1.40	9.33	1.26
17.	R_{17}	9.00	1.43	9.00	1.43
18.	R_{18}	8.92	1.46	8.92	1.46
19.	R_{19}	8.83	1.48	8.83	1.48
20.	R_{20}	8.67	1.51	8.67	1.51
21.	R_{21}	9.33	1.26	9.50	1.13
22.	R_{22}	8.00	2.48	8.00	2.48
23.	R_{23}	9.42	1.20	9.50	1.13
24.	R_{24}	9.33	1.26	9.58	1.05
25.	R_{25}	9.42	1.20	9.42	1.20
26.	R_{26}	8.33	2.20	8.33	2.20
27.	R_{27}	8.50	1.83	8.50	1.83
28.	R_{28}	9.00	1.43	9.00	1.43
29.	R_{29}	9.08	1.40	9.08	1.40
30.	R_{30}	8.42	1.96	8.42	1.96
31.	R_{32}	8.25	2.08	8.75	1.66
Average			**1.87**		**1.83**

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Sentiment Analysis and Opinion Mining - A Facebook Posts and Comments Analyzer

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***Abstract*-**Since last few years, the trend of social networking is at its peak. People post their personal feelings and thinking about any topic or product for social liking or for marketing. Such posts often get hundreds or thousands of comments and it becomes difficult for a reader to read all of these to assess public opinion. Sometimes one just wants to know common opinion, behavior, trend or thinking discussed there or to determine whether those opinions are positive or negative. Particularly in case of product marketing, the company would like to judge the success of an ad campaign or new product launch or which products or services are popular and what people like or dislike about particular features of a product. In such situations automatic sentiment analysis and opinion mining can help a lot. Hence, in this paper a novel sentiment analysis and opinion mining framework is proposed. This framework utilizes various techniques of computational linguistics to measure sentiment orientation of user's opinion around different entities. The proposed framework is used to perform sentiment analysis and opinion mining of users' posts and comments on social media through a Facebook App. Furthermore a user study is conducted to gauge performance of the proposed framework. The results of this study have shown that the framework is capable of finding opinions of the users and sentiments around those opinions with more than 85 percent accuracy when compared with actual human judges.

***Keywords*-**Sentiment Analysis, Opinion Mining, Comments Analyzer, Facebook

I. Introduction

With the advent of Web 2.0 now web is not a read only media anymore. Beside consuming information on Web now users can also contribute into it through comments, blogs, feedback etc. which has changed the way we consume and produce information. Online social media is among the paramount examples of those applications which have been realized through Web 2.0. Now, on an online social media platform people post their personal finding, feeling or thinking about any topic or a product for social communication, branding, marketing etc. A popular User's or Company's post usually attract hundreds or thousands of comments and it looks difficult for a reader to read all of these comments to assess general public opinion about the topic discussed in the post. Furthermore, in case of marketing, one may like to judge the success of an ad campaign or new product launch or which products or services are popular and what people like or dislike about a particular feature of that product [i]. In such situations automatic sentiment analysis and opinion mining can help a lot. The purpose of sentiment analysis from a set of comments is to determine the attitude of commenters with respect to some subtopic or their overall contextual polarity towards the topic. This attitude may be their actual evaluation or can be caused by any emotional communication [ii].

Recently, a tremendous focus has been observed in literature to design new techniques to meet different requirements of the sentiment analysis and mining of writer's opinion [iii]-[v]. In [vi] a rule based approach is proposed to analyze sentiments through association rule mining for opinion extraction related to different product features. Such techniques has been used in several application areas including product feature extraction, summarization and analysis [vii]-[ix], e-commerce [x], tourism [xi], recommender system [x-xi] etc. Detailed literature review of sentiment analysis and its applications could be found in [iii-iv].

In this paper, a framework is designed through which opinions from reviews of people and sentiments (positivity or negativity) around those opinions could be found. The proposed framework is applied and realized as an application in which opinion mining and sentiment analysis of Facebook posts and comments of those posts are determined. This application helps users to understand the sentiments discussed in a post, extracts the topics with their semantics and also brings up the entities which are under discussion by the reviewers. Moreover, trend and behavior of reviewers can also be judged through the comment with its polarity with topics and entities. To evaluate proposed effectiveness of the design application based on the proposed framework a user study is performed which has shown very promising results.

Rest of the paper is organized as follows, in section

II some background of various techniques used are described, details of proposed methodology and its implementation is presented in section III and IV while in section V user experiments and results are reported. Finally section VI carries a discussion with the future work.

II. Background

Sentiment analysis and opinion mining due to its social and commercial value has become a very hot topic of research these days. On other hand online social media has become a most significant mode of communication on Web 2.0. Hence sentiment analysis and user opinion mining on online social media has a great social and commercial importance. On social media for sentiment analysis twitter due to is simplicity has remained primary focus of researcher [xiv]-[xviii] while Facebook has been less addressed. Hence in this study a framework is proposed to analyze Facebook posts and comments for opinions and sentiments of the public.

Approaches used in literature for sentiment analysis and opinion mining are primarily based on three types which include machine learning, Lexicon and hybrid [iii], [xix]. Machine learning based approaches mainly use supervised learning [xix], [xx] where a piece of text is compared with human developed list of sentiment bearing words. In this approach an overall scores (more or less positive, negative or neutral) is assigned to the text based on the human designed list. This technique works better for short informal text where people are less formal in using grammar, which is the case in the people comments on the Facebook.

Second type of techniques [xxi] are based on proper grammatical check on the text using various methods of Natural Language Processing. These techniques are mandatory for text where proper grammar has been used. Finally, Hybrid techniques use combination of above mentioned and related techniques for sentiment analysis and opinion mining. For example in [xxii] a hybrid technique of opinion mining for e-commerce applications is proposed which is a combination of principal component analysis for feature reduction and supervised machine learning for prediction of opinions.

As the current study is focused on the sentiment analysis and opinion mining from the text of online social media namely Facebook and the text on Facebook carries formal as well as informal text expressions, hence the proposed framework is based on a hybrid technique. In the proposed framework, both machine learning based technique as well as natural language processing based techniques are used.

III. Methodology

Sentiment analysis is the process of detecting whether a chunk of text carries positive, negative or neutral feelings. Humans have their natural ability to find out sentiments. Human based sentiment analysis and opinion mining bears some limitations described as follows

a) un-scalable
b) can consume huge amount of time
c) un-suitable for real-time decision making
d) very time consuming
e) may be inconsistent if reviewed by different human

In order to deal with these limitation of human beings, a computational framework for sentiment analysis and opinion mining is proposed, in this work. Primary flow and functionality of the proposed framework has been shown in Fig. 1.

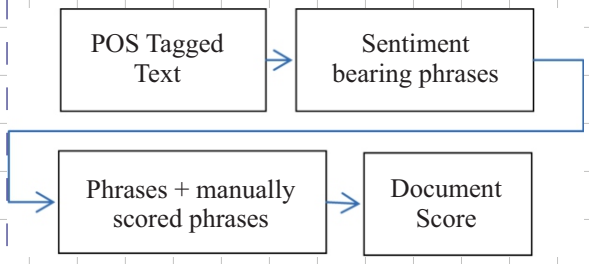

Fig. 1. Framework for Opinion and Sentiment Mining

The framework presented in Fig. 1 is capable of extracting sentiments from a text data set and the entities around which these sentiments are generated. Following are the core steps proposed in the framework which leads to get sentiment orientation of text around entities in a text data set.

In first step all sentences of the text documents are broken into its Parts of Speech (POS), which detects the elements of a document depending upon its grammatical structure (e.g. nouns, adjectives, verbs, and adverbs etc.). Then the rule base expressed in Table I is used to identify Sentiment Orientation (SO) in the text. The SO is determined by identifying whether bigram words are mutually independent or not. For example in phrase "beautiful flower", first word in a bigram is adjective while second is a noun. These two words are mutually dependent as expressed in first row of the Table I.

TABLE I
Rule Base for Identification of Sentiment Orientation (SO)

First Word	Second Word	Third Word (not extracted)
Adjective	Noun	Anything
Adverb	Adjective	Not Noun
Adjective	Adjective	Not Noun
Noun	Adjective	Not Noun
Adverb	Verb	Anything

After identifying sentiment orientation in the text, pre-tagged sentiment lexicons are used to compare with text documents to determine sentiment-bearing phrases. In Social media some phrases also bear Emoticons. To determine sentiment orientation of Emoticons phrases, pre-coded emoticon sentiments are used for example smiley is coded as positive sentiment. Emoticon phrases are of higher precedence among others i.e., with respect to sentiment-bearing phrases. Finally, each phrase polarity is combined to determine the eventual polarity of a sentence and entities in those sentences.

To determine that the sentiments of sentences calculated above are associated with which entity Named Entity Extraction (NEE) is performed. For NEE proper nouns from text are pulled out such as people, places and institutions from text data set. NEE provides valuable inside from text, like what people are talking about for example a company, more importantly what they are talking about that company, to avoid initial training by user, a sentence is checked by its grammar (Parts of Speech) tag. To improve accuracy of NEE a list of named entities is populated through Wikipedia data set this pre compiled list of named entities is used through which this framework has supported extraction of entities remarkably well. In Fig. 2, the basic process through which named entities are extracted from a piece of text is shown.

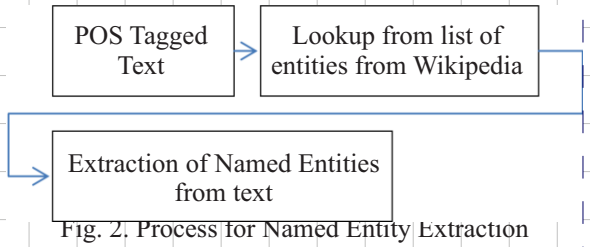

Fig. 2. Process for Named Entity Extraction

After performing above two steps as depicted in Fig. 1 and Fig. 2 the proposed framework is capable of determining sentiment orientation of phrases and the entities with which these sentiments are associated.

IV. Implementation of the Framework

The proposed framework is implemented as a client-server system named "Opinion Miner". In this system for opinion Mining and Sentiment Analysis, first of all comments of a user specified at a Facebook post are extracted. To do this, the user provides a URL of the post (status, picture or video) to this system and all comments by people are extracted by this system automatically to analyze sentiments and opinions.

User enters a URL of Facebook post. The URL firstly is verified that, Is it a Facebook URL? and If it is a URL of a status, picture or a video of Facebook then the system extract the Facebook Id of that content from the URL. It is worthy to mention that, as system is going to extract comments from a Facebook post, so the user has to login in Facebook to access Facebook contents.

On Facebook primarily there are three types of posts

1) Status
2) Picture
3) Video

Therefore, Facebook has constructed different types of URL structures to identify above categories few examples are given below.

https://www.facebook.com/Sohail.aka.Azizi/posts/**10151493851015848**

https://www.facebook.com/photo.php?fbid=**519234448124617**&set=a.277428618971869.60620.238358809545517&type=1&ref=nf

https://www.facebook.com/photo.php?fbid=**613105262047347**&set=at.101829533174925.4148.100000436370858.1498174194.1057787359&type=1&relevant_count=1&ref=nf

https://www.facebook.com/permalink.php?story_fbid=**447262618678275**&id=124433877627819

https://www.facebook.com/photo.php?v=**10102679448949689**&set=vb.20531316728&type=3

Overview of the application's data acquisition process is presented in Fig. 3.

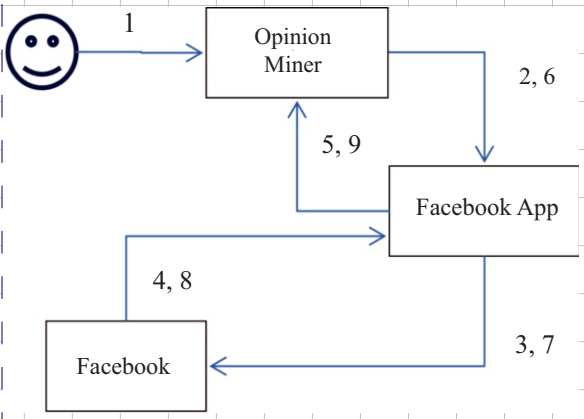

Fig. 3. Data Acquisition Process

Various steps depicted in the Fig. 3 are explained as follows:

1. The blue highlighted numbers in above URLs are the actual post ids of Facebook. Which then are extracted out to get all comments of the posts.
2. First of all it is checked whether the user is already login from Facebook? If not then the systems provides a window where he can login to Facebook in order to use this application.
3. The login user from Facebook is then checked by a Facebook App designed in this system.
4. On the successful login, Facebook provides an authorization key of that particular user to systems' Facebook App.
5. This Facebook App then provides that

authorization key to the system for further process for example getting comments.

6. At this step, this system uses Facebook post id (extracted in step 1) to get comments. So that, Id could be sent to the Facebook app.
7. Facebook App gives this post Id to Facebook in order to get all of comments related to that Id.
8. Facebook provides all the comments to Facebook App which were requested in step 7.
9. Facebook App provides all the comments to Opinion Miner.

At this stage, the Facebook App provides extracted comments to the system. Now Opinion Mining and Sentiment Analysis techniques are applied as described in the Section III.

As the process of fetching comments from Facebook and applying opinion mining and sentiment analysis algorithm on it is very time taking task therefore proposed framework divided this process into client and server programs. Each time server side of the implementation of the system fetches and analyzes100 comments then it shows cumulative sum to user/client side. These comments, their sentiments and opinions are displayed graphically on client site. Client server architecture and the overview of intercommunication protocol are depicted in the Fig. 4.

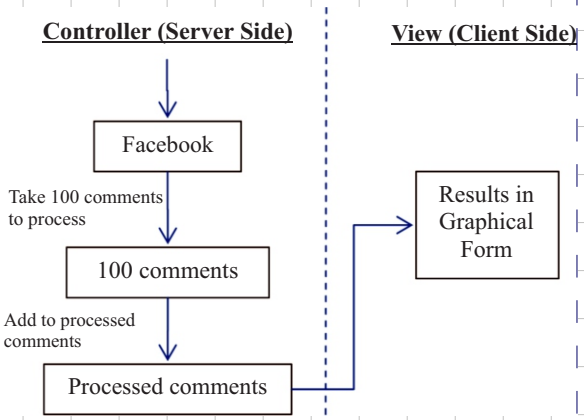

Fig. 4. Client and Server processes and their intercommunication

V. Experiment and Results

For the evaluation of the proposed system, human judgments are used. System is presented to public and they were asked to comment about the accuracy of this system. A set of randomly selected posts from Facebook and user comments on these post were collected. These posts with comments were given to a set of judges to gauge sentiment and opinions in these posts. These posts were classified in to three classes namely positive, negative, and neutral by the judges. Judges were briefed about these classes earlier on and they have provided their feedback accordingly. Randomly 100 post of each class (positive, negative, and neutral) were selected and presented to the system. The system fetched and analyzed posts with comments and accumulated sentiments and opinions depicted in those posts. After this a detailed comparison is performed between classification of human judges and the system and results are reported in follow paragraphs.

Table II presents results of above experiment. In this table the terms PC and AC stands for predicted class and actual classes respectively. Here PC means the class of sentiment of comments predicted by the system while AC means the class of sentiment of comments identified by the user which is considered as actual class.

In Table II details about confusion matrix or contingency table of the above experiment is represented. Through this confusion matrix several accuracy and performance measures of the proposed system could be easy observed like how much comments the system has classified truly as positive, negative and neutral, and how much these comments are wrongly classified as positive, negative and neutral etc.

TABLE II
Multiclass Confusion Matrix of the System's Performance

	Positive (PC)	Negative (PC)	Neutral (PC)
Positive (AC)	78	7	15
Negative (AC)	6	84	10
Neutral (AC)	21	13	66

First row entry in above table could be read as seventy eight (78) posts from positives post marked by human judges were classified as positive by the system while seven (7) and fifteen (15) of positives post marked by judges are classified negative and neutral by the system. Here it could also be observed from Table II that system has been facing a slight difficult in differentiating between positive and neutral sentiments and opinions, as fifteen (15) records which were positive were predicted as neutral and twenty one (21) neutral records were predicted as positive. It should be noted that system is not highly misclassifying between positive and negative classes which are in-fact opposite classes.

For aggregated analysis of this multiclass confusion matrix either of macro or micro averaging technique could be used [xxiii] as total number of records in sample are equally distributed among different classes. To calculate binary confusion matrix for above multiclass confusion matrix first we have construct binary confusion matrix for class namely positive, negative and neutral which are presented in Table III, Table IV and Table V respectively.

TABLE III
BINARY CONFUSION MATRIX FOR POSITIVE CLASS PREDICTION

	Positive (PC)	Not Positive (PC)
Positive (AC)	78	22
Not Positive (AC)	27	173

TABLE IV
BINARY CONFUSION MATRIX FOR NEGATIVE CLASS PREDICTION

	Negative (PC)	Not Negative (PC)
Negative (AC)	84	16
Negative (AC)	20	180

TABLE V
BINARY CONFUSION MATRIX FOR NEUTRAL CLASS PREDICTION

	Neutral (PC)	Not Neutral (PC)
Neutral (AC)	66	24
Not Neutral (AC)	25	175

Binary confusion matrix for the multiclass confusion matrix presented in Table II can be calculated as an accumulated binary confusion matrix using Table III, IV, and V presented as in Table VI.

TABLE VI
ACCUMULATED BINARY CONFUSION MATRIX FOR OVERALL PREDICTION OF VARIOUS CLASSES IN TABLE III, IV, AND V

	Neutral (PC)	Not Neutral (PC)
Neutral (AC)	228	62
Not Neutral (AC)	72	428

Now various measures for the proposed system's performance based on Table 6 could be calculated as True Positive (TP), False Positive (FP), False Negative (FN) and True Negative (TN) for the system are 228, 72, 62 and 428 respectively.

Accuracy of a binary classifier can be calculated as follows

$$Accuracy = \frac{TP+TN}{TP+FN+FP+TN} \quad (1)$$

From Eq. 1 and using data from Table III, IV and V it could be observed that the system has accuracy of 83.66% on positive posts while 88.00% and 83.10% on negative and neutral posts. To calculate average accuracy (the average of per-class effectiveness of the classifier) Eq. 2 is used which resulted average accuracy 84.92%.

$$Average\ Accuracy = \frac{\sum_{i=1}^{l} \frac{TPi+TNi}{TPi+FNi+FPi+TNi}}{l} \quad (2)$$

In Eq. 2 TPi and others represent True Positive of ith class etc. while *l* represents total number of classes.

Average Error Rate (the average of per-class classification error) is calculated using Eq. 3 as follows which resulted into 15.08%.

$$Average\ Error\ Rate = \frac{\sum_{i=1}^{l} \frac{FPi+FNi}{TPi+FNi+FPi+TNi}}{l} \quad (3)$$

Precision which tells an average per-class agreement of the human judges with the system classification is 75.86% which is calculated using Eq. 4.

$$Precision = \frac{\sum_{i=1}^{l} \frac{TPi}{TPi+FPi}}{l} \quad (4)$$

Recall which tells an average per-class effectiveness of the system to identify judgment of human judges is calculated using Eq. 5 which is 78.44%.

$$Recall = \frac{\sum_{i=1}^{l} \frac{TPi}{TPi+FNi}}{l} \quad (5)$$

VI. CONCLUSION

An enormous increase in online user generated text, has recently motivated researchers to focus on design of new computational techniques which could meet different requirements of the sentiment analysis and mining of writer's opinion in the text [iii]–[v]. Approaches used in literature for sentiment analysis and opinion mining could be dived into three types namely, machine learning, Lexicon and hybrid [iii], [xix]. Machine learning based approaches mainly use supervised learning [xix], [xx] where a piece of text is compared with human developed list of sentiment bearing words. While Lexicon based techniques [xxi] are based on proper grammatical check on the text using various methods of Natural Language Processing. These techniques are mandatory for text where proper grammar has been used. Finally Hybrid techniques use combination of above mentioned and related techniques for sentiment analysis and opinion mining.

As the current study is focused on the sentiment analysis and opinion mining from the text of online social media namely Facebook and the text on Facebook carries formal as well as informal text expressions, hence the proposed framework is based on a hybrid technique. In this paper a novel sentiment analysis and opinion mining framework is proposed. This framework utilizes various techniques of computational linguistics to measure sentiment orientation of user's opinion around different entities. A rule base is designed for identification of sentiment

orientation in the text and a list of named entities is populated from Wikipedia to recognize different Name Entities (NE). The proposed framework is used to perform sentiment analysis and opinion mining of users' posts and comments on social media through a Facebook App. Furthermore a user study is conducted to gauge performance of the proposed framework. The results of this study have shown that the framework is capable of finding opinions of the users and sentiments around those opinions with more than 85 percent accuracy when compared with actual human judges.

VII. Future Work

For future work a better sentiment lexicon could be designed to improve accuracy of the system. In particular as observed that the existing system muddled up positive and neutral sentiment, hence new sentiment lexicon can care about this. Also as current system extract only two types of entities, namely people and places. In future extensions it could be enhanced to cars, universities, drugs and many other types of entities which would be of great use. Moreover, as on social media people usually use slang and informal text, it would be an interesting challenge to understand informal expression so that a better sentiment analysis and opinion mining system could be developed.

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A Location Based Delay and Packet Loss Optimized Communication Mechanism involving Handoffs in Vehicular Ad Hoc Network

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Abstract-Vehicular ad-hoc network faces many challenges, in particular frequent handoffs due to high mobility of vehicles is a serious performance limitation factor and is probably the most critical process in terms of packet loss and delay. In this paper an efficient mechanism of Vehicular Ad-hoc Networks (VANETs) is proposed for making handoff decision that considers both Received Signal Strength (RSS) and Global Positioning System (GPS) information along with maps. Furthermore; the proposed mechanism focuses on nodes moving at high speeds while receiving and saving the relevant information in buffers. This particular approach not only minimizes delay and packet loss but is also used to retransmit the lost packets locally. The addition of this capability in the proposed mechanism contributes in improving the packet loss in less crowded areas having limited available connectivity.

Keywords-Ad-Hoc Networks, Mobile Ad-Hoc networks, Vehicular Ad-Hoc Networks, Intelligent Transport System, Short Range Communication

I. INTRODUCTION

Over the past few years, a lot of research has been done in the area of mobile ad-hoc networks (MANETs). In MANETs mobile nodes can connect and communicate with each other via one-hop or multi-hop communication links without the need for an infrastructure [i].

A VANETs is a special type of MANET having fewer limitations as compared to MANETs. In VANETs the movement of vehicles is predictable as they always move on predefined roads and the infrastructure only caters for movements along the road. Secondly, VANETs face no limitations of resources such as power or processing capabilities as almost all the devices have adequate power provided by their host vehicles. Thirdly, in VANETs all the messages are delivered by using broadcast instead of unicast [ii].

Mainly two types of communication modes are used in VANETs, Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I), both having connectivity issues as their prime problem. In V2V, variation in speed and high densities of traffic often results in low data transfer rates and limits the communication. In V2I mode, data communication rate is slower on highways due to the limited availability of Road Side Units (RSUs) [iii, iv]. The main considerations in design of VANETs solutions are to minimize delay and packet loss during communication.

Delay sensitive Intelligent Transportation System (ITS) applications (e.g., safety-related solutions) and value-added applications (such as entertainment and mobile commerce) require continuous Internet connectivity with minimum delay and packet loss [v]. Most of the VANETs applications require seamless mobility, with accessibility and service continuity, regardless of location and technology used. Many delay sensitive applications require fast handover. Fast handover is a crucial requirement to fulfil specially in small coverage networks like Wi-Fi etc. because vehicles spend only a short period of time at each access point due to their high speeds.

In this paper, we propose a novel approach that not only considers RSS parameters but also considers GPS location information along with maps for handoff decision. RSS alone, in fact is not considered much reliable for handoff decision as its accuracy may fluctuate significantly, especially in VANETs scenarios which can cause unnecessary handovers leading to delay and packet loss [vi].

We propose that every vehicle has a GPS enabled scanning module which scan and query the nearby vehicles to get their directions and speeds through on-board GPS enabled scanning module. The scanning module in each vehicle makes a queue of all available vehicles for connection. The vehicles with maximum availability (connectivity duration) are put on top of the queue and given priority. This will minimize the time to find the next best available vehicles for connectivity. When the connection from the previously connected

vehicle is about to end then the next best available vehicle will be maintained on top of the queue by the scanner module. This will minimize the delay time in transmission during routing and switching between vehicles.

The proposed system focuses on nodes moving and receiving information as well as saving the relevant information in buffer. This particular approach not only minimizes the packet loss but also helps to retransmit the lost packets later on. The addition of this capability in the proposed system contributes in improving the packet loss in less crowded areas having limited available connectivity. Packets are stored in the buffer before handoff takes place and the RSS level is about to reach its threshold level, the data packets for transmission are buffered and during handoff process the dropped packets are retransferred.

Rest of the paper is as follows: section II discusses the literature review, section III contains system mechanism, results and discussion is in section IV and conclusion is in section V.

II. Literature Review

As in today's world VANETs seems to be among one of the most emerging techniques, therefore one of the challenging research questions relating to VANETs is the Mobility management that helps in supporting a wide range of intelligent communication system based applications. The importance of VANETs for executing seamless inter-vehicle communication is quite appreciable because they offers infrastructure-less, economic and easily configurable communications. However, the integration of Interne requires a corresponding mobility assistance of the underlying vehicular ad-hoc network. Ravi and Neeraj [vii] have studied the network mobility method in detail in the context of vehicular ad-hoc network and proposed the model that has described the shifting of vehicles within several networks while they are moving. Their proposed handoff method was efficient at reducing the handoff latency and the overhead occurring due to packet loss.

The problem of finding the dead and blind spots and identifying out of coverage areas are severe problems occurring in the rural and some parts of the urban areas as the network infrastructure has not been deployed in those areas [viii]. For handling these issues a novel approach i.e. the hop to hop relay approach for vehicular transmissions has been proposed in order to extend the range of coverage and reducing the frequently generating handoffs. The proposed scheme [ix] allows for continuous connection of vehicles to the roadside infrastructure network which is the Universal Mobile Telecommunication Service (UMTS) for this particular research based project. The discovery of Relay vehicles and selection of the gateways have been discussed and investigated in detail. The proposed architecture of VANETs can be executed on top of any of the available routing protocols. The basic gateway selection have provided the finest performance with Ad hoc On-Demand Distance Vector (AODV) on top as compared to Destination-Sequenced Distance-Vector (DSDV).

Ankita and others [x] have introduced a cluster based method in their paper for implementation of VANETs. As VANET is an enhanced version of MANET, therefore several handoffs related problems that could not be removed earlier in MANETS have easily been removed using this proposed cluster based approach in VANETs. For implementing this infrastructure in VANETs, cluster oriented routing has been employed, by using AODV and AODV+ as the two routing protocols.

In VANETs, the fast moving vehicles and the limited coverage areas of 802.11 devices have made the Mobility Management as one of the challenging tasks to accomplish. This fast movement of vehicles leads to frequent occurrence of handoffs. The handover results in reducing the throughput of the network and causes sudden interruptions in previously build connections. The movement of vehicles in VANETs is assisted by the Mobile IPv6. Some of the most apparent issues of MIPv6 are the enhanced latency, packet loss and triangular routing. Therefore, a handoff structure based on FMIPv6 and HMIPv6 has been proposed [xi] that will eventually results in the lessening 802.11 based handoff latency by eradicating the DAD procedure and also by addressing other associated issues that rises when the structure is applied to the vehicular network.

Many wireless communication mechanisms have been anticipated for VANETs, such as IEEE802.11p is recommended for supporting the small to medium range transmissions in order to cope with the features of vehicular network environments [xii]. The vehicles in these environments are characterized by higher range of mobility which results in frequent disruption of already existing connections. Still, the task of mobility management is quite an attractive and challenging task particularly for VANETs and IEEE802.11p. Zagrouba and others [xiii] have proposed a new method of the handoff for the standard IEEE802.11p in perspective of the vehicular transmissions. The proposed handoff algorithm has been based on vehicle to infrastructure communications and helps in tackling the issues that have been caused either by listening the announcement of the frame service by the vehicle residing on the CCH based channel or by anticipating the full handover period before it begins. The results of simulation and evaluation of performance have shown that the proposed arrangement can reduce the handoff delay and the packet loss quite efficiently.

Hybrid Wireless Vehicular Network originates by integrating several types of networks to exploit their paybacks and optimize the overall network performance. The task of achieving ubiquity is quite

difficult in the presence of several different network types. The aim of the proposed architecture [xiv] is to achieve pervasiveness in Hybrid Wireless Ad-Hoc Networks, which is done by decreasing the handoff delays originating during the handoff mechanism and the existence of moving vehicular network nodes helps in removing the power constraint imposed on the moving nodes. The idea of choosing Ideal Access terminal has been presented in order to attain fast and quick handoff by means of the Early Handoff procedure.

In most of the previous work no one has used the pre scanner to make the queue to make the handoff fast. Our proactive technique find the next node for handoff well before the handoff process. This leads to minimize the time required for handoff.

III. System Mechanism

The proposed mechanism of VANETs is implemented in a highway scenario where vehicles on the road are moving in two directions. The two way roads are further divided into four lanes. The base stations are deployed at both sides of the roads but at alternate positions. There is only one road side unit (RSU) providing transmission facilities to both sides of the roads up to 500 meter. This range depicts the region of connectivity for the current base station. A network may be comprised of several base stations. The vehicles moving in connectivity zone of a base station can smoothly switch between various base stations by initiating the handoff process. The devised algorithm works for handover optimization on the basis of RSS. The idea is to implement handoff before the link failure occurs. This complete scenario is shown in Fig. 1

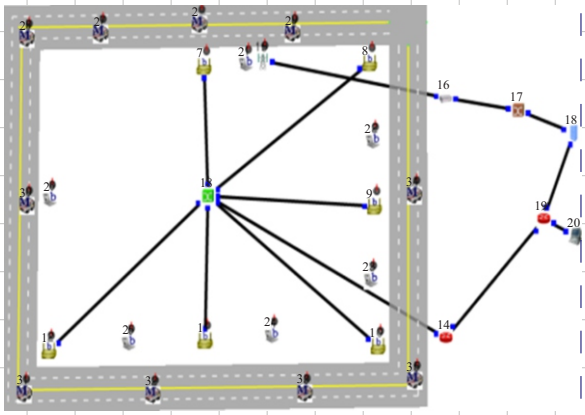

Fig. 1. System Structure

Vehicles communicate directly with the base stations or through other vehicles directly in range of base station. Whenever a moving vehicle i.e. a source vehicle senses the low received signal strength in its current connectivity range, it goes for a handoff process by checking the neighbouring cells having signal strength greater than the current one. The source vehicle sets the minimum value of its RSS in the current connectivity as a threshold value 'Y'. In case of reduced signal strength from the current cell boundary, the source vehicle firstly checks the RSS for the base station it is currently connected to, if the RSS still exceeds the threshold value than there is no need of handoff and the vehicle remains attached to the current base station.

The second case arises when the RSS from the currently connected base station lags behind the fixed threshold value. In such scenario, the source vehicle then searches for neighbouring cells except the current one having signal strength greater than the threshold value 'Y'.

Algorithm 1: Vehicle to Vehicle Handoff

Input: Vehicle to Infrastructure Threshold y, Vehicle to Vehicle Threshold z, Initial buffer size w, Vehicle Queue Q
Output: Connect with RSU/Vehicle

```
while true do
    RSU_c ← CurrentRSU Strength
    if RSU_c > y then
        Keep with current RSU
        continue
    newRSU:
    w = w + 5 (No RSU found increase buffer size)
    RSU_n ← New RSU Strength
    if RSU_n > y then
        Connect With New RSU
        continue
    vehicleQueue:
    Q = scanner(); Get current queue from scanner module
    if length(Q) == 0 then
        Buffer data and disconnect
        continue
    V_Q = dequeue(Q) Vehicle from queue with max signal strength
    if RSU_Vo < y then
        goto vehicleQueue:
    Connected to RSU_Vo via intermediate vehicle
    while true do
        if RSU_Vo < z then
            break; (RSS not satisfied start again) |
```

A. Checking the Desired Signal Strength

The algorithm works in a flow where a source vehicle originates the communication process with one of the neighbouring vehicles as shown in algorithm 1. To achieve the desired connectivity, the source vehicle checks the RSS of the neighbouring vehicles. When the source vehicle finds a neighbouring vehicle with signal strength greater than the currently connected vehicle, the source vehicle tries to connect with the new vehicle. Each vehicle sets a threshold value 'Y' of received signal strength; which is the lower bound of threshold value.

For the purpose of initiating the handoff process the vehicle starts adjusting its packet's window size. When the vehicle sense lower RSS, it immediately starts increasing the packets window size. This will eventually lower the rate of sending and receiving packets, which ultimately results in low packet loss and reduced delay that mostly occurs due to handoff initiation process.

B. Scanning Of Neighbouring Vehicles for Handoff Generation

The handoff occurrence process requires scanning of the neighbouring vehicles moving in the same direction as the source vehicle. The scanning module has been introduced in the proposed algorithm for the purpose of implementing the handoff process and finding the vehicle with best possible RSS. The scanning of vehicles is accomplished through GPS coordinates. The scanner then filter out the vehicles with best RSS and checks the selected vehicles for their speed, direction and velocities. If the scanner failed in searching any desired vehicle then the handoff process will be delayed till the presence of some nearby vehicle is suspected. The searched vehicle with almost similar speed and direction is selected for initiation of handoff process and the scanned results of the remaining vehicles with same direction and approximately same speed are shifted to the queue for later usage. The oppositely moving vehicles among the scanned vehicles are discarded as communication to these vehicles can no longer survive and therefore are not required in the process of handoff implementation.

C. *Introducing Queues for Handoff Generation*

As shown in algorithm 2, the vehicles added to the queue are arranged in the FIFO order. The vehicles with best matching speed and direction are added from the front of the queue. On de-queuing the vehicle entered first will be given precedence and it will be de-queued from the rear end of the queue. When the vehicle connected to the new RSU with greater RSS again receives less signal strength from the currently connected vehicle or RSU, and then instead of re-applying the whole scanning process, the source vehicle first checks the vehicles through the queue. The vehicles in the queue are computed for their RSS value. Upon acquiring the best RSS the corresponding vehicle/RSU is selected from the queue for the purpose of handoff initiation process. Ultimately the handoff process with the resultant vehicle is carried out and the process of communication is again resumed. The window size of buffer which has been increased before the handoff process is again narrowed down to its normal value and the process of packets transmission is restarted.

Algorithm 2: Scanner Module

```
Output: Q Queue of nearby vehicles
1  while true do
2      set P = {V_ss1, V_ss2, ..., V_ssn} of available vehicle signal strength
3      if length(P) == 0 then
4          continue
5      V_maxss ← V_ss1
6      for i ← 2 to n do
7          if V_ssi > V_maxss then
8              V_maxss ← V_ssi
9      N_GPS ← GPS coordinates of vehicle having V_maxss
10     d_N ← direction of vehicle using N_GPS
11     d_V ← direction of own vehicle from GPS coordinates
12     s_N ← speed of vehicle using N_GPS
13     s_V ← speed of own vehicle from GPS coordinates
14     if sign(d_N) <> sign(d_V) then
15         continue
16     if s_N ≈ s_V then
17         insert(Q)
18 return Q
```

D. Scenario of Handoff Generation with Multiple Intermediate Nodes Involved

While scanning process is in progress, it may be possible that the source vehicle does not find any base station in its direct range of communication. The vehicle must have been moving on the other side of the road where base station is not deployed for that specific communication zone. The source vehicle then sends the message for gathering RSS of the base station by involving the intermediate vehicle which is moving in direct communication range of the base station. The intermediate vehicles further deliver the message to its neighbouring vehicles. The process continues until the message is reached to the base station. The base station upon receiving the request message, prepares the reply message and sends it back to the intermediate vehicle which further transmits back the message parcel to the source vehicle.

The source vehicle checks the RSS of the base station with respect to the current threshold value Y. If the result is greater than Y, the source vehicle finally goes for the handoff process and shifts its connectivity to the new base station.

E. Scenario of Handoff Generation with Single Intermediate Node Involved

The alternative scenario for this handoff occurs when only a single intermediate vehicle is involved in the scanning process. For such situation, the intermediate vehicle on receiving the message, computes its own RSS against the threshold value Y of the source vehicle. For exceeded value of signal strength, the intermediate vehicle directly forwards the request to its base station and the source vehicle is successfully connected to the new base station sharing the connectivity to the intermediate vehicle. The intermediate vehicle can also search for the new roadside unit if it is receiving the less signal strength than the threshold value Y. The intermediate vehicle then becomes the source vehicle and the whole searching process is repeated for the intermediate

vehicle.

F. Setting *Threshold 'Z'for New Connection*

As shown in last step of the algorithm 1, the source vehicle sets the new threshold value i.e. 'Z' which is the minimum amount of signal strength it can receive from the new RSU. The source vehicle can enjoy communications in the networking zone of the new base station. Although, handoff has been conducted for once, yet the source vehicle keeps on checking the amount of RSS at every point against the new threshold value 'Z'. As long as the value is exceeding 'Z', the source vehicle can conduct communications. The moment it senses the value going below 'Z', the source vehicle starts searching process and the whole process of examining the signal strengths of other base stations continues. The searching process is a kind of an umbrella activity that is applied throughout the life span of vehicle on the road. The need for handoff has no end point except that the vehicle eventually reaches its destination.

The handoff process is initiated by sending the request message to the new base station for checking the signal strength of the new base station. The request message can be transmitted by forwarding through intermediate nodes or scanning the whole network. On availability of the new base station with required signal strength the handoff request is entertained.

G. Utilization of Maps in Handoff for GPS Coordinates

Handoff request can be implemented on the basis of information gathered through maps and GPS coordinates. The base stations are further connected to the mobile switching centres at the back end. The network servers are located at the back end mobile switching centres. All the required communications are conducted through the back end network server via base station at front end. The maps are added in the base station which provides services to the source vehicle in depicting the right path for its journey to the destination. The layout of the roads in the scenario of VANETs is organized in such a manner that it can place constraints on the movement of the vehicles. Furthermore, the movement of vehicles on the roads is strictly restricted by some traffic conditions that keep on changing at different intervals of time. The burst conditions of traffic can limit the comfortable and smooth initiation of handoff process.

The scheme of adding maps to the base stations is based on the utilization of vehicle's information for predicting the possibilities of handoff process to the neighbouring cells. The information of the vehicle includes uniform speed of the vehicle with which it is moving and the direction of moving vehicle. Along with that the base station uses information stored in the base station regarding road condition for prediction of the probability of handoff occurrence especially with the neighbouring cells. The information is stored in the map for once and then it is utilized for estimation purpose.

The information from the moving vehicles is submitted to the maps in the base stations by using GPS coordinates. All the vehicles on the road are equipped with the GPS devices that provide vehicles with the capability of predicting their accurate positions on the road. The position of the vehicles is then transmitted to the base station which is ultimately stored in the database at the base station. The base station has a back end database for the vehicles in the coverage area of the base station. The database is aimed at storing the transmitted vehicle's information required for probabilistic handoff conductance. Base station uses this information sent via GPS coordinates to perform calculations for all of the active vehicles in its coverage zone.

The above described scheme has been utilized in current research project of handoff optimization. The distinguishing feature of the scheme is that it makes use of the road information and limits the bandwidth usage to achieve efficiency in utilization of the shared resources.

H. Advantage of Using Maps

The vehicles are attached to the Base Stations through the back end network consuming the limited reserved bandwidth assigned to each base station. In mobile ad-hoc networks, vehicles can specifically be designated as the mobile stations. As discussed earlier, each mobile station is equipped with a GPS system for sending GPS coordinates to the Base Station. On the basis of transmitted coordinates, the Base station calculates the location of the vehicle and can further predict its path based on probabilistic approach [xv].

The base stations uses a map service for receiving GPS coordinates as reference points and defining the structure of roads hierarchy and traffic conditions in an efficient manner. Therefore, the utilization of maps can be proved as an effective approach in predicting either the current scenario of handoff or the probability of taking handoff. The overall bandwidth reserved for the network is attuned dynamically whenever there is a possibility of handoff to occur [xvi].

I. Reasons for Generation of Handoff

The need for initiating the handoff process is a result of the less amount of received signal strength in functional channel of the cell. The issue of reduced signal strength may arise due to various possible reasons including the maximum operating capacity of the channel, the amount of bandwidth reserved for the channel and the extreme signalling range of the channel. The operating capability of the channel depends on the number of requests arriving at the channel due to handoffs occurring in the network [xvii]. Depending on the arrived requests, the received signal strength of the channel can therefore be measured.

IV. Experimental Setup and Evaluation Results

The experiments have been conducted on ESTINET [xviii] for different scenarios. Vehicles are equipped with devices capable of having network connections. Transmissions among the vehicles are carried out for varying parameters including frame rate, bit rate and bandwidths. Each experiment has been conducted twice, once for the 802.11p where handoff optimizations are carried out without any available scanning option. The second experiments are conducted for our proposed work which is named as Delay and Packet loss based Optimized Vertical and Horizontal Handoff algorithms (DePOVHH), where scanners are involved for pre-scanning of nearby vehicles. The experimental setup chosen for transmitting video data among vehicles is shown in Table I. The encoding scheme chosen for this specific media type is MPEG-4and maximum of 30 frames are transferred per second.

TABLE I
Video Transmission Parameters During V2V Handoff Simulation

Media Type	Video
Encoding Scheme	MPEG-4
Frame Rate	30 frames/Second
Payload Type	26
Bit Rate	150 kbps
Sampling Rate	90kHz
Bits/Sample	3 Bit
Session Bandwidth	1600kbps
Road Topology	A four lane road

As MPEG-4 format uses less bandwidth [xix, xx], therefore this encoding scheme is used with 150kbps bit rate. Simulation has been run and performance of the scanner and non-scanner algorithms is evaluated. The evaluation results are shown for delay, packet loss and throughput.

A. Average Packet Loss

The simulation results in Fig. 2 and Fig. 3 shows that as the vehicle's velocity increases, the packet loss also increases. The performance of vehicle increases as compared to the existing handoff velocity in DePOVHH. The effect of DePOVHH is more prominent when the velocity of vehicle is less than 25m/s which is the optimize speed on highway, where the packet loss is less than 1000. The number of packet loss is 1297 for ten number of vehicles, where DePOVHH value is 726. This shows that DePOVHH algorithm enhanced the network performance.

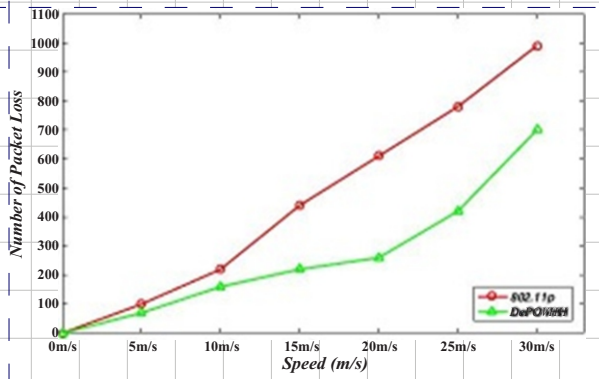

Fig. 2. Packet Loss for five moving vehicles

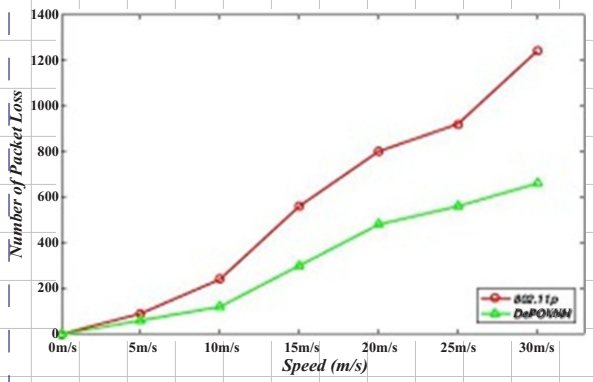

Fig. 3. Packet Loss for ten moving vehicles

B. Average Packet Delay

The simulation results show that as the velocity of vehicle increases, it affects the handoff delay in every handoff algorithm. When the vehicle velocity increases then there is a little time for transmission and scanning at the same time which increased the delay, but, in DePOVHH, as the velocity of vehicle increases it has no reasonable effect on handoff delay. Because before handoff performing active scanning is performed. In the Fig. 4 and Fig. 5 indicates that the packet delay comparison for of different number of vehicles, 5and 10 respectively. The result shown that the at the velocity of 25m/s, the DePOVHH's average packet delay in 5 moving vehicles is 138.69ms, 154.73ms in 10 moving vehicles. It shows that as with the increase in number of vehicles, the packet delay also increases. The reason for that is since there are so many vehicles to establish the next connection before the signal became weak.

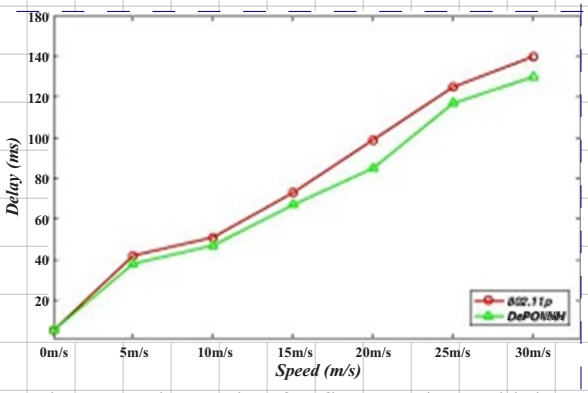

Fig. 4. Packet Delay for five moving vehicle

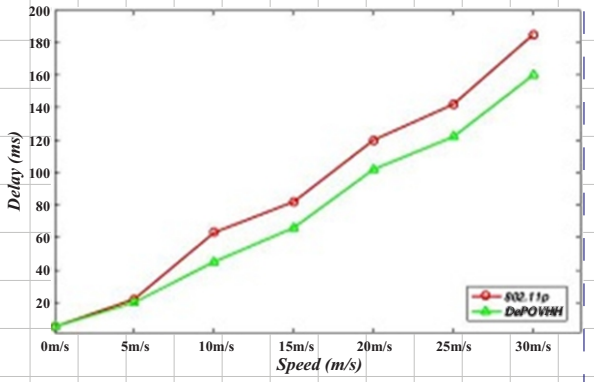

Fig 5. Packet Delay for ten moving vehicle

C. Average Throughput

The simulation results of Fig. 6 and Fig. 7 shows the average throughput for different vehicle velocities. From the simulation result it is clear that increase in vehicle velocity greatly affect the average throughput. Packet loss and delay results in scanning phase which also affects the average throughput. As the vehicle's velocity increases, the packet lost increases and throughput decreases. From Fig. 7 it is clear that as the velocity of vehicle increases, throughput decreases for five moving vehicles. From all of these simulation results it is clear that the association and authentication process between the base station and vehicle is not much affected as the velocity of vehicle is increase.

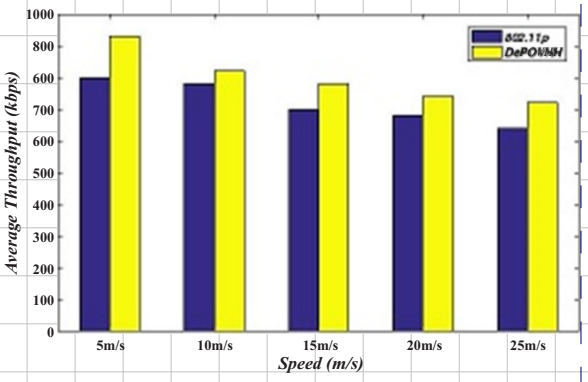

Fig. 6. Average Throughput for five moving vehicle

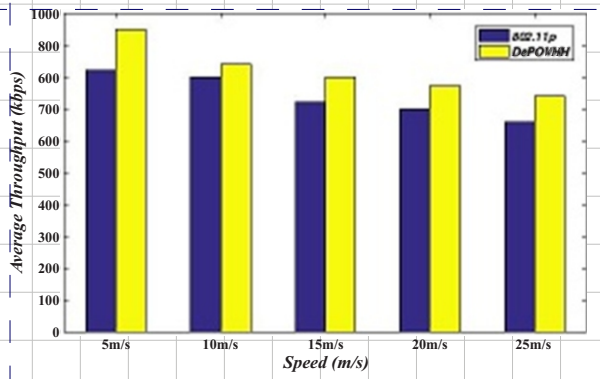

Fig. 7.Average Throughput for ten moving vehicle

V. CONCLUSION

This research based project was aimed at providing delay tolerant optimization techniques for horizontal and vertical handoff occurrences particularly for Vehicular Ad-hoc Networks. An improved technique for handoff has been proposed that caters for delayed packet losses and frequent link failures. The underlying mechanism has been organized to provide maximum throughput while handoff process is in progress. The parameter selected for proposed algorithm to work upon is the Received Signal Strength and the desired information for smooth processing of algorithm is provided through GPS. For experimental purposes, the vehicles on the road are allowed to move randomly with varying speeds and velocities, creating a road map scenario of a two-way traffic. The optimization is achieved by introducing a scanner module through which vehicles pre-scanned their neighbouring vehicles and creates a priority queue for buffering the location of nearby vehicles. On link failure, vehicle selects the top queued item with maximum priority for immediate connectivity. This particular pre-scanning approach saves time in searching for a new connectivity and hence, proved to be the best approach in reducing amount of packet loss due to link failures. Moreover, the proposed system also offers an opportunity for buffering the relevant information of vehicles during on-going communications, which in turn can be sufficient in achieving maximum throughput even on link failure. The packets stored in the buffer are later on retransmitted on finding the new connectivity in range.

The results of simulations for the proposed algorithm clearly depicts the efficiency measure of the algorithm achieved in terms of the reduced packet loss, delay and increased throughput compared to previous approaches adopted for handoff implementation.

The algorithm can be further improved in terms of efficiency by implementing it for infrastructure optimization, where vehicles can also communicate with infrastructure.

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Co-firing of Brown Coal &Bagasse for Sulfur Reduction

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***Abstract*-**Biomassresources such as bagasse, sawdust, rice husk, wheat husk, coconut etc play the vital role in reducing the concentration of SOx and NOx gases when used in co-combustion mode. This study focused on characterization and emission analysis of coal and coal-biomass blends. The blends of brown coal with bagasse in weight proportion10%(CBg-1), 20%(CBg-2), 30%(CBg-3)respectively were characterized by thermal techniques. Proximate and ultimate analysis of coal, bagasse and coal-bagasse blends was carried out. The study reveals that CBg-1 releases 4.18%, CBg-2 emits 3.65% and CBg-3 contained 2.87% of elemental sulfur. Muffle furnace flue gases analysis depicted that coal-bagasse blends samples CBg-1 releases CO_2, NO_2, NO and SO_2 16.573%, 0.01435%, 0.008237%, 0.4384% respectively. It was concluded that sulfur contents were reduced by addition of biomass, SO_2 and NO_x emissions were reduced, whereas CO_2 emissions were increased. Reduction inSO_x, NO_x and enhancement in CO_2 showed efficient and environmental friendly combustion.

***Keywords*-**Brown Coal, Baggase, Characterization, Sulfur Reduction, Co-Firing, Emission Analysis

I. INTRODUCTION

Pakistan is ranked 7th in terms of coal containing country [i] ranging fromsub-bituminous to brown coal [ii]. These resources mounted to more than 185Billion Ton, from which 175 Billion Ton are located in Thar desert of Sindh province and named Thar coal [ii] which is still unused. Presentaly Lakhra coal power is running with capacity150MW [ii].Although it contains high percentage of sulfur, ranges from 1.2% to 14.8%[i]. Presently, coal covers 5.4% of energy demands in Pakistan [ii].Biomass is a renewable and environment friendly source of energy, which is mainly derived from agricultural, municipal solid waste and animal manure. It can play the vital role in utilizing these low quality coal resources in blend combination for generation of electricity and heat. Countable amount of biomasses are available from these resources; 0.000055 Billion Ton/dayof MSW, 0.000225 Billion tons/day of AR and 0.001 billion tons/day of (AM)animal manure [iii][iv].It is estimated that globally 220 billion tons of dry biomass produced annually by photosynthesis [v, vi]. From these available biomass resources, bagasse is the major source that is commercially being utilized as single source or in blend with coal for energy generation.

Bagasse covers 7% energy demand of these countries [iv]. Pakistan is 5th largest sugarcane producer country in the world and potential of bagasse available is 0.015 billion tons in the year 2012-13[vii] [viii].Hence there is the available capacity to generate 2000MW of electric power using bagasse as fuel [ix].

Co-firing of coal and biomass is a cost effective and sustainable option for producing energy. Co-firing reduces NO_x, SO_x and CO and CO_2 emissions [x]. Blending ratio of biomass upto 10 to 30% is optimum for reduction of hazardous pollutants [xi]. Blending ratio of up to 40% of biomass lower the temperature and reduce energy efficiency up to 8% [xii]. Co-firing of coal with biomass eliminate some negative aspects, which frequently occurs during the combustion of biomass alone. Moreover, at high temperature co firing of coal and biomass, chlorine content present in biomass are limited [xiii]. During co-firing combustion properties i.e. overall ash loading, emissions of sulfur oxides and thermal input can be predicted whereas slagging, fouling, burnout, No_x emissions and ignition behavior cannot be estimated [xiv, xv].Aim of this study is to analyse the composition of coal and bagasse blends in various combinations such as 90:10, 80:20 and 70:30 by weight % respectively and to determine the impact of these blending ratio on emission gases..

II. MATERIALS AND METHODS

Coal samples were collected using ASTM D346/D346M-11[XXII] and prepared using ASTM D2013 [xxiii] for Analysis. Bagasse samples were collected using standard representative sampling method. Binding agent (molasses) was obtained from sugar mill. Coal samples were crushed using jaw crusher and gyratory crusher, then passed from sieve analysis to obtain size 208 µm. Bagasse samples were air dried for about10 days in open air. Bagasse samples

were crushed using Hammer mill. Bagasse samples were sieved in similar manner and mean size obtained. Finally coal and bagasse samples were stored respectively.

A. Proximate Analysis of Coal and Bagasse

Proximate analyses of samples were carried out according to ASTM D3172 standard [xxiv], Moisture, volatile matter, fixed carbon and ash contents were analyzed.

1) Moisture Content

Moisture contents were analyzed in accordance with ASTM D3173/D3173M-17 [xxvi] using electric oven. 1g of coal in platinum crucible was heated at temperature 110^{0}C at time 1hour.

Moisture content was determined as follows;

$$M = \frac{(wi - wf) * 100\%}{wi} \quad (1)$$

M = Moisture
W_i = Initial weight of sample
W_f = Final weight of sample

2) Ash Content

Ash contents were analyzed in accordance with the ASTM D3174-12 [xxviii] using muffle furnace. After removal of moisture contents sample was put into muffle furnace for 1hour by raising temperature gradually from 450^{0}C to 600^{0}C, then heated at temperature from 600^{0}C to 700^{0}C for 1hour. Color of samples from black became yellowish.

Ash content was determined as follows:

$$Ash = \frac{(wi - wf) * 100\%}{wi} \quad (2)$$

W_i = Initial weight of sample
W_f = Final weight of sample

3) Volatile Matter

Volatile matter contents were analyzed using standard ASTM D3175-17 [xxx] in electric oven. 1g of coal sample was heated in electric oven at 900^{0}C for 7minutes. Bagasse samples were heated at same temperature for 5minutes. The color of samples was changed into black.

Vollatile Matter was determined as follows:

$$Weight\ loss\ \% = \frac{(A - B) * 100}{A} \quad (3)$$

A = weight of sample used (g)
B = weight of sample after heating (g)

$$VM\ \% = C - D \quad (4)$$

VM = Volatile Matter
C = Weight Loss %
D = Moisture %

4)Fixed Carbon

Fixed Carbon present in samples was calculated by following relations;

$$FC = 100 - (M\% + VM\% + Ash\%) \quad (5)$$

FC = Fixed Carbon

B. Ultimate Analysis of Coal and Bagasse

Ultimate analysis of coal, bagasse and coal-bagasse blends were carried out using ASTM D3176 [xxv]. Ultimate analysis includes carbon, hydrogen, nitrogen, oxygen and sulfur contents in an elemental form with or without ash addition. Determination of experimental procedure of each component is given below [xvi].

1) Determination of Carbon and Hydrogen

According to standard ASTM 3178-84 [xxvii], 0.2g of each sample was taken. Samples were combusted in oven in the presence of air (oxygen). Carbon and hydrogen react with oxygen and converted into CO_2 and H_2O respectively. CO_2 and H_2O are absorbed using KOH and $CaCl_2$ respectively in the tubes of known weights. The increase in weights of the tubes is then determined using the following calculations:

C% = increase in weight of KOH *12*100/initial weight of coal sample*44

H% = increase in weight of $CaCl_2$ *2*100/initial weight of coal sample*18

2) Determination of Nitrogen

According to standard ASTM D3179 [xxix], 1 gof each sample was heated with H_2SO_4 and K_2SO_4 in a long necked flask (kjeldhal flask). Potassium sulfate K_2SO_4 act as a catalyst. After the completion of reaction solution was treated with KOH. Ammonia was formed. Ammonia was distilled and absorbed using standard acid solution of known volume. For liberation of ammonia un-dissolved acid was titrated with NaOH.

N% = (volume of acid used*normality14)/ (weight of coal taken*44)

3) Determination of Total Sulfur Content (Eschka method)

1gof each sample was mixed with 3g of Eschka mixture based on ASTM D4239-14e2 [xxxi]. The mixture was heated at 800^{0}C for one hour. After heating, the mixture was digested in water. The dissolved sulphate was precipitated using barium chloride. The precipitate was filtered and reduced to ashes. The amount of Sulfur was determined gravimetrically.

Note: Eschka mixture was a mixture of magnesium oxide and anhydrous sodium carbonate in the ratio of 2:1.

4) Determination of Ash

The percentage of ash was determined by same method as proximate analysis.

5) Determination of Oxygen

The percentage of oxygen was determined by the formula written below;

O_2% = 100 – (C%+H%+S%+N%+ ash %)

6) Coal-Bagasse Blends

Bagasse was blended with coal at ratio of 10, 20 and 30 respectively. Molasses (binding agent) was added 5% constantand 5% of Sulfur fixation agent $Ca(OH)_2$was addedin the coal-bagasse blends.

Calculation for Single blend

Suppose the composition of coal-bagasse blend 1 (CBg-1). Total weight was 40g.

90% of coal

40*90/100 = 36g of coal

Similarly;10% of bagasse

40*10/100 = 4g of bagasse

36g of coal (90%) was blended with 4g of bagasse (10%), molasses and sulfur fixation agent was added 2g(5%) each. Blend was formed in briquettes formation machine.

In this way three different samples of blends was formed. Namely CBg-1 contains 90%coal and 10% bagasse, CBg-2 contains 80% coal and 20% bagasse and CBg-3 contains 70% coal and 30% Bagasse.Blends were dried and stored.

7) Emissions Analysis of Coal-Biomass Blends

Hazardous emissions such as CO, CO_2, NO, NO_2 and SO_2 were analyzed using muffle furnace (for co-firing) and stack gas analyzer (for emissions). Coal-bagasse blend samples were heated at temperature of 850^{0}C. By co-firing emission were released. The emissions were analyzed from the stack of muffle furnace using stack gas analyzer. Stack gas analyzer has ability to analyze CO, CO_2, NO, NO_2 and SO_2 emissions.

III. Results and Discussion

A. Proximate analysis of Coal and Bagasse samples

As depicted in Fig.1 the coal contains higher percentage of fixed carbon 24.49%) , ash (29.37%) and moisture (17.6%) and lower in volatile matter (28.41%). Whereas bagasse is the highest in volatile matter (76.6%), lowest in fixed carbon (11.1%), moisture (10.4%) and ash (1.9%). The other investigators have reported the Lakhra coal results in specific range of these components i.e fixed carbon in the range 9.80%-38.20%, moisture 9.70%-38.10%, volatile matter 18.30%-38.60% and ash 4.30%-49.00%. While the other research reported similar results for bagasse i.e fixed carbon 11.35%, volatile matter 37.70%, moisture 48.8% and ash 2.15% [xviii]. [xvii] showed fixed carbon 9.80%-38.20%, moisture 9.70%-38.10%, volatile matter 18.30%-38.60% and ash 4.30%-49.00% [xvii].

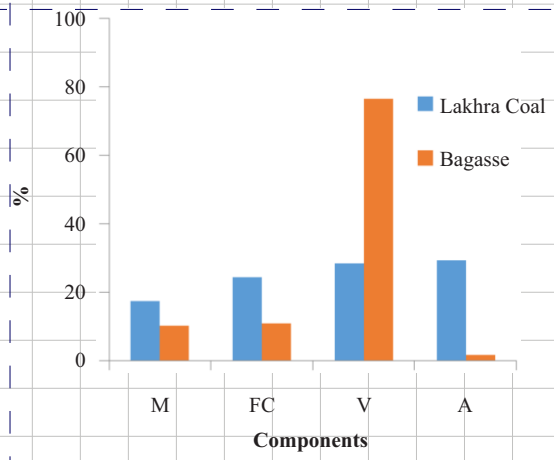

Fig. 1. Proximate analysis of raw materials

B. Ultimate analysis of Coal and Bagasse Samples

Ultimate analysis of coal sample carried out on moisture ash free basis gave carbon content 68.84%, Hydrogen 10.2%, nitrogen 1.42%, Oxygen 14.7% and sulfur 4.2% as shown in Fig. 2.Previous research showed sulfur range of 1.2% to 14.8% [xvii]. Bagasse sample gave 49.84% of carbon, 6% of hydrogen, 0.2% nitrogen, 43.9% of oxygen and 0.06% of sulfur as shown in Fig. 2. [xviii] showed carbon 44.1%, Hydrogen 5.62%, Nitrogen 0.19%, oxygen 44.4%. Basic composition of bagasse varies depending on its source and environmental conditions.

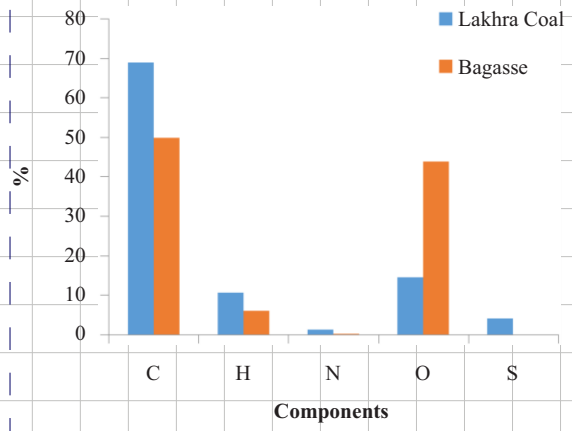

Fig. 2. Ultimate analyses of raw materials

C. Proximate analysis of coal-bagasse blended Samples

The different samples of coal-bagasse blends CBg-1, CBg-2, CBg-3 were analyzed. CBg-1 gave higher moisture 16.91%,fixed carbon 23.15% and higher ash content 26.62%.CBg-3 gave higher volatile matter content 42.94% as shown in Fig. 3.

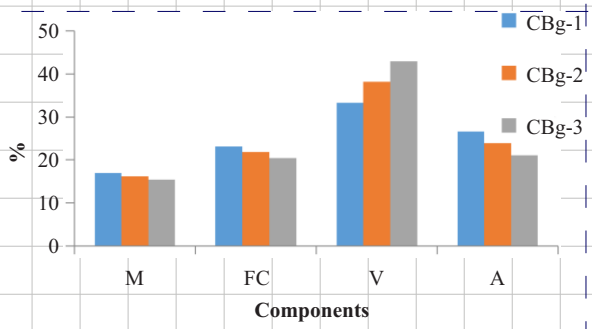

Fig. 3. Proximate analysis of Coal-bagasse blends

D. Ultimate analysis of coal-bagasse blended Samples

Ultimate analysis of coal-bagasse blends were carried out CBg-1 gave higher amount of carbon 67.22%, Hydrogen 9.5%, Nitrogen 1.9% and sulfur 4.18%. It was examined that over all percentage of sulfur reduced to 0.05%.Whereas carbon and hydrogen content were increased. CBg-3 sample gave higher amount of oxygen 23.07%.

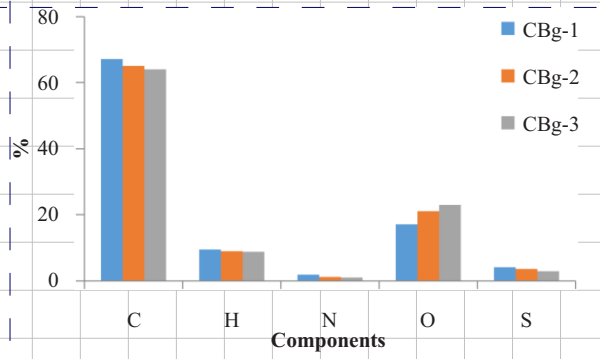

Fig. 4. Ultimate analysis of coal-bagasse blends

E. Emission Analysis of Coal-bagasse blends

Emission analysis is part of a combustion process carried out for improving the fuel economy, reduction of undesirable exhaust emissions and for improving the life of fuel burning equipment. Combustion analysis begins with the measurement of flue gas concentrations.

Flue gas emissions were carried out at Petroleum of natural gas Institute of MUET using muffle furnace for co-firing and flue gas analyzer for emissions such as CO_2, CO, NO_2, NO, NO_x, SO_2, and H_2 ,O_2 etc. results were shown in Table I.

TABLE I
EMISSION ANALYSIS OF COAL-BAGASSE BLENDS

Component	O_2 %	NO_2 %	NO %	NO_x %	SO_2 %	H_2 %	CO %	CO_2 %
CBg-1	0.9189	0.01435	0.008327	0.2267	0.4384	2.1064	1.427	16.573
CBg-2	1.0965	0.01246	0.00725	0.1971	0.3844	2.7453	1.9543	15.136
CBg-3	1.2845	0.01065	0.00695	0.176	0.3486	3.1019	2.3658	14.326

1) Emissions of Oxides of Carbon

CO_2 emissions are released based on the carbon content as obtained from the elemental analysis of the coal and the excess air (oxygen) used in the power plants and plant (equipment) efficiency.CO_2 emissions varies by varying the excess air during combustion as well as carbon content in the coal. CO_2 emissions cannot determined/estimated without experimental investigation [xix]. CO emissions released are by product of CO_2. CO emissions released because of incomplete co-firing.

CBg-1 released CO_2 emissions (16.573 %) was the highest percentage of CO_2 emissions, the byproduct CO emissions released were 1.427% which showed lower percentage of CO emissions evolved. CBg-2 samples release CO_2 and CO emissions were 15.136% and 1.9543% respectively and CBg-3 released 14.326% and 2.3658% of CO_2 and CO emissions respectively as shown in Fig. 5. There is release of higher percentage of $CO_2$and lower percentage of CO emissions in samples CBg-1, CBg-2 and CBg-3 showed efficient co-firing.

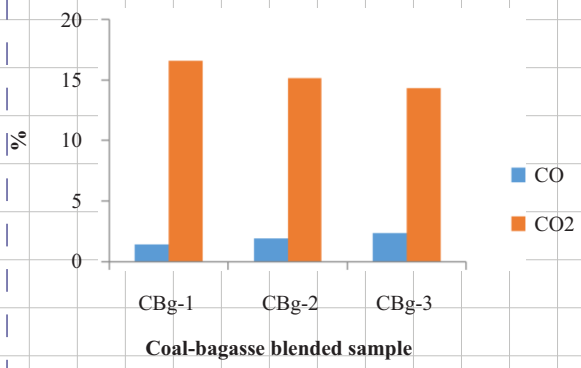

Fig. 5. CO_2 and CO Emission analysis of coal-bagasse blended samples

2) Emissions of Oxides of Nitrogen

Nitrogen oxides NO_x are one of the most important emissions resulting from the combustion of fuels.

Typically Nox emissions released from co-firing are NO, NO_2, N_2O, N_2O_3 and N_2O_5. NO and NO_2 are major NO_x emissions. Nitrogen oxides are environmentally the most harmful. The research has been done for reduction of NO_x emissions. NO_x emissions depend upon presence of nitrogen in the raw material, excess air (oxygen) and co-firing process conditions [xx].

NO_2 emissions released by coal-biomass blends samples CBg-1, CBg-2 and CBg-3 were 0.01435%, 0.01246% and 0.01065% respectively. NOx emissions released were 0.008272 for CBg-1, 0.00725% for CBg-2, 0.00695% for CBg-3 respectively as shown in Fig. 6.

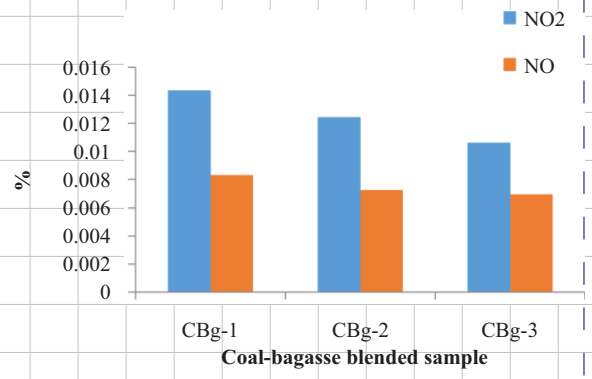

Fig. 6. NO_x Emission analysis of coal-bagasse blended samples

3) Emissions of Oxides of Sulfur

SO_2 emission released depends upon the presence of sulfur content. None of any practical accessory has been found for reduction of SO_2 emissions in the atmosphere [xxi]. It is estimated that all the sulfur present in the coal is converted into SO_2 emissions during co-firing.

Coal-bagasse blends i.e. CBg-1 sample released 0.4384% SO_2, CBg-2 released 0.3844% SO_2 and CBg-3 sample released 0.3486% SO_2 as shown in Fig. 7. Collectively all the SO_2 emissions released were significantly reduced.

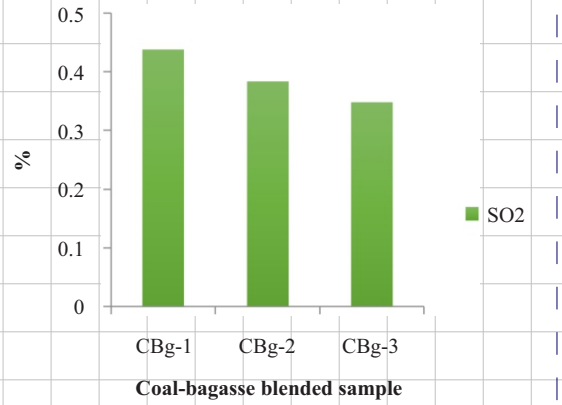

Fig. 7. SO_2 Emission analysis of coal-bagasse blended samples

IV. Conclusion

Lakhra coal contain higher amount of sulfur ranges from 2.0-14%. By addition of bagasse (biomass) in coal basic composition of coal varies, gave lower sulfur content as compared to coal. Sulfur present in the coal converted into SO_2 emissions was reduced. Bagasse (biomass) is a CO_2 neutral fuel. By addition of bagasse to form blends transport, dispose and environment problem of biomass were reduced and Coal dust is become useful. Coal-bagasse blends gave efficient combustion, reduce CO emission. Finally NO_x emissions reduced to significant level were released in very small quantity.

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Papers may be submitted any time throughout the year. After receipt of paper it will be sent to concerned referees, at least one from a technology advanced countries. Papers reviewed and declared fit for publication will be published in the coming issue. The journal is quarterly publication, having four issues annually. A soft copy of paper must be submitted through online submission system by using the following link:-
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Authors are required to read the following carefully for writing a paper.

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Text should be type-written with M.S word, Times New Roman Font size 10, at single space and with margins as 1 inch top,1 inch left, 0.5 inch right, and 1 inch bottom, on an A-4 size paper. The manuscript should be compiled in following order:-

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The Title page should contain:

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- Author names and affiliations
- Postal and email addresses
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Abstract

An abstract up to maximum of 200 words should be written in the start of paper. The abstract should give a clear indication of the objectives, scope, methods, results and conclusions.

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Include at least five keywords (Title Case) in a separate line at the end of the abstract.

Body of the Paper

Body of the paper may include introduction and literature review, materials and methods, modeling/experimentation, results-discussions and conclusions etc.

- Define abbreviations and acronyms the first time they are used in the text, even after they have already been defined in the abstract. Do not use abbreviations in the title unless they are Unavoidable.
- Use zero before decimal places: "0.24" not ".24".
- Avoid contractions; for example, write "do not" instead of "don't."
- If you are using *Word,* use either the Microsoft Equation Editor or the *MathType* add-on (http://www.mathtype.com) for equations in your paper (Insert | Object | Create New | Microsoft Equation *or* Math Type Equation). Number equations consecutively with equation numbers in parentheses flush with the right margin, as in (1). Refer to "(1)," not "Eq. (1)" or "equation (1)," except at the beginning of a sentence: "Equation (1) is ... ."
- Symbols used in the equations must be defined before or immediately after it appears.
- Use SI units only.

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Only original contributions to Engineering, Science and Management literature should be submitted for publication. It should incorporate substantial information not previously published.

Length

Research paper should be consisting of 5-8 pages as per specifications given above.

Accuracy

All the technical, scientific and mathematical information contained in the paper should be checked with great care.

Figures

All figures should be at least 300 dpi in JPG format. It is to be also ensured that lines are thick enough to be reproduced conveniently after size reduction at the stage of composing. All figures (graphs, line drawings, photographs, etc.) should be numbered consecutively and have a caption consisting of the figure number and a brief title or description of the figure. This number should be used when referring to the figure in the text. Figure may be referenced within the text as "Fig. 1" etc.

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Tables should be typed in a separate file using M.S. Word 'table' option. All tables should be numbered in Roman numerals consecutively. Tables should have a caption in Upper Case, must be centered and in 8 pt. consisting of the table number and brief title. This number should be used when referring to the table in text. Table should be inserted as part of the text as close as possible to its first reference.
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Acknowledgments
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Reference may be cited with number in square brackets, e.g. "the scheme is discussed in [iii]". Multiple references are each numbered with in bracket. e.g. the scheme is discussed in [iv-vii]. Do not use "Ref." or "reference" except at the beginning of a sentence: "Reference [xi] illustrates... ."

Please do not use automatic endnotes in Word, rather, type the reference list at the end of the paper using the "References" style. Reference list/bibliography and in text references, both will be cited in roman alphabet. "Within text citations must be in chronological order in the first appearance. The subsequent appearance(s) of the same may be random as per need of the paper."

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