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Section A

CIVIL/ENVIRONMENTAL/ ARCHITECTURE/ TRANSPORTATION ENGG./ CITY AND REGIONAL PLANNING

Assessment of Drought Risk by Using Vegetation Indices from Remotely Sensed Data: A Perspective from Hot and Arid District of Pakistan

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Abstract-The Shaheed Benazir Abad District is situated at the center of Sindh Province, which is one of the hottest and driest part of Pakistan. In the past few decades, the extreme and moderate droughts had been reported in the district with peak value -2.4 recorded using the Standardized Precipitation Index (SPI). In this study, satellite remote sensing and digital image processing techniques were used to monitor the drought conditions in the district. Multiple drought indices were calculated by using Thematic Mapper (TM) data of the Landsat satellite program, jointly managed by the U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA), including Land Surface Temperature (LST), Normalized Vegetation Index (NDVI), Vegetation Condition Index (VCI) and Temperature Vegetation Index (TVX). These indices provided the agricultural drought conditions for the duration of 1992-2011. The VCI maps indicated the high drought conditions in the plain land, away from the built-up areas, while the proximity of the built-up land is under a moderate drought. However, in cultivated lands, the agriculture drought condition is not obvious due to canal irrigated cultivation. A drought in year 2011, was more severe than in the year 2000. It is an indication of climate change impacts in the region.

Keywords-Drought, Remote Sensing, GIS, Vegetation Indices, NDVI, VCI, LST

I. Introduction

A universally accepted definition of drought does not exist because this natural disaster is a complex but least understood phenomenon [i]. The major reason of this disaster is a deficiency of precipitation or shortage of water [ii]. Depending on the specific interest of different people, drought has different meanings. For a former, it is a shortage of moisture in the root zone of crops; whereas hydrologists suggest that it is below the average water level in stream, reservoir and lake, and economists define it as a shortage, which affects the established economy. The drought is considered as a unique event in its spatial expansion, climate characteristics and impact [iii].

Pakistan is facing by and large arid to hyper-arid climate condition in which its limited surface and ground water availability have been reduced from 5600 cubic meters per capita to 1200 cubic meters per capitafor the duration of 1947-2001[iv]. In the last few decades, extreme and moderate droughts have been observed in many parts of the country including Shaheed Benazir Abad, wherea peak value of Standardized Precipitation Index (SPI) was assessed -2.4 during 1975-2003 [v]. The SPI is an empirical drought monitoring index that is calculated as the difference of precipitation from the mean divided by the standard deviation. It is a theoretical probability distribution, which is calculated based on a long-term precipitation record of data for a desired period. Drought occurs when the SPI value reaches -1 or less [vi]. Using SPI for drought monitoring have some

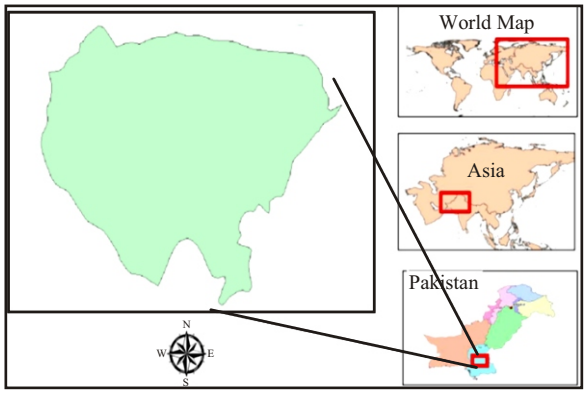


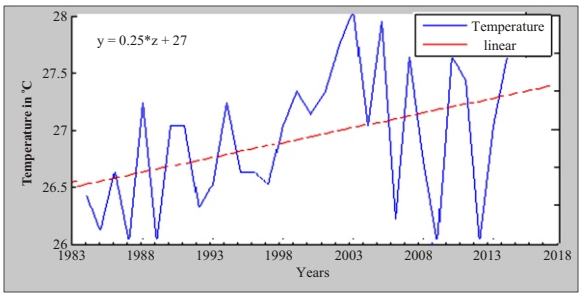
Fig. 1. Study Area "Shaheed Benazir Abad"

disadvantages, the first being the assumption that a suitable theoretical probability distribution can be found to model the raw precipitation data prior to standardization. The second disadvantage is that the extreme drought condition occurs over longer period with the same frequency in all locations; therefore, identification of the drought prone region is difficult [vii, viii]. Moreover, area with small seasonal precipitation causes misleading the large positive and negative values of SPI [vii , viii].

Integrated remote sensing and GIS technologies have become the most efficient way to systematically retrieve information from the atmosphere, land surface, and water resources. The long time period and large region data collection represent a great advantage for the natural resource monitoring, disaster risk assessment and dynamics processes studies. These are cost effective and give the up-to-date information over a large geographical area [ix, x]. The vegetation index NDVI is most frequently used to classify the land cover of a region [xi]. It has been successfully and effectively employed by geographers in different studies to appraise vegetation vigor all over the world [xi]. The statistical relationship between drought indices and NDVI at regional scale has been presented in many studies, for instance Boushaki [xii]. Many researchers, including Ramesh [xiii] and Kogan [xiv] have used the Advanced Very High Resolution Radiometer (AVHRR) onboard the National Oceanic and Atmospheric Administration (NOAA) series of satellites to show the application of vegetation and temperature condition indices for drought monitoring. A comparison of vegetation Indices over a Global set of TM Images with EOS-MODIS has been done by Huete [xv]. Liu [xvi] highlighted the VCI as a useful tool to analyze temporal and spatial evolution of the regional drought as well as to estimate regional agriculture production qualitatively. The VCI can give a comprehensive picture for drought analysis and decision- making [xvii].

Shaheed Benazir Abad is known as a lush agricultural area irrigated by canal network, which is situated in the geographical center of the Sindh province of Pakistan (see Fig. 1). It is one of the hottest and driest part of the country and it has arid environment due to the less precipitation.

The average temperature of Shaheed Benazir Abad is 26.6°C and precipitation averages is 143 mm. Using



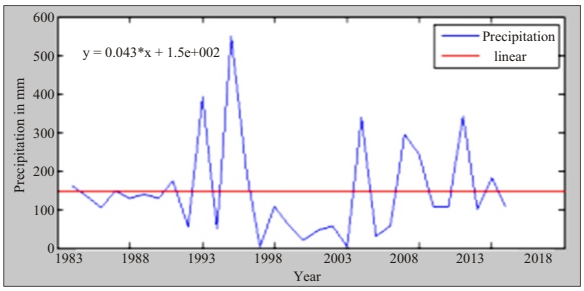


Fig. 2. Precipitation and Temperature Pattern in Shaheed Benazir Abad during 1983 to 2013

the Matlab software, temperature and precipitation trends are observed in Shaheed Benazir Abad for duration of 1980 to 2013 as shown in Fig. 2, which indicate a rising trend in temperature and no change in precipitation trend over the time.

The focus of this paper is to monitor the drought risk in Shaheed Benazir Abad, using remote sensing and GIS techniques by calculating NDVI, LST, TVX and VCI for the duration 1992-2011. These vegetation indices have identified drought prone regions.

II. Materials and Methods

NDVI and VCI can provide a comprehensive picture for drought monitoring, analyzing, and decision-making. Lower value of VCI in percentage, indicates higher degree of drought, whereas higher percentage value reflects lower drought Table I. It provides a quantitative estimate of weather impact on vegetation and also measures the vegetation condition. It gives a synoptic view of the land surface and a spatial context for measuring drought impacts in a convenient spatio-temporal approximation. VCI can be represented by the following equation:

$$VCI = \frac{NDVI - NDVImin}{NDVI\ max - NDVImin} \quad (1)$$

Where, NDVI, NDVImax, and NDVImin are given year NDVI, multiyear maximum NDVI and multiyear minimum NDVI, respectively, for each grid cell [xviii].

TABLE I
VCI-Criteria of Drought Conditions

Drought Condition	VCI (%)
Extreme	1 - 10
High	10 - 20
Moderate	20 - 30
Low	30 - 40
No Drought	40 >

The ratio of LST and NDVI, known as TVX, gives more spectral information for drought detection because it integrates both reflective and thermal bands

of remotely sensed data [vii]. It is also used to examine the local moist conditions [xix]. It can be defined as follows:

$$TVX = \frac{LST}{NDVI} \quad (2)$$

ArcGIS, a geographical information system software, works on both raster and vector maps, has been used for calculating the LST and vegetation indices. Landsat-5 TM images for the month of June (1992, 2000, 2009, 2010, and 2011) were used for generating the maps. First, all historical images were radiometrically corrected by converting digital number DN into Spectral radiance with the help of the given equation:

$$L\lambda = Lmin + (Lmax - Lmin) * \frac{DN}{255} \quad (3)$$

Where,
Lλ = Spectral radiance,
Lmin = Spectral radiance of DN value 1
Lmax = Spectral radiance of DN value 255,
DN = Digital Number.

In the next step for calculation of LST, the brightness temperature was computed from the spectral radiance at the thermal band (band 6) by the equations [xx]:

$$Tb = \frac{K2}{\ln\left(\frac{K1}{L\lambda}\right)} + 1 \quad (4)$$

Where, K1 and K2 are constants (for Landsat 5 TM: K2 = 1260.56 and K1 = 607.76)
Lλ is the spectral radiance at band 6.
Then, the surface temperature has been computed from the brightness temperature as:

$$LST = \frac{T_b}{\varepsilon_0^{0.25}} \quad (5)$$

where, emissivity is:

$$\varepsilon_0 = 1.009 + 0.047 * ln(NDVI) \quad (6)$$

Source: Ahmad [xxi]

The relation is only valid for NDVI values greater than 0.16. Therefore, an adjustment has been made for NDVI less than 0.16, emissivity has been set to 0.92 and for NDVI less than 0 (normally water surface), the emissivity has been set to 1.

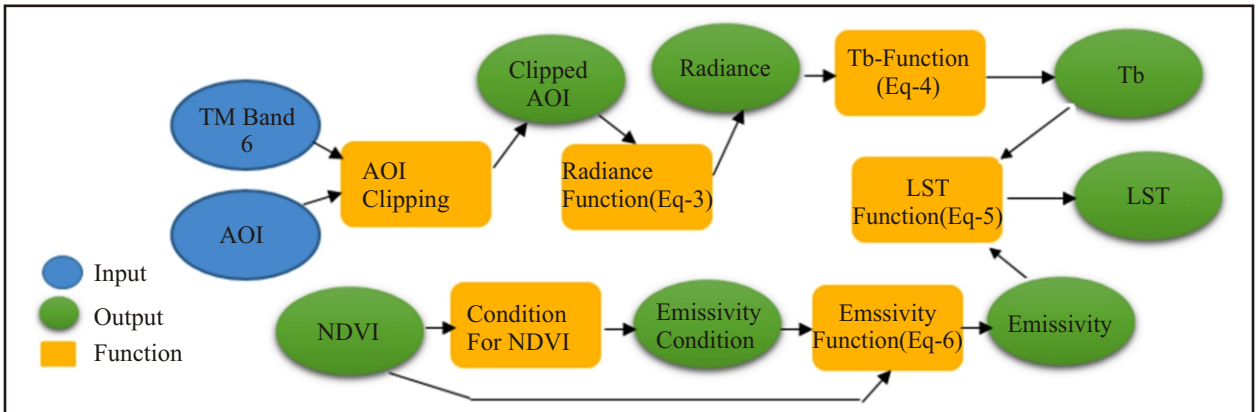


Fig. 3. GIS Process Model for Land SurfaceTemperature Assessment

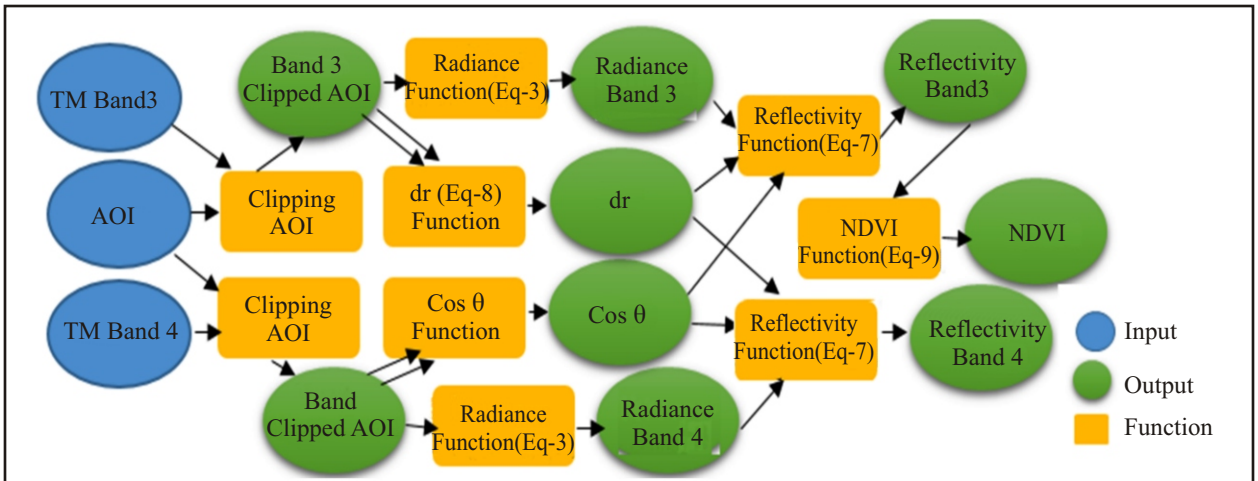


Fig. 4. GIS Process Model for NDVI Assessment

Spectral Reflectance can be calculated by equation:

$$\rho_\lambda = \frac{\pi \cdot L_\lambda}{ESUN_\lambda \cdot \cos\theta \cdot d_r} \quad (7)$$

Where, ESUN is mean solar exo-atmospheric irradiance for each band, θ = 90 - sun elevation, d_r is the relative distance between the sun and Earth.

$$d_r = 1 + 0.033 \cos\left(DOY \frac{2\pi}{365}\right) \quad (8)$$

Where DOY is the sequential day of the year

The NDVI is a measure of the amount and vigor of the surface vegetation and has been calculated by reflectance in near infrared and red band of the visible spectrum as follows:

$$NDVI = \frac{\rho_4 - \rho_3}{\rho_4 + \rho_3} \quad (9)$$

With the help of LST and NDVI model as shown in Fig. 3 and Fig. 4, VCI and TVX have been calculated.

III. Results and Discussion

The outcome of NDVI shows that during the study time period from 1992 to 2011, the highest calculated value was in 1992 i.e. 0.657. Whereas, the maximum value of NDVI in 2011 was only 0.35; therefore, this year has less vegetation as shown in Fig. 7.

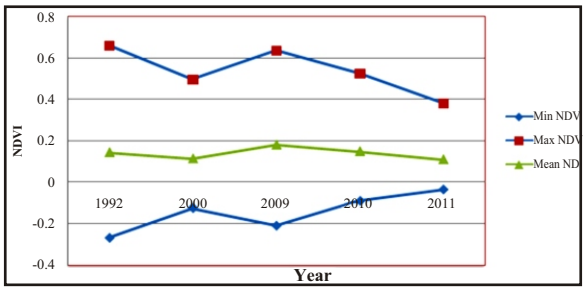


Fig. 5.NDVI for the duration for 1992 to 2011

With the graphical representation shown in Fig. 5, decreasing trend has been noticed for the given duration that indicates the presence of drought condition in the study area.

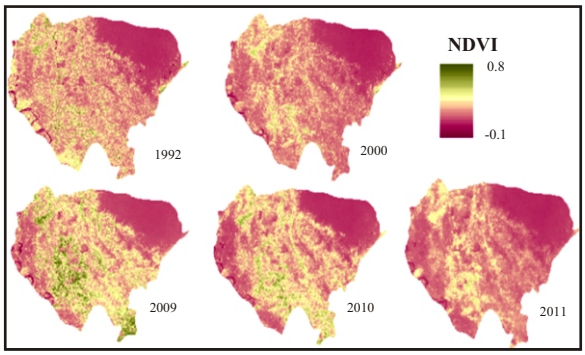


Fig. 7. NDVI for the duration of 1992 to 2011 (Shaheed Benazir Abad District)

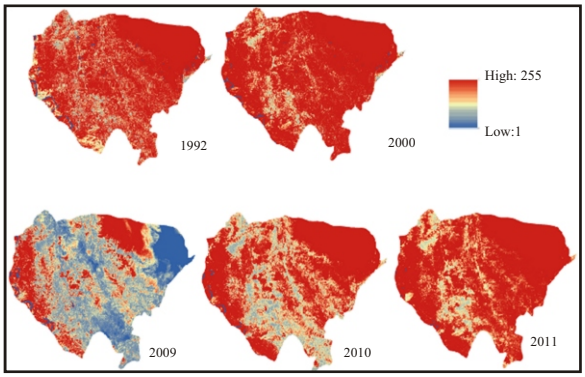


Fig. 8. TVX for the duration of 1992 to 2011

The TVX higher value indicates a drought condition (low soil moisture) whereas the lower value shows no drought condition (see Fig. 8)

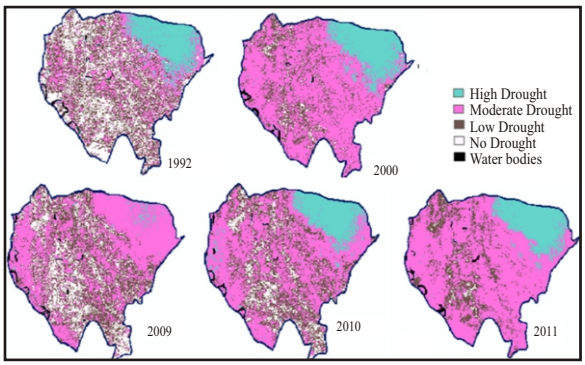


Fig. 6. VCI for the duration of 1992 to 2011

The VCI maps shown in Fig. 6 indicate that the high drought conditions have been observed in deserted region that is outside the irrigated land. However, the agricultural areas with open land are indicated with the moderate drought conditions. As most of the regions of Shaheed Benazir Abad are canal irrigated agricultural lands, therefore severe agriculture drought conditions is not present in such areas; but in particular years, these areas contain low or moderate drought conditions. It

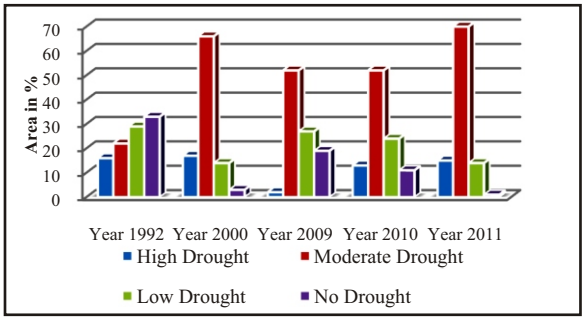


Fig. 9. Distribution of Drought Area (%)

has also been noticed that moderate drought is present near the water bodies areas which are suitable for the agriculture. The dryness of these areas is an alarming situation because these water bodies can provide water

for the land in the absence of precipitation. NDVI and TVX maps also verified this condition as in 1992 agriculture land was spread over a large area near the water bodies but later the situation has been changed. In 2009 vegetation condition was slightly better as compared to 2010 and 2000 because drought is a stochastic phenomenon that repeats after a certain time period. Therefore, it is possible to observe this pattern and make predictions for the future.

The VCI graphical representation with respect to the percentage of area covered, as shown in Fig. 9, indicates that moderate drought conditions have been observed in Shaheed Benazir Abad during 1992 to 2011 that covered 50% to 60% of the area. But in 1992, the moderate drought condition was observed only in 20% of the area, which is the lowest percentage as compared to others. In this graph, on an average, high drought conditions are present only in 10 percent of the area.

IV. Conclusion

The vegetation indices are helpful for estimation of vegetation health and drought. VCI has excellent capability to detect drought and measure the time of its onset, strength, duration, and impact on vegetation. The VCI presents accurate information about drought not only for well-defined, widespread and severe droughts, but also for non well-defined, short-term, and very localized droughts. In this study, the vegetation indices; NDVI, VCI, and TVX provided continuous spatial surface data for monitoring the drought condition over a region, which is impossible to get from the discrete and distant meteorological stations.

From the VCI map analysis, we concluded that most parts of the Shaheed Benazir Abad are perpetually affected by a moderate drought condition. The TVX map also validated the drought conditions. During last decade, it has become more prominent and indicating some possible impacts of climate change in the region.

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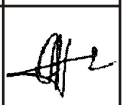
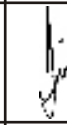
List of Abbreviations:
SPI - Standardized Precipitation Index
NDVI - Normalized Vegetation Index
VCI - Vegetation Condition Index
TVX -Temperature Vegetation Index
GIS - Geographical information System
Landsat-5 (TM) - Landset-5 (Thematic Mapping)
USGS - U. S. Geological Survey
NASA - National Aeronautics and Space Administration
AVHRR - Advanced Very High Resolution Radiometer
NOAA - National Oceanic and Atmospheric Administration
EOS-MODIS - Earth Orbiting system - Moderate Resolution Imaging Spectroradiometer

List of Mathematical Symbols:
$L\lambda$ - Spectral radiance
Lmin - Spectral radiance of DN value 1
Lmax - Spectral radiance of DN value 255,
DN - Digital Number.
Tb - Brightness Temperature
K1 = 607.76 (for Landsat 5 TM)
K2 =1260.56 (for Landsat 5 TM)
ε_0 - Emissivity
ρ_λ - Spectral Reflectance
ρ_4 - Spectral Reflectance of band 4
ρ_3 - Spectral Reflectance of band 3
ESUN - Solar exo-atmospheric irradiance
$\theta = 90$ - Sun elevation
d_r - Relative distance between sun and Earth
DOY - The sequential day of year

Authorship and Contribution Declaration			
	Author-s Full Name	**Contribution to Paper**	
1	Ms. Rabia Tabassum (Main /Principal Author)	Proposed topic, statistical analysis and manuscript writing	
2	Dr. Mudassar Hassan Arsalan (2nd Author)	Basic study design, methodology and interpretation of results	
3	Ms. Anam Khalid (3rd Author)	Literature review & referencing, data collection and statistical analysis	
4	Prof. Dr. Ijaz Ahmad (4th Author)	interpretation and discussion writer and quality insurer	
5	Dr. Ali Iqtidar Mirza (5th Author)	Cartographic interpretation and illustration preparation	

Study of Polluted Water Mixing on Sediment of Lahore Canal

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***Abstract*-**People living in societies along the canals which pass through the urban areas, are adding domestic & industrial waste water and wastes into them like Lahore canal. This untreated industrial and municipal waste and contaminated water may become a risk to irrigation water quality and sediment moving in it in the form of suspended load. The results disclose that as suspended sediment concentration increases the pH value drops. Consequently it can be established from results that they are inversely related to each other but this behaviour is generally due to effect of rain water runoff. The suspended sediment content was at its highest during monsoon season. Similarly pH values varied considerably from limit of 6.5-8.4. Other water quality chemical parameters did not stray from their recommended limits. The dumping of waste water from pipes did not have any major effect on the water quality of the canal due to its less percentage to the total canal discharge.

***Keywords*-**Suspended Sediments, pH, Water Quality, Electrical Conductivity, TDS.

I. Introduction

Lahore Branch canal was originally off-taking from Upper Bari Doab Canal System, from Madhupur Headworks in District Gurdaspur India. The system was irrigating the area of district Gurdaspur, Amritsar and Lahore District before partition. After partition of the sub-continent, supplies from India were cutoff and BRBD Canal was constructed to feed the various truncated channels including Lahore Branch Canal. This canal is off-taking from BRBD canal near Jallo village Fig. 1. It carries discharge of 11.38 cumecs and is 30 km long. Its banks are brick lined through its length. The bed width and full supply depth varies through its length. The average bed width is 11.58 m and average full supply depth is 1.22 m. The culturable command area is about 17 km^2.

Presently, people are releasing/draining/adding domestic & industrial waste water and wastes into this canal. The drainage water contains trace metals in addition to biological contaminations. These untreated industrial and municipal wastes and polluted water have created multiple hazards and have become a threat to irrigation water quality and sediment moving in it. Also, this contaminated water adds pollution to our food chain when used to irrigate the crops in addition to groundwater contamination.

Therefore, this study has been designed mainly to investigate the effects of this polluted water mixing on the temporal and spatial variation of suspended load and Irrigation water quality in Lahore Canal.

II. Literature Review

Over the years, different researchers have experimented on the effects of sediments on the water quality, these are discussed below.

A. International research/studies

Sediment and its effect on water quality were discussed. It was defined that what the water uses are affected by sediments, how these uses are affected, and the influence of sediment on water quality in New Mexico and the factors which contribute to its presence [i].

The correlation between water quality and sediment transport was studied. Also discussed was that the effect of sediments on water quality, the influence of water quality on sediments, and the use of sediments as environmental indicators, are not widely understood; as yet, only limited use of sediment data has been made in most environmental and water quality studies [ii].

The cation exchange capacity of a soil is the sum of interchangeable cations that a soil or soil component can adsorb at a specific pH was concluded. Thus, the cation exchange capability is a measure of a soil's adsorption capacity and sediment can absorb nutrients at certain pHs [iii].

The suspended sediment load in a stream, which drains a rural watershed, is derived primarily from soil erosion arising on the watershed and due to agricultural undertakings. The suspended sediment load is a water quality component with two aspects. Its removal from the soil in surplus quantities might be damaging to the productivity of the soil. On the other hand, the suspended sediment in a stream is a contaminant, by itself and by being a carrier of adsorbed chemicals like metals and organics [iv].

Decrease of sediment loads enhanced water clarity, and thus allowed more handling of nutrients in shallow waters. The degraded water quality in Chesapeake Bay was attributed to algal blooms and reduced water clarity due to excess nutrient and sediment inputs [v].

Clay particles add to suspended sediment in surface waters when soil dispersion occurs. The dispersed soil or sediment vulnerable to being eroded retains nutrients and contaminants via adsorption to clay particles. Therefore, more information is needed regarding the effect of dispersive clays and suspended sediment on water quality [vi].

Soil mineralogy affects water quality in several ways. Soil mineralogy determines the dispersivity of the clay portion of the soil and dispersive clays are likely to end up as suspended sediment in surface waters, weathering reactions contribute elements to water as dissolved load, and clay minerals, with their absorption properties, contribute to soils' ability to filter and carry pollutants. Suspended sediment in surface waters is a concern for water quality because it results in decreased availability of oxygen for aquatic life, an increase in algal blooms with an increased rate of sedimentation. Suspended particles also carry contaminants and excessive nutrients [vii]

Water quality study was done in the Koga Irrigation Project, Ethiopia. Some important conclusions of this study were that the water used for irrigation showed good values for conductivity. The values of the parameters works fine for some crops grown in Koga, but not all. Calcium and alkalinity levels were overall too high, especially downstream. Ingesting crops without proper preparation is not recommended due to high bacteria counts. The spatial difference in water quality in the sampled canals of Koga was not that large. Most of the parameters displayed relatively uniform values. The physical parameters, turbidity and temperature, are the only parameters that progressively increases down the irrigation canals however, to draw conclusions more samples need to be taken [viii].

B. National research/studies

A study on the canal system of Punjab regarding its water quality was performed. In the observing period, five rivers at head works, 27-canals and 19 drains at their head, middle and tail were sampled. The analysis was carried out in the laboratories of Directorate of Land Reclamation. The analytical data reveals that water quality of rivers and canals towards irrigation parameters (pH, EC, SAR and RSC) are excellent. In case of trace metals (Cu, Ni, Pb and Zn) the detected values range within limit. The values of Cu slightly stray from FAO limit, occasionally. The drains waters are generally unfit for irrigation parameters and also have heavy load of trace metals but their influence is not so substantial on our irrigation system [ix].

The pollution status of Lahore branch canal was studied by physical, chemical and metal constituents analysis as this water is used for irrigation of lands nearby. They selected twelve different sites along the canal for sampling. The results of their samples were compared with FAO. All physical and chemical parameters were found to be within limits specified by FAO. While trace metals were found to vary considerably from limits, as cadmium, copper and chromium concentration were much higher than limits. Turbidity of water was also high [x].

A study was conducted to find pollution load of Lahore canal. Four different sites were selected on the canal. Sampling was done for surface water at the middle of the canal. Water samples were analyzed for physiochemical parameters such as temperature, pH, EC, DO, BOD_5, turbidity, nitrates, phosphates and biologically for bacteria, coliform and fungi. These parameters were analyzed from May to August. The results showed that the water was fit for irrigation purposes but with treatment for high microbial load [xi]

A study concluded that BRB and Lahore canal were being polluted by municipal and industrial wastes. The need for a comprehensive study was felt to observe the concentration of pollutants in the Lahore canal and their effects. Sampling was done from twelve locations between February and March 2008. pH, EC, TDS, BOD, COD, SAR, RSC, cations, anions and heavy metals like Pb, Zn, Fe were analyzed. The results showed that BRB canal water quality was better than Lahore canal water quality. Water from both canals can be used for irrigation but is unfit for general public use. pH and Electrical conductivity (EC) of canal water had a wide variation in results but remained in limits as specified by irrigation department. TDS was also within limits for canal water [xii].

In the light of the above reviewed literature, studies have been done on suspended sediment load's effect on water quality regarding the ability of suspended sediments to absorb contaminants. Similarly, research has been done on irrigation water quality parameters but these polluted water chemical parameters have not been linked to suspended sediments. Likewise, no specific study has been done on effect of contaminants/ polluted water mixing on the suspended load, whether the change in water quality chemical parameters due to polluted water /waste has an impact on the suspended sediment load concentration. For this purpose this study has been designed with the following objectives.

III. Study Objectives

The objectives fixed for of this study were:

a. To collect suspended sediment and water samples and assemble relevant water discharge data from Irrigation Department and observe sediment

deposits/ solid waste depth and gradation of bed deposits in the canal during closure.

b. To analyze the temporal and spatial variation of suspended sediment load due to addition of waste water from pipes and household waste.

c. Make a comparison of standard/normal irrigation water (quality) standards with the present water quality of the canal after mixing of polluted water/waste from pipes.

d. Develop relationship between suspended load concentration and each tested chemical parameter of water quality.

Fig. 1. Location map of Lahore canal and sampling sites for water quality parameters and suspended sediments

IV. METHODOLOGY

A. *Sampling for Deposited Sediment*

During closure of canal in January 2014, a field visit was made to the specified stations and the depth of deposited sediment was measured along the cross section. These depths were measured by calculating the depth with reference to the bank of the canal. The total depth of the canal was known from the data from irrigation department. The depth comprised of full supply depth and free board. Total vertical distance was measured from the bank to the top of the deposits for each selected site at center line of the canal and left and right sides at extreme width of the canal bed at that specified site/ station. The depths obtained were cross checked with the help of bhal safai workers after excavating the bed material. The samples from these deposits were collected in polythene bags. Basic purpose of this sampling was to find the gradations of deposited sediments and maximum depth of deposits along the canal. Sieve analysis was done by ISRIP WAPDA.

Gradation of deposited sediments was done using USGS sieve analysis. Wet and dry sieving method were used as per guidelines of USGS. Wet sieving method was used to separate coarse fraction (gravel and sand) from fine fraction (silt and clay). Samples were soaked for up to 2 hours for disaggregation. Then the samples were washed into the sieve using a squeeze bottle. When on the sieve the fine fraction was washed through it using hands/fingers into a bowl. This fine fraction was then sealed in a Mason Jar. It was afterward analyzed using a pipette. The coarse fraction was put into a pre-weighted beaker and oven dried. Oven dried sample was then dry sieved. For dry sieving a pan was placed below stacked sieves. The finest mesh/ sieve was placed at the bottom most above the pan.

Forty grams sample was placed on the top sieve and a cover was attached. It was then placed into a mechanical shaker. After 10-15 minutes the sieves were separated and then each sieves contents were measured. This gave the particle size distribution.

B. *Sampling for Suspended Sediment*

Sampling for suspended sediment was carried out using USGS instrument. US-DH-48 sampler shown in Fig.2 was used for this specific study, however; only one sample was taken from a cross section due to cost constraints. This sample was taken from mid of the section at the RD's specified in this research. This sampling was done at alternate weeks on Saturdays. Sampling was started in the 2nd week of February 2014 after the canal was opened after bhal safai and was continued up to start of September 2014 for 8 months. One alternate week was skipped in end of April because of canal closure. The samples were submitted to ISRIP (International Sediment Research Institute Pakistan) for gradation and PPM of sediment concentration.

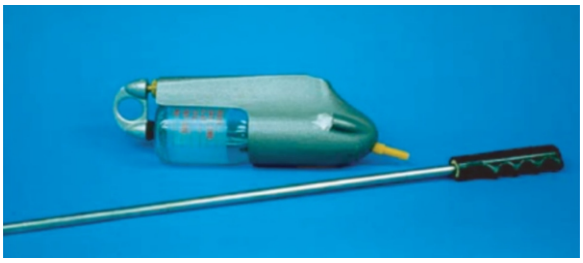

Fig. 2. US-DH 48 sampler used for suspended load data collection

At each selected station, this sampler (US- DH 48) was lowered with the help of a wading rod at a uniform rate into the deepest point of the section and then raised again at the same uniform rate to the surface of the canal. Special care should be taken that the sampling bottle is not over filled as it may not be a true representative of the vertical. After all the samples have been collected they are allowed to settle and then are analyzed further for suspended sediment concentration.

For suspended sediment load USGS methods were followed. These are:

a. USGS VA Tube method (Visual Assessment Method)
b. Pipette Method
c. Sieving USGS method

C. Sampling for Water quality

Water sampling for chemical parameters was done using Grab sampling technique. USGS has also specified samplers for water quality analysis, but due to cost constraints such sampler could not be arranged for water sampling.

Bottles of 1 liter attached to self-made wading rod were lowered into the canal at mid-section and raised at a uniform rate at each selected site. Mouth of the bottle was directed toward the direction of flow. Materials such as leaves, twigs and other floating material were avoided. Collected samples were labeled with the sample number, date, collection hours, location and information about surroundings. The samples were brought to the laboratory within two hours of collection and processed accordingly for the analysis of different water quality chemical parameters. Irrigation water quality analysis was done at Soil and Water testing laboratory, Thokar Niaz Baig, Lahore.

V. Data Collection

In order to begin research on a specific project, the first step is to collect relevant data about that project. In this study, the general information for Lahore branch canal was collected in October 2013, from Irrigation department offices located near Mughalpura on Canal Bank road. This data included the line diagram of Lahore branch canal specifying its RD's. On the basis of RD's specified on the line diagram the sampling sites were selected. The sampling sites were not equidistant and simply selected on the basis of waste water dumping locations. These locations were identified by the Irrigation Department people and on personal observation of the canal during closure period of January 2014 and ten locations were selected starting from upstream as shown in Table I.

TABLE I
Sampling Locations on Lahore Canal

Sr. No	Station	Location
1	10	Khaira Head Bridge
2	9	Rani Pindi Bridge
3	8	Harbanspura Underpass
4	7	Tajbagh Bridge
5	6	Tajpura Bridge
6	5	Mughalpura Underpass
7	4	Dharampura Underpass
8	3	FC College Underpass
9	2	New Campus Underpass
10	1	Jinnah Hospital Underpass

Sampling for canal water and suspended sediments was conducted over a period of 8 months from February 2014 to September 2014 on a specific day at alternate weeks. The dates for sampling of suspended sediments and canal water are shown in Table II.

No specific discharge data for waste water dumping into the canal at various stations could be obtained from irrigation department. This was because the dumping was illegal therefore no legal record could be found. However, on personal observation the locations where most discharge from embedded waste water pipes was entering the canal were recorded i.e. between Khaira Head Bridge (Station 10) and Tajbag bridge (Station 7). A visit was made to observe the pipe sizes at these locations, as given in Table II.

TABLE II
Timings for Sampling and Waste Pipe Location and Size

A. Timings for sampling		B. Waste pipe location & sizes	
Sampling Date	Set No.	Station	Pipe Size (m)
15-02-2014	1	9	0.3048
01-03-2014	2	1.046 km D/S of 9	0.3048
15-03-2014	3	1.33 km D/S of 9	0.1524
29-03-2014	4	1.39 km D/S of 9	0.3048
12-04-2014	5	R/S 1km U/S of 8	0.3048
10-05-2014	6	L/S 1km U/S of 8	0.1524
24-05-2014	7	0.733 km D/S of 8	0.3048
07-06-2014	8	0.219 km U/S of 7	0.1524
21-06-2014	9	7	0.3048
12-07-2014	10		
09-08-2014	11		
09-09-2014	12		

The samples were sent to International Sediment Research Institute Pakistan (ISRIP) WAPDA for gradation of sediment concentration in PPM [xiii].

The collected samples for chemical parameters and suspended sediments were analyzed by Soil and Water Testing Laboratory, Thokar Niaz Baig and International Sediment Research Institute Pakistan, respectively for a period of about 8 months.

Apart from suspended sediment and pH data for canal water shown in Table III, rest of the parameters namely bicarbonates, electrical Conductivity, sodium absorption ratio, residual sodium carbonate and chloride were within permissible limits. SAR and RSC values were almost zero for various samples and therefore they do not have significant impact.

RSC data is shown in Table III while SAR, bicarbonates, electrical conductivity and chloride values for this study and their standard values for irrigation water quality are tabulated in Table IV.

TABLE III
SUSPENDED SEDIMENT, pH AND RSC DATA FOR LAHORE CANAL

Station	Timings for sampling											
	Set 1 15 Feb	**Set 2** 1 Mar	**Set 3** 15 Mar	**Set 4** 29 Mar	**Set 5** 12 Apr	**Set 6** 10 May	**Set 7** 24 May	**Set 8** 7 Jun	**Set 9** 21 Jun	**Set 10** 12 Jul	**Set 11** 9 Aug	**Set 12** 9 Sep
Suspended sediment concentration in PPM												
10	213	32	27	128	861	316	168	377	361	893	692	11
9	173	24	29	107	1647	246	176	301	329	825	1486	14
8	146	28	20	115	2375	241	188	335	280	1048	952	25
7	71	31	21	100	448	241	290	327	351	1007	751	23
6	56	34	17	110	618	440	154	374	339	799	650	23
5	121	27	24	111	437	291	53	265	428	934	593	18
4	128	25	19	135	433	256	111	246	398	1031	641	22
3	76	32	25	121	346	247	183	232	314	960	614	45
2	63	28	36	127	531	285	129	193	312	909	445	41
1	191	33	26	143	510	210	162	131	343	832	507	28
pH (permissible range 6.5-8.4)												
10	7.9	7.8	7.6	7.8	6	9.1	9.5	6.8	5	5	5.8	6.9
9	7.8	7.7	7.6	7.8	7	7.8	8	7	5	5.5	5.3	5.7
8	7.7	7.7	7.6	7.6	6.1	6.4	7.2	6.4	4.6	5	5.6	6.8
7	7.5	7.6	7.6	7.7	6.9	6.6	7.2	6.7	5.7	5	6	6.1
6	7	7.6	7.6	7.3	5	7.1	6.2	6.8	6.9	6.4	5.9	5.2
5	7.8	7.7	7.6	7.2	5.7	8.3	8.8	6.9	6	6	5.9	6.9
4	7.9	7.8	7.6	7	6.1	9.3	7.5	7	6.8	6.3	6.3	6.1
3	7.9	7.7	7.5	7.5	5.7	9.2	6.9	6.7	7.4	6.3	6.5	6.9
2	7.9	7.5	7.4	7.4	6.4	8.8	5.8	6.4	7	6.1	6.3	6.4
1	7.9	7.5	7.4	7	6	7	6.8	6.2	4.8	6.1	5.9	6.7
RSC in meq/l (permissible range 0-2.5)												
10	1.0	0	0	0	0	5.2	0.6	0	0	0	0	0
9	1.2	0	0	0	0	0	0.1	0.1	0	0	0	0
8	1.0	0	0	0	0	0	0	0	0.1	0	0	0
7	1.0	0	0	0	0	0	0	0.1	0.1	0	0	0
6	1.2	0	0	0	0	0	0	0	0	0	0	0
5	1.0	0	0	0	0	0	0	0	0	0	0	0
4	1.0	0	0	0	0	0	0	0	0	0	0	0
3	1.0	0	0	0	0	0.2	0	0	0	0	0	0
2	0.9	0	0	0	0	0	0	0	0.1	0	0	0
1	1.1	0	0	0	0	0	0	0.2	0	0	0	0

TABLE IV
SAR, BICARBONATES, EC AND CHLORIDE DATA FOR LAHORE CANAL

Station	Timings for sampling											
	Set 1 15 Feb	**Set 2** 1 Mar	**Set 3** 15 Mar	**Set 4** 29 Mar	**Set 5** 12 Apr	**Set 6** 10 May	**Set 7** 24 May	**Set 8** 7 Jun	**Set 9** 21 Jun	**Set 10** 12 Jul	**Set 11** 9 Aug	**Set 12** 9 Sep
SAR in meq/l (permissible range 0-10)												
10	1.9	0	0	0	0	0.1	0	0.1	0.1	0.09	0	0
9	1.9	0	0	0	0	0.1	0	0.3	0.1	0.09	0	0.6
8	1.9	0	0	0	0	0.5	0	0.2	0.1	0.09	0	0.6
7	1.9	0	0	0	0	0.1	0	0.2	0.1	0.06	0	0.6
6	1.9	0	0	0	0	0.5	0	0.2	0.1	0.09	0.1	0.6
5	1.9	0	0	0	0	0.3	0	0.2	0.1	0.08	0.1	0.6
4	1.9	0	0	0	0	0.5	0	0.1	0.1	0.08	0.2	0.6
3	1.9	0	0	0	0	0.2	0	0.2	0.1	0.09	0.2	0.6
2	1.9	0	0	0	0	0.3	0	0.2	0.4	0.1	0.2	0.6
1	2.2	0	0	0	0	0.1	0.1	0.3	0.1	0.2	0.2	0.7
Bicarbonates in meq/l (permissible range 0-6)												
10	2.4	2.6	2	2	1.8	7.2	3	1.9	1.7	2.2	2	2
9	2.6	2.6	2	2	1.8	2	2.6	1.9	2	2	2	2
8	2.4	2.4	2	2.2	1.8	2	1.6	1.9	2	2	2	2
7	2.4	2.6	2	1	1.8	2	2	1.9	2	2	2	2
6	2.6	2.6	2	2.4	1.8	2	2	1.9	1.6	2	2	2
5	2.4	2.6	2	2.4	1.8	1	1.6	1.9	2	2	2	2
4	2.4	2.6	2	2.4	1.8	0.4	2.2	2	2	2	2	2
3	2.4	2.6	2	2.4	1.8	1.8	1.8	2	2	2	2	2
2	2.4	2.8	2	2.4	1.6	1.8	2.2	2	1.8	2.1	2	2
1	2.4	2.6	2	2.6	2.6	2	2.2	2.2	1.8	2	2	2
EC in microS/cm (permissible range 0-1250)												
10	310	316	300	274	271	225	200	200	190	249	206	285
9	313	324	309	274	270	285	212	211	210	256	200	289
8	312	322	300	256	283	310	220	213	200	261	200	290
7	317	324	305	200	274	250	210	208	205	257	204	296
6	314	317	306	292	280	317	210	210	189	250	210	289
5	314	319	310	296	275	282	215	210	213	268	210	297
4	310	318	292	291	280	255	221	212	215	267	223	288
3	310	321	295	235	278	218	220	219	210	256	220	285
2	310	321	290	235	260	290	235	218	209	254	220	292
1	311	325	291	346	275	295	255	235	218	256	220	293
Cl in meq/l (permissible range 0-4.5)												
10	0.5	0.36	0.6	0.4	0.4	0	0	0	0	0	0	0
9	0.5	0.44	0.6	0.3	0.4	0	0	0	0	0	0	0
8	0.6	0.72	0.7	0.7	0.4	0	0	0	0	0	0	0
7	0.5	0.44	0.9	0.6	0.4	0	0	0	0	0	0	0
6	0.6	0.47	0.7	0.6	0.5	0	0	0	0	0	0	0
5	0.5	0.39	0.7	0.7	0.4	0	0	0	0	0	0	0
4	0.5	0.38	0.8	0.6	0.5	0	0	0	0	0	0	0
3	0.5	0.45	0.5	0.6	0.5	0	0	0	0	0	0	0
2	0.6	0.31	0.7	0.6	0.5	0	0	0	0	0	0	0
1	0.5	0.45	0.7	0.8	1.4	0	0	0	0	0	0	0

Note: Sampling skipped on 26 APR due to canal closure

VI. Results and Discussion

It can be seen that the suspended sediment concentration was at its peak during the 5th week (5th set) on 12th April 2014 with value of 2375 PPM at Harbanspura Underpass Fig. 3. This high concentration was due to the rainfall in early April 2014 and storm water being dumped from pipes just upstream of Harbanspura. Water clarity was reduced due to excessive sediment input.

Another result on the same day also showed high concentration of 1647 PPM at Rani Pindi Bridge. Other high concentrations occurred on 12th July and 2nd August with concentrations of 1048 and 1486 PPM respectively for two of the results.

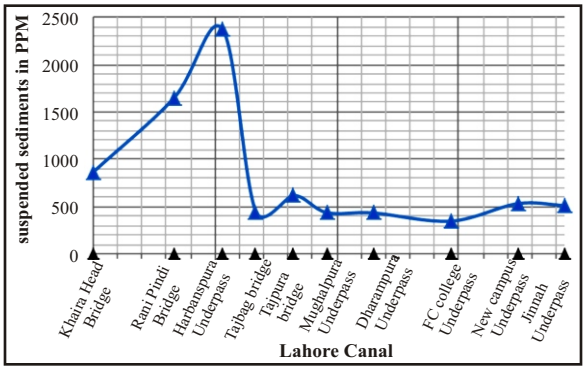

Fig. 3. Maximum Suspended sediment concentration on 12th April at Harbanspura underpass.

After the 5th week, that is after 12th of April the sediment concentration shows a rapid decline. 12th July and 2nd August that are 10th and 11th week (sets) again showed high concentration of suspended sediments as this was the monsoon season.

The allowable limits for various water quality parameters are given in TableV.

TABLE V
Limits for Various Water Quality Parameters

Water quality parameter	Unit	Range of values		
		Suitable	can be used	not suitable
Electrical conductivity (EC)	microS/cm	0-1000	1001-1250	>1250
Sodium Absorption Ratio (SAR)	meq/l	<6	6 to 10	>10
Chloride	meq/l	0-4.5		>4.5
pH		6.5-8.4		<6.5 &>8.4
Bicarbonates (HCO_3)	meq/l	<1.5	1.5-6	>6
Residual Sodium Carbonate (RSC)	meq/l	<1.25	1.25-2.5	>2.5

The normal range for irrigation water requirement by international and WAPDA standards is 6.5-8.4. From 15th February to 29th march, for 1st four sets/weeks of samples all pH values were within permissible range at all stations/RDs. Set 5 (5th week) on 12th April 2014 showed a minimum value of 5 pH at Tajpura Bridge. Value of 5 on pH scale shows acidic nature of the water. This is highly unsuitable for irrigation. Set 6 (6th week) showed alkaline water with high values of pH of 9.2 and 9.3 at FC college Underpass and Dharampura underpass respectively while a maximum value of 9.5 was on 24th May (7th week) at Khaira Head Bridge Fig. 4.

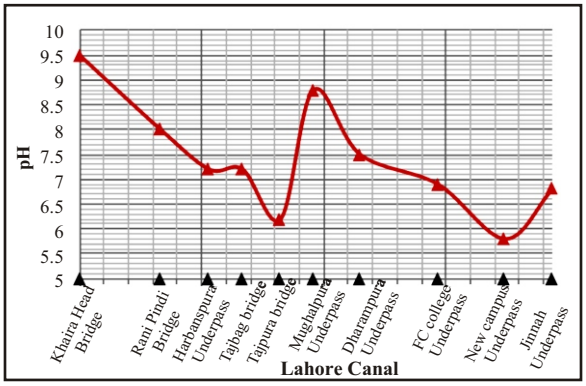

Fig. 4. pH variation on 24th May 2014

When water is of alkaline nature pH > 8, it may contain high level of bicarbonates concentration which in turn reduces the calcium and magnesium content that can have an impact on plant growth. While a pH of below 4 can cause soil acidification which can also cause plant damage. In this research the minimum value of pH is 4.6 was recorded on 21st June 2014 (9th week/set) at Harbanspura Underpass.

All the values of electrical conductivity for all weeks were well within the range specified of 0- 1250 microS/cm. Maximum value of 346 microS/cm was observed on 29th March 2014 (4th week) at Jinnah Underpass and minimum of 189 microS/cm on 21st June 2014 (9th week) at Tajpura bridge during the study period.

Maximum value of bicarbonates was 7.2 meq/l on 10th may 2014 (6th week sampling) at Khaira Head Bridge. Minimum value was 0.4 meq/l on same day at Dharampura Underpass. Most values were near 2 meq/l. The value of 7.2 meq/l was termed as unsuitable for irrigation by Soil and Water Testing Laboratory at Thokar Niaz Baig. Most stations showed declining values after 3rd week. After the 5th week of sampling i.e.during 6th and 7th week and onwards showed zero concentration of chloride for all stations. All values were within irrigation water quality guidelines.

Maximum concentration of calcium and magnesium was 4.8 meq/l on 1st March 2014 (2nd week sampling) at New Campus Underpass. While

minimum value was 1.3 meq/l on 15th Feb. 2014 (1st week) at Jinnah Underpass. Most values were near 2 meq/l. Overall trend was decrease in concentration with time.

The average temporal and spatial variation of suspended sediments and pH parameters is represented by taking average of respective values and the equations only represent the behaviour of the parameters within the reach of the canal for the months from February to September, 2014. Most variation was of suspended sediment and pH concentration whereas rest of the parameters were in limits.

Average spatial and temporal suspended sediment variations are related by the following given Equations 1 & 2:

$$S_s = 3E\text{-}12D^3 - 2E\text{-}06D^2 + 0.5585D - 46547$$

Where S_s is the avg. spatial suspended sediment concentration in PPM and D represents the reach length in m.

$$S_t = -0.0005T^3 + 0.1341T^2 - 7.307T + 218.47$$

Where, S_t is the avg. temporal suspended sediment concentration in PPM and T represents the time in days

Average spatial and temporal pH variation are related by the following given Equations 3 & 4:

$$P_s = -2E\text{-}14D^3 + 1E\text{-}08D^2 - 0.0037D + 319.32$$

Where, P_s is avg. spatial pH concentration and D represents the reach length of Lahore Branch canal in m.

$$P_t = 0.0035T^3 - 0.0699T^2 + 0.2184T + 7.4666 \quad (4)$$

Where, P_t is the avg. temporal pH concentration and T represents the time in days.

These equations (1-4) only represent the behavior of suspended sediments and pH for this research only. These relationships are poor and should not be used for research purposes.

A. Comparison between canal water quality and waste water quality from pipes

For this purpose data of discharges from drainage/sewer pipes was measured by filling a cube of 7 inches/side using a stop watch and samples were taken for chemical parameter analysis at these locations. Samples could not be collected from other sites as most of the pipes were not flowing. The recorded discharges from these pipes are given in Table VI.

In this table values of EC, RSC and bicarbonates for the pipe discharges exceed the limits for irrigation requirement and hence are deemed unsuitable for irrigation purposes. The canal water near these pipe locations showed chemical parameters were within the specified limit.

The total dissolved solids (TDS) have a relationship with the salinity of water [xiv]. We can get TDS from EC by a multiplication factor of 0.64 to get PPM of TDS.

For example, the TDS for pipe at Station 9 Ranipindi Bridge are 1562.88 ppm, which is 1.56 grams/litre of water. However, when it is mixed with canal water the TDS in canal water is 168.32 ppm, which is 0.168 grams/litre of water. Hence the TDS concentration of canal water with respect to TDS from waste water of pipe is reduced by 89.23 % and is only 10.76 % of original concentration.

Waste water may have affected the canal water quality at some places but this effect is negligible and the mixing of polluted water has no impact on overall water quality of the canal.

B. Comparison between pH of current canal water and previous studies

In the previous studies of water quality conducted in 2011 [x-xi] and later on in 2014 [xii], the range of pH values along the length of Lahore canal were within the normal range for irrigation water requirement by International and WAPDA standards i.e. 6.5-8.4. However, in this research the values of pH were within range for 1st four weeks of sampling. For 6th set of sampling on 10th May showed mostly "basic" nature of water at different locations and 10th set of samples on 12th July showed "acidic" nature. A comparison of these results is shown in Table VII.

C. Comparison between suspended sediment & pH of canal water

Various types of rocks and soil can release acidic and alkaline compounds into the water. In the presence of calcite ($CaCO_3$), carbonates (HCO_3) are released into the water causing the alkalinity of the water in contact with soil/rock. When sulphide minerals (pyrite or fool's gold "FeS_2") are present, water and oxygen react with these minerals to form sulphuric acid (H_2SO_4). This causes the water in contact to become acidic in nature. Drainage water from forests and marshes is often slightly acidic in nature because decaying vegetation produces organic acids. Since rain water itself is slightly acidic, because of that monsoon rain water of this canal become acidic in nature Fig. 5.

The high concentration of suspended sediments at Harbanspura was may be due to water entering from storm drain pipes just upstream of Harbanspura. The stream power was not enough and the sediments were deposited just before Taj Bagh Bridge.

TABLE VI
WATER CHEMICAL PARAMETER DATA FOR DRAINAGE/SEWER PIPE FALLING INTO THE CANAL AND CANAL WATER

Station	sample	Q ft^3/s	EC µS/cm	Ca+ Ma meq/l	Na meq/l	Bi-carbonate meq/l	Cl meq/l	RSC meq/l	SAR meq/l	pH	Remark
9	pipe	0.0135	2442	8.5	15.9	15.2	4.1	6.7	7.7	6.9	Unfit
9	Canal	402	263	2.6	0	2.2	0.2	0	0	6.9	Fit
1.33 km D/S of 9	pipe	0.0152	2035	6	14.3	12	3.2	6	8.2	7.3	Unfit
L/S 1km U/S of 8	pipe	0.0189	2120	7	14.7	13	4.4	6	8	8	Unfit
8	canal	402	264	2.6	0	2.1	0.3	0	0	6.6	Fit
0.73 km D/S of 8	pipe	0.018	2400	6.6	15.1	13.4	3.7	6.4	7.9	6.5	Unfit
7	canal	402	254	2.4	0	2	0.3	0	0	6.7	Fit

TABLE VII
pH VARIATION COMPARISON WITH PREVIOUS STUDIES

Location	Station	pH concentration (limit 6.5-8.4)					
		This research (2014)			Tayyaba et al.(2011)	Tahir et al. (2011)	Ansari et al. (2014)
		1st week	6th week	10th week			
Khaira Head Bridge	10	7.9	9.1	5	7.76		
Rani Pindi Bridge	9	7.8	7.8	5.5	7.74		7.4
Harbanspura Underpass	8	7.7	6.4	5	7.69	6.9	7
Tajbag Bridge	7	7.5	6.6	5			
Tajpura Bridge	6	7	7.1	6.4			
Mughalpura Underpass	5	7.8	8.3	6	7.45	6.7	7.2
Dharampura Underpass	4	7.9	9.3	6.3	7.53		7.5
FC College Underpass	3	7.9	9.2	6.3	7.63		
New Campus Underpass	2	7.9	8.8	6.1	7.54		7.3
Jinnah Underpass	1	7.9	7	6.1			

D. Bed deposits in the canal

The depth of bed deposits were measured during canal closure in January. Deposits were mostly comprised of sand sized particles and sludge from waste material entering the canal. Fig. 6 depicts that most of the waste material was entering between Rani Pindi bridge and Tajpura Bridge. Apart from sand deposits, different types of materials were thrown into the canal, which included things such as: bottles, handis, ladies purses and other house hold items. Waste water from different pipes was stagnant in some reaches/sections of the canal. The maximum bed deposits of 762 mm on right side and 609.6 mm on center and left sides were measured at upstream of Tajpura bridge.

Generally, the average depth of deposited material was about 152.4 mm. The grain size distribution of bed sediment deposits varied from smallest particle size of 0.088mm to a max particle size of 0.35 mm. These particle sizes classify the deposits as sand fraction. This range of sand fraction deposits was similar for all stations

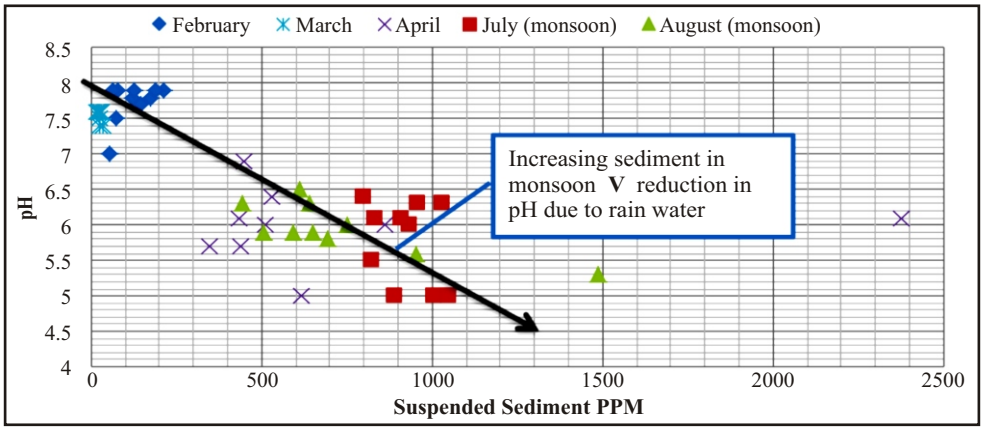

Fig. 5. Increase in suspended sediment concentration and reduction in pH - a function of monsoon season.

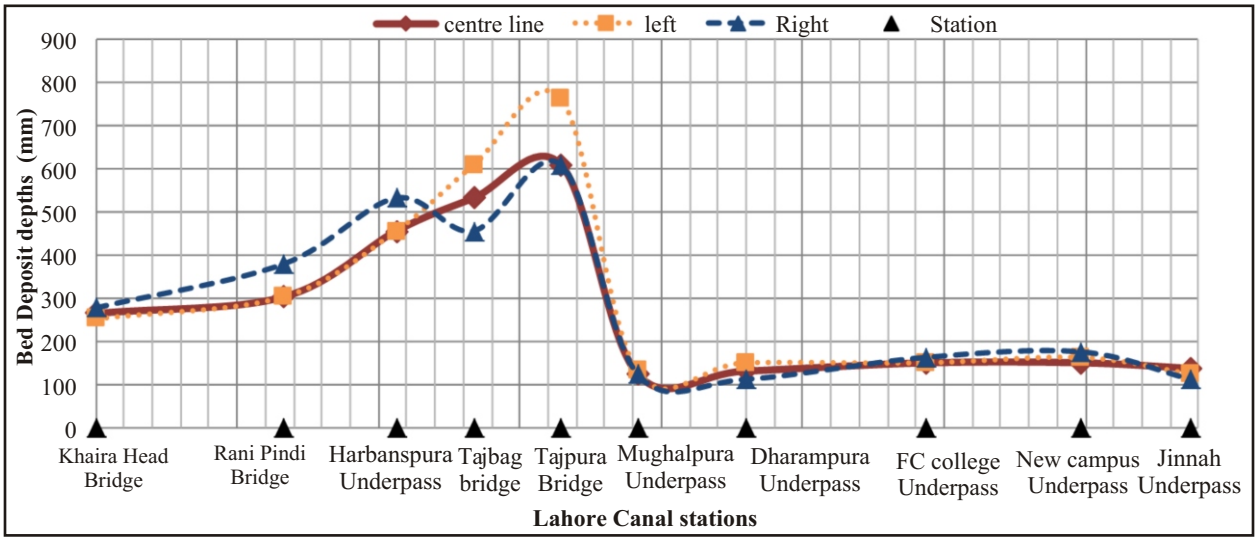

Fig. 6. Bed deposits along the canal with maximum deposits near Tajpura Bridge

VII. Conclusions

The suspended sediment samples were collected at specific sites and timings according to schedule. They were submitted to ISRIP for testing. After testing of samples for suspended sediment concentration, the results were collected. By observation and measurement during canal closure, the sand bed deposits were found maximum between Harbanspura and Tajpura Bridge partly due to short distance from the canal intake. Overall deposits may be classified as of sandy type- dominated by sand particles.

Sediment concentration was at its peak on 12th April 2014 and during the monsoon season (Jul-Aug 2014) and measured maximum near Harbanspura due to water entering from storm water pipes upstream of Harbanspura Underpass. Variation of suspended sediment concentration was independent of addition of waste water. Irrigation water quality of samples varied from being basic to acidic in nature due to sediment input with pH value ranging from 9.5 to 4.6. In general the quality of 58 % of samples canal water was found good for irrigation during dry period. Other chemical parameters were within limits by Irrigation department and FAO.

For reach between Rani Pindi and Tajbag Bridge, addition of waste water from sewer pipes had no effect on the water quality of canal related to irrigation.

The results showed that only suspended sediments and pH trends vary inversely proportional to each other but pH of canal water has no effect on suspended sediment concentration. It is the suspended sediment concentration which is affecting the pH of canal water. Any relationship between suspended sediment and other water quality parameters could not be developed as variation of suspended sediment was not following any direct and indirect relationship to variation of other water quality parameters other than pH.

VIII. Recommendations

In order to improve data quality and thus results further water sampling should be done on daily basis instead of alternate weeks. Likewise, the number of cross sections/stations should be increased.

Although sewage water has not been found deteriorating the water quality however further detailed data should be collected for comprehensive results.

Furthermore, water should also be tested for trace metals as industrial waste is being dumped into this canal that may include trace metals which are harmful for irrigation purpose.

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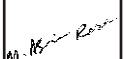
1	Mr. Muhammad Asim Raza (Main /Principal Author)	Literature review, data collection, statistical analysis, manuscript writing and interpretation of results.	
2	Mr./Dr./Prof. Muhammad Ashiq Kharal (2nd Author)	Proposed topic, basic study design, methodology, referencing and quality insurer	

Improvement of CBR and Compaction Characteristics of Bauxite Rich Dispersive Soils Available in Pakistan: A Case Study of Khushab Soil

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***Abstract*-**Dispersion of dispersive soil occurs when it comes in contact with water and clay particles deflocculate and disperse away from each other. Thus dispersive soils undergo erosion under low seepage velocity leading to instability problems of slopes and earth retaining structures. The amount of dispersion depends upon the mineralogy and geochemistry of clayey soil as well as the dissolved salts of the pore fluid. The dispersivity of the soil mainly depends on the amount of exchangeable sodium present in its formation. Under saturated conditions, the attractive forces are less than the repulsive forces and this will help the particles to disperse and go into colloidal suspension. The use of chemical stabilizers such as lime and cement to bind the clay particles and reduce the dispersivity of soil and to improve the compaction and CBR characteristics of bauxite rich dispersive soil present in Khushab district have been studied in this research. Soil behavior was studied after addition of 2%, 4%, 6% and 8% Lime and Cement, at optimum level of 6% for Lime and Cement; it has been observed that the CBR and compaction characteristics of Khushab soil have been improved.

***Keywords*-**Dispersive Soil, Repulsive Forces, Chemical Stabilizers, CBR Test, Compaction Characteristics, Bauxite

I. INTRODUCTION

Soils that are dislodged easily and rapidly in flowing water of low salt concentration are called dispersive soils. Structures such as embankments, channels, roads, pavements and other areas are susceptible to severe erosion, when such soils are used for construction. The erodabilty of clayey soil due to flow of rain water is a critical factor in long term performance of earth structures. The presence of dispersive soils at any construction site causes serious design and constructional challenges. The degree of dispersion is dependent on the chemistry and mineralogy of clay and salt dissolved in the interstitial fluid. Soil dispersivity is mainly due to the presence of exchangeable sodium present in the structure. Dispersive soils are defined as soils which ,when come in contact with relatively pure and still water, will disintegrate with some particles going into suspension. Dispersivity occurs in those soils wherein the repulsive forces between the clay particles when saturated exceed the forces of attraction. This is caused by a reduction in the concentration of cations in the pore fluids, resulting in deflocculation and dispersivity of the clay particles. Clays are renowned of their mysterious & dramatic behavior all over the world. One of the most important characteristics associated with them is a large variation in properties with the fluctuating index and physical properties such as relative density, degree of compaction and field moisture content etc. Such soils are known as problematic soils [i]. One of the most recognized problematic soils is dispersive, which loses attractive forces among the particles when come in contact with water. This dispersive property is also present in naturally available soil of Khushab District which has a very rich content of bauxite. This soil is structurally unstable dispersion of aggregates of the soil and collapse when the floor is wet, because the individual clay particles are dispersed in the solution. The problems associated with dispersive soils include surface erosion, tunnel formation, gully formation, sinkholes and high suspended sediment loads that can cause instability, cracking and breakup of pavements, building foundations, slab-on-grade members, and reservoir and channel linings. In Pakistan, many researchers have identified a number of potential soil sites exhibiting dispersive behavior such as in Kotly, Muzaffarabad, Ziarat, Sibbi, Attock, Hazara, Loralai and Khushab districts. Bauxite reserves of Pakistan are estimated about 74 million tons by Geological Survey of Pakistan [ii].

III. IDENTIFICATION OF DISPERSIVE SOIL

Successful use of the dispersion of soil requires the identification, proper recognition and when used in large construction works, appropriate engineering measures must be taken. Primarily any investigation in all fields should be done to determine whether there are any apparent surface indication, such as unusual erosion, deep ravines, Siwa and tunnels, concurrent with excessive turbidity in the water storage. Poor production acreage can also give an idea of saline soils, many of the dispersive character. However ELGES [iii] concluded that the variance of the soil may occur in neutral or acidic soils and can withstand the test lush grass surface can give a clear indication .Good tip soil if it clearly shows the type of soil and other research should continue.

Experiences has shown that dispersive soils cannot be identified by conventional tests such as visual identification, particle size distribution, Atterberg limits, specific gravity and compaction characteristic. One point should also be kept in mind during identification of dispersive soils that all materials having erosion gullies and channeling in the field are not necessarily dispersive. The materials could just be highly erodible and different construction techniques or material treatment would be necessary.

Therefore dispersive characteristics should be properly identified by performing various specialized tests on representative soil sample. Recently there are four laboratory test for the identification of dispersive soils which are being commonly used .these tests are the crumb test Pinhole test, double hydrometer test and various chemical analysis of the soil .usually the combination of the results obtained from these methods is used to determine the extent of soil dispersivity.

III. METHODS OF STABILIZATION OF DISPERSIVE SOILS

In most failures caused by the dispersive soils, the collapse of embankments is usually the first sign of the presence of dispersive soils in that area. Because the problems caused by the dispersive soils are more speedy, permanent and catastrophic so during the early stages of investigation, the suitable plan of available construction material and the possible presence of dispersive soils should be considered.

In case of earthen dams Elges [iii] suggested that the permeability of the densified material should be below or equal to 10^{-5}cm/sec. According to Elges [iii] the permeabilities of clayey material should be between the ranges of 10^{-5} to 10^{-7} cm/sec.In some cases, sand filters also can be used to prevent the leakage of dispersive material and hence sealing the material from erosion. But if the clay particles are in suspension then these filters cannot prevent the colloidal particles to pass through them. Another important method of stabilizing the dispersive soils is chemical treatment .by the addition of chemical agents such as hydrated lime (calcium hydro-oxide), gypsum (calcium sulphate), and alum (aluminum sulphate).these chemical agents provide the calcium source to replace sodium in the cation exchange complex providing the cohesion between the clay particles. These reagents enhance both the soil solution electrolyte concentration and the levels of exchangeable calcium in the soil, which reduce the swelling power and also the dispersivity of the soil. For a soil samples used for the research were obtained from Osun State (Nigeria) known as lateritic soil having similarities with Khushab soil having bauxite for aluminium-rich cemented crusts. Capacity of the samples A, B and C from above mentioned soil enhanced lime stabilization optimal to 8, 6 and 6%, respectively. Adding lime to the samples resulted in a decrease in plasticity indices. CBR increased from 10.6% to 29.0% 0% to 8% lime, while C was improved by 2.5% to 8.6% to 6% lime. Compressive strength is increased and shear compressive strength improved uncured B 119.13 kN / m2 at 0% to 462.81 kN / m2 to 6% lime [iv]. California Bearing Ratio (CBR) is a measure of the resistance of soil quality. In the design of flexible pavements value of this parameter is often used wet; whose evaluation laboratory test is a long and time-consuming [v]. The geotechnical properties of fly ash as a specific gravity, permeability, internal friction bearings and consolidation features make it suitable for use in the construction of roads and dams, structural fill and especially in clay soils [vi]. Admixture carbonate, lime or the fly caused an increase in the limit of plastic, while the yield strength, the swelling index decreases ductility soil. Other cost increase California bearing relationship obtained when the soil sample is mixed with lime. Increasing the optimum moisture content value increased CBR, in particular a high percentage of lime or flyash. Further, the maximum dry density decreases with the addition of lime and fly ash [vii]. In soft soil, fly ash can be used to reduce the compaction of the filler. Reference [viii] reduces swelling clay after stabilization of fly ash. The maximum density of dry clay, sand and fly ash mixture decreases with the addition of fly ash increases the optimum moisture content. Significant improvement occurred during pressing and CBR test compound containing clay, sand and fly ash [ix].

Hydrated lime is most commonly used chemical modifier because it is easily available and cheap chemical and its solubility is also high. Gypsum is also more effective reagent to reduce the dispersivity if the clay particles but its use is limited to some extent due to its less soluble qualities and relatively high cost. According to Elges [iii] 0.2% of lime or gypsum by mass of clay material is adequate in the laboratory but in actual practice in the field 2% of these stabilizers are generally used.

If precautionary measures are taken properly like proper compaction of dispersive soil at appropriate moisture content and provision of appropriate filter to prevent erosion of material, then chemical treatment of dispersive soil is not necessary. Elges [iii] suggested that for the slope protection, chemical stabilization is necessary.

Wagener et al. [x] recommended that for the construction of embankment dams in dispersive soil areas, five options should be kept in considerations. The first option is the choice of another site for the construction of dam which is not practical in most of cases. The second option is the construction of the dam at proposed site having dispersive soils but special measures should be taken under controlled conditions to cope with the problems associated with such type of soils. Another modification is the protection of upstream side of the dam structure by providing lining protections. The rest of the two options are the considerations of chemical stabilization techniques.

In case of road construction, if dispersive soils are susceptible in cuts then two options should be keeping into considerations, first is to remove the dispersive soils from the cuts to avoid the erosive problems and second is to stabilize this soil with chemical treatment. It states that care should be taken to not to let the material between the compacted layers of the soil to dry up because it may initiate the desiccation cracks [xi]. In a recent research, another method of stabilization of the dispersive soils is suggested by Paige-Green [xii] which states that it is also possible to use the sulphonated petroleum product (SPP) treatments, which will replace the sodium in the clays and stabilize the material.

IV. Research Methodology

Three sites were initially selected for preliminary studies in Khushab District and only two sites adopted for the detailed investigation. The sites were explored using test pitting and auguring. Representative samples were collected for laboratory investigations. The methods of sampling and sample preparation as well as test conducted are discussed.

A. Soil Sampling

Test pits were excavated using pick axe and shovel. The pits were sometimes supplemented with auger boring. The dimension of the test pit was 1meter-length by 1.5meter-breadth by 3meter-depth. A depth of three meters was chosen because the swell and shrinkage phenomena of dispersive soils have greatest effect on light weight structures such as pavements, one- and two- story buildings usually founded at depths shallower than three meters. Disturbed samples were taken from within 0.3m-1.4m from the Khushab area, packaged, labelled and sent to the laboratory for testing.

B. Evaluation of Dispersiveness of the Soil

Field and laboratory tests were conducted on selected samples retrieved from the pitting and borings to evaluate their physical and geo mechanical characteristics. The tests performed include the evaluation of the following: Free Swell Tests, Double Hydrometer Tests [ASTM D 4221-99], Crumb Tests [ASTM D 6572-00] and Chemical Tests.

V. Analysis of Experimental Results

A. Free Swell Tests

The soil sample of 10gms was mixed with 2, 4, 6, and 8% of lime by weight of soil. The mixture was diluted with water and made up to 100 ml and kept in a measuring jar. The mixture was left over for 24 hrs and the percentage dispersion was calculated. The dispersion was nearly 1000% for 0% of lime and there was no change for 1%, but significant decrease was observed for higher concentration of lime with the optimum content being 5% and the percentage dispersion being 400. This would have been due to availability of higher concentration of lime for flocculation of the particles, ion exchange reactions and thus increasing the force of attraction but for 9% there is not much decrease due to the saturation level of lime. As the higher percentage only helps in formation of cementatious compounds which are time dependent. Table I presents the variation of dispersiveness with lime addition. The addition of only lime to control the dispersion did not cause any predominant changes and the percentage of dispersion remained at 1000. The cement was the type of class A which has no good cementing properties due to the absence of calcium compounds so the process of flocculation and aggregation was not developed. But with the addition of activators like lime, cementing characteristics was imparted to mixing. 2% of lime was increased as according to above and then amount of cement was varied as 2, 4, 6, and 8% separately. The lime induces the flocculation process and the cement acts as a binding agent. The combined action of aggregation and mechanical binding reduces the dispersion. The percentage of dispersion reduces to nearly 420% for cement of 15% which was equivalent to the one with optimum lime content of 5% as can be seen from experiment, So the use of lime can be reduced to a very less quantity as it is very expensive and the amount of cement can be increased. As cement is a byproduct from the different mix industry and present in abundance, this can be a suitable and economical way for its disposal [xiii].

B. Double Hydrometer Tests

The double hydrometer test also known as soil conservation service laboratory dispersion test was performed to identify the dispersiveness of soil. Particle size distribution is determined first ground using a hydrometer nonstandard test where the soil was

dispersed in distilled water under vigorous mechanical agitation and chemical samples dispersant. Parallel hydrometer replicated in a soil sample, but without mechanical agitation and without the chemical dispersant is a dispersion percent dry weight ratio particle size less than 0.005 mm in diameter of the second test are expressed on the first percentage. The value of greater than 50 is highly dispersive. The percentage of dispersion was calculated for different percentage of additives, the soil sample is highly dispersive with a dispersive percentage of 71 [xiii]. Smaller percentage of lime was not sufficient to reduce dispersiveness, the addition of 2%.then 4%, then 6% & at last 8% was highly suitable.

C. Crumb Tests

The crumb test was carried out as it gives a good quick indication of the dispersiveness of the soil. This test is used in conjunction with the pinhole test, and the double hydrometer test. Based on the tendency for clay particles to go into colloidal suspension that is observed after 5-10 minutes of immersion, soils are classified as non-dispersive or dispersive based on the reaction observed. The specimen of 1.5cm cube is placed in about 250ml of distilled water. The soil sample showed strong reaction getting into colloidal form in 5 to 10 minutes, whereas the other samples with additives took a longer time for dispersion. Thus from these tests it was clearly shown that the addition of lime, cement improves the properties of the dispersive soil. The degree of dispersion decreases for increasing percentage of additives [xiii].

D. Chemical Analysis

The chemical testing of the Khushab Soil is carried out to find the concentration of different ions [xiv]. This is important as there is a relationship between electrolyte concentration of the soil pore water and the exchangeable ions present and also to check the equilibrium of the soil with the environment. The presence of high sodium concentration makes the soil more dispersive. The two parameters which are often used to check the chemical compatibility are Sodium Absorption Ratio (SAR) and Percent Sodium (PS) [xv]. The soil samples, diluted to 1:10 ratio were acid digested for one day and the extracts were used to conduct chemical analysis. The concentration of Ca++ and Mg++ was found by titration methods and Na+ and K+ were determined by atomic absorption spectroscopy method. The values of SAR and PS were compared with Sherard Curve; Sherard et al [xxi] developed curves as Zone-A [PS≥60] for dispersive soil, Zone-B [PS: 0 to 40] for non-dispersive soil and Zone-C [60<PS≥40] for intermediate soil. From the comparison, it was observed that the original sample is reasonably dispersive, for the other samples, the sodium ion concentration was replaced by the calcium ions supplied by addition of lime & cement. And hence the values of SAR and PS were very less and classified as non-dispersive. The results of the chemical analysis are given in the Table I. In the 1960 Australian scientists recognized the exchangeable sodium as the main factor contributing to the behavior of the clay dispersion chemistry [xv]. The main parameter to quantify this effect, ESP (exchangeable sodium percentage), where:

ESP = Exchangeable Sodium x 100/CEC
CEC= (Cation Exchange Capacity)

Chemical evaluation of dispersive soil can also be compared as Harmse and Gerber [xxii] described a chart showing SAR <6 for non-dispersive, SAR 6-10 for intermediate and SAR >10 for dispersive, in addition to that pH was also indicative as pH <7.8 for non-dispersive, and pH >7.8 for dispersive Soil ESP value 10 or higher, free filtrate is subjected to the salt by filtration or relatively pure water are classified as dispersant. Another parameter commonly evaluated in the quantitative role of sodium with respect to the dispersion-free salts are present in an (sodium absorption rate), SAR of the pore water where:

SAR = Na/0.5 (Ca + Mg) with units of meqlL

Very often, this measure is used in terms of milliequivalents of solute per litre of solvent (or milliNormal, where meq/l = mN). SAR method is not applicable, if not free of salt present. Using SAR is based on the fact that the soil in nature is in equilibrium with the environment. In particular, there is a correlation between the concentration of electrolyte in the pore water and soil exchangeable ions in the adsorbed layer of clay. Australian researchers have shown that all the floors were so dispersed SAR exceeded 2. This shows a reasonable agreement on soils with TDS (total dissolved salts) from 0.5 to 3 mEq / L, but not outside of this range of soils [xv]. The currently accepted method of assessing chemical effect on the behavior of the dispersion in the USA is:

Percent sodium = Na (100)/ TDS with
TDS = Na + Ca + Mg + K

and all units in meq/L of saturation extract. In accordance with the above explained criterion, chemical analysis report for Khushab soil has been elaborated in Table I.

E. Physical Analysis

This laboratory is performed to determine the boundaries of fine-grained soils and the liquid plastic [xvi]. Liquid limit (LL) is soil moisture content, expressed as a percentage of the weight of oven dry soil at the interface between the liquid and plastic states consistency. The water content, in percent, where in the

TABLE I
CHEMICAL TEST RESULT FOR KHUSHAB SOIL SAMPLES

S. No.	Condition		PH	Co_{3-}	HCO_{3-}	Cl^-	SO_4^{++}	Ca^{++}	Na^+	SAR	PS	CEC	Description
				meq/lit	meq/lit	meq/lit	meq/lit	meq/lit	meq/lit				
1	OS		10.7	1.6	4.4	5.3	27.8	15	71.3	8.83	58	12.4	Dispersive
2	CEMENT	2%	12	2	3	3.6	6.44	10	4.84	6.12	18	11.3	Non-Dispersive
3		4%	12.3	4.8	2.8	1	6.62	5.1	10.1	5.06	15	11.4	Non-Dispersive
4		6%	12.4	6.6	3	1.1	6.06	6.1	10.7	4.12	13	12.6	Non-Dispersive
5		8%	12.5	9.6	3.8	1.3	5.6	8.5	11.8	3.21	11	15.3	Non-Dispersive
6	LIME	2%	12.4	6.4	3	1.2	6.85	6.8	7.75	6.69	20	10.9	Non-Dispersive
7		4%	12.7	8.6	3.2	1.9	0.45	4	10.2	5.34	17	5.37	Non-Dispersive
8		6%	12.8	15.8	7.6	4.2	19.5	26	15.9	4.72	13	31.7	Non-Dispersive
9		8%	12.7	18.3	4.2	2	13.3	32	23.5	3.83	11	42	Non-Dispersive

pH & Sodium Absorption Ratio (SAR)tested according to Harmse and Gerber [xxii] & Percent Sodium (PS) Sherard et al [xxi] .

belt surface in the cup, and reduce the size of a standard gaming thus flowing to the bottom of the groove when subjected to the distance 25 mm punches cup drop assembly 10 in the reference liquid limit 13 mm (1/2 in.) operated at two strokes per second. Plastic limit (PL) is the percentage of water content, at which a soil can no longer be deformed by rolling into 3.2 mm (1/8 in.) diameter threads without crumbling. For Khushab Soil, different analysis were performed to check the disperse behavior and also tests were performed after addition of lime with different percentage to check the stabilization. Three samples for 2%, 4%, 6% & 8% ration each were taken with the variable no. of blows the final results showed that from original sample to increased lime ration showed variable results, trend can be seen in given Fig 1.

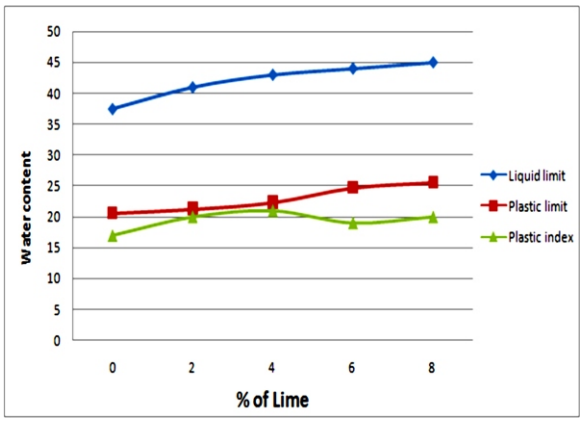

Fig. 1. L.L,P.L&P.I result for Khushab Soil(Original Sample+Lime)

For Khushab Soil, different analysis were performed to check the disperse behavior and also tests were performed after addition of cement with different percentage to check the stabilization. Three samples for 2%, 4%, 6% & 8% ration each were taken with the variable no. of blows the final results showed that from original sample to increased cement ratio showed variable results, trend can be seen in given Fig. 2.

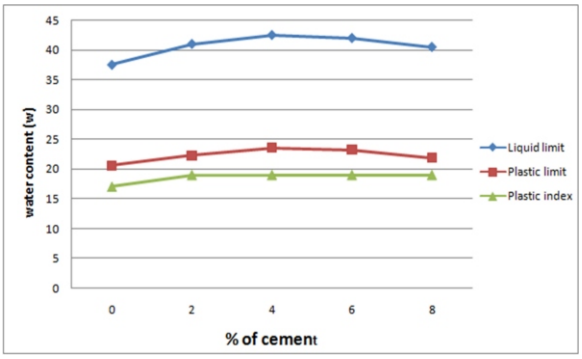

Fig. 2. L.L, P.L & P.I result for Khushab Soil (Original Sample +Cement)

F. Modified Proctor Test

The purpose of these tests is to test the soil generally and to determine the optimum moisture content for the subjected soil. In addition to soil other substance, such as a global, gravel or sand, may be measured. It is also used as a measuring device for testing the strength of the soil. As Khushab soil sample chemical testing as a dispersion stabilizer with the addition of various stabilizers and modified Proctor test was applied. Comparison of optimal water content for the original soil sample + 2%, 4%, 6% and 8% lime in the Fig. 4.

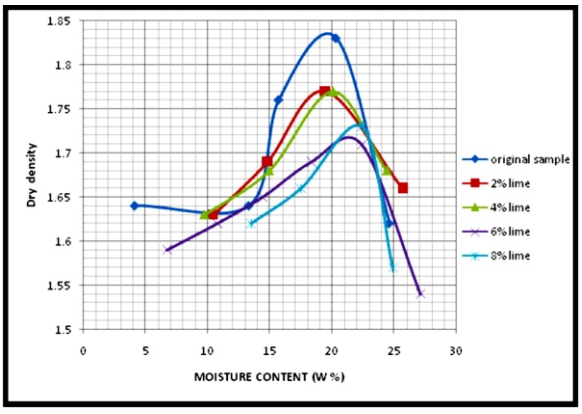

Fig. 4. Modified Proctor result for Khushab Soil(O.S+%Lime)

The purpose of the testing the soil generally is to determine the optimum moisture content for the soil. In addition to soil other substance, such as a global, gravel or sand, may be measured.

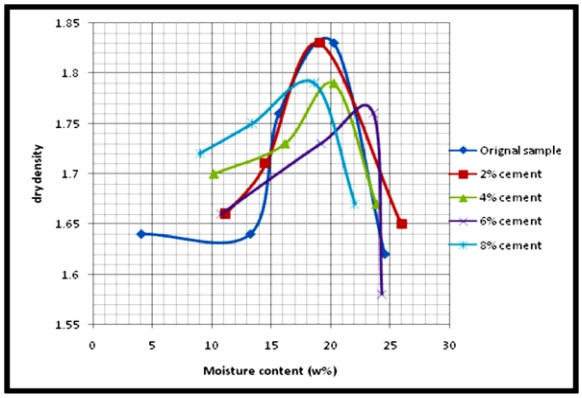

Fig. 5. Modified Proctor result for Khushab Soil(O.S+%Cement)

It is also used as a measuring device for testing the strength of the soil. As often Khushab soil sample chemical testing as a dispersion stabilizer with the addition of various stabilizers and modified Proctor test was applied. Comparison of optimal water content for the original soil sample + 2%, 4%, 6% and 8% cement shown in the Fig.6.

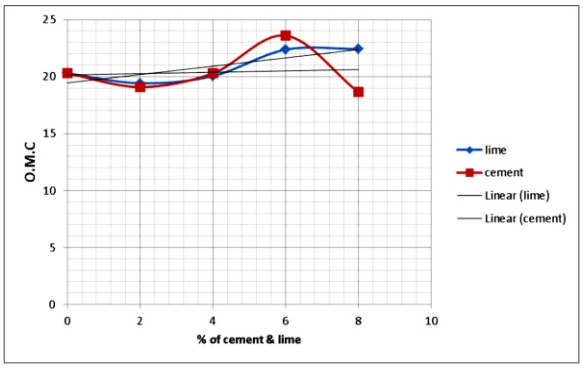

Fig.. 6. Modified Proctor result for Khushab Soil (O.S+%Cement)

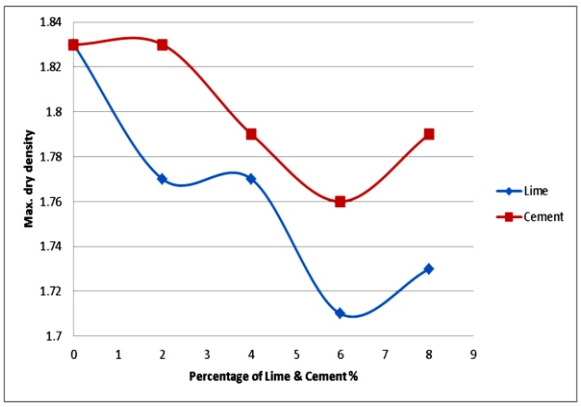

Fig.7. Modified Proctor result - The variation of Maximum dry Density with different

The aim of the soil test is to analyze the soil generally, to determine the optimum moisture content for the soil. In addition to soil other substance, such as a global, gravel or sand, may be measured. It is also used as a measuring device for testing the strength of the soil. As I often Khushab soil sample chemical testing as a dispersion stabilizer with the addition of various stabilizers and modified Proctor test was applied. Comparison of optimal water content for the original soil sample+ 2%, 4% and 6%, 8% limes & Cement can be seen in the Fig. 7.

G. CBR Test

CBR-value is used as an index of soil strength and load capacity. This value is a widely used and applied to the base structure and the underlying layer of material on the ground. Soil stabilized with fly ash and limestone, often used for the construction of pavement layers and filling. CBR-value is a relative measure of the test is used to evaluate the resistance of the soil for these applications [xvii]. CBR-test was performed to characterize the ability of resistance and support of the three studied soils and lime and cement mixture. Test procedures and preparation of samples were prepared according to standard procedures.

CBR-test was performed to characterize the ability of resistance and support of three of the soils and lime and cement mixtures with different percentages of 2%, 4%, 6% and 8% of them. Test procedures and preparation of samples were prepared according to standard procedures shown in Fig. 8.

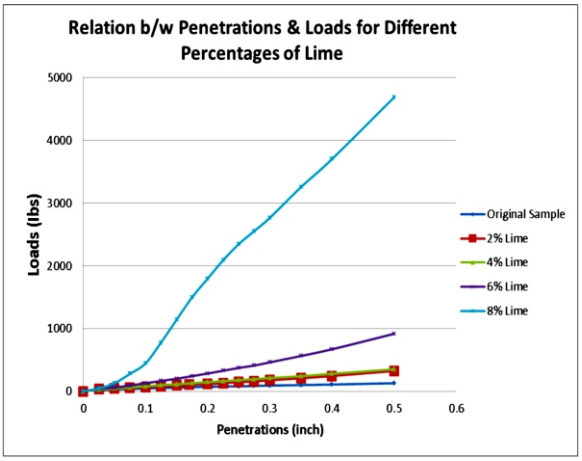

Fig. 8. CBR Test Analysis result for Khushab Soil(Original Sample+% Lime)

CBR-test shown in Fig. 9 was conducted to characterize the stability and support of three of the soils and lime and cement mixtures with different percentages of 2%, 4%, 6%, 8%, 10% and 12% thereof.

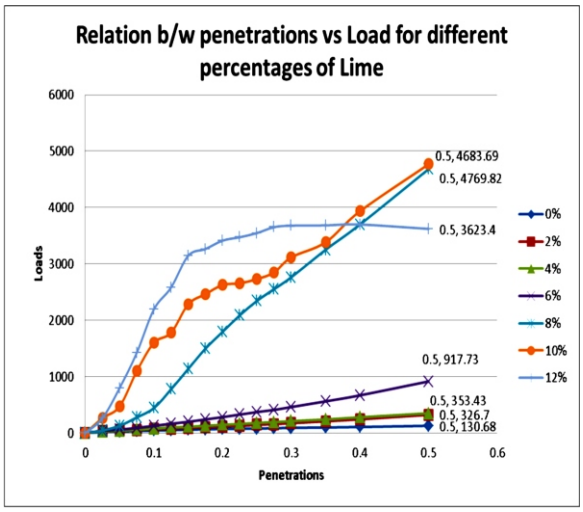

Fig. 9. CBR Test Analysis result for Khushab Soil(Original Sample+% Lime)

CBR-value is used as an index of soil strength and load capacity. This value is a widely used and applied to the base structure and the underlying layer of material on the ground. Soil stabilized with cement, often used for the construction of pavement layers and filling. CBR-test the relative indicator is used to assess the stability of soil for these applications. [xvii] CBR-test shown in Fig 10 was performed to characterize the ability of resistance and support of the soils and cement mixtures with different percentages of 2%, 4%, 6% and 8% of them. Test procedures and preparation of samples were prepared according to standard procedures

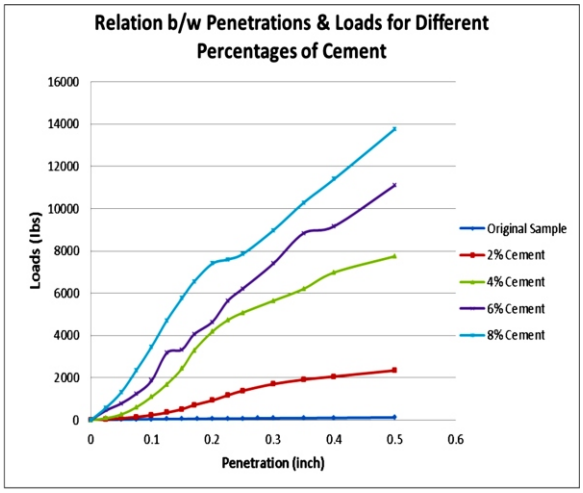

Fig. 10. CBR Test Analysis result for Khushab Soil(O.S+% Cement)

VI. Conclusions and Recommendations

Based on the results obtained from the Chemical along with Physical testing and analysis of experimental results, the following conclusions have been drawn

1. Chemical testing for soil sample showed that a reasonable quantity of sodium chloride was causing dispersion as the Khushab Distt. is linked with Salt Range. SAR (Sodium Adsorption Ratio) & Percent Sodium (PS) values showed that that there was an intermediate level of dispersion. After addition of stabilizing agents like Cement & Lime, non-dispersive behavior was observed with increase in percentage.
2. The Free Swell Test was performed for testing the dispersion of the given soil sample which was not obvious that there is some dispersion property in the soil.
3. Soil behavior was studied after addition of 2%, 4%, 6% and 8% Lime and Cement, from results CBR was improved at optimum level of 6% addition of different percentages of Lime and Cement, so it has been observed that compaction characteristics of Khushab soil has been improved.
4. The Double Hydrometer Test was performed for testing the dispersion of the given soil sample which was obvious that there is some dispersion property in the soil. After addition of stabilizing agents like Cement & Lime, non-dispersive behavior was observed with increase in percentage.
5. The Crumb Test was performed for testing the dispersion of the given soil sample which was obvious that there is some dispersion property in the soil. After addition of stabilizing agents like Cement & Lime, non-dispersive behavior was observed with increase in percentage.
6. In this research, the ASTM D 4221 - 99 [18], Standard Test Method for Dispersive Characteristics of Clay Soil by Double Hydrometer, ASTM D 422 - 63 [19], Standard Test Method for Particle-Size Analysis of Soils & ASTM D 4647-06 [20], ASTM D 6572 - 00 (2000), Standard Test Method for Determining Dispersive Characteristics of Clayey Soil by the Crumb Test, were performed to analyze dispersive nature to non-dispersive improvement. More tests with other standards can be performed within advance laboratory setups.
7. The Physical properties were studied with three test procedures Atterberg Limit, Modified Proctor Test especially. Finally conclusions were in favour of successive stabilization process i.e addition of Cement & Lime.
8. Finally the CBR test results showed that Khushab Soil can also be used in Roads as after stabilization this soil can be helpful in accordance with economical point of view considering 6% of addition stabilizer like lime and cement as optimum.

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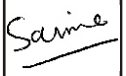
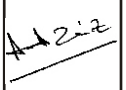
Authorship and Contribution Declaration			
	Author-s Full Name	**Contribution to Paper**	
1	Mrs. S. Batool (Main /Principal Author)	Proposed topic, basic study Design, methodology and manuscript writing	
2	Prof. Dr. Akhtar Ali Malik (2nd Author)	Data Collection and interpretation of results etc.	
3	Prof. Dr. Aziz Akbar (3rd Author)	Literature review & Referencing and quality insurer	
4	Mr. Tahir Sultan (4th Author)	Statistical Analysis	

Investigation of Lateral Strains Involved in Ultrasonic Pulse Velocity Test by Using Finite Element Methods

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***Abstract*-**In a previous study it was found that dynamic modulus (E) obtained from Impulse Load Test (ILT) is lower than dynamic modulus obtained from Ultrasonic Pulse Velocity Test (UPVT), which is theoretically not correct. In order to investigate this problem, the theoretical aspects involved in E-Calculations were checked by calculating the lateral strain involved in UPVT. Two finite element software programs (Marc and Patran) were selected for this purpose. In addition the effect of diameter on lateral strains of 12 inch length concrete samples was also investigated.

***Keywords*-**Dynamic Modulus, Impulse Load Test, Ultrasonic Pulse Velocity Test, Finite Element Methods, Lateral Strains

I. Introduction

Concrete is used in most civil engineering structures and therefore requires certain performance characteristics such as quality, workability and economy. Among them quality is most important and is measured by its strength, durability and dimensional stability. The strength of concrete is measured by Dynamic Modulus (E) Compressive Strength (Fc) etc. Among them Dynamic Modulus corresponds to a very small strain. This strength parameter is used in design for pavements and structures subjected to earthquake or impact loading. A large number of testing procedures are presently available for its determination. These procedures, used either in the field or the laboratory, are broadly classified in to destructive tests and non-destructive tests (NDT).

Destructive testing has been in use for a number of years. The structural evaluation of concrete can be made successfully with these tests. However, for existing structures, the tests are expensive and time consuming. On the other hand, NDT procedures are useful in that they are economical and provide a quick evaluation of concrete sample. Moreover, these testing procedures allow repeated testing of the same sample and make possible a study of the variation in properties with time. For Dynamic Modulus evaluation ILT and UPVT are available which in a previous study gave different results of the same sample.

These in-consistent results in Dynamic Modulus evaluation is theoretically not correct as the same phenomenon of wave travelling through a sample causing its vibration is involved in both these methods.

In UPVT wave velocity and ILT the natural frequency of the sample is used for dynamic modulus evaluation. Since the same wave is involved in both these methods, the dynamic modulus should be the same (ACI, 1976).

For the justification of these results, it is important to mention the detail of the solutions available for the dynamic modulus calculations in UPVT. Such solutions suggested by ACI (1945) and Long (1945) for the laboratory specimens, pavements, and mass concrete are given in Table I. Among them the one suggested for laboratory specimens was used to calculate the dynamic modulus [i]. In this solution it was assumed that in laboratory specimens, lateral expansion or contraction reduces the velocity of the longitudinal wave (ACI, 1976), which causes the wave to travel at a slight greater velocity. The situation represented by pavements is intermediate between those represented by laboratory specimens and the mass concrete (ACI, 1976) because the lateral displacements in pavements are suppressed in the direction of width but not in the direction of thickness.

The next step in this research was to check the extent to which the assumption of lateral expansion or contraction of laboratory specimens affects the wave velocity. For this purpose, two finite program were used to calculate the lateral strains in the 6×12-inch concrete samples tested by UPVT. Also the effect of diameter on the lateral strain of 12 samples was investigated in this study.

TABLE I
Solution for Dynamic Modulus in Time Travel Method [v], [vi]

Situation	Solution
Laboratory Specimen	$E = V^2*\rho$
Pavements	$E = V^2*\rho*(1-\mu^2)$
Mass Concrete	$E = V^2*\rho*[(1+\mu)(1-2*\mu)/(1+\mu)]$

E = Dynamic Modulus of Elasticity
V = Pulse Velocity
□ = Density of the Concrete sample
μ = Poison's Ratio of Concrete sample

The ultrasonic pulse velocity has been used on concrete for more than 60 years. Powers in 1938 and Obert in 1939 were the first to develop and extensively use the resonance frequency method [viii]. Since then, ultrasonic techniques have been used for the measurements of the various properties of concrete [ixxxviii]. Also, many international committees, specifications and standards adopted the ultrasonic pulse velocity methods for evaluation of concrete. Examples are the ASTM C597, BS 1881: Part 203 and ACI 224R, ACI 228.1R, ACI228.2R and ACI228.2R [xxvixxviii].

The variation of the results due to the surface properties, presence of steel reinforcement, presence of voids and cracks, properties of aggregate and mix proportions have been studied and shown in the literature [xii,xiv,xvi, xvii,xxviii]. Many attempts have been made to correlate the velocity to the strength of concrete either directly or by the use of combined ultrasonic and rebound hammer [xv, xxi, xxii, xxv, xxviii]. Special techniques for investigating damage in concrete by the use of wave velocity through cracked concrete have been introduced by Toutanji [viii], Selleck et al. [xxiii], Nogueira and Willam [xxiv].

From the literature review, it can be concluded that the ultrasonic pulse velocity results can be used to:

a. Check the uniformity of concrete,
b. Detect cracking and voids inside concrete,
c. Control the quality of concrete and concrete products by comparing results to a similarly made concrete,
d. Detect condition and deterioration of concrete,
e. Detect the depth of a surface crack and
f. Determine the strength if previous data is available.

II. Details of Ultrasonic Pulse Velocity test

The ultrasonic pulse velocity test is used for assessing the quality of concrete by measuring the longitudinal pulse velocity. The pulse is produced by an electro-acoustical transducer that is held in contact with one surface of the concrete sample being tested and received by a similar transducer in contact with the other surface. The equipment used in this (Model C-4901) was designed for both laboratory and field testing by James Instrument, Inc. the accuracy involved in this equipment is ±0.1 microsecond. It generates low frequency ultrasonic pulses and measures the time taken for them to pass from one transducer to the other through the material interposed between them.

It gives a direct reading of the transmission time of an ultrasonic pulse passing from transmitting to a receiving transducer. Two time ranges are incorporated covering from 0.1 μsec. to 999.9 μsec. (in units of 0.1μsec), and 1.0 μsec. to 9999.0 μsec. (in units of 1.0 μsec.). an over range LED indicates when a range has been exceeded. The transmit time is displayed on a 4 digit, 0.5 inch Transflective Liquid Crystal. A nominal 0.5 to 8 microsecond variable delay control enables the instrument to be set to a reference reading with different types of transducers and cables. The control is used in conjunction with a standard reference bar, supplied with the instrument, and having a transmission time of 26 μ-sec. The exact time is being marked on the bar. If the transmitted pulse is not received, or when the transducers are removed from the test piece, the LCD display will automatically blink and the O/R indicator will flash once per second. This provides a warning if the instrument has inadvertently been left switched on. The instrument has been designed with site testing particularly in mind, to be fully portable, simple to operate and with a high degree accuracy and stability. Currently, there are at least three such instruments available commercially. In all these equipment the contact with the concrete is made with a suitable acoustic coupling medium, such as grease, petroleum jelly, etc.

There are three ways of measuring pulse velocity through concrete. One is the direct transmission method, in which the transducers are attached to opposite faces of the member; preferred wherever access to opposite sides of the component is possible because it provides a well-defined path length and results in maximum sensitivity. The same method was used to test the concrete samples placed in a container on sand. Later two transducers coated with vacuum grease were pressed on both faces of the concrete samples. When the reading on the time display unit was stabilized noted for calculating the dynamic modulus of the concrete samples.

III. Finite Element Method (FEM)

The purpose of using FEM in the study was to find the lateral deformations of 12 inch length concrete samples of different radii tested by UPVT. In this testing arrangement two types of loading conditions were applied. First a static loading condition was applied through the transducers by the operator. Secondly, a dynamic loading condition was applied due to pulses travelling from one transducer to the other. Two finite element software programs, Patran and Marc, were used for this purpose. The reason for using this software was the fact that, neither of the software was able to perform the analysis alone. As an example, Patran is not able to perform the dynamic analysis of a structure. On the other hand, Marc is not capable of reading the output or result files. It also cannot create the session files that represent the geometry, materials properties, and loading and boundary conditions of a

structure. For this reason, it was decided to use Patran for creating the session files. The type of the element used in the file was a hexahedron. A total of 1476 elements were created to represent the geometry of 12 inch length concrete samples of different radii. Some of the nodes at the center of the concrete sample were fixed in this file. The reason was that the software selected for the dynamic analysis was not able to handle the free-free boundary condition.

A. Details Software for FEM

The general applicability of the finite element method makes it a powerful and versatile tool for a wide range of problems. Hence, a number of computers program packages or software have been developed for the solution of a variety of structural and solid mechanics problems. Some of the programs have been developed in such a general manner that the same program can be used for the solution of problems belonging to different branches of engineering with little or no modification. Among these programs, only two were used for lateral deflection of concrete samples tested by UPVT.

Also lateral deflections in 12 inch length concrete samples of different radii were investigated in this research. Details of both of these software are given below:

1) Patran

This finite element program has been designed to provide for easy and efficient utilization of human as well as computer resources. It has been implemented on a wide variety of computers, such as the Hewlett-Packard HP 90000. Patran is a solid modeler; a graphing imaging system; a modeler for finite element, boundary element, and finite difference analysis; an analysis too; and a result evaluation system. As requirements change, Patran's flexibility provides an efficient mechanism to help the engineer meet the challenges of his work environment (Kart, 1985).

2) Marc

Marc is a general purpose finite element program designed for the linear and non-linear analysis of structures in the static and dynamic regime. Its extensive element library makes it useful in elastic analysis and its broad coverage of the structural mechanics area makes it invaluable as a non-linear analysis tool. It is written in Fortran IV in general form with variable dimensions passed down to the subroutines. The user defines his own working space depending on element type, the size of the problem, and available memory (Kant, 1985).

IV. Lateral Strain Evaluation

In this study lateral deflections of the concrete sample tested by UPVT (Fig.1 (a)) was obtained by using FEM. These deflections were needed to check the validity of the assumptions used for the solution of a laboratory specimen.

Fig. 1. (a). Ultrasonic Concrete Tester

For this purpose, a concrete sample was made and tested by the ultrasonic pulse velocity test for its dynamic modulus evaluation. The value of dynamic modulus obtained in this testing was 6450967 psi, which was used for calculating the lateral deflection of the sample. At his stage, it is important to mention again that in ultrasonic pulse velocity test, two types of loading conditions are involved. First, a static loading condition which were applied by the operator through two transducers. Secondly, a dynamic loading condition, which was applied due to, pulses travelling from one transducer to the other.

The approximate value of the static loading was found by approximately applying the same amount of load by the operator on the weighing machine. Dividing this load by the area under the two transducers (Fig. 1(b)), a stress of 2.9 psi was obtained. This stress was applied by the operator through transducers on both faces of the concrete samples.

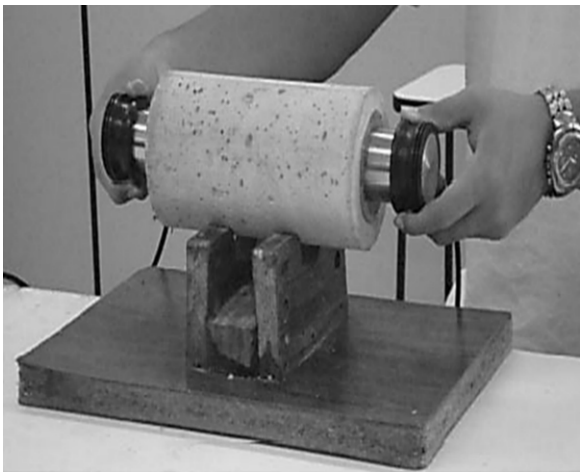


Fig. 1. (b). Sample Tested by Ultrasonic Concrete Tester

The loading conditions involved in the dynamic load are shown in Fig. 2. The loading condition indicates that a load of 0.01 pound is applied for a period of two micro-seconds with a frequency of ten cycles per second.

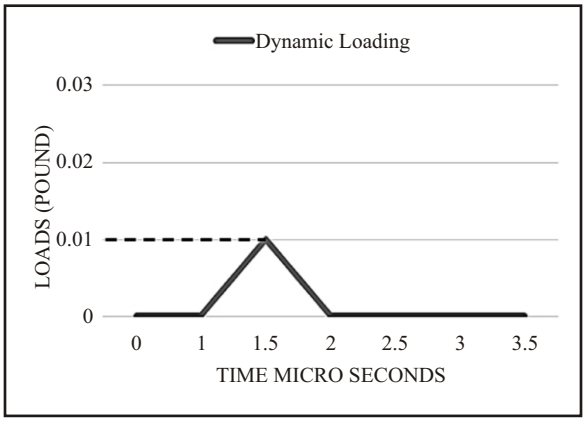


Fig. 2. Dynamic Loading (Ten Hz Per Second) involved in UPVT

After obtaining information about loading conditions, the next step was to analyze the lateral deflections with the help of FEM by using software Patran and Marc as mentioned earlier. Two programs were necessary because neither of the two was available to perform the analysis alone. Specifically, Patran is not able to perform the dynamic analysis of a structure. On the other hand, Marc is not capable of reading the output or the result files and cannot create the session file, which presents the geometry and properties of a structure. Moreover, it does not perform the analysis free-free conditions.

Considering all the limitations described above, it was decided to use Patran for creating session files, as well as to extract the results from the output files. The limitation of boundary conditions is Marc was overcome by fixing some of the nodes at the center of the sample. These nodes were located on the face that had a radius of 0.985 inch and was perpendicular to the direction of wave propagation.

After making all the decisions about loading and boundary conditions, Patran. ses was created. Later, when the same session file was run by Patran, two other files, Patran. dat and Patran. out, were obtained. Using the 'Patmar' program a translation of Patran. out was made. Marc made it readable. Later with the help of a subroutine, named 'Kludge. For', the transformed files were run by Marc for finite element analysis. In the first run, all the loads were treated as if they were static in nature. For the dynamic analysis, a modification was made in the Marc. dat file. Listing of Patran. ses, and Marc. dat (modified) files is given in Annexure 1.Now, using the modified file, a second run was made, and several output files of the same type were obtained. Again, the file 'Marc. T16' was transformed back by the 'Marpat' program. As a result of which two output files, Patran.I0so.Dis, and Patron.I0so.Els were obtained. Both files are readable by Patran.

Patran.I0so.Dis files can be used to get the deformed shape of the sample. The values and contours for displacement in different directions can also be obtained from this file. Patran.I0so.Els can be used to get the values and contours for stresses in different directions. Patran.I0so.Dis with higher numbers can also be used to get the plot of deformed shape and the value of natural frequency of a sample in different modes of vibration. Patran.I0sl.Dis will give the plot and natural frequency in the first mode of vibration. Similarly, Patran 10s2. Dia will give the plot and natural frequency in the second mode of vibration and so on.

After obtaining the above results, the next step was to find the lateral deflections in the concrete sample. Fig. 3 shows the plots of contours and values of deflection in X- direction. Y=0, the deflection in the X-direction can be used for lateral or radial deflections. Since these deflections are changing in the Z-direction, it was decided to calculate the average lateral deflections in the concrete sample. Three locations, at the middle and at each end of the sample, were selected for this purpose. The locations of these deflections are also shown in Fig. 3. Once the three deflections were known, the average deflection and ultimately the average strain in the lateral direction was obtained. The value of this strain was 2.2×10^{-8} inch/inch, which is very small. Later the same type of analyses was made for 12 -inch length concrete samples of different radii Annexure 2. From these results the lateral strains at different radii were calculated. The plot of these lateral strains at different radii is given in Fig.4. The following observations given in Table II can be made from this figure:

TABLE II
EFFECT OF RADIUS ON LATERAL STRAIN

Diameter	Lateral Strain
(1) As diameter decreases (2) Below 4" diameter (3) Above 4" diameter	(1) Lateral Strain increases (2) Lateral Strain increases dramatically (3) Change in Lateral Strain is relatively small.

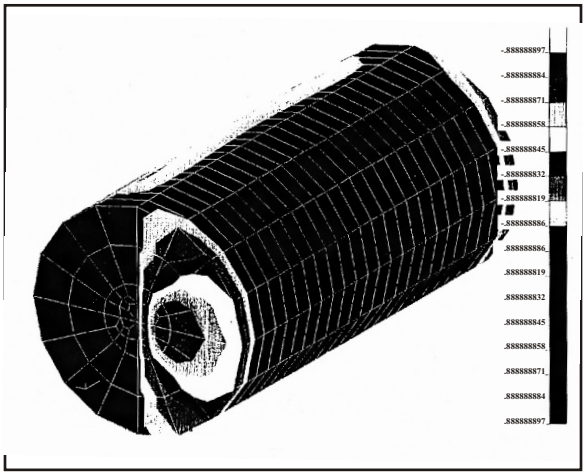


Fig. 3. Deflections (X-Direction of Concrete Samples tested by UPTV by Using Finite Element Methods

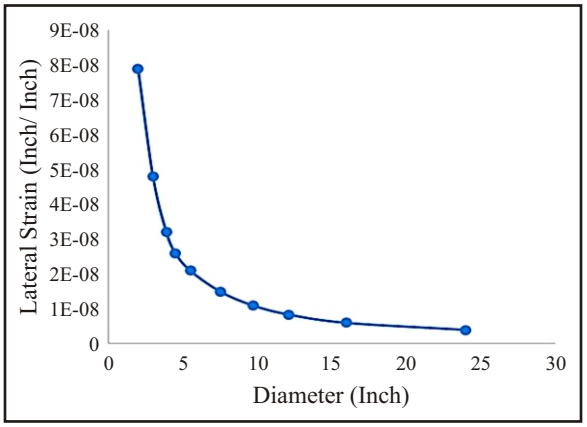


Fig. 4. Effect of Diameter on Lateral Strain of 12 Inch Long Concrete Sample

V. CONCLUSION

The results obtained from FEM show that lateral strain in 6×12 inch concrete samples due to UPVT are so small that cannot affect the wave velocity as reported by Shah 1970. Under these circumstances for 6×12 inch laboratory specimens the ACI suggested solution is not appropriate. Hence 6x12 inch concrete samples should be treated as mass concrete which require poisons' ratio of concrete for its Dynamic Modulus evaluation as given in Table I.

```
HEX/8/0                .
N                      5
2                      3
2                      1
4                      P
12                     WI
ME                     4
H14                    PL
HEX/8/0                11
N                      7
2                      4
2                      PF, H1T #, HEX/8/0, 1
4                      END
12                     6
ME                     3
H15                    1
HEX/8/0                2
N                      7
2                      5
2                      1
4                      1
12                     1
ME                     CONCRETE CYLINDER UNDER ULTRASONIC TESTING
H16                    N
HEX/8/0                10
N                      6
2
2
4
12
FEG
2
N
1
N
PMAT, 1, ISO, 6. 55E6, , . 22, 2. 2803E-4
DF
DF, H13T16,PRESS, / / -2. 9, 1, FA6
DF, H5T8, PRESS, / /2.9,1,,FA5
DF, H5T8, FORC, / / .01,1,,FA5
DF, H13T16, DIS, 0/0/0, 2, FA5
DF, H5T8, DIS, 0/0/0, 2, FA6
END
```

Fig. 5. Listing of Patran.ses File (Continued).

Annexure 1
Using of Patran.ses and Marc.dat (Modified Files)

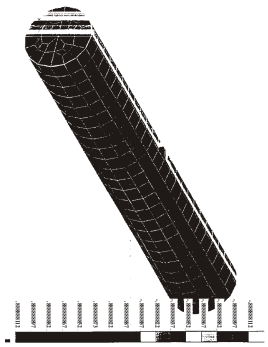
GO	ME	HEX/8/0	HEX/8/0	
1	H3	N	N	
1	HEX/8/0	2		2
1	N	2		2
GR, #, , O	2	4		4
LI , 4# , ARC, . 985/0/0/				
. 985/0/. 985/360, 1	4	12		12
GR, #, TR, -2. 065, 1	2	ME	ME	
LI, 4#, ARC, . 985/0/0/				
. 985/0/. 985/360, 5	4	H9	H9	
PA, 4#, 2L, , 1/2/3/4,				
5/6/7/8	12	HEX/8/0	HEX/8/0	
GR, #, TR, . 985, 1	ME	N	N	
LI, 2#, ST, , 1/9, 9/3	H4	2		2
PA, 4#, 2L, , 1/2/3/4,				
9/10/10/9	HEX/8/0	4		4
VI	N	2		2
1	2	4	4	
23, -34	4	12		12
PL	2	ME	ME	
VI	4	H10	H10	
2	12	HEX/8/0	HEX/8/0	
O, -180	ME	N	N	
PL	H5	2		2
PA, 8#, TR, / /6.02,				
1T8	HEX/8/0	4		4
HP, 8#, 2P, , 1 T8,				
9T16	N	2		2
HP, 8#, TR, / / 6. 02, 1				
T8	2	4		4
SET, LABEL, OFF	2	12		12
PL	4	ME	ME	
END	12	H11	H11	
ME	ME	HEX/8/0	HEX/8/0	
H1	H6	N	N	
HEX/8/0	HEX/8/0	2		2
N	N	4		4
2	2	2	2	
4	2	4	4	
2	4	12	12	
4	12	ME	ME	
12	ME	H12	H12	
ME	H7	HEX/8/0	HEX/8/0	
H2	HEX/8/0	N	N	
HEX/8/0	N	2		2
N	2	4		4
2	2	2	2	
4	4	4	4	
2	12	12	12	
4	ME	ME	ME	
12	H8	H13	H13	

Fig. 6. Listing of Patran.ses File

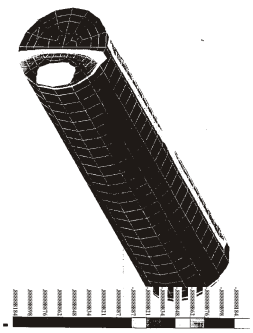
```
DYNAMIC                 1               3       1
END
END OPTION
MODAL SHAPE
40,
CONTINUE
RECOVER
                        2
CONTINUE
DYNAMIC CHANGE                  0.00001         2       1       1
0.00001
FORC
2, 0.01,
H5T8, FA5
CONTINUE
DYNAMIC CHANGE
0.00001                 0.00001         2       1       1
FORC
2, -0.01,
H5T8, FA5
CONTINUE

DYNAMIC CHANGE
                        0.001
0.00002                                 49      3       49


TRACTIONS       1
        2       2
        1       2
CONTINUE
```

Fig. 7. listing of Marc.dat file

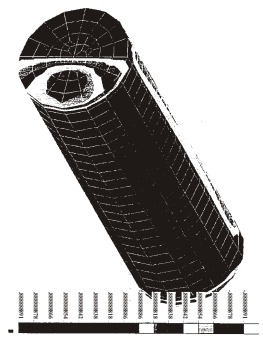
Annexure 2
Test Results Obtained from Finite Element Analysis of
12 inch Length Concrete Samples of Different Radii



2-1: Displacement In (X-direction)
(2x12 Inch Concrete Sample)

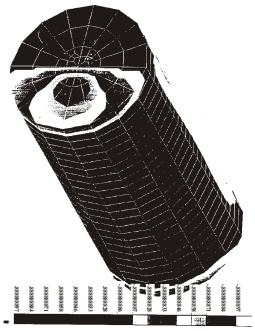


2-2: Displacement In (X-direction)
(3x12 Inch Concrete Sample)

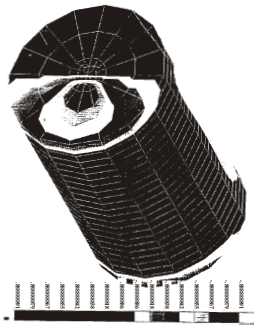


2-3: Displacement In (X-direction)
(4x12 Inch Concrete Sample)

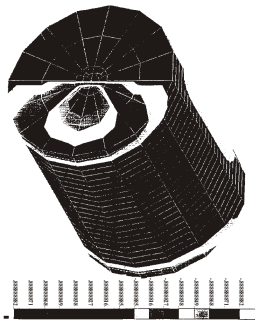
2-4: Displacement In (X-direction)
(5x12 Inch Concrete Sample)



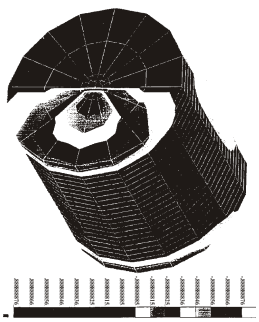
2-5: Displacement In (X-direction)
(6x12 Inch Concrete Sample)



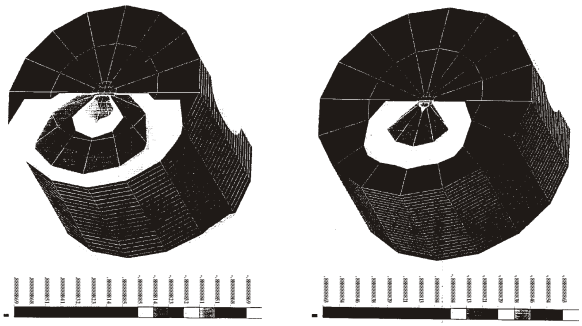
2-6: Displacement In (X-direction)
(8x12 Inch Concrete Sample)



2-7: Displacement In (X-direction)
(10x12 Inch Concrete Sample)



2-8: Displacement In (X-direction)
(12x12 Inch Concrete Sample)



2-9: Displacement In (X-direction)
(16x12 Inch Concrete Sample)

2-10: Displacement In (X-direction)
(24x12 Inch Concrete Sample)

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Section B
ELECTRICAL/ELECTRONICS

A Novel Binary Mask Estimation based on Spectral Subtraction Gain-Induced Distortions for Improved Speech Intelligibility and Quality

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Abstract-An alternate binary mask is constructed to improve the speech intelligibility and quality based on constraints of the magnitude spectrum. Motivated by previous studies of speech intelligibility obtained using processing strategies based on ideal binary masks, a new method for deriving a mask is proposed that separates noisy speech into time-frequency channels. The binary mask decisions are made on the basis of speech constraints imposed by the spectral subtraction Gain-induced distortions. All time-frequency channels satisfying the constraints are retained while time-frequency channels violating the constraints are discarded. The speech signals degraded at various signal-to-noise levels (-5dB, 0dB, +5dB) using babble and street makers are processed by the proposed mask and are presented to the normal hearing listeners in experiments measuring speech intelligibility. The results revealed significant improvements in speech intelligibility and quality even at low SNR levels.

Keywords-Ideal Binary Mask, Noise Estimation, Speech Intelligibility, Spectral Subtraction

I. INTRODUCTION

Approaches for enhancing the target speech in noisy situations via binary time-frequency masks primarily take advantage of the sparsity and disjointness of speech spectrums in their short-time-frequency illustrations, constructing a mask that only retains the spectro-temporal regions where the target speech is governing. The enhanced speech is then reproduced after imposing this mask to the noisy signal spectrums. The cues for estimating these masks can be attained either using single-microphone techniques [i-ii] or multi-microphone methods [iii-iv]. A comprehensive literature review on the time-frequency masking can be found in [v]. In this framework, efforts have been made to express a so-called ideal binary mask as the objective of binary mask estimation. This all-or-nothing conclusion is established on basis of a local or a fixed signal-to-noise-ratio (SNR) threshold in the time-frequency channels and the prefix *ideal* illustrates the prior statistics of the speech and noise spectrums. Methods employing binary masks have been revealed to yield substantial intelligibility improvements in extremely low SNR situations in these ideal sceneries. These positive outcomes have encouraged the researchers to estimate/develop the binary masks and proposed as the goal of computational auditory scene analysis (CASA) [iii], [vi], [vii]. Given this obvious evidence of intelligibility improvement using binary masks, work has been done in the recent past in trying to estimate these masks [ii], [viii] and describing the benefits of such masking [ix-xii], all with an interpretation to using these methodologies in auditory prostheses. It is discussed in [v] that binary masks should be favored over soft-masks for the purpose of complexity decline unless a soft-mask method can expressively improve the speech intelligibility. Still intelligibility improvement in the single-channel speech enhancement algorithms remains an indescribable goal [xiii], [xiv] primarily because of inaccurate estimation of the parameters for the filtering. In this paper a new method for deriving a binary mask is proposed that only retains the spectro-temporal regions where the target speech is dominant. The paper is organized as: the signal model and a brief introduction of the proposed approach are presented in the Section 2. In Section 3, we present the tests conducted to evaluate the proposed mask. We wish to evaluate the potential of the mask to improve the speech intelligibility and quality in adverse listening situations.

II. THE PROPOSED SPEECH ENHANCEMENT ALGORITHM

The prior studies [xv], [xvi] revealed enormous gains in speech intelligibility when proper constraints are enforced on the gain-induced speech magnitude distortions. On basis of the promising outcomes of past studies, a technique to estimate the binary mask is proposed which depends on magnitude spectrum constraints. Fig. 1 shows the block diagram of the proposed speech enhancement (noise-reduction)

algorithm, consists of the noise estimation and gain computation as pre-processing step and ideal binary masking as the post-processing (intelligibility enhancement) step, which is described next section.

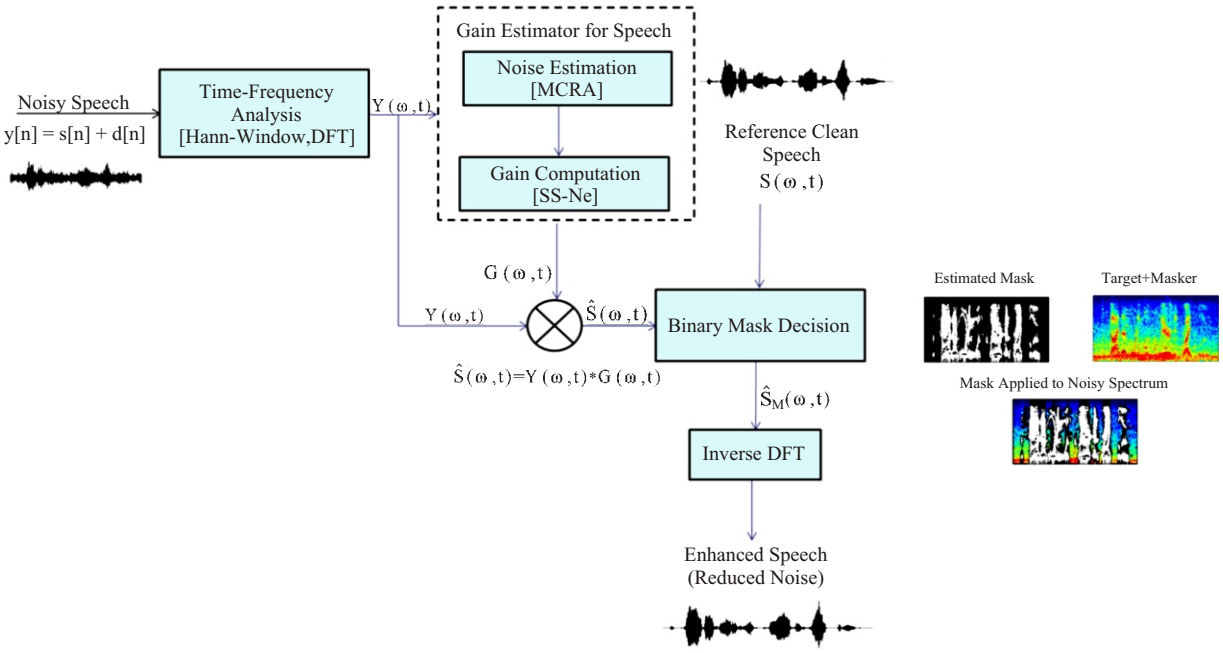

Fig. 1. Block diagram of proposed noise reduction algorithm

A. Constraints based Binary Mask Estimation

The noisy speech sentences were processed by conventional spectral subtraction algorithm [xvii]. The spectral subtraction method estimates magnitude spectrum of underlying novel speech by subtracting an estimate of the masker spectrum from noisy speech spectrum in short-time Fourier transform (STFT) domain. The greatest advantage of this technique lies in its simplicity, since all that is required is an estimate of the mean noise power. Let noisy speech, clean speech and noise signal be defined by y(n), s(n) and d(n) respectively and expressed as:

$$y[n] = s[n] + d[n] \quad (1)$$

The noisy speech was first segmented into frames with50% overlap among successive frames. Every frame was Hann windowed and STFT was computed. Let Y(ω,t), S(ω,t) and D(ω,t) denotes the noisy, clean and noise signal spectral components at time frame *t* and frequency bin *ω*. The estimate of the speech spectrum magnitude $|\hat{S}(\omega,t)|$ from the noisy observation is achieved by multiplying Y(ω,t) with the spectral subtraction gain function G(ω,t) as:

$$|\hat{S}(\omega,t)| = |Y(\omega,t)| \times G(\omega,t) \quad (2)$$

The spectral subtraction gain function G(ω,t) is computed as;

$$SNR_{POST}(\omega,t) = \frac{|Y(\omega,t)|^2}{E\{|D(\omega,t)|^2\}} = \frac{|Y(\omega,t)|^2}{|\lambda(\omega,t)|^2} \quad (3)$$

$$SNR_{PRIO}(\omega,t) = \frac{|X(\omega,t)|^2}{E\{|D(\omega,t)|^2\}} \quad (4)$$

The binary mask is constructed by considering only the *a posteriori* SNR information at every frequency bin. The spectral subtraction gain function G(ω,t) and *a posteriori* SNR is computed as; From equation 1;

$$|\hat{S}(\omega,t)| = ||Y(\omega,t)| - |D(\omega,t)|| \, e^{j(f,\omega)} \quad (5)$$

$$||\hat{S}(\omega,t)|^2 \approx |Y(\omega,t)|^2 - \alpha|D(\omega,t)|^2 \quad (6)$$

$$G(\omega,t) = \sqrt{1 - \frac{\alpha|D(\omega,t)|^2}{|Y(\omega,t)|^2}} \quad (7)$$

$$G(\omega,t) = \sqrt{\frac{\gamma(\omega,t) - \alpha}{\gamma(\omega,t)}} \quad (8)$$

α is over-subtraction parameter which is set to 1 in the proposed mask and λ(ω,t) is the estimate of background noise variance acquired by the noise estimation algorithm proposed in [xviii]. G(ω,t) is known as gain function in speech enhancement. Note

that G(ω,t) is real and, in principle, is always positive, taking values in range of $0 \leq G(\omega,t) \leq 1$. Negative values are sometimes obtained owning to inaccurate estimates of noise spectrum. It is important to note that equation 6 is an approximation because of the presence of cross terms [xix]. These cross terms are zero only in the statistical sense assuming that the signals are stationary. Speech, however, is non-stationary but in noise reduction applications, signals are processed on frame-by-frame (20-30 ms windows) basis where we consider the speech to be stationary. We assumed the prior knowledge of the clean speech as this was necessary in order to impose constraints. Therefore; to impose the constraints, the estimated magnitude spectrum $|\hat{S}(\omega,t)|$ was compared against the true speech spectrum $|S(j,k)|$ for each time-frequency channel. The time-frequency channels satisfying the constraints ($|\hat{S}(\omega,t)|<|S(\omega,t)|$) were retained whereas time-frequency channels violating the constraints ($|\hat{S}(\omega,t)|>|S(\omega,t)|$) were discarded. The modified magnitude spectrum, $|\hat{S}_M(\omega,t)|$ was computed as;

$$|\hat{S}_M(\omega,t)| = \begin{cases} |\hat{S}(\omega,t)| & \text{if } |\hat{S}(\omega,t)| \leq |S(\omega,t)| \\ 0 & \text{Elsewhere} \end{cases} \quad (9)$$

The mask in the equation (11) was found to be reasonably effective in improving the speech intelligibility [xv]. However, the mask is ideal magnitude-constraint binary mask as it involves the access to true magnitude spectrum, which is not available in real-time applications. Following the above selection of time-frequency channels, an inverse STFT was applied to the modified speech spectrum $|\hat{S}_M(j,k)|$ using the phase of noisy speech spectrum and the overlap-and-add method was finally used to synthesized noise-suppressed speech.

III. Performance Evaluation Scales and Discussions

A new method for deriving a binary mask is proposed which is discussed in section 2. We evaluate the proposed approach on the basis of two performance measures (1) the speech intelligibility enhancement under the low SNR environments and (2) quality of the synthesized speech in terms of the perceptual speech quality and overall quality.

A. Speech Intelligibility Tests

We evaluated our novel method to estimate binary mask with intelligibility listening tests in two phases.

1)Phase I: Effect of frame length on intelligibility

In phase I, the intelligibility listening tests were conducted to evaluate the performance of proposed mask for different frame lengths N, the parameter used in proposed speech enhancement algorithm. Speech sentences were selected from the IEEE database [xx], a database to facilitate the evaluation of the speech enhancement algorithms. Every sentence is sampled at 8 kHz frequency and has an average duration about 2.5 seconds. Sentences were recorded in silent room and were produced by two male and two female speakers. The noisy stimuli were generated by degrading the clean stimuli with the babble and street noise at -5dB, 0dB and 5dB SNRs using ITU-T recommendation P.56 [xxi]. The noise sources were taken from AURORA database [xxii]. Eight normal-hearing listeners were engaged to conduct listening tests. Out of the eight, four listeners participated in the first phase of the listening test. The tests were conducted in the quiet room and the participants were familiar of the listening tasks during a pre-experiment session. We changed the frame length *N* from 128-points to 1024-points and computed the mean intelligibility scores, shown in the Fig. 2, where the highest gain in

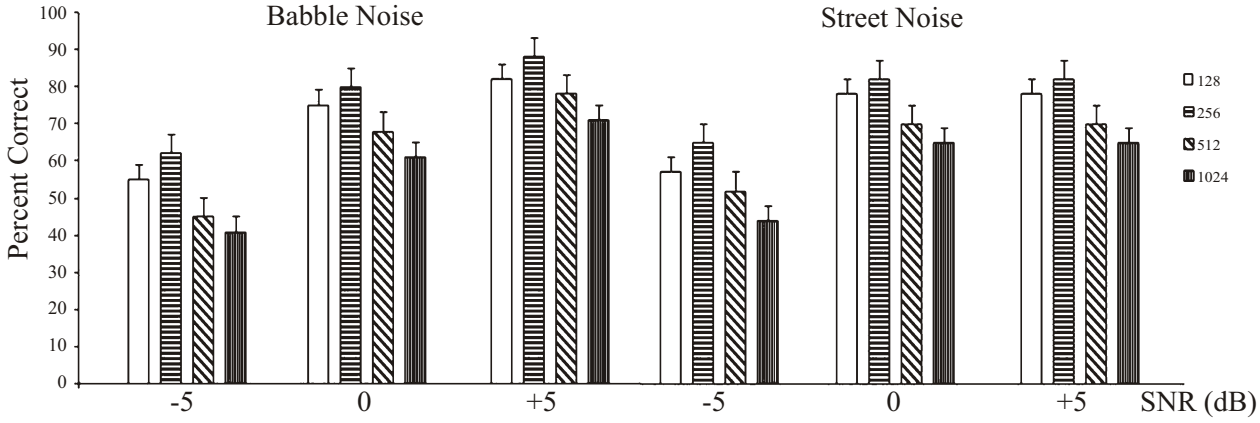

Fig. 2. The mean speech intelligibility scores for the Babble and Street maskers with different Frame lengths N

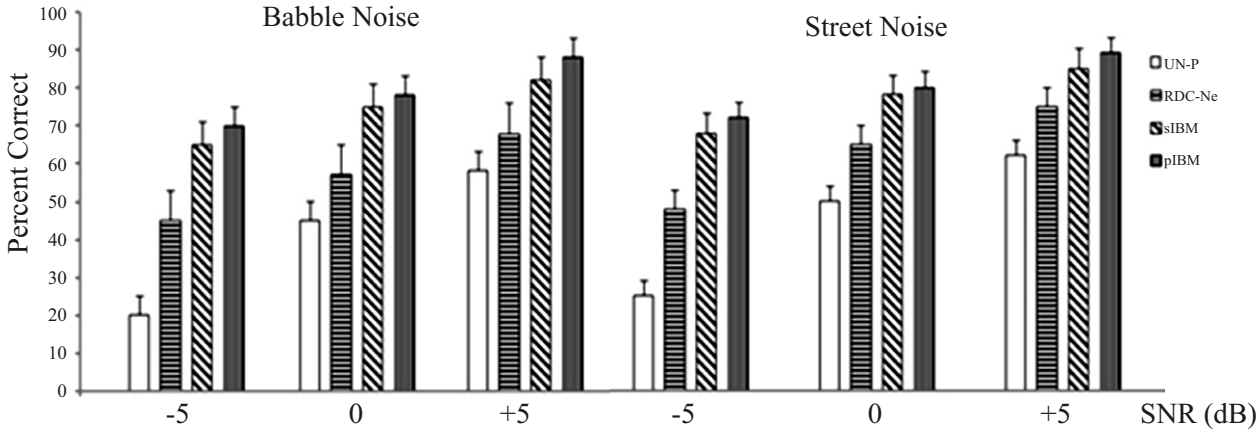

Fig. 3. Mean intelligibility scores as a function of SNR levels for babble and street maskers across the IEEE Sentences for different processing strategies

the speech intelligibility was observed for the frame length N=256-points in all noisy conditions.

2)Phase II:Comparison with other methods for speech intelligibility

In previous phase, the performance of the proposed binary mask has been evaluated in terms of speech intelligibility for different frame lengths *N*. Now we wish to assess the robustness of pIBM in terms of speech intelligibility against different speech enhancement approaches. The listeners participated in the four processing situations including un-processed stimuli (UN-P); speech processed by the SNR based binary mask (sIBM), speech processed by the spectral subtraction using noise estimation (SS-Ne) and speech processed by proposed binary mask (pIBM). In this particular experiment, another 60 IEEE sentences were used to evaluate the performance of the proposed algorithm against other algorithms. The remaining four listeners participated in the particular listening test.

Fig. 3 illustrates the results of the speech intelligibility tests. With pIBM a significant improvement in speech intelligibility was noted compare to that achieved with un-processed speech and SS-Ne. A significant improvement in the speech intelligibility was observed for both the pIBM and sIBM Fig. 3. But question is whether one maskprovides some advantage over the other?, to answer this question; the *t*-test based statistical analysis was computed for the mean intelligibility scores obtained with the SS-Ne, sIBM and pIBM respectively. We examine whether improvement in speech intelligibility is statistically significant or not. The results are given in Table I. The computed value of *t* determines the acceptance or rejection of the null hypothesis. If the value of *t* is found to be greater than a critical value, then the null hypothesis is rejected and concludes that there is statistically significant difference in intelligibility. All the *t*-tests in this paper have been carried out at 95% significance level. If $t<t_{critical}$ and *p*-value is smaller than

TABLE I
THE T-TEST BASED STATISTICAL ANALYSIS

Noise	SNR (dB)	Mean intelligibility scores obtained in % for SS-Ne and pIBM				
		SS-Ne	pIBM	*t*-test statistical analysis		
				$t_{statistic}$	$t_{critical}$	P_{value}
Babble	-5	65.90	75.30	10.03	2.262	p<0.00017
	0	70.90	82.90	15.79	2.262	p<0.00017
	5	75.90	92.90	22.36	2.262	p<0.00016
Street	-5	69.00	78.20	13.29	2.262	p<0.00017
	0	73.92	86.10	17.71	2.262	p<0.00014
	5	78.70	95.70	23.10	2.262	p<0.00014

Noise	SNR (dB)	Mean intelligibility scores obtained in % for sIBM and pIBM				
		sIBM	pIBM	*t*-test statistical analysis		
				$t_{statistic}$	$t_{critical}$	P_{value}
Babble	-5	72.80	75.30	09.30	2.262	p<0.00016
	0	79.10	82.90	10.58	2.262	p<0.00017
	5	90.10	92.90	12.58	2.262	p<0.00017
Street	-5	75.70	78.20	09.47	2.262	p<0.00016
	0	82.21	86.10	10.81	2.262	p<0.00017
	5	92.23	95.70	10.22	2.262	p<0.00017

0.05, then the given results are statistically insignificant. It can be observed from Table I that the *p*-values obtained for pIBM against SS-Ne and sIBM in all noisy conditions are smaller than 0.05 and $t > t_{critical}$, suggesting that the improvement in the speech intelligibility is statistically significant.

TABLE II
PESQ AND C_{OVL} RESULTS FOR NOISE REDUCTION ALGORITHM WITH DIFFERENT FRAME LENGTHS *N* (WITH 95% CONFIDENCE INTERVAL)

Noise	Frame Lengths (N-points)	PESQ-MOS			Overall quality (C_{OVL})		
		-5dB	0dB	5dB	-5dB	0dB	5dB
Babble	128 samples	2.18±0.05	2.53±0.05	2.81±0.05	2.09±0.05	2.41±0.05	2.72±0.05
	256 samples	2.31±0.04	2.71±0.04	3.02±0.05	2.48±0.04	2.94±0.04	3.21±0.05
	512 samples	2.15±0.05	2.49±0.05	2.73±0.06	2.11±0.05	2.38±0.05	2.67±0.06
	1024 samples	2.03±0.04	2.19±0.04	2.31±0.05	1.97±0.04	2.08±0.04	2.22±0.05
Street	128 samples	2.26±0.05	2.58±0.05	2.92±0.05	2.19±0.05	2.49±0.05	2.84±0.05
	256 samples	2.52±0.05	2.82±0.05	3.24±0.04	2.63±0.05	2.87±0.05	3.29±0.04
	512 samples	2.32±0.06	2.54±0.05	2.88±0.05	2.12±0.06	2.41±0.05	2.77±0.05
	1024 samples	2.12±0.05	2.35±0.05	2.58±0.04	2.01±0.05	2.21±0.05	2.51±0.04

TABLE III
PESQ AND C_{OVL} RESULTS AND COMPARISON BETWEEN THE UNPROCESSED STIMULI (UN-P), SPECTRAL SUBTRACTION WITH MCRA NOISE ESTIMATION (SS-NE), SNR BASED BINARY MASK (sIBM) AND PROPOSED BINARY MASK (pIBM) IN THE VARIOUS MASKER CONDITIONS(WITH 95% CONFIDENCE INTERVAL)

Noise	Algorithms	PESQ-MOS			Overall quality (C_{OVL})		
		-5dB	0dB	5dB	-5dB	0dB	5dB
Babble	UN-P	1.46±0.04	1.68±0.04	2.01±0.04	1.30±0.04	1.52±0.04	2.02±0.04
	SS-Ne	1.51±0.04	1.81±0.04	2.33±0.04	1.40±0.05	1.82±0.05	2.37±0.05
	sIBM	2.21±0.05	2.61±0.05	3.01±0.05	2.43±0.05	2.81±0.05	3.09±0.05
	pIBM	2.31±0.03	2.71±0.05	3.02±0.05	2.48±0.04	2.94±0.04	3.21±0.05
Street	UNP	1.39±0.04	1.77±0.04	2.16±0.05	1.34±0.04	1.71±0.04	2.11±0.05
	SS-Ne	1.50±0.05	1.93±0.06	2.34±0.04	1.63±0.05	2.11±0.05	2.63±0.05
	sIBM	2.41±0.05	2.71±0.04	3.27±0.04	2.58±0.05	2.79±0.05	3.31±0.05
	pIBM	2.52±0.04	2.82±0.05	3.24±0.05	2.63±0.05	2.87±0.05	3.29±0.04

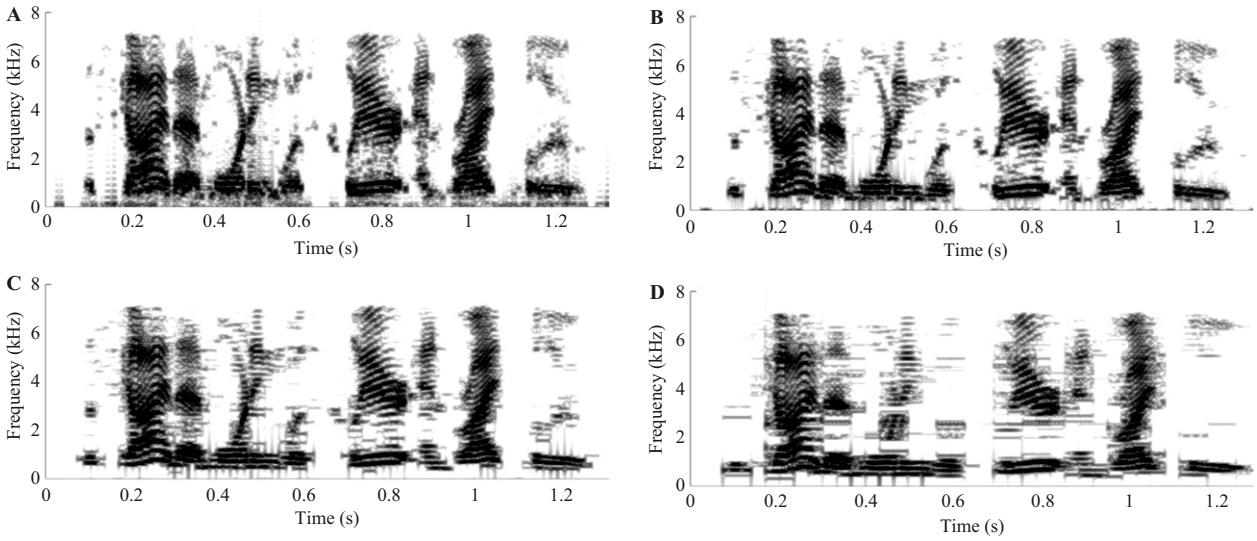

Fig. 4. Spectrograms of utterance by a male speaker from IEEE database. The speech enhanced by proposed binary mask at different frame lengths N (A) N= 128-Points, (B) N= 256-Points, (C) N= 512-Points and (D) N= 1024-Points

B. Objective Speech Quality Evaluation

To evaluate the quality of synthesized speech objectively, we use the quality evaluation measure, the perceptual evaluation of speech quality (PESQ), which is suggested by the ITU-T [xxiii] for speech quality evaluation. We also used the objective speech quality evaluation method recommended by the ITU-T [xxiv], which was referred to as the composite measure (C_{OVL}). Again, we changed the frame length *N* from 128-points to 1024-points and computed the PESQ and C_{OVL} scores respectively. The highest gain in the PESQ and C_{OVL} scores was recorded for 256-points in all noisy conditions shown in Table II. By observing the results of the experiments for the different frame lengths *N*, optimum frame length of 256-points was chosen as the best compromise for the proposed speech enhancement algorithm. At longer frame lengths *N,* a slurring effect was noticed which is visible in the spectrograms shown in Fig. 4 (D). Since the proposed mask is applied to the spectral subtraction processed spectrums instead of the degraded spectrums, we supposed that the pIBM produces better speech quality. To test our supposition, the PESQ and C_{OVL} measures were used to evaluate the speech quality of processed speech against SS-Ne and sIBM. Table III compares the PESQ and C_{OVL} results for three algorithms and un-processed condition. For pIBM, we observed high PESQ and C_{OVL} scores in all noisy situations compared to un-processed noisy speech and speech processed by the SS-Ne. Moreover, the PESQ and C_{OVL} scores for speech processed by the pIBM were found to be consistently higher in all SNR conditions than those processed by the sIBM. The highest gain in PESQ (0.17) was recorded for the street noise at 5dB and lowest gain in PESQ (0.01) was obtained for babble noise at 5dB. Similarly, the highest gain in C_{OVL} (0.13) was observed for the babble noise at 0dB and lowest gain in C_{OVL} (0.01) was obtained for babble noise at 5dB. We believe that higher PESQ and C_{OVL} scores were recorded with pIBM technique can be endorsed to the fact that better noise reduction was attained since spectral subtraction gain function was enforced to noisy stimuli before binary masking. The performance difference is observable which implies that the pIBM approach is efficient in the noise reduction at acceptable speech distortion. The spectrograms for the clean, noisy and processed speech by different techniques are illustrated in the Fig. 5. It is seen that the speech spectra by proposed binary mask are well preserved while residual noise spectra are effectively reduced as shown in Fig. 5(E) and 6 (E).

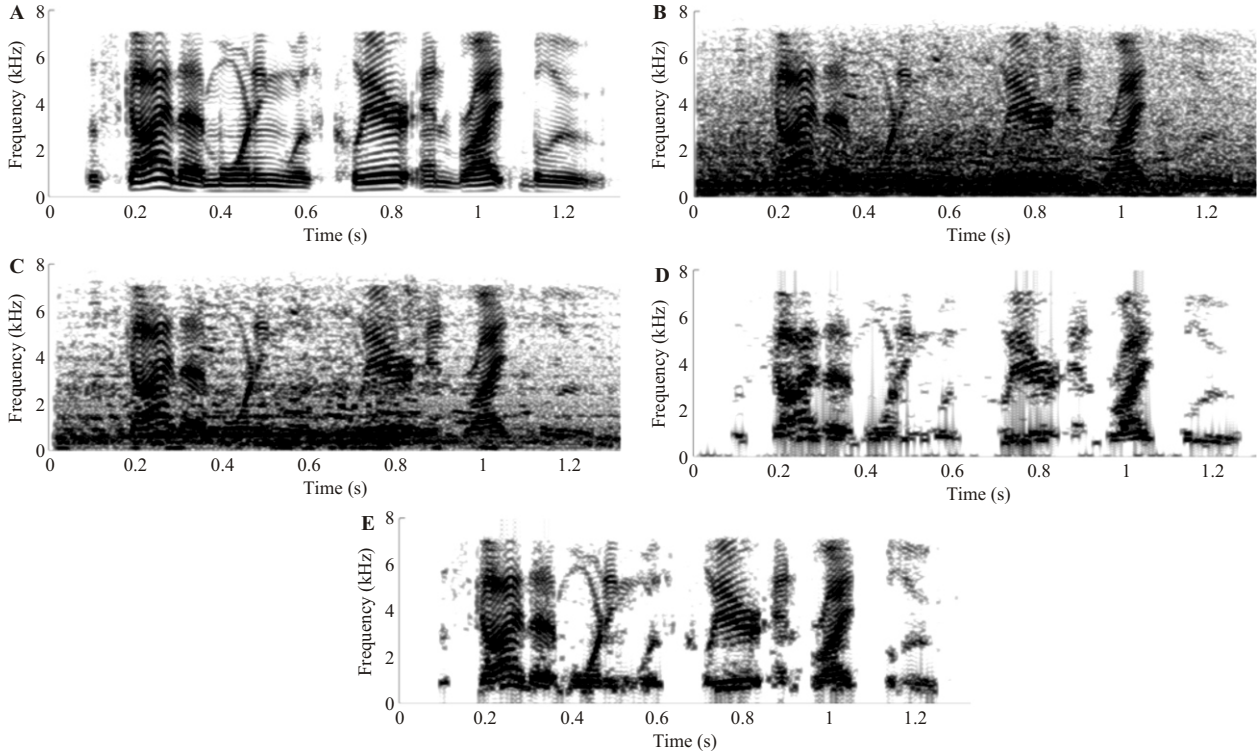

Fig. 5. The spectrograms of (A) clean speech, (B) noisy speech and processed speech by (C) Spectral subtraction with noise estimation (SS-Ne), (D) SNR based BM (sBM) and (E) Proposed binary mask (pBM)

IV. CONCLUSIONS

We proposed a novel noise reduction algorithm to reduce background noise and improve speech intelligibility and quality using time-frequency mask which was based on the spectral subtraction gain induced distortions. The binary mask retains all time-frequency channels satisfying the constraints ($|\hat{S}(j,k)|<|S(j,k)|$) while discard all time-frequency channels violating constraints ($|\hat{S}(j,k)|>|S(j,k)|$). The results of listening tests with the normal-hearing listeners showed a remarkable gain in the speech intelligibility. The statistical analysis suggests that the improvement in the speech intelligibility is statistically significant. Moreover, the speech synthesized using proposed mask revealed high quality even at very low SNR than that attained by speech processed with instantaneous SNR based mask and spectral subtraction with noise estimation. By observing the results of experiments for different frame lengths *N*, the optimum frame length of 256-points was chosen as the best compromise for the proposed noise reduction algorithm.We conclude that the proposed mask provides an improved benchmark for future research.

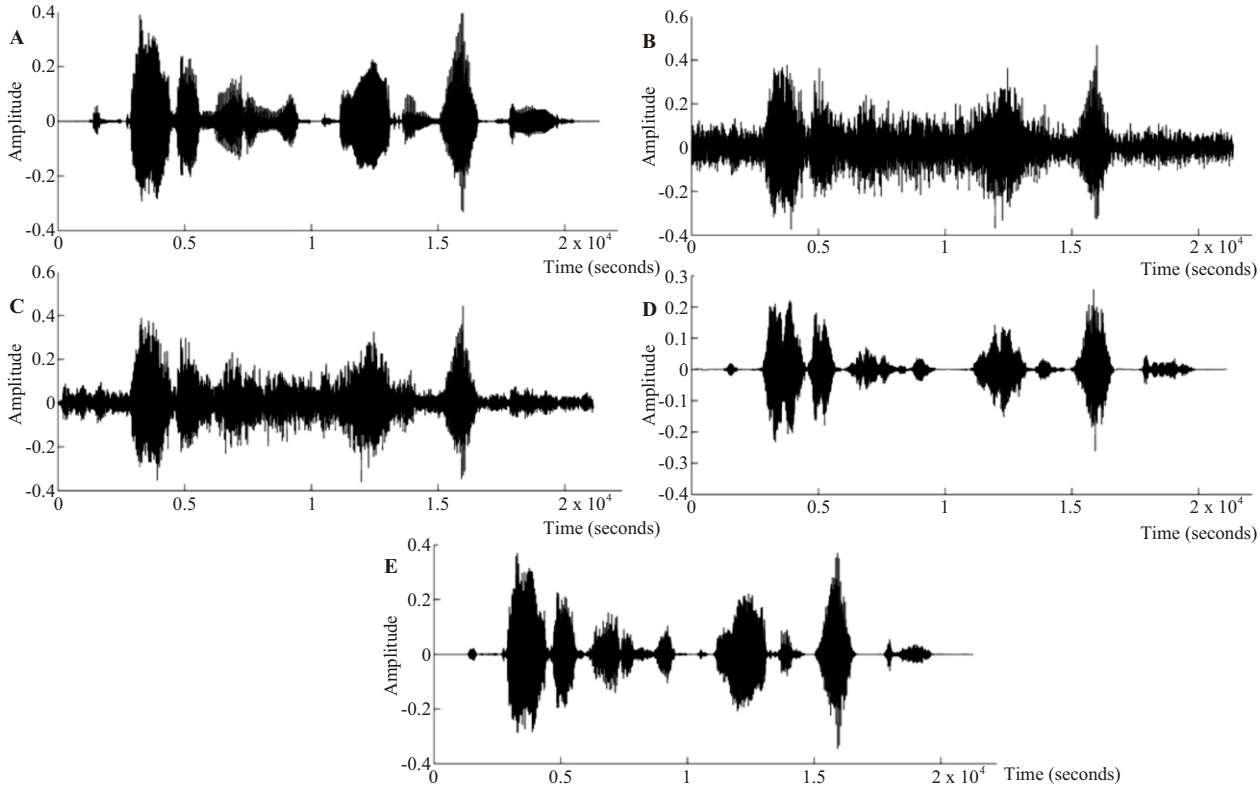

Fig. 6.The Time-domain waveforms of (A) clean speech, (B) noisy speech and processed speech by (C) Spectral subtraction with noise estimation (SS-Ne), (D) SNR based BM (sBM) and (E) Proposed binary mask (pBM)

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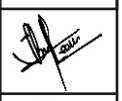
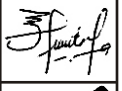
Authorship and Contribution Declaration			
	Author-s Full Name	**Contribution to Paper**	
1	Engr. Nasir Saleem (Assistant Professor)	Proposed topic, basic study Design, methodology and manuscript writing	
2	Dr. Muhammad Shafi (Associate Professor)	Statistical analysis, interpretation of results and manuscript writing	
3	Engr. Ehtasham Mustafa (Lecturer)	Data Collection, Literature review	
4	Engr. Aamir Nawaz (Lecturer)	Literature review & Referencing and quality insurer	

Linear Regression-Based Power Analysis for Digital Electronic Systems

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Abstract-This paper presents the linear regression-based power estimation technique uses the input patterns with the predefined characteristics. These patterns help to analyze the power consumption of the different intellectual-property (IP) cores in digital electronic systems. Our technique can accurately deals with combinational as well as sequential logic circuits at register-transfer level (RTL). Genetic algorithm (GA) is used for the generation of sequences with the statistical characteristics. During the power analysis procedure, the Monte Carlo simulation is performed and model function is extracted with the help of Look-Up-Table (LUT) approach. This function uses IPs primary inputs values for the analysis of power consumption. Our model demonstrates accurate and fast power estimation for IP-based digital system.

Keywords-Digital Systems, Power Estimation, Macro-Model, Input Metrics.

I. INTRODUCTION

Low-power consumption is nowadays very important design goal in very-large-scale integrated (VLSI) circuits. A key objective in low power-based system is to analyze power accurately. Power estimation at high design abstraction level, such as electronics and software engineering, is called for to facilitate new solutions to efficient power problems. Hence, a design and estimation approach for low-power is the key challenge to a successful System-on-chip (SoC) design. The rapid growth of transistor density and the operational frequency in digital electronic circuits have made power an important design constraint. Power optimization and estimation of SoC has nowadays become a difficult task for which the conventional approaches often prove to be inadequate. In order to handle the power, electronic design automation (EDA) tools have been introduced. These tools are very helpful for the minimizing of power dissipation in digital devices. The accurate power estimation EDA tools are needed from high to low abstraction levels.

In literature, there are several power analysis techniques for estimating the power consumption at different abstraction levels. Power estimation can be categorized in dynamic or static approaches at low level. Dynamic approaches are efficient and explicitly simulate the circuit with a typical input signal sequences. Statistical approaches such as Monte Carlo zero delay simulation [i] that helps the problem of input pattern dependencies. However, this technique assumes the transition activities and signal probabilities are independent and may therefore give inaccurate results. On the other side, static approaches do not simulate the design. Instead, they are dependent on the static knowledge (like correlations, switching-activities and signal-probabilities) about the input signal and estimate the same statistical properties for the internal circuit to measure the average power dissipation of the circuit. The input-dependence problem is faced by using selected statistical characteristics of the input patterns. These approaches are accurate and fast which can be obtained from large simulation results.

It is observed that the highest power optimization can be achieved at higher-level of the design abstractions. High level approaches can be roughly split into two types: bottom-to-up and top-to-down. The bottom-up approaches [ii-iv] are more accurate with the reused IP modules. In those modules, the internal details of the design are given and the power macro-model can be constructed easily with the power characterizations that are helpful in low to high level simulation estimates. In top-to-down techniques [v-vii] the design is specified without the technical information on the design implementation. Therefore these techniques are only helpful when the design was not previously implemented. However, they may not have accurate power analysis due to the insufficient information of the design implementation details.

RTL approaches [viii-ix] have been proposed to measure the switching activities of the design. These approaches are accurate but relatively slower and expensive, which limits the length of input streams. Power consumption in digit electronic systems are input pattern dependent. To measure accurate power dissipation, set characteristics of input samples are needed. Usually these input samples have large sample size. If samples are selected arbitrarily, may not be able to measure the expected behavior of the power dissipation of the circuit. To handle this important problem, vector compaction approach was introduced in [x]. This approach was used in input patterns into a

Stimulus sequence which has smaller size. These approaches are more accurate but they can not efficiently considered factors like propagation delay, glitch-generation etc. RTL power macro-modeling technique was developed with the variety of equations and Look-Up-Table based approaches. Among those, building power macro-model for the digital system was popular technique for analysis of the average power dissipation. In the literature survey, most power model increases in complexity to capture the accuracy requirements. To reduce the simulation time, input sample compaction technique was introduced that captures the exact power behavior of the circuit.

In this work, we used our research in [xi-xiv] developing for the low-power modeling approaches in the power estimation method for more complex digital test system. Our proposed power model in this paper is the linear regression-based LUT approach at RTL. We use genetic algorithm to investigate the statistical properties of the input sample streams that influences power consumption of digital system. The average input statistical characteristics of our model are the transition-density '*TD'*, signal-probability *'SP'*, spatial-correlation '*SC'* and temporal-correlation '*TC'*. We use IP-based macro-modules for our experiments and achieve comparatively good accuracy.

The paper is organized as follows: Initially we give the brief problem statement and we discuss the introductory background of our linear regression-based power analysis method. Then we explore our GA algorithm and the model is evaluated in experimental results. Finally, we summarizes our work.

II. Problem Statement

The problem solved in this paper is to find a statistical method which accurately and fast estimates the power consumption in any digital system by the addition of its each IP-module. This method makes the power analysis of digital system an easy task that helps for the analysis of power features at higher level.

III. Linear Regression-based Power Analysis

The flow of our high-level power macro-modeling method is shown in figure 1. Our approach consists of the following steps:

1) Characterization of each IP module at high-level design library by simulating it under pseudo random signals and fit statistical variables regression curve to the power dissipation results using a least-mean-square (LMS) error fit.
2) Extractions of the power function from parameter model of IPs with using Monte Carlo simulation approach. The high-level simulator is used to collect power values for various IP modules in the SoC System.
3) Evaluation of the power macro-model function at high-level IP design which are found in the library by plugging the parameter values in the corresponding macro-model function.

The proposed model is linear regression-based LUT approach. To obtain power macro-model, a linear function is used in (1) that estimates power of the given input vector streams.

$$P_{IP_{avg}} = \beta_0 + \beta_1.\alpha_1 + \beta_2.\alpha_2 + \ldots + \beta_{n-1}.\alpha_{n-1} + \beta_n.\alpha_n + \varepsilon \quad (1)$$

Where P_{IP_avg} is the average power dissipation of the individual IP core, $\beta_0, \beta_1, \ldots \beta_{n-1}, \beta_n$ are the regression coefficients obtained from the regression analysis, $\alpha_1, \alpha_2, \ldots, \alpha_{n-1}, \alpha_n$ are the statistical characteristics of each input and ϵ is the error. The parameters of the regression are determined using the linear regression by finding the least-square fit. Equation (1) can be expressed in (2):

$$P_{IP_{avg}} = \beta_0 + \beta_1.TD + \beta_2.SP + \beta_3.SC + \beta_4.TC + \varepsilon \quad (2)$$

where *TD, SP, SC, TC* are the statistical characteristics of our model.

The regression equation in (2) can be computed by applying the set defined input pattern values of *TD, SP, SC,* and *TC*. The determination coefficient p^2 is measured to improve the quality of (2). It determines the proportionality of data set patterns of the input characteristics that helps to predict the accurate power. p^2 varies from 0 to1 and it is defined in (3):

$$p^2 = 1 - \frac{\epsilon_s}{r} \quad (3)$$

Where ϵ_S and r is defined in (4) and (5):

$$\epsilon_s = \sum(x_i - y_i)^2 \quad (4)$$

$$r = \sum(x_i - \bar{x})^2 \quad (5)$$

With $\bar{x}$ is the mean of the estimated data, x_i predicts the values and y_i is the data set value.

The proposed signal generation algorithm generates input streams of different values with the characterizations of *TD, SP, SC,* and *TC*. These values with different combination stored in LUT that allows the power analysis with minimum error. It measures the average power dissipation P_{IP_Module} in (6).

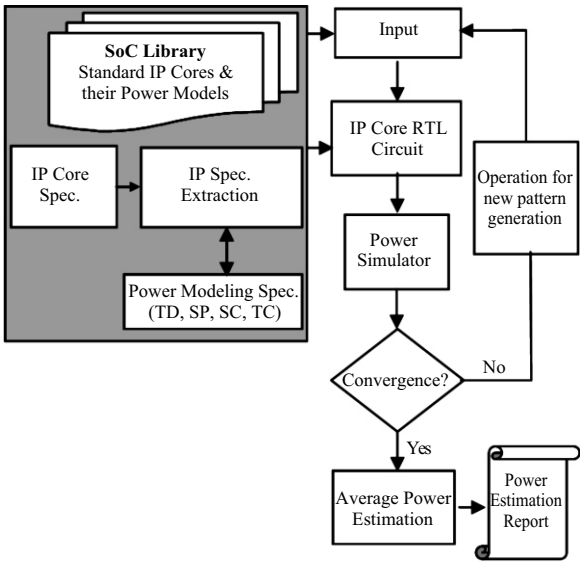

Fig. 1. Power estimation methodology.

$$P_{IP\_Module} = f\ (TD, SP, SC, TC) \quad (6)$$

The *f(.)* is a mapping-method to be performed during the characterization of the input characteristics. To find function *f(.)*, we must sample a set number of streams with several *TD, SP, SC,*and *TC* values. The power dissipation of IP modules-based system P_{IP_Module} is obtained in (7) using (6).

$$P_{IP\_System} = \sum_{i=1}^{n} P_{IPi\_Module} \quad (7)$$

In this technique, the pattern of input singles are generated according to the input statistical properties (*TD, SP, SC,*and *TC)* and power dissipation P_{IP_Module} is predicted in (6). Then Monte-Carlo zero delay method [viii] is used with several input streams of their statistical knowledge and evaluated the accuracy of P_{IP_Module}. The accuracy of the model on each module requires information of the statistical signals. While maintaining accuracy to obtain this knowledge, several simulations are performed with various values of *TD, SP, SC,* and *TC* of each IP module. In Fig. 2, the inputs of the module *IP-M* are the inputs of the IP-based digital system and outputs of *IP-M* are inputs of $IP\text{-}M_{1a}$, $IP\text{-}M_{1b}$, $IP\text{-}M_{1c}$, and $IP\text{-}M_{1d}$, and continues till the final outputs. The output statistical characteristic values for each IP module can be used as input signal statistical values of the related connected IP modules. For *IP-M* module, we generate random signals of several different patterns of *TD, SP, SC,* and *TC*. Then to build LUT, we performed several simulations in our test system. For each module different values of average input statistical properties are predicted by using large simulations. The different values of the system's power dissipation are determined using power simulator. The simulated power is compared by using HSPICE simulator with estimated power model P_{IP_System} in (7).

IV. Algorithm Exploration

Genetic algorithm generates randomly input sequences of *TD, SP, SC,* and *TC* for the power estimation of IP-based test system. Finding the optimal solution that satisfies the convergence criteria of the power waveforms during simulations of the system is the main purpose of power estimation. Our GA procedure is as follows:

1. Generate an initial population P_i, and then set p_{cross} and p_{mut} which are crossover and mutation probabilities respectively. Where $p_{cross} \in (0,1)$ and $p_{mut} \in (0,1)$. Set the generation counter with $counter\_t := 1$.
2. Evaluate the fitness function value F for all possible chromosomes in P_{chrom} with the selection of an intermediate population P'_{chrom} from the possible current population P_{chrom}.
3. Generation of random number from (0,1) with every chromosome in P'_{chrom}, then add to evolve each chromosome to the parent set PS_{chrom}, if

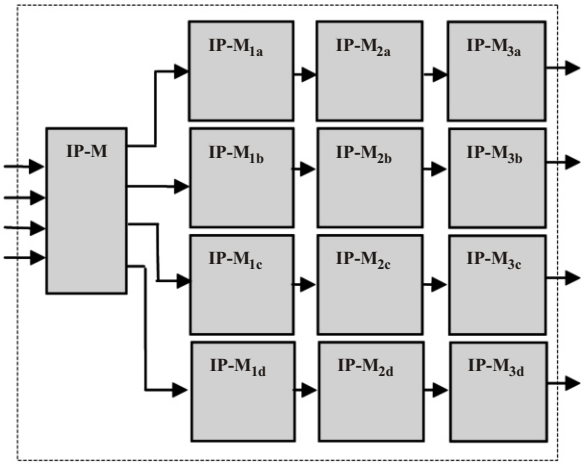

Fig. 2. IP-based test system

related number is less than p_{cross}. Following steps must repeat until all parents in PS_{chrom} are mutually mated: (a). Select two parents p_a and p_b from PS_{chrom}. Mate p_a and p_b to regenerate children c_a and c_b. (b). The children pool set PS_{child} updating through $PS_{child} := PS_{child} \cup \{c_a, c_b\}$ and $PS_{chrom} := PS_{chrom} - \{p_a, p_b\}$

4. Associated random number generation from (0,1) for all possible gene in every chromosome in P'_{chrom}. Then mutation of this gene is performed, if the associated number is less than p_{mut} and further add the mutated chromosome only with the children pool set PS_{child}.
5. Finally, if the stopping criteria is satisfactory, then terminate the population generation. Else the selection for the next generation $P_{chrom+1}$ from $P_{chrom} \cup PS_{child}$. Set $PS_{child} := \{\}$, set

counter_t := *counter_t* + 1, and go to the step 2.

V. Experimental Results

In experimental results, we discuss our accurate technique for IP-based test system is shown in Fig. 2. We have developed this technique and build the power macro-model at architectural abstraction level. Accuracy of genetic algorithm is implemented on IP-based macro-modules. For these modules, random input pattern is generated for several *TD, SP, SC,* and *TC* values. The input pattern generation of our new technique is highly auto-correlated. The power consumption is measured by using Monte Carlo zero delay method. Several values are predicted by LUT based approach and these power values are compared with simulation results. Finally, we performed different error analysis to compare our macro-model results with the commercial tool. The maximum, minimum, average and root mean square (rms) errors are computed using (8) and (9).

$$\varepsilon_{rms} = \frac{1}{n}\sum_{i=0}^{n}\sqrt{\left(\frac{P_{sim_i} - P_{est_i}}{P_{est_i}}\right)^2} \quad (8)$$

$$\varepsilon_{avg} = \frac{\sum_{i=0}^{n} P_{sim_i} - \sum_{i=0}^{n} P_{est_i}}{\sum_{i=0}^{n} P_{est_i}} \quad (9)$$

Where P_{sim} and P_{est} are the simulated and estimated powers respectively.

The results demonstrated that the proposed GA can generate random patterns with high convergence and produce accurate statistical values. For the input pattern characterizations of *TD, SP, SC,* and *TC* we select the probabilistic range of [0, 1]. Our algorithm generated 740 different input streams with width of 8, 16 and 32-bits. The signal stream length is 4000 for macro-module. Analysis of convergence on power may help us to find the simulation interval, by determining when the power value is more close to the appropriate interval length in the steady state waveform. The sequence generator has high value of convergence and uniformity. The appropriate length is found 3650 for the test system. The warm up interval is close to 550 and the steady state interval is obtained 2050.

The power dissipation is observed of *IP-*M_{1a}, *IP-*M_{1b}, *IP-*M_{1c}, and *IP-*M_{1d}, modules with different input characteristic values. The result demonstrates that among other characteristics, the transition activity *TD* is more important for the power consumption. The power and *TD* are considerable linear with each other. The input correlation factors *TD* and *SC* are not very effective with the power and not very sensitive as compared to *TD*. To fit the coefficient's in the model, regression method is obtained. For several modules, the coefficient of correlation is estimated about 94%.

The selected number of the input signals and the estimate values error obtained with our macro-model function is shown in table 1 and Fig. 3. From Table I that *f(.)* in (6) is more accurate enough for estimating the average power consumption for IP-based test module. Columns two, three, four and five gives the minimum, maximum, average and rms-errors for the estimates used with our IP-based macro model. HSPICE have been used as power simulator in our power estimation procedure. In experiments, we computed the average minimum error 1.65%, average maximum error 3.49%, average error 2.70% and average rms error 5.93%. Our results demonstrated that our approach can be used to achieve accurate and fast power estimates in the early stage of digital system design. For the entire test system with interconnects/wires the error increases by 12-20%. This error can be improved by implementing different techniques that deal with the data path of interconnects/wires with IP macro-modules. The average error of the entire IP-based test system is 7.15%. The reference results of the system's power dissipation are determined using commercial power simulator. The table illustrates the function has less accuracy in some cases than others. We have found in a given specified range of statistical characteristic values between [0.3-0.7] is more accurate and comparatively less accurate between [0-0.3] and [0.7-1]. The experimental result shows that *TD* is more dominant factor for power dissipation in the test system and normally proportional to the power measurements. The correlation factors are not very effective to power dissipation and are significantly not more sensitive than the switching density. The number of input/output (I/O) is important to the (I/O) characteristics for the system.

TABLE I
Power Estimation Accuracy

Test System	εmin	εmax	εavg	εrms
IP - M	1.32%	3.58%	2.16%	6.54%
IP - M_{1a}	2.13%	4.87%	3.64%	7.33%
IP - M_{1b}	2.45%	5.56%	4.43%	8.43%
IP - M_{1c}	2.50%	4.98%	3.68%	6.89%
IP - M_{1d}	2.76%	4.90%	4.61%	8.38%
IP - M_{2a}	1.34%	3.43%	2.28%	5.56%
IP - M_{2b}	0.60%	1.45%	1.19%	4.32%
IP - M_{2c}	0.75%	2.45%	1.34%	4.12%
IP - M_{2d}	1.45%	4.32%	2.56%	5.78%
IP - M_{3a}	1.89%	2.90%	2.46%	5.14%
IP - M_{3b}	1.08%	1.89%	1.42%	3.97%
IP - M_{3c}	1.50%	2.70%	3.01%	4.58%
IP - M_{3d}	1.76%	2.32%	2.42%	6.15%
Average	**1.6%**	**3.4%**	**2.70%**	**5.93%**

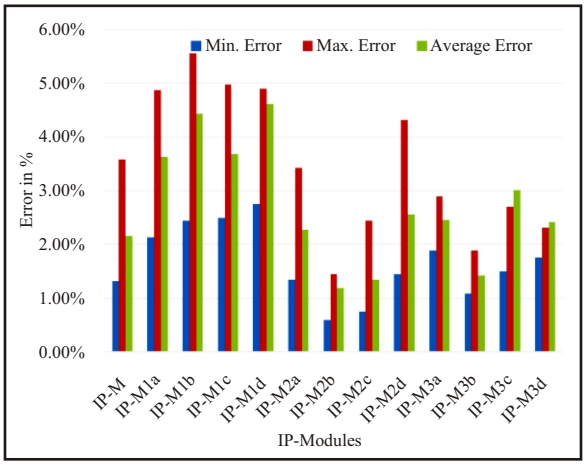

Fig. 3. Error analysis of IP-modules in digital system

VI. Conclusions

The presented work is an accurate simulation-based power analysis technique at the architectural level implemented on IP test system. In this work, for each IP module, we measure just 2.70% average and 5.93% rms errors respectively. But for whole test system with interconnects, the average error is found 7.15% and a correlation coefficient is observed around 94%. The results showed the accuracy has been improved in some cases than in others. Nowadays, we are using complex systems for evaluating this model and making it more accurate as compared to other models in this area.

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Section C

MECHANICAL/INDUSTRIAL/ MATERIAL/ENERGY ENGG. AND ENGINEERING MANAGEMENT

Estimation of Effective Atomic Numbers of Polyethylene and Coal Using Compton Scattering

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Abstract-In this study, effective atomic numbers of composite materials, polyethylene and coal have been estimated by using Compton scattering of 662keV gamma rays emitted from ^{137}Cs source. In order to estimate the effective atomic numbers, the Klein-Nishina theoretical cross sections were obtained from 50^0 to 100^0 angles. Then, the scattering cross sections of the samples were experimentally determined. By using this method, effective atomic numbers of polyethylene and coal are obtained as 2.25 and 2.39 respectively.

Keywords-Compton, Scattering, Effective Atomic Number, Polyethylene, Coal

I. INTRODUCTION

According to recent researches, the effective atomic number is a measure of the average number of electrons of the material that participate actively during the interaction. It is important in concrete, polymers, and the rare earth compounds [i-vi].

Polyethylene (PE), which is obtained from the polymerization of ethylene, is one of the simplest and most inexpensive polymers and most widely-used plastic material in the world [vii]. Ethylene molecule has a C = C double bond. In the polymerization process, the monomer double bonds are broken, and instead, a simple bond is formed between carbon atoms and N molecules. Coal is composed primarily of carbon hydrogen, sulfur, oxygen, and nitrogen. The typical carbon content for coal (dry basis) varies from 60 percent for lignite to more than 80 percent for anthracite [viii]. Therefore, polyethylene and coal are not pure elements with a reasonable standard for their atomic numbers. One of the various methods used to determine atomic number of composite materials is Compton scattering.

In early 1920, the Compton Effect was observed for the first time. Gamma rays interact with matter, resulting in three major processes that play an important role in radiation measurements in the intermediate energy range from 10 keV to 10 MeV: *photoelectric absorption, Compton scattering,* and *pair production.* The photoelectric effect predominates in the low energy region in high atomic number elements, while Compton scattering dominates in the medium energy range in elements with low atomic number. Also, if the gamma-ray energy exceeds twice the rest-mass energy of an electron (1.02 MeV), the process of pair production is energetically possible [ix-xiii].

The innovation of this study is to estimate the effective atomic number of polyethylene and coal using the Compton scattering.

II. MATERIALS AND METHODS

Interaction cross section is a function of photon energy and atomic number. In other words, the interaction of photons with certain amount of energy is proportional to Z^n where n is the expected value and has different values for different interactions. The value of n is defined as a value between 4 and 5 for the photoelectric effect, 1 for the Compton scattering, and 2 for pair production.

In the interaction of gamma rays with a composite, the effective atomic number is replaced by the atomic number, depending upon the radiant energy of the constituent elements. The effective atomic number for each material, is expressed by following equation [xiv]

$$Z_{eff}^{n-1} = \in\ p_i Z_i^{n-1} \qquad (1)$$

Where Z_{eff} is the effective atomic number, ε is the correction factor, P_i is the fractional part by weight of the whole mixture, Z_i is element atomic number and n is expected value [ix]. As mentioned above, for Compton scattering the value of n is equal to 1. It is seen that Eq. (1) cannot be used to obtain the effective atomic number for Compton interaction. Consequently, the scattering cross section is used to obtain it. The scattering cross sections at an angle (θ) is given by [xiv]

$$\sigma(\theta) = \sigma_{kn}(\theta) S(X, Z) \qquad (2)$$

Where scattering cross section $\sigma(\theta)$ is in millibarns per atom per steradian and Klein-Nishina cross section $\sigma_{kn}(\theta)$ is in millibarn/electron/steradian. S(X, Z) is the incoherent scattering function that is an indicator of the number of electrons participating in the scattering. The momentum transferred in the scattering (X) is given by [xiv]

$$X = \frac{sin(\frac{\theta}{2})}{\lambda}(A^0) \quad (3)$$

where ν is the frequency corresponding to the incident photon. If the electrons that participate in scattering are completely released from atomic binding, S(X, Z) will be equal to the atomic number Z. Therefore, Eq. (2) can be written by the following approximation [xiv]

$$\sigma(\theta) = Z\,\sigma_{kn}(\theta) \quad (4)$$

In this equation, Z is the atomic number for a pure element and Z_{eff} is the effective atomic number for the material [xiv].

In this study, following Klein-Nishina equation was used to calculate the scattering cross sections for 662 keV gamma rays emitted from the ^{137}Cs source at angles ranging from 50° to 100 ° in steps of 10°.

$$\frac{d\sigma_{kn}(\theta)}{d\Omega} = \frac{r_0^2}{2}(\frac{E'}{E})^2\left(\frac{E'}{E} + \frac{E}{E'} - sin^2(\theta)\right) \quad (5)$$

$$\sigma_{kn}(\theta) = \frac{3}{4}\sigma_T\left[\frac{1+\alpha}{\alpha^2}\left(\frac{2(1+\alpha)}{(1+2\alpha)}\frac{ln(1+2\alpha)}{\alpha}\right) + \frac{ln(1+2\alpha)}{2\alpha}\frac{1+3\alpha}{(1+2\alpha)^2}\right] \quad \text{[xvi]} \quad (6)$$

$$\sigma_T(\theta) = \frac{{r_0}^2}{2}\left(1+\cos^2(\theta)\right) \quad (7)$$

$$\alpha = \frac{E}{mc^2} \quad (8)$$

In these expressions, σ_T is the Thomson cross section, σ_{kn} is the Klein-Nishina cross section, θ is the scattering angle, r_0 is the classical radius, E is the photon energy, E is the scattered photon energy and m is the electron rest mass [xvi]. The results are listed in the Table I.

TABLE I
THE RESULTS OF KLEIN-NISHINA SCATTERING CROSS SECTIONS, THE TOTAL SCATTERING CROSS SECTIONS AND THE EFFECTIVE ATOMIC NUMBER FOR DIFFERENT ANGLES

Angle(degree)	50	60	70	80	90	100
Klein-Nishina scattering cross section	21.61	19.11	17.08	15.75	15.28	15.74
Total scattering cross sections for polyethylene	52.95	42.00	42.77	34.16	33.64	31.47
Effective atomic number for polyethylene	2.45	2.20	2.50	2.17	2.20	2.00
average atomic number	2.25					
Total scattering cross sections for coal	-	-	49.68	19.10	11.87	73.52
Effective atomic number for coal	-	-	2.91	1.21	0.78	4.67
average atomic number	2.39					

A. Experimental details and method of measurements

Fig.1 shows the experimental setup of the system used to determine the cross sections. In experimental investigations, the intensity of photons scattered from polyethylene and coal are measured. Therefore, a cylinder of polyethylene with a radius of 2 cm and a height of 10 cm, and an irregularly shaped lump of coal with an average diameter of 2 cm and a height of 10 cm, were placed in the center of Compton scattering palate at a distance of 11 cm from the surface of 2in×2in NaI(Tl) detector. From ^{137}Cs source with an activity of 100 Micro Curie (μCi), 662 keV gamma rays were emitted to the samples at angles of 50^0 to 100^0 in steps of 10^0. As shown in Fig.1, a lead shield with dimensions of 10 × 10 × 5 cm^3 was placed between the detector and the source to avoid any energy loss as the particles travel from the source to the detector and to

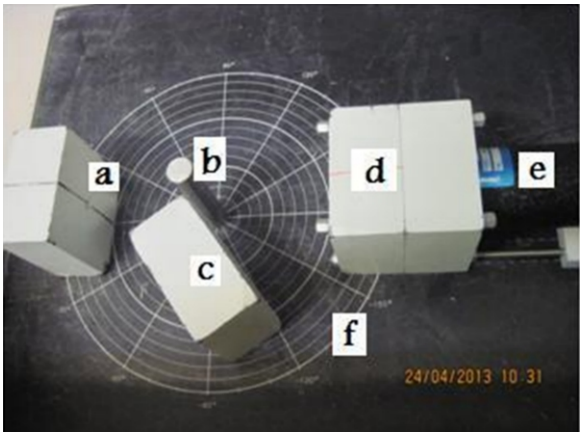


Fig.1. Photograph of experimental set up: a) ^{137}Cs source, b)sample, c)lead shield, d)lead container, e) NaI (Tl) detector, f) Compton scattering plate.

restrict any background radiation scattered into the detector. The spectrum that recorded by MCA and Cassy lab software, was analyzed. This spectrum showed the change of counts versus channel number. It must be mentioned that the channel number bears a linear relation with photon energy. The number of photons depositing their energy in the detector can be determined by calculating the area under the spectrum. According to the following equation, these photon numbers are related to the total scattering cross section.

$$\sigma(\theta)= \int \frac{d\sigma}{d\Omega} d\Omega - \int \frac{d\sigma_0}{d\Omega} d\Omega \qquad (9)$$

Where $N = \frac{d\sigma}{d\Omega}$ and $N_0 = \frac{d\sigma_0}{d\Omega}$ are the scattering probability with and without the source respectively. The counting time was 20 min in all the spectrums. Therefore, Eq. 9 is converted to Eq. 10

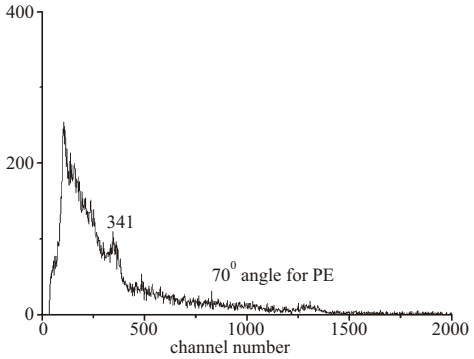
$$\sigma(\theta)=\frac{N-N_0}{1200} \Delta\Omega \qquad (10)$$

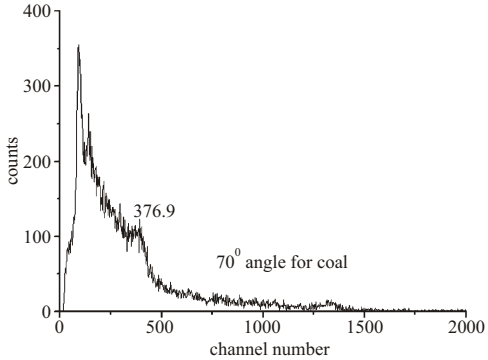
$\Delta\Omega$ is the ratio of the detector surface (3.14 cm^2) to the squared distance from the detector to the sample (121cm^2). For example, Fig.2 shows the spectrum from polyethylene and coal samples at angles of 70, 90, and 100 degrees.

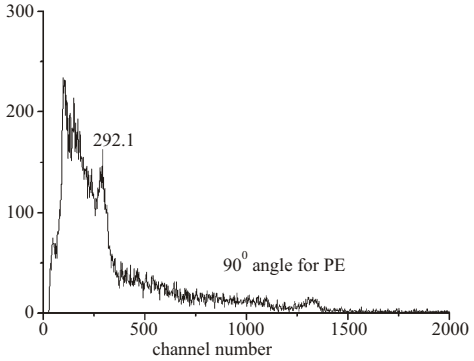
III. Results and Discussion

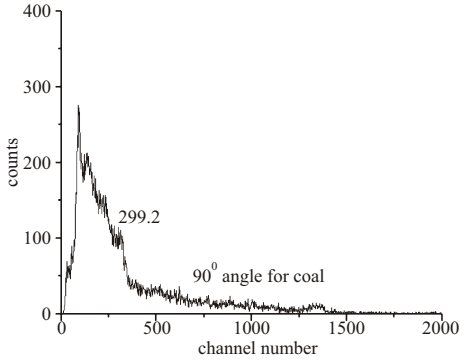
Fig. 2 shows that full-energy peaks for polyethylene are in 341, 292.1, and 245 channels at 70^0,80^0, and 100^0 angles respectively. For coal, these channels are 376.9, 299.2, and 252.1 at the same angles. It is indicated that the Compton scattering depends on the external shell electrons. Compton attenuation coefficient varies via photon energy. In this research, the photon energy is fixed at 662 KeV that emitted from ^{137}Cs. The difference of channel numbers for polyethylene and coal at same angles shows the atomic number effects on Compton scattering.

By comparing these numbers, it is clear that full-energy peaks are obviously observed at small angles. This implies that photon intensities decrease with the increasing scattering angle of radiation due to Compton scattering. By changing the intensity, the center of the peak moves slightly. This shift shows a change in photon energy that is known as the Compton defect. Because of the decrease in scattered photon energy at large angles, the channel numbers are slightly shifted to the left in Fig. 2.









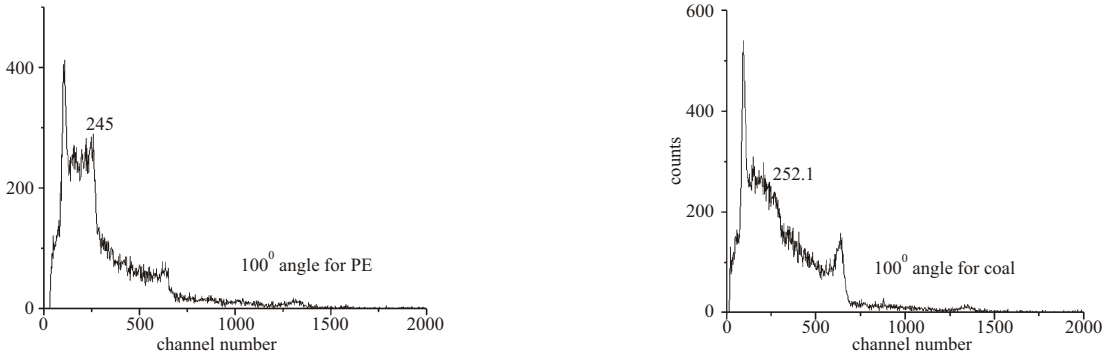


Fig.2. Spectrum of variation of counts versus channel number (energy) for polyethylene (PE) and coal at 70^0, 90^0 and 100^0 angles.

The present work focuses on the calculation Z_{eff} of polyethylene and coal by a direct experimental method. The results of Klein-Nishina scattering cross sections, the total scattering cross sections, and the effective atomic numbers for different angles obtained by using equations (4-10) are given in the Table I. It is calculated that the effective atomic numbers (the average atomic number) for polyethylene and coal are 2.25 and 2.39, respectively. In the present study, due to the irregular shape of coal, the obtained results are not satisfactory at angles of 50^0 and 60^0. We can notice that Klein-Nishina scattering calculations are in acceptable agreement. Since type and amount of elements in the samples of polyethylene and coal vary, as the amount of impurities in the material differ, no accepted values for their atomic numbers have been reported in other research studies. Thus, one limitation of this study is that the obtained results have not been compared with findings from other research.

IV. Conclusion

The Compton scattering of gamma-ray photons is governed by the atomic number of material. Therefore, it is indicated that the Compton scattering can be used to estimate the effective atomic numbers (Z_{eff}) as useful parameter in studying of attenuation coefficient, photon interactions with matter, and radiation shielding.

This study investigated the Compton scattering of photons from stationary electrons in samples of polyethylene and coal. The effective atomic numbers of the materials were estimated by calculating the area under the spectrum of full-energy peaks. It is calculated that the effective atomic numbers of polyethylene and coal are 2.25 and 2.39, respectively.

It is recommended that in the future studies, effective atomic number of other composite be estimated by Compton scattering. In addition, it is proposed that the present study be carried out for other sources of photons.

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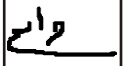
2	Miss Atefah Vasseh Mosalla (2nd Author)	Data Collection, statistical analysis and interpretation of results etc.	
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Tensile Strength changeability of Multilayered Composites, fabricated through Optimized "VARTM" Technology, An experimental Approach

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***Abstract*-**Life span estimation up to tensile fracture of different fiber reinforced composites, Kevlar Fiber Reinforced Polymer (KFRP) & Glass Fiber Reinforced Polymer (GFRP) along with the strain rate effects on dynamic properties is mainly viewed on experimental basis in this paper. Lab-scale Vacuum Assisted Resin Transfer Molding (VARTM) technique is used to fabricate flawless dog bone specimens considering ASTM standard D638-03and by using LY5052 resin and HY 5052 hardener. In this research, it is tried to maintain 65% of fiber participation in whole specimen composition matrix. Detail design description of VARTM is also discussed and optimized up to maximum scale to acquire compact, uniformly strengthen and porosity banned standard specimens. A conventional stress-strain curve is established to compare the tensile validity of above mentioned competitive composites. Crack Opening Displacement (COD) of research materials after equal intervals of time is observed; results depict the shear stability and reinforcement perfection of these materials. The crack penetration behavior is examined transversely and longitudinally in this research.

***Keywords*-**KFRP, GFRP, VARTM, Multilayered Composites, COD

I. INTRODUCTION

A composite (or composite material) is an artificially made multiphase material in which consisting materials are different from each other physically and/or chemically. The combining components retain their specific properties in the composite but the composite overall exhibits superior properties than the individual components. The modern advancements in the technology demand unique combination of materials in order to attain the desired properties [i]. These properties have increasing demand in marine applications, transportation and aerospace industry. The aircraft industry demands anti-corrosion structural material that will have more strength, stiffness and less density. Mostly the strong material will be denser and vice versa. Therefore such desired properties could not be achieved using conventional materials. So the concept of principle of combined action was evolved according to which, a multiphase material is got by combining different materials and the resulting material has prominent exhibition of the properties of participating materials [i, ii]. This material is named as composite material or simply composite. Most common polymer based composites consists of two parts, substrate and the resin. The resins have unique shapes and can be reheated above their glass transition temperature (Tg). Upon heating, they become flexible and retain their new shapes when cooled. This is one of their major advantages that these can be repeatedly heated and shaped without affecting material properties. The most attractive property of composites, ultimate tensile strength, is enhanced by a process named reinforcement. Reinforcement increases rigidity and resists crack propagation. The pattern of the fibers decides the strengths of the reinforcement, If well attached with the matrix, thin fibers can have high strength and overall composite properties. Short and long fibers are in the form of chips are used in operations like compression molding and sheet molding etc. [iii]. Continuous reinforced materials have layered structure. A complete schematic of layered and solitary composites are described in Fig. 1. The physical properties of composite materials are usually anisotropic rather isotropic. The stiffness of composite will depend on orientation of the forces applied and design of the panel like the fiber reinforcement and matrix used orientation of the fiber

axis etc. These anisotropic properties of the materials prove themselves useful in mortise and tendon joints (in natural composites) and Pi Joints in case of synthetic composites. Carbon-fiber reinforced plastic and glass-reinforced plastic together constitutes Fiber-reinforced polymers. Aramid fiber and carbon fiber are used in epoxy resin matrix in the advanced systems [iv]. Thermoplastic composite materials can be combined with specific metal powders for gaining density equivalent to that of lead (2 g/cm³ to 11 g/cm³). Such material is termed as "high gravity compound" (HGC) or lead replacement. These materials can replace metals such as stainless steel, brass, aluminum etc. in the applications like balancing, weighting, and radiation shielding.

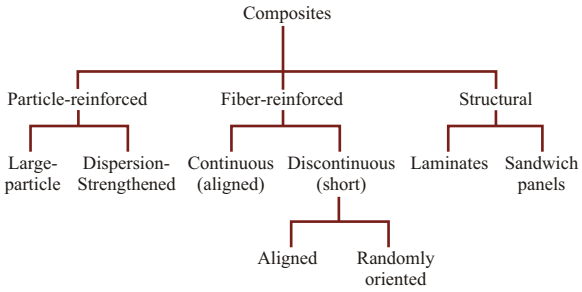

Fig. 1. A classification scheme for various types of composites

When two thin and stiff skins are attached with a lightweight and thick core, the resulting fabricated material is termed as sandwich-structured composite, providing high bending stiffness and low density. Due to shock impacts and/or repeated stresses, Composites can fail microscopically or macroscopically. Compression failure can happen at both microscopic and macroscopic level whereas tension failures can occur at a section or individual layer in the composite [v]. Different composites have different strengths and deformation levels. In this paper two types of composites materials are discussed with respect to their strength named as GFRP and Kevlar. Kevlar has important feature that it blends very well with other fibers like glass and carbon [vi]. Due to this fantastic blending ability carbon-aramid “hybrid” are used in constructions and they give the strength of carbon and impact protection of aramid [vii]. It has high strength and modulus but is weak in compression [viii]. It has best toughness and has very good resistance to damage, impact and abrasion [ix]. It can support high temperatures up to 500°C.

II. Experimental

Dog bone specimen of already mentioned two composites fabricated according to ASTM standards D638-03 by VARTM technology. The material test system used to examine the tensile validity of specimens is MTS 810 furnished with an advanced extensometer. The standardized dimensions along with allowable tolerances of desired specimen are mentioned in Fig. 2.

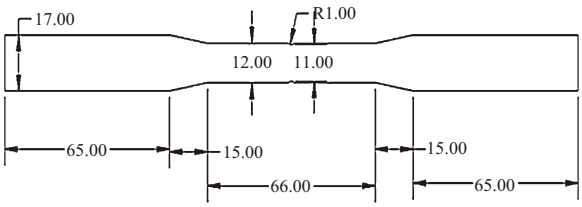

Fig. 2. Dog bone Specimen & its dimensions

A. Mold Preparation

Different metals are used as mold materials. Materials are important for better results and good experimentations. Majority of mold tool metal used lie in following categories. 1 Ni-Cr Alloy Steel 2 Mild Steel 3 Aluminum. For this research mild steel was selected as a mold material and mold contain three parts. An electric discharge wire cut and die sinking machine is used to fabricate different parts of molds.

B. Upper Mold

Upper mold play a major role for the resin to enter into the mold as it consists of inlet port and outlet ports which are opening into runners. Runners ensure smooth flow of resin from the inlet towards the channels. The diameter of inlet and outlet port is 7mm as shown in Fig. 3. Outlet opening is connected to resin trap with the help of small pipe. Inlet opening is attached with 7mm diameter nozzle which is further connected with resin chamber through 7.5mm diameter transparent gas pipe.

After machining, Viton seal of 5mm width is made around the mold. The Viton seal is placed in this cavity and permanently fixed. This seal ensures vacuum tight mold. 7mm diameter screws were used instead of clamps to achieve air tight mold.

Fig. 3. Upper Mold

C. Lower Mold

Lower Mold is the heart of the mold as it consists of three specimen cavities, which contains 5mm diameter channel on each end. Channels are in contact with the runner of the upper mold and resin flows through these channels to fill the specimen cavities as shown in Fig. 4. Specimen cavities are

7mm thick and dimensions made follow the standard D-638 exactly. Lower mold plate is removable plate so that finished product can be easily removed from the mold. Due to this reason supporting plate is placed below the lower mold.

Fig. 4. Lower Mold

D. Supporting Plate

It is actually a support to the upper two plates. Its basic function is to support the whole mold and to avoid any kind of vibrations in the mold. It allows the solid foundation of the mold and helps to get a smoother and good finished product

Fig. 5. VARTM setup

E. VARTM setup

A Typical VARTM setup consists of following parts. (1) Resin chamber and Degassing unit (2) VARTM Mold (3) Resin Trap (4) Vacuum pump. Resin chamber & degassing unit was made from Galvanized steel. It consists of two nozzles one attached to a valve and one is attached on the upper portion of the chamber. The nozzle which is attached bellow to the ball-valve is connected with the mold inlet port, from here resin flows to the mold with the help of vacuum pressure. Attaching the upper nozzle was necessary because degassing of resin was required to remove air trapped inside the resin solution [x]. The nozzle is connected with vacuum pump and degassing is done for 30 minutes to completely remove the bubbles. Resin is poured into the chamber in premixed ratio with hardener. Capacity of chamber is 400ml approx. Resin trap is one of the essential parts of the setup.

It saves the pump by preventing the excess to flow directly to vacuum pump which can cause damage the pump. So it traps the excess resin which can be reused. We designed resin trap by using a laboratory beaker. Excess resin flows through the mold outlet to the resin trap .It also helps to remove trapped bubbles inside the mold by removing the air from the mold. Clamp is used to stop the flow further to the resin trap when the mold is completely filled. Diaphragm pump was used as Vacuum pressure. This pump is used specifically or filtration purpose in research and is low pressure vacuum pump. This pump has been chosen for VARTM setup because of its advantage that it flow the resin smoothly and without any interruptions.

III. Results and Discussion

The two polymers used in this research are composed of two constituents 1. Matrix Phase 2. Resin. The detail mechanical properties of two polymers are listed in Table I. The resin used in this research was epoxy resin. It was Huntsman LY-5052 Which can be cured at room temperature. Accordingly Huntsman hardener was used (HY-5052) .Properties of Epoxy resin are listed in Table II. To optimize the VARTM setup and to produce porosity restricted dogbone specimens Mold is first cleaned with some organic solvent to remove the rubbish of the previous experiment and wax.

TABLE I

Polymer	Specific Gravity	Tensile Modulus	Ultimate Tensile Strain
GFRP	2.1	45GPa	2.3
KFRP	1.4	76GPa	1.8

TABLE II

Resin Type	Aspect	Color (Gardner, ISO 4630)	Viscosity at 25° C cps	Density at 25° C g/cm3	Flash point
LY-5052	Clear Liquid	≤2	1000-1500	1.17	≥140

Acetone was used for cleanliness; other material can be used depending upon the availability and research objective. Mold was than triple coated with mold release wax. This arrangement was allowed to sit for 10 minutes, before applying another coat [viii]. Epoxy Resin LY 5052 was mixed with hardener HY 5052.After mixing the mixture was mechanically stirred for about 15 minutes to ensure proper mixing. While mixing care was taken that stirrer the mixture slowly so that no air bubble created in it. Degassing was done with the help of a degassing chamber designed locally. Degassing chamber is connected to vacuum pump. Degassing for all type of resin was done for 15 minutes. After fabricating a flawless dog bone specimen is mounted on MTS 810 system.

The dog bone specimens of two materials, kevlar

and GFRP, selected for stress strain curve are according ASTM standard code. As we are only interested in the gauge length of specimens so the area away from two necks of specimens is used for clamping. The upper calves of MTS-810 has a load cell which gives the load feedback history to data acquisition system while the deflection at the center of gauge length of specimen is observed by the extensometer attached on it. The initial application of load is selected according to specimen's geometry. Data accusation system saves each deflection along with its corresponding load. Micro excel tool is used to filter the raw data and plot the stress strain curves of the studied material. These all test are performed on room temperature. All tests are tension nature.

A deterministic route is conventional approach to explore the strength of material. In this method a single value is considered to exist which is the characteristic of the material. Practically when it is tried to find out single value strength, a researcher always faces a scattering of results. If it is supposed that the research material is perfect then the scattering of results is tagged with uncontrollable experimental variables. This method gets not much appreciates in technical sciences because according to this method, the results would be same if the same experiments are performed on test specimens of different gauge lengths. But according to already research data it is viewed that the failure stress for uniformly prepared specimen of large gauge length is less than that of the specimen having small gauge length. This difference is not totally defined by experimental random variations; however it includes imperfection random nature in yarn structure. Weibul analysis is the mostly used approach to explain the fiber strength variations as a function of fiber gauge length. In 2-parameters weibul equation the density is,

$$P(\sigma) = 1 - \exp\left[-\left(\frac{\sigma}{\sigma o}\right)^{m}\right] \quad (1)$$

In the eq.1 the 'σ' is the tensile strength and σ_o is the reference strength related to mean value and 'm' is the weibul shape parameter. The cumulative density is estimated by using eq. 2

$$P = \frac{i}{N+1} \quad (2)$$

Where 'i' is the recent test number and 'N' is total number of tests.

As in the recent research the gauge length of the specimen is kept constant so here weibul equations are not considered. The forces obtained from machine data acquisition system is converted into stresses by using eq. 3.

$$F = \sigma \int dA \quad (3)$$

The result interpretation is easier to understand with the help of Fig. 6, where the load sequence is represented with respect to area dimensions.

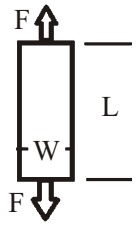

Fig. 6. Schematics of load sequence at gauge length of the specimen

As the basic dimension of the tested specimens are already known so with the help of initial design load and calculated area, which is constant for both materials specimens, one can easily determine the applied stress at the our area of interest. So as the load value is increased then its corresponding stress values are also increased causing the increment of strain rate in the specimen. On the basis of these strain rate increment behavior, it is tried to distribute stress-strain curve in different zones. As each zone of stress strain curve has its own morphology with respect to other zones even with the same zone of other material. It is also tried to relate local young's modulus with strain rates associated to that points. From conventional stress-strain curves shown in Fig.7 it is clearly viewed that at a specific stress the output strain produced is less in KFRP; however these results are plotted only in completely elastic zone [xii]. From experiments it is concluded that the area between yielding and UTS point is very minute in KFRP with respect to GFRP. However these plasticity specifications are only approachable in multilayered composite case. During solitary layer case both composite of this research show ignorable region after yielding [xiii]. As the case discussed here is multilayered and after yielding the plasticity zone explanation gets no much appreciates in these research composites, so a stress-strain behavior before yielding is enough to compare the integral parts strength.

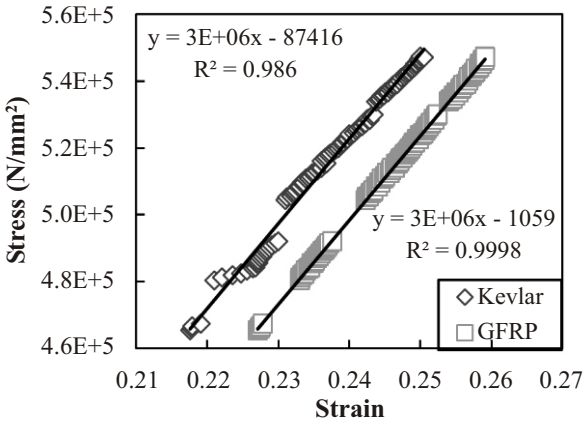

Fig. 7. Stress-Strain behavior of two polymer composites

It is explained from Fig. 6 that initially there is non-linearity between stress-strain behaviors for Kevlar but then dramatically it decreases and get smooth trend which is due to failure of fibers, however GFRP didn't show such behavior. The stress-strain trend for these composites have actually four distinct regions, three of them are graphically viewable in Fig. 7 and last is above elastic limit towards failure, not aim of this research. The first one is crimp region in which the strain increases more rapidly than that of stresses. In real cases the crimp region of each fiber has its own distinct boundary and when load applied then firstly straightens the fibers and removes their individual crimp regions. After the crimp region the elastic zone starts, now the crimp of fibers are removed and fibers are already straight so more stress is required for small increment of strain and stress strain graph shows more slope. It is the region from where we can define the Young's modulus of the material by considering the slope zone. But in this case however both of materials show a perfect elastic zone but GFRP shows ignorable crimp region, it is suggested that fibers in GFRP get already straightness while matrix is getting dried. The third region is before tensile strength, here again nonlinearity is viewed and it is possibly due to random failure of fibers but the behavior of GFRP is non-varying with respect to elastic region which shows the uniformity in strength delivery in individual fibers making the GFRP more trustable in tensile loadings. The final region is post peak regions here the required stress is very minute with respect to strain because of rapidly failure of fibers. Stress-strain curve is analyzed and used to measure the apparent Young's modulus, tensile strength, max strain and toughness for all specimens.

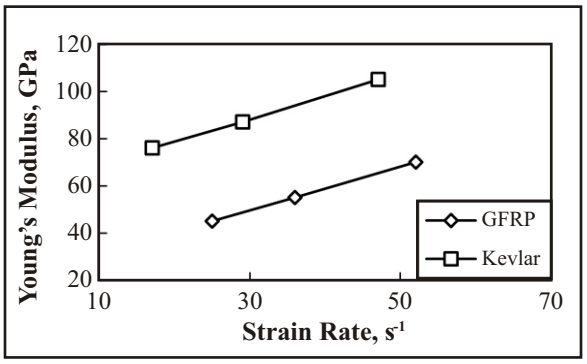

Fig. 8. Strain rate effects on Young's modulus

While discussing about elongation consistency, it is stated that in multilayered case GFRP shows more normal behavior than KFRP as shown in Fig.7. It is thought it is due to reinforcing fibers compactness variability in both composites [xiv]. It is also Expected that this behavior is due to variation in resin density distribution. Some researchers tells the reason of this phenomenon is the time based changing straightness of the fibers while the matrix is getting dried due to which inter fibers resin clotting takes place at some part of composites while uniformity is present at other part due to which minute strain variation takes place [xv].

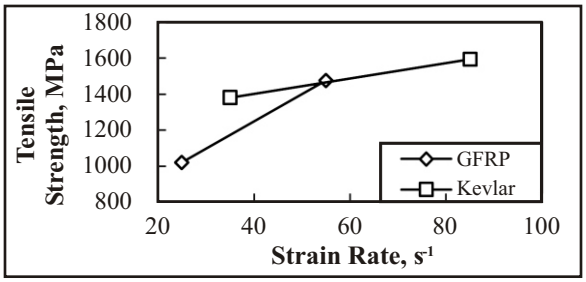

Fig. 9. Strain rate effects on Tensile Strength

In the Fig.8 the dynamic material properties of the research materials are explained in term of apparent tensile strength and Young's modulus with respect to strain rate. It is easily concluded that dynamic material properties apparently depend on the strain rate. Young's modulus behavior of Kevlar and GFRP with respect to strain rate is similar, however in the case of tensile strength there are variations between the competent materials as shown in Fig. 9. The dynamic properties behavior is studied for a fixed gage length. For Kevlar the Young's modulus increases from 76 ± 6 GPa at a strain rate of 17 s-1 to 87 ± 5 GPa and 105 ± 6 GPa at the strains rate of 29 s-1 and 47 s-1 respectively. Similarly for GFRP the Young's modulus increases from 45 ± 6 GPa at a strain rate of 25 s-1 to 55 ± 5 GPa and 70 ± 6 GPa at the strains rate of 36 s-1 and 52 s-1 respectively.

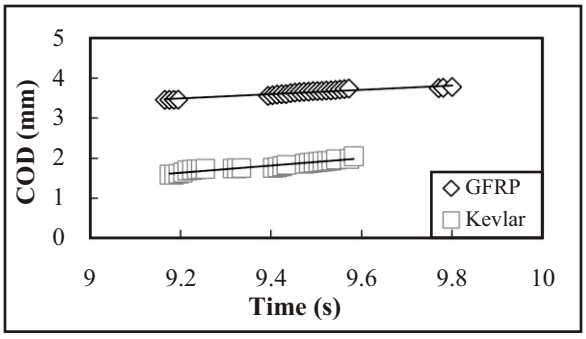

Fig.10. Time based Crack Opening Displacement curves of two composites

From Fig. 9 it is viewed that tensile strength of Kevlar increases from 1380 ± 52 MPa at the strain rate of 35s-1 to 1595 ± 40 MPa at the strain rate of 85s-1 while the behavior of GFRP didn't match with Kevlar, the tensile strength values are lower than Kevlar but abruptly increasing as the strain rate increases. Tensile strength value for GFRP raises from1020 ± 54 MPa at the strain rate of 25s-1 to 1476 ± 42 MPa at the strain rate of 55s-1.

In phase II experiments the dog bone specimens are examined with respect to time based crack opening displacement. The crack travels easily between the fibers than to cross the fibers. From Fig.10 it is depicted crack opening displacement COD in GFRP is increasing constantly which supports already mentioned hypothesis of equally distributed matrix-resin mixture in inter fiber zones IFZ [xvi]. It also justify that in GFRP the reinforcing structures remain straight without any bend to disturb the rectangular IFZ. While in KFRP the COD is less than GFRP but the behavior is increasingly in zigzag manner.

As the crack continue to propagate in IFZ in KFRP the COD behavior is linearly increasing, it deviates when a reinforcing fiber loses its straightness and obstruct the crack propagation resultantly diminish the COD with respect to previous reading supporting the fact of unequal matrix clotting in IFZ [xiii, xvii].

VI. Conclusion

In this research after a series of experiments, the following results are concluded;

1. VARTM is an acceptable technique to form fiber reinforced composite material if care is done to avoid air porosity beneath the fibers.
2. The stress-strain curves obtained for both tested material are totally material dependent. Effects of specimen geometry are not considered in this research.
3. The obtained young modulus values are totally localized nature against a specific zone. Overall value of young modulus for a specific material may be different than the local one.
4. The presented results are totally elastic nature. Plasticity induced during the testing is totally ignored due to complexity of mechanics and beyond from the scope of this research.
5. This study also quantifies that KFRP is two time stronger than GFRP in multilayered case in elastic zone. However, composition variation is also a known reason of inter fiber uniform clotting of resin-matrix in multilayered KFRP than GFRP.
6. Variations in strain rate affect the dynamic properties of research materials specifically on tensile strength of GFRP.
7. The crack opening prediction at specific load is more perfect in GFRP rather than KFRP due to resin coagulating in IFZ of Kevlar. The crack propagation in reinforced composites speeds up longitudinally while fades up transversely.

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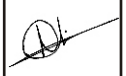
1	Dr. Muhammad Ali Nasir (Main /Principal Author)	Proposed topic, basic study Design, methodology and manuscript writing	
2	Prof. Dr. Zaffar M. Khan (2nd Author)	statistical analysis and interpretation of results etc.	
3	Dr. Saad Nauman (3rd Author)	Data collection, Literature review & Referencing, VARTM,	
4	Mr. Saad Anas (4th Author)	Manufacturing of Composite Laminates using VARTM	
5	Prof. Dr. Asim Pasha (5th Author)	Results interpretation	
6	Prof. Dr. Shahid Khalil (5th Author)	Quality Insurer	
7	Dr. Masood Shah (5th Author)	Mechanical Testing and Data interpretation	

Microstructural Study & Assessment of Endurance Limit Through Numerical Simulation in TIG welded Aluminum Alloy (AA2219-T87)

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Abstract-Tungsten Inert Gas (TIG) welding is the most common practice in aluminum alloys. It is necessary to devise a fail-safe design against fatigue failure of welded structures. Under the presence of cyclic load fatigue life is usually predicted by endurance limit of working material. In this research paper a comprehensive effort is made to investigate the endurance limit of aluminum alloy AA2219-T87. A four point rotating & bending fatigue testing machine is used to test the fatigue life estimation of the said alloy. Results obtained through experimentations are verified through numerical simulation by using software package ANSYS Workbench 14. 0. A brief microstructural study is also performed using metallurgical microscope. A gigantic contrast in grain structure is observed in different zones, formed due to TIG welding. Variation in material strength due to grains shifting from unwelded base metal (BM) to weld nugget zone (WNZ) is also studied in this research.

Keywords-Fatigue Life, TIG Welding, S-N Curves, Finite Element Analysis (FEA), Microstructure

I. INTRODUCTION

In the start of nineteenth century, some engineers found that in some mechanical component failure is taken place at a stress value that was lower than the yield point [i]. It was very interesting for them that the components like shafts and bolts made of a ductile material were some time failed unexpectedly like brittle material. They observed that initially there was no flaw in workmanship of that material; however all fractured components were experiencing the fluctuating or cyclic load and this feature was common to all such cases [ii]. So such type of failure occurring at a stress lower than the yield strength in the presence of cyclic load was named as fatigue failure. Fatigue failure is the most prominent factor of failure being studied from previous 160 years and it is happened due to the microstructural variations in the service material. In design of engineering components it is necessary to fully estimate the fatigue life [iii]. To avoid from fatigue cracking a comprehensive troubleshooting is performed before putting the model in service. The main approaches used in fatigue crack modeling are as: (1) Stress based, S-N Curve (2) Strain Based (3) Fracture Mechanics Approach [iv]. Fracture mechanics based approach is widely used in tackling the fatigue problems in metal world.It is conventional to check the fatigue life of notched specimens. It is investigated that there are two types of effects that are related to notches, statistical size effect and geometrical size effect. Statistical size effect is estimated with the maximum depth of already initiated crack in subjected material provided that the fluctuation in stresses in effective area is very high [v]. In other words it is tried to describe as when specimen is experiencing varying cyclic load then there are a large number of micro cracks are generated in its whole volume and sometimes the crack branches are created and these may totally different on both side of whole thickness [vi]. If the geometry of structure and situations of loadings are completely known then fatigue strength is calculated by fatigue-damage theory by applying S-N curves. However it is explored that this type of fatigue prediction acknowledge a little bit about the behavior of that component [vii]. After welding of the components there is aging takes place and fatigue strength lowers due to the aging of the materials. So S-N curves entertain the designer valuable information about the durance of structure as shown in Fig. 1.

The most portion of the curve is called endurance limit [viii]. Endurance limit is the boundary below which the structure bears infinite numbers of cycles without failure.

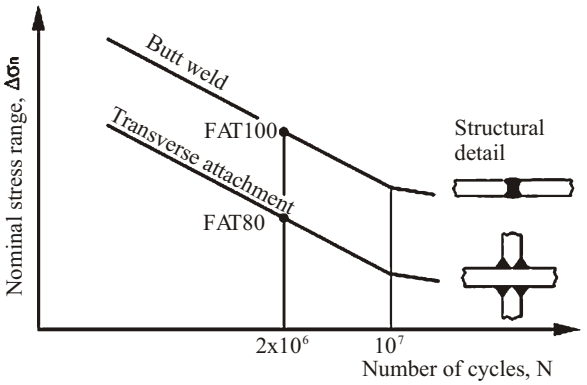

Fig. 1. S-N curves for different types of attachment of weldment

However there is one limitation about these curves is that these cannot predict the fatigue life of the material for stress ratios which are other than the designed ones [ix]. However for these stress ratios which are not covered by S-N curves can be easily tackled by Goodman Diagram but these are also helpless to predict the fatigue life under various specimen's geometry, conditions of surface and special characteristic of material.Crack closure has played a central role in the study of fatigue crack propagation as shown in Fig. 2 [x].

TABLE I
CHEMICAL COMPOSITION OF BASE METAL & FILLER ALLOY

Alloy	Al	Si	V	Cu	Mn	Mg	Zr	Ti	Fe	Zn
AA2219	Balance	0.2	0.04	6.3	0.3	0.02	0.18	0.06	0.23	0.04
AA2319	Balance	0.2	0.02	6.3	0.3	0.02	-	0.015	0.3	0.18

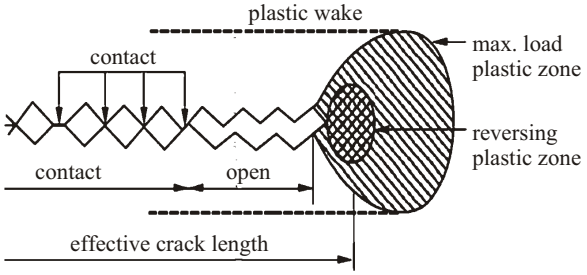

Fig. 2. Crack closure behavior [x]

A large number of researches have made attempts to understand the influence of the mean stress on the fatigue crack growth rate based on the crack closure argument. Except for high stress ratios, the fatigue crack growth can be affected more or less by the crack closure induced by plasticity in the two-parameter crack growth rate relation zone, Paris regime, or by oxidation and surface roughness. TIG welding is the most common welding in aluminum alloy [xi]. This type of welding has appreciating joint strength with respect to other types of welding especially in alloys mostly used in aerospace industry like AA2219-T87. In aeronautical structures it is the more suitable to weld the specimen rather than riveting. TIG welded aluminum alloys show lower notch sensitivity with respect to unwelded base metal. There is somehow tempering of specimens is also taken place due to welding temperature [xii]. During the TIG welding of aluminum plates it is visualize that a continuous bead structure is formed and these beads have a very drastic effect on fatigue life of specimen [xiii].

It is also concluded that there is large effect of temperature produced during TIG welding along with the mixture of shielding gases on total fatigue life of the specimen. Normally for aluminum alloys the fatigue life is increased when the testing is performed on low temperature while it is decreased when shielding is increased [xiv]. Different grain refinement techniques actually define the intergranular or transgranular fatigue crack propagation. Grain boundaries concentrations also affect the fatigue crack speed [xv]. Grain boundaries with different concentration of secondary particles in aluminum alloys have different fatigue strength.

In this research paper the variation in tensile strength and hardness after TIG weldment is elaborately discussed. The calculation of fatigue strength of TIG welded AA2219-T87 is also monitored through S-N curves. All fatigue related data is also tested and verified through numerical simulation using ANSYS software. Grain structure is also studied to view the microstructural changes taken place after TIG weldment.

II. EXPERIMENTAL

A. Material

In this research AA2219 is used to study the fatigue crack propagation in base metal and TIG weld nugget zone. It is wrought aluminum alloy and due to its vast applications in aerospace industry, it is necessary to study it on experimental basis especially under cyclic loading as the most adverse factor for aerospace structures is fatigue loadings or repeating loads. The chemical composition of subjected aluminum alloy is shown in Table I.

The dominating alloying component in AA2219 is Cu. Due to high strength to weight ratio it is used

In manufacturing of cryogenic tanks. Actually the abundance of Cu in this alloy of 2XXX series furnishes the subjected alloy with aerospace desired properties. The solidus and liquidus temperature for AA2219 is noted 543°C and 643°C respectively. However the annealing temperature of research material is nearly 413°C. The mechanical properties of research materials are described in Table II.

TABLE II
MECHANICAL PROPERTIES OF AA2219

Sr. #	Property	Value
1	Hardness, Vickers	149
2	Modulus of Elasticity	73.1 GPa
3	Tensile Strength	170 MPa
4	Poison Ratio	0.33
5	Shear Modulus	27 GPa

In this research the base metal AA2219 is optimized by using pre weld heat treatment process instead of post weld heat treatment process studied and investigated by many researchers. According to ASTM [xvi] international for best aerospace properties, the performed heat treatment is designated with a code T87. The detail description of this type of heat treatment process is explained in Fig. 3.

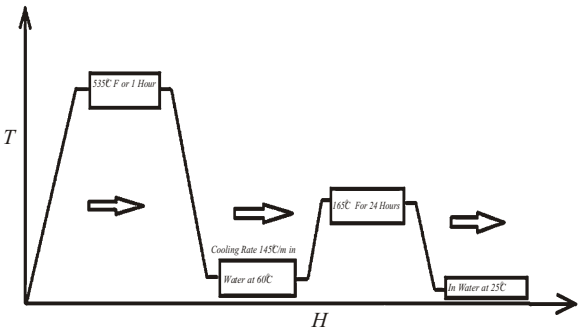

Fig. 3. Details of T87 Heat Treatment

B. Specimen Preparation

Dogbone specimens are prepared for tensile and fatigue test according to ASTM standards [xvii]. The specimens used in fatigue tests are cut from round circular bar while the specimen used in tensile test are cut from alloy sheet. The dimensions of the specimen are shown in Fig. 4.

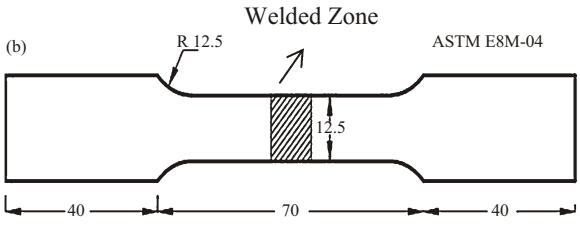

Fig. 4. Dogbone Specimen

The specimen used for fatigue tests are cut and tapered from the center and then TIG welded using AA2319 filler alloy. A V-notch of depth 1mm is grooved in the center of the welded specimen [xviii]. The welding parameters are shown in Table III.

C. Experimental procedure

Brinnell hardness tests are performed to evaluate the changes taken place after TIG welding. A series of reading from WNZ to BM is taken by using hardness tester of model HBRVU-187.5. The tensile tests are performed to find out the percentage reduction in tensile strength after TIG welding. Tensile tests are performed on a servo hydraulic universal testing machine of model MTS 810.In order to study the fatigue behavior of the notched specimens, 4 point rotating bending fatigue testing machine as shown in Fig. 5.

Fig. 5. Fatigue test experimental setup

D. Optical Microscopy

The metallography of welded specimens is performed by using Olympus DP-20 metallurgical microscope. Small pieces of welded section of weldment were cut-off and further surface preparations techniques are made to visualize the grain growth behaviors. Firstly the specimens are made scratches free by using emery paper ranging from 800 to 1200 grits. After this the specimens are creamed with universal polishing paste (Model no. UPP 841-0602) and rubbed with leather pad. Finally the specimens are polished with synthetic diamond crystal paste of grades (W-40) and (W-1.5) respectively. For AA2219 the chemical etchant according to ASM standards is Keller's reagent (5ml HNO3 (conc.), 2ml HF (48% conc.), 3ml HCL (conc.), and 190ml distilled H_2O) [xix].

III. MODELING AND SIMULATION

After created a model in Pro/ENGINEER wildfire 5.0, IGS file of this modeling is created to open this on ANSYS software. The specimen selected for thorough finite element analysis on software package ANSYS Workbench 14.0 is 2D plane stress model. The purpose of using this software package is to achieve the objective of research easily without the interruption of

unnecessary parameters. As the specimen loading on four point rotating & bending machine is supposed to just like a beam so stress distributions are considered uniform. Stress application points are shown in Fig. 6. Linear elastic conditions are considered to just obtain the value of bending stresses which are responsible for deflection in the specimen. These numerically obtained values are then used in the formula designed for non-linear behavior of S-N curves. Non linearity consideration during the simulation will yield a value of bending stress that is incompatible with the formula generally developed for S-N curves due to overlapping effects. At such situation, a new complex calculation is advised with so many parameters which make the application of research much more difficult. So in this research, simplicity is preferred over super accurate value obtained through non-linear complex equations. And it is the core reason to use the liner elastic model instead of elastic-plastic model.

For different loading conditions ranging from 150 N to 350 N and the number of cycles at which a specific loaded specimen shows failure, the resulting stresses are found by simulations. In the conventional method of crack analysis at the notch root, the crack tip is modeled by a focused concentric ring of triangular, 3-node linear plane stress (CPS3) type elements. Around this crack tip six concentric rings of 4-node, bilinear plane stress quadrilateral elements with reduced integration (CPS4R) are modeled. The loading and boundary conditions are applied same as adopted in experimentations as shown in Fig. 6.

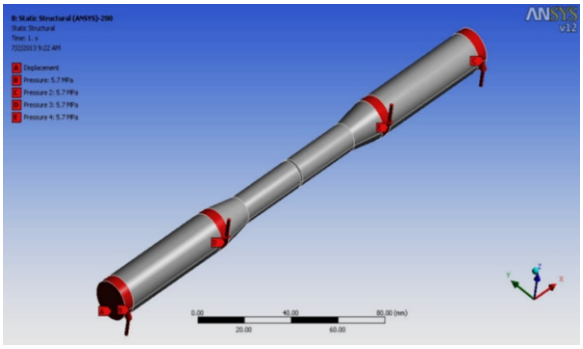

Fig. 6. Loading & Boundary conditions applied

In meshing of the elements the triangular and quadrilateral rings are concentric in the same geometry so there centre point is defined as crack front. The 2D FEA mesh consists of 950 elements and 1020 nodes. The partition line or crack path can be established by a transverse plane which extends from the specimen edge to the crack tip defined by the centre of the concentric ring mesh. During simulation, the software automatically duplicates the nodes around the crack plane, separating the two surfaces. This produces a singularity at the crack front. Small strain analysis is run to remove the errors due to presence of singularity. The equivalent stresses produces under the action of bending and rotating loads are shown in Fig. 7.

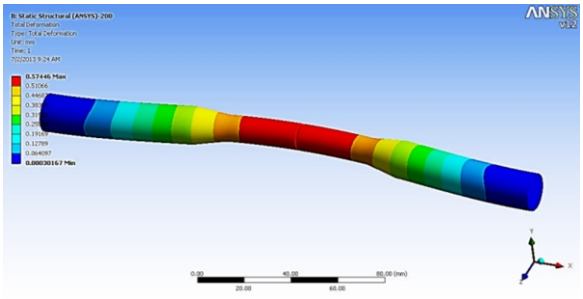

Fig. 7. Analysis of stresses in ANSYS workbench

The maximum stresses are generated at the centre of the specimen where the notch exist and crack initiation and propagation is taken place. The intensity of stresses is gradually decreases from crack front to edges of the specimens. The whole simulation is performed by considering the total linear elastic model. There are many complexities and limitations in elastic-plastic model due to specimen's geometry and combined loadings (cyclic & bending) conditions in this research simulations.

IV. Results Discussion

A. *Tensile Test*

After TIG welding it is observed that there is reduction of tensile strength is taken place up to 10-12%. The reduction in tensile strength in welded specimens is represented in Fig. 8. Actually the sudden cooling of molten metal pool at WNZ is the prime factor of tensile strength decline at the weldment. Because there is no time for the proper arrangement of grains in a sequenced manner resultantly welded material fails to establish a primary network of bonding. Thermal residual stresses are another cause of tensile strength lowering which are induced in weldment due to high temperature flame of TIG welding. Due to this cause there is also loss of ductility in weldment and welded material become more brittle.

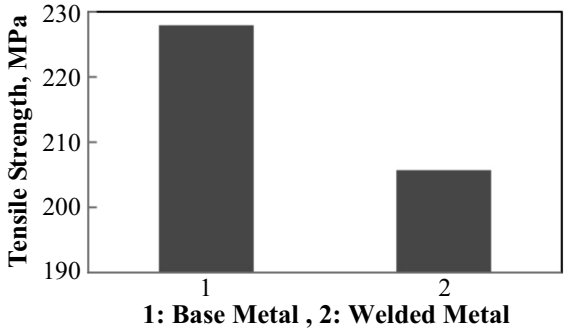

Fig. 8. Tensile strength of BM and welded specimens

B. Hardness Test

The reason of high hardness number of BM is due to presence of high amount of α-Al; however some amount is disturbed while performing pre-heat treating. The intermetallics are arranged in such a manner that they are providing the maximum strength to base metal. As it is very far away from heat source so the effects of welding temperature are very negligible on this zone.The hardness number of HAZ is greater than weld nugget zone while lower than the base metal as shown in Fig. 9. The thickness of this zone is totally varying from notch tip to the end of the specimen. In this zone the hardness number is suddenly lost due to improper recrystallization of semi-melted portion of metal. The readjustment of second phase particles in this zone is not helpful to provide proper strength to the subjected alloy. Due to high temperature, the main alloying component, Cu, is melted and move away from this zone to molten pool of weld nugget zone causing the strength decrement of this zone. WNZ is the most important area of weldment because it is the real joint portion of two bulk materials. This zone is created by a molten pool of base metal and filler alloy. It is the most fragile zone having the lowest hardness number as compared to other competitive zones. In this zone the recrystallization of molten metal pool is taken place very quickly. During rapid recrystallization of grains the strengthening particles failed to find proper positions in grain structure. In this zone some secondary particles concentrate on grain boundaries are also helpful in decreasing the hardness of the WNZ. There is dendritic structure is formed after recrystallization in this zone and as the dendritic structure depicts the softer area so resultantly this zone has lowest hardness number.

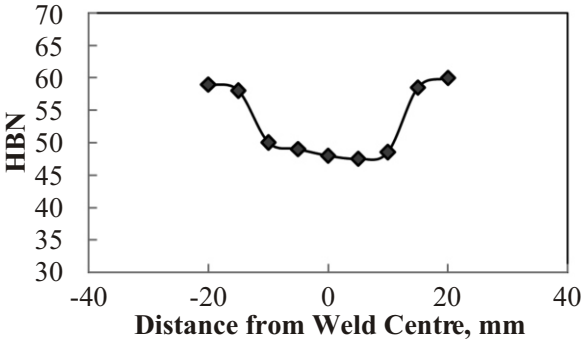

Fig. 9. Microhardness of TIG welded AA2219-T87

C. Fatigue Test

The fatigue test is performed on four point rotating and bending fatigue testing machine. The loads applied on the test specimens are converted to equivalent stresses so that the assessment of the S-N curve becomes possible. The equivalent stresses for each respective load can be calculated by using following equations

$$\frac{\sigma}{C} = \frac{M}{I} \tag{1}$$

$$\frac{\sigma}{\frac{D}{2}} = \frac{W*\frac{l}{2}}{\frac{\pi}{64}*D^4} \tag{2}$$

By putting the l=110, a general equation is achieved to convert the load into equivalent stresses

$$\sigma = \frac{W(N)*55(mm)*32}{\pi D^3\ (mm^3)} \tag{3}$$

$$\sigma = \frac{560.51\,W}{D^3}\left(\frac{N}{mm^2}\right) \tag{4}$$

Where,

W= Applied load & D= diameter of the specimen on tested section.

A relation developed between equivalent stresses and applied loads for both experimentation and simulation as shown in Fig. 10. The results show smooth relations between loads and equivalent stresses. For a specific load the higher stress in experimentation with respect to simulation represents that there is some notch sensitivity is present in actual environment while in simulation it is considered that the stresses are uniformly distributed on the tested section of the specimen. Due to notch sensitivity it is common practice to multiply the equivalent stresses with stress concentration factor, Kt, resulting into the higher values of stress for corresponding load in experimentation. The stress concentration factor is totally dependent on the geometry of the notch present on the tested section.

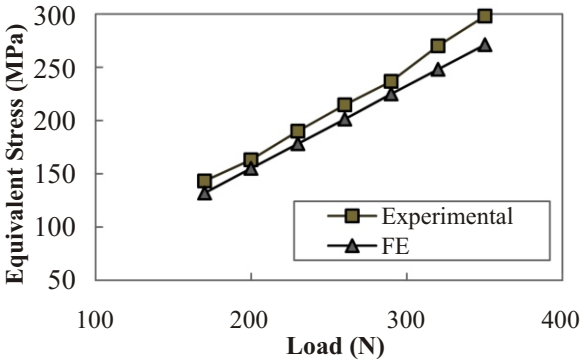

Fig. 10. Comparison of equivalent stress for their specific loads

As the specimens are under combined loadings so due to bending there is deflection observed in the tested specimens. The deflection is calculated by using Eq. 5

$$y_{max} = \frac{ML^2}{8EI} \tag{5}$$

Where, M= Bending moment

The more deflection in experimental work with respect to simulation as shown in Fig. 11 is due to the effect of varying equivalent stresses.

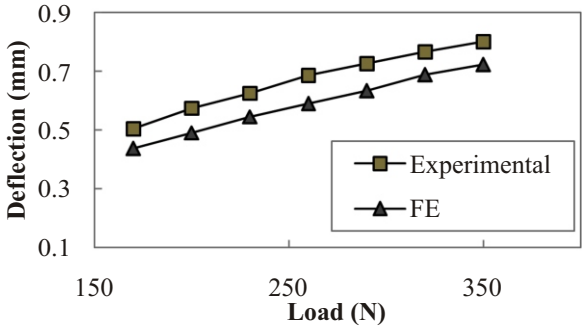

Fig. 11. Comparison of deflections for their specific loads

The prediction of fatigue life is generally made with the help of S-N curve for that specific material. The most important portion of this curve is the 'knee' portion because it defines the endurance limit or fatigue life. Below this portion of the curve the material withstand infinite number of cycles without failures. The S-N of the experimental and simulation data for the subjected material is shown in Fig. 12.

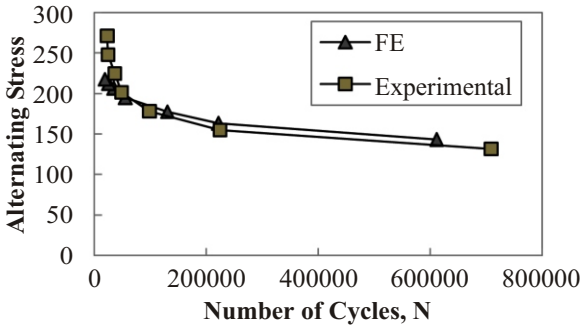

Fig. 12. S-N curves

The knee portion of the both curves is nearly same which represents the verification of the experimental results with the help of numerical simulation. From Fig. 12, it is also represented that both curves becomes nearly parallel to x-axis of the figure after knee point which shows that there is no fatigue failure is taken place regardless of the applying number of cycles or cyclic load.

V. Microstructure

The base metal (BM) is in the form of solid solution type. The strengthening particles of Al2Cu are randomly scattered in this mechanical mixture of aluminum alloy as shown in Fig. 13. The grains are rolled and of average size. The microstructure of BM is observed after the solution heat treatment when there is no aging of the metal is taken place at all. However due to non-uniformity of temperature distribution during the heat treatment, some precipitate free zones (PFZ) are also observed in Fig. 13.

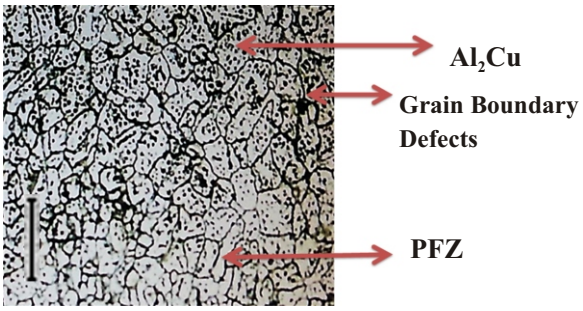

Fig. 13. Microstructure of base metal

These PFZ's are created due to artificial aging of the alloy. At some rare places the grain boundaries defects are also seen due to the crucial thermal or mechanical stresses, applied during preparation of specimens. The zone which is present in between the BM and weld nugget zone (WNZ) is heat affected zone (HAZ). The grain structure of HAZ is small sized and equiaxed as shown in Fig. 14.

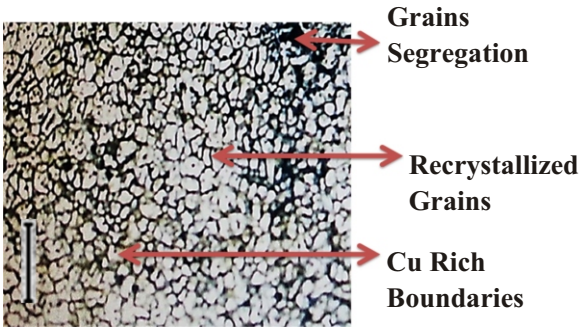

Fig. 14. Microstructure of HAZ

There is somehow recrystallization of grains is taken place. However due to neighboring of WNZ it also experiences very high temperature of welding torch and this causes the migration of strengthening particles towards grain boundaries.Depletion of copper containing particles from grains makes this zone the most fragile one. Some very near portions of HAZ toward WNZ also show the grains detachments due to thermal imbalance. While in WNZ there is molten metal pool is formed during welding. When the sudden cooling of this molten metal is taken place then a dendritic structure is observed under metallurgical microscope as shown in Fig. 15.

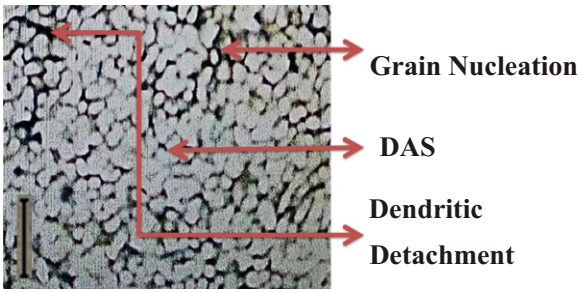

Fig. 15. Microstructure of WNZ

This rapid cooling imparts the brittle properties to the welded parts. When there is improper cooling of the molten pool is happened then the dendrite arm spacing (DAS) is increased very rapidly. The origination of the dendritic structure in WNZ is always started with nucleation at micro level.

VI. Conclusion

It is concluded from this research that due to TIG welding of AA2219-T87, using filler alloy of AA2319, different zones are produced. The sudden loss of mechanical properties, hardness & tensile, are observed in HAZ & WNZ with respect to BM. It is tried to estimate the fatigue life of the subjected alloy after TIG weldment by assessing the S-N curves. The effects of stresses due to combined loading (cyclic + bending) are experimentally calculated and verified through numerical simulation. It is also found the relation between the alternating stresses and the failure cycles is $S_a = 1842 \times N^{-0.19}$ for this specific alloy with the specific welding type.A fine distribution of second phase particles (Al_2Cu) due to pre-heat treatment is observed in round and semi elongated grains. Due to cooling rate instability precipitate free zones (PFZs) are also observed in base metal which are responsible for sudden crack propagation. The grain shifting towards boundaries is the prime cause of fragileness of HAZ. The sudden cooling of molten metal pool in WNZ imparts the brittleness properties to weldment.

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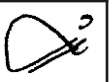
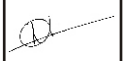
Authorship and Contribution Declaration			
	Author-s Full Name	**Contribution to Paper**	
1	Mr. Mudaserullah (Main/principal Author)	Proposed topic, basic study Design, methodology and manuscript writing	
2	Prof. Dr. Ghulam Yasin Chohan (2nd Author)	statistical analysis and interpretation of results etc.	
3	Mr. Qasim Ali (3rd Author)	Data collection, Literature review & Referencing	
4	Dr. Muhammad Ali Nasir (4th Author)	Mechanical Testing and Data interpretation, Results & Discussion	

A Simple Multi-Criteria Inventory Classification Approach

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***Abstract*-**Organizations classify inventory for an efficient control that supports managers to make policies to procure, store, handle, manufacture and distribute items accordingly. ABC classification is a well-known technique to classify according to which very important items are in class 'A', moderately important items are in 'B' and relatively unimportant items are in class 'C'. Inventory classification on multiple criteria gives a better control for inventory handling with respect to single criteria classification. On the bases of previous work, it was found that the multi-criteria inventory classification methods are complex to be used by managers with less experience and knowledge. So a simple equal weighted normalized methodology is proposed for multi-criteria inventory classification to help inventory manager of each organization whether small, medium and large. This proposed model is implemented along with an example from literature and compared with previous work. This comparison showed that this model is simple to implement and gives a better classification on multiple criteria.

***Keywords*-**Inventory, Inventory Classification, Model Development, Model Simplification, Inventory Optimization

I. Introduction

Organizations of all sizes may have inventory items in thousands and more than it. The required resources including finance and time are often inadequate to manage these inventories. To optimize the inventory, it is the most suitable to use available resources according to the importance of inventory items. To control SKUs efficiently, an approach is to classify SKUs into different groups when organization has huge amount of inventory SKUs. Among all inventory control methodsand techniques ABC analysis is the most widely used and ABC analysis is based in Pareto's Principle of 80,20 rule[i-iii]. ABC analysis classifies inventory items in three classes. Highly important itemswith respect to classifying criterion/criteria are usually classified in 'A' class. Items with moderate importance in 'B' class and remaining items in 'C' class. These classes of inventory items require different control levels for each class. In Silver et al work, inventory control policies have been detailed according to classes of inventory items [iv].

Traditionally ABC analysis was based on just single criteria that was annual dollar usage (ADU) of inventory items [v]. However, in addition to this criterion, inventory holding unit cost, obsolescence, certainty of supply, reparability, scarcity, order side requirement, part criticality, average unit cost, substitutability, durability, commonality , demand distribution, length and variability of replenishment lead time, stock ability, number of request per year, mode and cost of transportation and stock-out unit penalty cost may affect the items classification [ii, vi-ix]. ABC analysis is successful only when the inventory being classified is fairly homogeneous and the main difference among the items is in its annual use value. In practices inventory items are not homogeneous. As range of product or customers changes, the need to increase the variety of inventory items also increases. So it has been realized that inventory should be classified on multi-criteria bases because traditional ABC analysis is inefficient for classifying inventory items properly [x-xii].

To classify inventory on multi-criteria, several inventory classification models have been suggested in literature. In classification, there are usually three steps including selection of criteria, selection of alternatives and weight assigning with respect to criteria. It is found in literature that to assign weights to criteria, researchers used subjective judgments or artificial intelligence techniques. Weights on subjective judgment could not be optimistic and it is complex for inventory managers to find weights with the help of artificial intelligence (AI) techniques.

To cover both problems for weight assigning and complexity of previous models depending on AI techniques, a model has been proposed in this work. This model will also help inventory managers which do not have professional knowledge and skills to classify inventory and adopt policies accordingly considering relevant factors for MCIC.

II. Literature Review

Many decision tools of multi criteria inventory classification (MCIC) have been developed in last two

decades. Flores et al classification was based on bi-criteria and they proposed cross-tabulate matrix methodology [vii]. But cross-tabulate matrix methodology given by Flores et al becomes complex when it is extended with more criteria. Authors in [xiii] identified that the multi-criteria inventory classification becomes complex when three or more criteria are involved. To group and classify items according to their similarity, multi-variate techniques is a good approach. In Flores et al work a solution procedure is described which blends operations constraints and clustering analysis in [xiv].

Many multi-criteria decision making tool have been proposed in literature to classify inventory as analytical hierarchy process (AHP) was proposed in [xiii, xv]. But AHP limitation is its requirements of subjective judgment when items are compared pair wise. Sophisticated meta-heuristic tool like artificial neural network (ANN), practical swarm optimization and genetic algorithm (GA) have been applied to solve MCIC problem [xii, xvi, xvii]. Yu discussed about application of some other artificial intelligence based classification techniques like k-nearest neighbour algorithm, support vector machines and back propagation networks [xviii].

Research work showed that these meta-heuristic techniques are complex enough to apply and to understand by inventory managers [viii, xix, xx]. Ramanathan developed a weighted linear optimization to solve MCIC problem and his model has similarity to the concept of data envelopment analysis (DEA) [ii].

In Ramanathan model a scalar score is calculated from converting all criteria measures. This scale score is a weighted sum of measures under individual criteria. Weights in Ramanathan model are generated by a DEA-like linear optimization to avoid subjectivity when weights are assigned. The items are grouped on the bases of the generated score to classify in different classes. However a linear optimization is required for each item. When inventory items are in large number as in thousands the processing time for each linear optimizationis very long.

W.L.Ng proposes a novel and easy methodology for classification that does not need a linear optimizer for ABC analysis[viii]. Besides its many advantages, Hadi-Vench [xxi] discusses that he Ng-model leads to a situation where the Ng-index for each item is independent from the obtained weights. Consequently, Hadi-Vench [xxi] improves the Ng-Model and constructs a nonlinear programming model that keeps the impacts of weights when calculating the final indices. The HV-model is solved for each inventory item repeatedly and a different set of weights is obtained for calculating the final index of each item. Both the HV and Ng model need prior assumption on the importance order of criteria which is determined subjectively by the decision maker. It should be noted that when the number of criteria is large, it is an overwhelming task for the decision maker to rank all criteria.

A fuzzy rule based system in multi-criteria classification is discussed in Rezaei and Dowlatshahi [xxii]. In their work, they took account the existing inherent ambiguities in the reasoning process of classification. Bhattacharya, Sarkar, and Mukherjee presented a distance-based multi-criteria consensus framework to classify inventory [xxiii].Their work demonstrate Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) model in inventory classification of a pharmaceutical company. They judged TOPSIS method with analysis of variance and used a simulation model to compare their results with the traditional ABC classification technique.The conclusion of their work shows that constructing fuzzy. Their conclusion is constructing fuzzy models such as fuzzy TOPSIS and neuro-fuzzy hybrid will be helpful when the values of attribute are ambiguous.

Kabir classified inventories into different categories by using a methodology in which fuzzy Delphi method and fuzzy analytic hierarchy process (FAHP) were used. In this work fuzzy Delphi method is used to identify the important criteria and the fuzzy AHP is then used to calculate the relative weights [xxiv].Hadi-Vench and Mohamad ghasemi illustrated an integrated fuzzy analytic hierarchy process-data envelopment analysis (FAHP-DEA) methodology for multi-criteria inventory classification by taking a real case study. FAHP was used to determine the weights of criteria from five levels from very high to very low and DEA was used to determine the values of linguistic term and overall score of each item was aggregated by using simple additive weighting (SAW) [xxv].

Chen et al. presented a case-base distance model for multi-criteria ABC classification [xxvi].Chen et al. used weighted Euclidean distances and quadratic optimization program are used to find preferences and optimal threshold respectively. Their work reduces the number of misclassification and lessens the impact of outliers by improving the multiple classification problem. Chen et al [xxvi] case-based distance model is extended by Ma [xxvii]. Ma developed a two-phase case-based distance methodology for inventory classification for multiple criteria. The proposed model evaluates a set of cases for alternatives classification and improves classification as well as multiple solution problems. Many author like Rezaei and Dowlatshahi [xxii], Bhattacharya, Sarkar, and Mukherjee [xxiii] and Kampen, Akkerman and Donk [xxviii] presented multi-criteria inventory classification in a comprehensive way in their work so interested reader should read their work for more detail in this field.

Teunter, Babai, and Syntetos proposed new criterion of average order quantity for MCIC [xxix]. Stanford and Martin considered constant demand for classification [xxx]. Mohammaditabar, Ghodsypour, and O'Brien integrated model classifies item as well as

simultaneously finds the best policy for inventory control. Appropriate solution was found by using simulated annealing technique [xxxi]. An Approach in which classification is done on the bases of loss profit when there is a correlation in loss and profit between inventory items can be seen in Xiao, Zhang, and Kaku work [xxxii].

Many methods in MCIC deals with quantitative criteria and the methods developed for qualitative criteria are just few. Qualitative methods for inventory classification can be found in Flores, Olson, and Dorai [xiv] and Partovi and Burton [xxxiii]. Their method considers both quantitative and qualitative criteria. AHP based methods have some limitations due to its pair wise comparisons and decision maker's subjective judgment. In analysis, AHP technique becomes complex due to increased pair wise comparison when the number of criteria are increased. An optimum solution can be effected by a large matrix due to consistency and decision subjectivity [xix].

Hatefi et al. presented an extension of a linear optimized model based on Cook, Kress, and Seiford data envelopment analysis (DEA) for inventory classification [xxxiv]. Hatefi model is applicable for both quantitative and qualitative criteria at the same time. Lolli et al. introduces a new hybrid method based on the AHP and the K-means algorithm to solve the MCIC problem [xxxv].

Hatefi et al. proposed an alternative optimization-based model in which the composite performance scores of all inventory items are calculated simultaneously via a set of common weights [xx]. In his model no subjective information is required to run the proposed model which is essential in an accurate and fair decision environment.

Although the MCIC is now a well-known research area in operation management and researchers are working in this area. But the problem found is that there is so much gap between research work and its implementation. Small and Medium Enterprises (SME's) managers are unable to use these techniques. So there should be a simple and easy to implement MCIC model which can help these managers to classify their inventory on multiple criteria bases. This MCIC will help SME's managers to make policies accordingly.

The rest of the paper is organized as follows. Model development along with its formulation, solution scheme, illustration of model for acase study of inventory from literature and its comparison with MCIC models in literature. Finally, concluding remarks are given in this paper.

III. Model Development

A. Formulation

To formulate model, it is supposed that inventory has 'Y' number of SKUs that have to classify on 'Z' number of criteria for ABC analysis. 'x_{yz}' will denote the value of inventory item 'y' with respect to 'z' criteria.

where

$$y=1,2,3,\ldots\ldots\ldots\ldots,Y$$

and

$$z=1,2,3,\ldots\ldots\ldots\ldots,Z$$

To simplify all criteria are assumed in a positive relation with the importance of inventory items. Even if there are inversely related criteria, reciprocals of the scores could be used to make them positive criteria. In the proposed model, an equal weighted additive function is used to find normalized score of items which will convert all measurements in a 0-1 scale for all items.

$$\boldsymbol{Score\ (y'th\ item\ w.r.t\ z'th\ criteia) = S_{yz}} = \frac{\boldsymbol{x_{yz} - min_{y=1,2,\ldots\ldots,Y}\{x_{yz}\}}}{\boldsymbol{max_{y=1,2,\ldots\ldots,Y}\{x_{yz}\} - min_{y=1,2,\ldots\ldots,Y}\{x_{yz}\}}} \quad (1)$$

After calculating the sum of normalized score, it may be needed for decision making process to rank the importance of criteria. But in proposed model, it is assumed that all the criteria have equal importance and weight for inventory classification and controlling of inventory items. This assumption will facilitate the inventory classification under multiple criteria for inventory managers with less skills, knowledge and experience.

The sum of item scores for all criteria will be calculated using following iteration.

$$\boldsymbol{S_y} = \sum_{y=1}^{Y}\{\boldsymbol{S_{yz}}\} \quad (2)$$

where, S_y is the sum of transformed score for 'y'th item with respect to multiple criteria 'z'.

To rank the sum of items score

$$\boldsymbol{S_y - S_{(y+1)} \geq 0, y = 1, 2, \ldots, (Y-1)} \quad (3)$$

After ranking in the descending order, the classification will be done of Vilfredo Pareto rule [i]. On the bases of Pareto rule of (20, 30, 50) will be applied on of ranked S_y [i]. Top ranked 20% items of inventory will be ranked in 'A' class and lower ranked 50% items will be in 'C' class while remaining 30% in between of these classes will be in 'B' class.

B. Solution Scheme

1) Guidelines to Classify Inventory for Proposed Model

i) Collection of Data for 'Y' items with respect to 'X' criteria

In this step an inventory manager will finalized the factors for classification already have been described in literature

review. After the selection of considerable criteria, the data of items for criteria will be collected.

ii) *Transforming the Items data in score of (0-1)*
The items data will be transformed for inventory items under each criterion by using Eq. (1). This scoring will be done for each criterion for each item.

iii) *Calculating the sum of scores under each criterion for each item*
After scoring each items for each criterion the sum of scores under each criterion will be calculated for '***I***' items using Eq. (2). Sorting and Ranking of items with respect to sum of scores of items

iv) *Sorting and Ranking of items with respect to sum of scores of items*
The items will be sorted and ranked in descending order with respect to the sum of scores of items by using Eq. (3).

v) *Assigning Classes to Inventory Items*
The inventory items sorted and ranked in above 20% of total items will be assigned '**A**' class, 21%-50% of items will be assigned '**B**' class and remaining 50% items will be in 'C' class.

C. Illustration of proposed model

The base of data and the criteria for the implementation of model is described above. To implement this model MS Excel Spread Sheet has been employed. These minimum and maximum values aid in the transformation of score for each criterion. The transformed scores for each item w.r.t. each criterion are calculated using Eq.(1).

1) Steps in Model Implementation for Inventory Classification

To implement proposed model for a small enterprise inventory classification, the given b e l o w steps are followed.

i) *Collection of Data for 'I' items with respect to 'J' criteria*
As it is discussed in guidelines that first steps is to finalize criteria for inventory classification. For this classification, the criteria considered are Annual Rupee Usage (ARU), Average Unit Cost (AUC) and Lead Time (LT). After criteria finalization, data of inventory items according to these criteria is collected and extracted from purchase order, procurement list, invoices etc. This was a relatively wearisome step and it took a lot of time. But it may be easy for those enterprises which are keeping their inventory records proper and update.

ii) *Transforming the Items data in score of (0-1)*
After collecting necessary information for each item under each criteria, the minimum and maximum value of items in each criteria are calculated. These minimum and maximum values are used to transformed item data in 'x' value where 'x' is equal to 0 or 1 in in between of 0 and 1. This transformed score normalizes the items data. To calculate the transformed score for Annual rupee usage, minimum and maximum values are calculated which are 25.38 and 5840.64 respectively. The transformed score of item no. 1 which Annual rupee usage is 5840.64 is calculated as

Transformed Annual Rupee Usage score of Item no. 1

$$= \frac{(5840.64 - 25.38)}{(5840.64 - 25.38)}$$

$$= \frac{5815.26}{5815.26}$$

$$= 1.00$$

To calculate the transformed score for Average Unit Cost, minimum and maximum values are calculated which are 5.12 and 210 respectively. The transformed score of item no. 1 which Average Unit Cost usage is 49.92 is calculated as

Transformed Average Unit Cost score of Item no. 1

$$= \frac{(49.92 - 5.12)}{(210 - 5.12)}$$

$$= \frac{44.8}{204.88}$$

$$= 0.22$$

To calculate the transformed Lead Time score, minimum and maximum values are calculated which are 1 and 7 days respectively. The transformed score of item no. 1 which Lead Time is 1 is calculated as

Transformed Lead Time score of Item no. 1

$$= \frac{(2 - 1)}{(7 - 1)}$$

$$= \frac{1}{6}$$

$$= 0.17$$

This transformation of values for all inventory items has been calculated in a similar way as described above.

iii) Calculating the sum of scores under each criterion for each item

After scoring each items for each criterion the sum of scores under each criterion will be calculated for '***i***' items using Eq. (2). Sorting and Ranking of items with respect to sum of scores of items.

sum of scores for Item no. 1 = 1.00 + 0.22 + 0.17 = 1.39

The sum of score for all inventory items has been calculated in a similar way described above.

iv) Sorting and Ranking of items with respect to sum of scores of items

The items are ranked according to the sum of score if inventory items in a descending order. The item ranked 1 will have high sum of score than the item at ranking 2.

v) Assigning a Class

After the ranking of inventory items 20% of top ranked inventory items have been assigned 'A' class, 50% of bottom ranked have been assigned 'C' and remaining 30% have been assigned 'B' class. After this inventory data is ready to make policies for purchase and inventory control policies. Manager can make policies and implement according to the item class.

After calculating the transformed score, the sum of score is calculated and listed in a column 'Sum of Scores' in descending order. Classification percentages for A, B and C classes are similar to Reid ABC principle to compare results [v]. Table I illustrates proposed model with a case study of 47 items taken by Reid [v].

TABLE I
PROPOSED MCIC MODEL ILLUSTRATION

	Raw Data			Transformed					
Item No. [v]	Annual Dollar Usage [v, viii]	Average Unit Cost [viii]	Lead Time [viii]	Annual Dollar Usage	Average Unit Cost	Lead Time	Sum of Score	Item Rank	Proposed Model
2	5670	210	5	0.97	1.00	0.67	2.64	1	A
29	268.68	134.34	7	0.04	0.63	1.00	1.67	2	A
10	2407.5	160.5	4	0.41	0.76	0.50	1.67	3	A
9	2423.52	73.44	6	0.41	0.33	0.83	1.58	4	A
13	1038	86.5	7	0.17	0.40	1.00	1.57	5	A
3	5037.12	23.76	4	0.86	0.09	0.50	1.45	6	A
1	5840.64	49.92	2	1.00	0.22	0.17	1.39	7	A
14	883.2	110.4	5	0.15	0.51	0.67	1.33	8	A
28	313.6	78.4	6	0.05	0.36	0.83	1.24	9	A
8	2640	55	4	0.45	0.24	0.50	1.19	10	A
5	3478.8	57.98	3	0.59	0.26	0.33	1.19	11	B
18	594	49.5	6	0.10	0.22	0.83	1.15	12	B
45	34.4	34.4	7	0.00	0.14	1.00	1.14	13	B
40	103.36	51.68	6	0.01	0.23	0.83	1.07	14	B
34	190.89	7.07	7	0.03	0.01	1.00	1.04	15	B
31	216	72	5	0.03	0.33	0.67	1.03	16	B
23	432.5	86.5	4	0.07	0.40	0.50	0.97	17	B
19	570	47.5	5	0.09	0.21	0.67	0.97	18	B
6	2936.67	31.24	3	0.50	0.13	0.33	0.96	19	B
39	119.2	59.6	5	0.02	0.27	0.67	0.95	20	B
7	2820	28.2	3	0.48	0.11	0.33	0.93	21	B
4	4769.56	27.73	1	0.82	0.11	0.00	0.93	22	B
12	1043.5	20.87	5	0.18	0.08	0.67	0.92	23	B
33	197.92	49.48	5	0.03	0.22	0.67	0.91	24	B
22	455	65	4	0.07	0.29	0.50	0.87	25	C
20	467.6	58.45	4	0.08	0.26	0.50	0.84	26	C
37	150	30	5	0.02	0.12	0.67	0.81	27	C
15	854.4	71.2	3	0.14	0.32	0.33	0.80	28	C
43	59.78	29.89	5	0.01	0.12	0.67	0.79	29	C
47	25.38	8.46	5	0.00	0.02	0.67	0.68	30	C
21	463.6	24.4	4	0.08	0.09	0.50	0.67	31	C
17	703.68	14.66	4	0.12	0.05	0.50	0.66	32	C

16	810	45	3	0.13	0.19	0.33	0.66	33	C
38	134.8	67.4	3	0.02	0.30	0.33	0.66	34	C
35	181.8	60.6	3	0.03	0.27	0.33	0.63	35	C
44	48.3	48.3	3	0.00	0.21	0.33	0.55	36	C
24	398.4	33.2	3	0.06	0.14	0.33	0.53	37	C
36	163.28	40.82	3	0.02	0.17	0.33	0.53	38	C
26	338.4	33.84	3	0.05	0.14	0.33	0.53	39	C
46	28.8	28.8	3	0.00	0.12	0.33	0.45	40	C
27	336.12	84.03	1	0.05	0.39	0.00	0.44	41	C
32	212.08	53.02	2	0.03	0.23	0.17	0.43	42	C
11	1075.2	5.12	2	0.18	0.00	0.17	0.35	43	C
42	75.4	37.7	2	0.01	0.16	0.17	0.33	44	C
30	224	56	1	0.03	0.25	0.00	0.28	45	C
41	79.2	19.8	2	0.01	0.07	0.17	0.25	46	C
25	370.5	37.05	1	0.06	0.16	0.00	0.22	47	C
Minimum	25.38	5.12	1	0	0	0	0.215	1	
Maximum	5840.64	210	7	1	1	1	2.637	47	

IV. Comparison of Proposed Model with Previous Work

When it was compared with proposed model with all MCIC Models developed up till now [ii, viii, xiii, xxi, xxxvi, xxxvii] and which are discussed in Hatefi [xx], it was found that only 3 items (Item no 2, 3 and 9) are classified as Class A items among all MICIC models. There is only one item (Item no 19) which has been commonly classified in class B by all MCIC models and only 12 items coincides in class C by all MCIC models. It is also found that all models including proposed model in this study have different classification for these 47 items and no coincidence of these models have been found for all items. This comparison also clear that the items classified with proposed model have a different model and algorithm among these all multi-criteria inventory classification.

TABLE II
Comparison of Developed MCIC ABC Models

	ABC Classification Models							
Item # [v]	Hatefi [xx]	Chen [xxxvi]	ZF [xxxvii]	R [ii]	HV [xxi]	NG [viii]	Reid [v]	Proposed Model
2	A	A	A	A	A	A	A	A
29	A	A	A	A	A	A	C	A
10	A	A	A	B	A	A	A	A
9	A	A	A	A	A	A	A	A
13	A	A	A	A	A	A	B	A
3	A	A	A	A	A	A	A	A
1	B	A	A	A	A	A	A	A
14	A	A	A	B	A	B	B	A
28	A	A	A	A	B	B	C	A
8	B	A	B	B	B	B	A	A
5	B	B	B	B	A	A	A	B
18	A	B	A	A	B	B	B	B
45	A	B	B	A	B	B	C	B
40	B	B	B	B	B	B	C	B
34	B	C	B	A	B	B	C	B
31	B	B	B	B	B	B	C	B
23	B	B	B	C	B	B	B	B
19	B	B	B	B	B	B	B	B
6	C	B	C	C	B	A	A	B
39	B	B	B	B	B	B	C	B
7	C	B	C	C	B	B	A	B
4	C	B	C	B	A	A	A	B
12	B	C	B	B	B	B	B	B
33	B	B	B	B	B	B	C	B
22	B	B	B	C	C	C	B	C
20	B	C	B	C	C	C	B	C

37	C	C	B	B	C	C	C	C
15	B	B	C	C	C	C	B	C
43	C	C	C	B	C	C	C	C
47	C	C	C	B	C	C	C	C
21	C	C	C	C	C	C	B	C
17	C	C	C	C	C	C	B	C
16	C	C	C	C	C	C	B	C
38	C	C	C	C	C	C	C	C
35	C	C	C	C	C	C	C	C
44	C	C	C	C	C	C	C	C
24	C	C	C	C	C	C	B	C
36	C	C	C	C	C	C	C	C
26	C	C	C	C	C	C	C	C
46	C	C	C	C	C	C	C	C
27	C	C	C	C	C	C	C	C
32	C	C	C	C	C	C	C	C
11	C	C	C	C	C	C	B	C
42	C	C	C	C	C	C	C	C
30	C	C	C	C	C	C	C	C
41	C	C	C	C	C	C	C	C
25	C	C	C	C	C	C	C	C

V. Results & Discussion

The multi-criteria inventory classification of proposed model is more effective due to its simplicity in the understanding of inventory managers of all organization especially for small and medium enterprises (SME's). This model is very simple in the comparison of previous work of inventory classification. Previous multi-criteria inventory classification models are complex ones due to the weights assigning to different factors with complex techniques which are difficult to learn for inventory managers with less skills, knowledge and experience. This weight assignment is mostly subjective in previous multi-criteria inventory classification models which cannot give accurate classification of items on these weights. But proposed model considers all weights equally due to importance of all classifying factor and part in inventory management and control for enterprise operations in production and services.

VI. Conclusions

In this paper, a simple equal weighted normalized model is proposed to classify inventory on the bases of multiple criteria. This model is based upon Ng model to make inventory classification more simple and easy to use for inventory manager of all type of organization and with some basic knowledge of inventory management. In this model, a transformation function is used to transform the item scores in a normalized score. Then items are ranked and classified on the bases of the score sum of inventory item. After the proposition of MCIC model, guidelines are given to classify inventory on multiple factors. The illustration and comparison of this model for a case study from the literature is given to check the validity of this model. The limitation of this model is that it equally ranks the criteria for inventory classification which is also an advantage to consider all the criteria under consideration for classification on equal bases. Because the ranking of criteria on the bases of different factor is either subjective or complex when AI techniques are considered to rank criteria.

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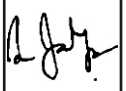
2	Salman Hussain (2nd Author)	Data Analysis, Manuscript writing, Model Development	
3	Mirza Jahanzaib (3rd Author)	Assisted in overall model development during supervision and indeed quality work etc.	
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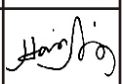
5	Haris Aziz (4th Author)	Quality insurer, validation writing	

Development of Econometric Models for Cost & Time Over-runs: An Empirical Study of Major Road Construction Projects in Pakistan

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***Abstract*-**The construction industry is flourishing worldwide and contributes about 10% to the GDP of the world i.e. up to the tune of 4.6 Trillion US dollars. It employsalmost7%ofthetotalemployedpersonsand, consumes around 40% of the total energy. The Pakistani construction sector has displayed impressive growth in recent past years. The efficient road network is a key part of construction business & plays a significant role in the economic uplift of country. The overruns in costs and delays in completion of projects are very common phenomena and it has also been observed that the projects involving construction of roads also face problems of delays and cost over runs especially in developing countries. The causes of cost overruns and delays in road projects being undertaken by the premier road construction organization of Pakistan National Highway Authority (NHA) have been considered in this study. It has been done specifically in the context of impact of cause(s) determined from project report of a total of one hundred and thirty one (131) projects. The ten causative factors which we recognize as Design, Planning and Scheduling Related problems, Financial Constraint Related reasons, Social Problem Related reasons, Technical Reasons, Administrative Reasons, Scope Increase, Specification Changes, Cost Escalation Related reasons, Non-Availability of Equipment or Material and Force Majeure play a commanding role in determination of the cost and time over runs. It has also been observed that among these identified causes, the factors of Administrative Reason, Design, Planning and Scheduling Related, Technical Reasons and Force Majeure are the most significant reasons in cost and time overruns. Whereas, the Cost Escalation related reasons has the least impact on cost increase and delays. The NHA possesses a financial worth of around Rs. 36 billion and with an annual turn over amounting to Rs. 22 billion is responsible to perform road construction project in entire Pakistan and abroad do faces such problems of increase in completion cost and delays in completion time as compared to targeted project cost and duration. The study revealed that there was an increase in cost in 62% projects i.e. out of 131 road construction projects 82 Projects observed cost over runs (Table I,Fig. 1).

***Keywords*-**Cost Overruns, Delays, Road Projects, Time Overruns, Economic Model.

I. INTRODUCTION

The noticeable point in construction projects is that they are often not well planned. The improper financial estimation and cash flows are very common reason hampering the timely and within schedule costs of projects and usually leads to failure of a project but also gives birth to other cost-time overrun related dilemmas. The reasonable Cost estimation and scheduling are among the core values of a project's success and these should be analyzed carefully & monitored throughout the course of a project life cycle for its successful completion within schedule cost and time for deliverance of its objectives. Not with standing their immense importance, the construction project managers frequently do not follow these core values resulting in cost and time overruns.

It is fairly common to observe projects having cost-time overruns and it is very common in nearly all construction industry of the globe due to one or more reasons. However, in developing countries the cost & time overruns in projects has become a rather grave matter and in some cases the cost-time overrun exceeds more than 100% of their original cost-time calculation. This is due to various causative factors that have been explained in similar studies. In practice, many public infrastructure works undergo delays and cost overruns.

The Reviewed two hundred and fifty eight (258) transport infrastructure projects [i] which were implemented world wide during the period from the years 1920's to the 2000's and found that

about 90% of them experienced considerable cost overruns. According to the World Bank database, which is composed of about 110 road development projects in the 2000s, Africa's road projects were delayed by 10 months on average [ii].

The infrastructure based works are highly customized and extremely dependent upon the correct selection of site and technical requirements. It is worth mentioning that not many contractors are able to carry out such infrastructure project. Resultantly, competition is generally limited as far as public infrastructure projects procurement is concerned. The literature commonly finds that only about three to six companies compete in competitive bidding for public infrastructure bidding [iii] [iv] [ii].

Due to these characteristics of infrastructure procurement, governments are likely to be facing hold-up problem in timely and within stipulated cost completion of projects. In general, there is potential for hold-up if either party involved in the contract is not satisfied and cease to fulfill the contractual obligations [v]. The literature discusses how to design a contract to avoid the hold-up problem [vi]. In infrastructure procurement, contracts are imperfect and rebidding or re-awarding is exorbitantly costly. Therefore, governments have no choice but to allow these cost overruns and delays.

The provision of component of cost adjustments in contracts is very essential; [vii] observed that there was adjustment in costs at about $2.70 per $1.00 of adjustment in the US highway sector in 19952000. [viii] The Comparison of around 160 traditional road projects and another 60 public-private partnerships in Europe revealed that there was24% risk premium of cost overruns in total road project costs. A concessionaire will include the expected cost overruns and the cost of delays in the initial contract because the concessionaire and not the government have to deal with the costs later on.

The Finance planning of regulatory bodies of public and private organizations should control the construction in road construction related projects. The measures to avert causative factors via planning before the finalization of projects and before execution are essentially required to be taken into account by clients, consultants and contractors in order to avoid any unforeseen changes/additions in design and scope during different phases in the life of projects. All efforts should be made to acquire land and resources before commencement of work and qualified staff should be deployed by all stake holders including client, consultant and contractor organization for close monitoring in terms of quality and management. In order to avoid all kind of frauds, corruptions, kickbacks and contract rigging by incorporating fair and transparent mechanism be evolved .It will help for fair competition to get promoted and consequently shall also minimize cost and time overruns in construction projects in Pakistan.

The construction industry has brought new innovations in almost all fields of life i.e. living style, transportation system, irrigation facilities, water storage methods, sub-sea construction, underground constructions, desert and mountains masterpieces etc. The use of technical knowledge with innovative technology like modern planning/scheduling and design software may assist in better controlling of cost-time overrun factors to a considerable extent. Due to revolution in information technology, arrival of up to date designing, planning and monitoring software packages, advance monitoring techniques and precise/skilled control of construction projects has completely transformed the principles of the entire construction industry which was not possible in past years.

Due to revolution in information technology, arrival of up to date designing, planning and monitoring software packages, advance monitoring techniques and precise/skilled control of construction projects has completely transformed the principles of the entire construction industry which was not possible in past years. With the help of the developed tools one can control various projects parameters like monitoring and controlling, client requirement, specification alteration, cash flows, financial impediments, allocation of resources, effective utilization of available resources, material management, progress tracking, quality of the output work, project speed, optimization of resources and material etc. within a meager span of time enabling the successful completion of the endeavor being undertook.

The construction industry today is considered as a prime sector for boasting development & the economy of a country. The quantum of construction work in a country is the barometer which depicts development category and state of economy. In any country of the world, the construction industry is the basic which shares a major portion in the development of that country. The infrastructure development status and its quality may be considered the determining factor for the development status of the country. The more the construction quality is found in its land, the more it is closer to development rank. The industry, however, holds heterogeneous characteristics instead of exhibiting the characteristics of a homogenous entity. Starting from a small home to high rise buildings for residential and commercial purpose, landscaping and development of colonies, schools, hospitals, airports, roads, bridges, parks etc. all are a part of this ever expanding construction industry. This industry has also given a boom to the other related business like real estate, renting and commercialization of high profile buildings.

As is the case in other developing countries, the construction projects in Pakistan also exhibit time and cost overruns due to various reasons like

mismanagement, political disorder, unexpected changes in government policies in respect of development schemes/projects, malpractices and corruption, financial drawback, unaccounted inflation rates, expensive equipment services, bidding irregularities and old procedure of procurement, lax site administration, provision of incomplete design/drawings at bidding time, miscalculation in the bill of quantities (B.O.Q.) and Financial estimations, Extension in scope of work, improper planning and scheduling, site handing over issues, restructuring laying of additional services at site, social and religious barriers/opposing of the plan, problems in having the expert labor and quality materials, late payments of the work and financial constraints due to government policies, security and law & order considerations in design and implementation phase, climatic intensity and lack of facilities at site, non-hiring of expert staff/manger/consultants, lack of government collaboration etc. However, in this study which we have conducted after careful analysis of 131 project reports a lot has been revealed. National Highway Project the most common and recurring 10 causative factor has been identified as responsible for cost and time over run these causative factors are Design, Planning and Scheduling Related (DPSR), Financial Constraint Related (FCR), Social Problem Related (SPR), Technical Reasons (TR), Administrative Reasons (AR), Scope Increase (SI), Specifications Change (SC), CER-Cost Escalation Related (CER), Non Availability of Equipment or Materials (NAEM), Force Majeure(FM).The regression techniques have been used to formulate a regression model for cost and time overrun.

The causative factor pertaining to Design, Planning and Scheduling Related (DPSR) may be referred as any variation encountered due to change in design or creation idea of a plan for the completion of a construction project such as change in architectural blueprints, engineering design drawings that may lead to cost and time overruns. Similarly any departure from plan and schedule to implement a design also hamper the implementation of project within targeted milestones. The Financial Constraints Related (FCR) reasons are usually comprised of issues pertaining to imbalance cash flows faced during the different stages of a project lifecycle which affect the amount of anticipated cost and planned timelines of the project. The factors of Social Problem Related (SPR) issues arise due to social vision and behavior of people associated with the project either in the design/feasibility stage or during the execution of the project. Such issues have an imperative impact on the time and cost of the project. The Technical Reasons (TR) usually concerns with the technical glitches being faced in the life cycle of project involving the technical parameters of design that need to be changed as per factual position and site requirement. Such issues are known to affect time-plan work and cost estimation of the project and usually extend it. The Administrative Reasons (AR)relate to the issues which cause cost & time overruns due to staff behavior, local and international laws, national policies and tendencies, working environment, work ethics & attitude of the people deployed for governing the project as the issues have vital effects on the planned timelines and targets. The Scope Increase (SI) relates to the issues that happen due to utilization of any item or items worked out during execution on factual requirement in contrary to the planning/estimation phase requirement of these item(s) worked out in construction feasibility or estimate. This factor may change the cost-time framework of the project significantly. Specification change (SC) pertains to the matters of changes in designed specification due to site requirement or requirement to change the specs as a result of obsolete material/equipment or aesthetic aspects of the project as per desire of client. These changes cause to suffer the work schedule and cost of the project. The Cost Escalation Related (CER) factor deals with cost increase due to inflation, and escalation of cost & their claims etc. Any delay to address such phenomena may alter the cost anticipated and schedule programmed for the completion of the project. The Non Availability of Equipment or Materials (NAEM) handles the variation in cost-time spectrum of the project due to miscalculation of availability of resources, incapability to arrange the required equipment or materials, difference in planned and actual work conditions etc. The Force Majeure (FM) factors concerns cost-time schedule variation where arise due to any natural disaster such as earthquake, flood etc. social or political turmoil/disorder that may cease the project activities and disengages the project resources from it. In such situation the binding parties are set free from their obligation and raise the cost-time overruns of a project.

II. METHODOLOGY

The construction of a highway project involves several technicalities one of which is that the risk factor may be determined in a linear manner dependent on certain variables. In order to develop an economic model for cost & time overrun, the study has been carried out in 02 stages. In the first stage the causative agents for cost and time overruns have been sorted out. The first phase involves the identification of various factors causing cost overrun and delay. This was done through the study of National Highway Authority report on each project. These factors have been identified based on common reasons affecting cost & time overruns. In the second phase, critical factors have been grouped in 10 faculties which were initially identified in the first phase. This was done by studying project reports of each project in the first phase and each factor was based on the effect and causing the

delay of the project.

The factors pointed out in the second phase have been molded into a Linear Step-to-Step Multiple Regression model in which the dependent variable is calculated through these variable i.e. cost and time overruns.(Table I, Fig. 1).

TABLE I
DEPICTING COST OVER-RUNS IN 82 NOS. (62%) PROJECTS OUT OF 131 NHA ROAD CONSTRUCTION PROJECTS UNDER STUDY

Sr. No.	Description	Nos. of Projects	%age of Projects
1	Projects Completed Over and above scheduled or budgeted cost	82	62.6
2	Projects Completed within scheduled or budgeted cost	39	29.8
3	Projects Completed below the scheduled or budgeted cost	10	7.6

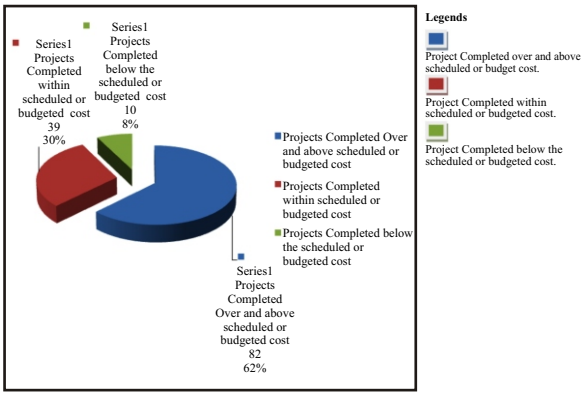

Fig. 1. Depicting Cost Over-runs in 82 nos. (62%) projects out of 131 NHA Road Construction Projects under study

Incorporation of Linear Multiple Regression with the independent factors viz. Design, Planning and Scheduling Related (DPSR), Financial Constraint Related (FCR), Social Problem Related (SPR), Technical Reasons (TR), Administrative Reasons (AR), Scope Increase (SI), Specifications Change (SC), CER-Cost Escalation Related reasons (CER), Non Availability of Equipment or Materials (NAEM), Force Majeure (FM) and putting dummy variable (explanatory or indicative variable) as regression value one and has been inserted for projects which suffer cost/time overruns and a few project which does not observe cost/time overruns. The underlying role of the summary of the regression with coefficients for the regression model is shown in the following Table II.

TABLE II
DESCRIPTIVE STATISTICS PROJECT COMPLETION PERIOD OVER-RUNS % AGE WISE *(PCPORPW)*

Mean *PCPORPW*	130.7118
Standard Error	10.52287
Median	100
Mode	0
Standard Deviation	120.4397
Sample Variance	14505.72
Kurtosis	5.200724
Skewness	1.80347
Range	700
Minimum *PCPORPW*	0
Maximum *PCPORPW*	700
Sum *PCPORPW*	17123.24
Count of Projects	131
Largest (1) *PCPORPW*	700
Smallest (1) *PCPORPW*	0

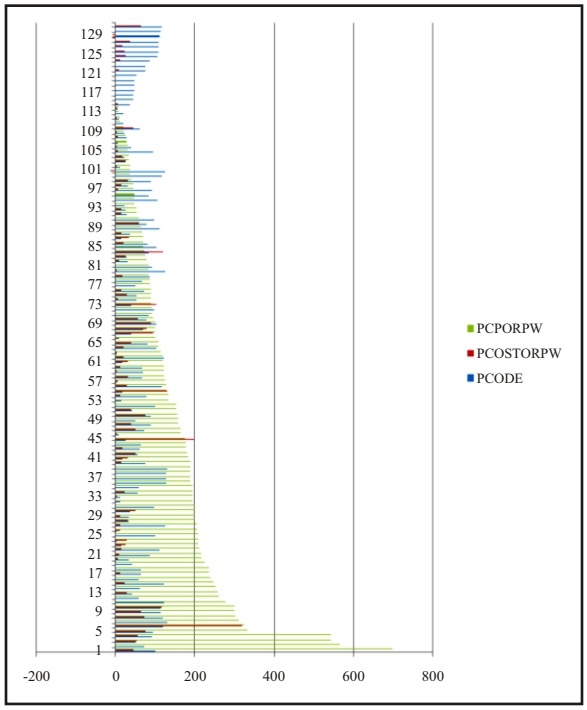

Fig. 2. Cost and Time Over-Runs in 131 NHA Projects

Where
PCPORPW= Project Completion Period Verrun Percentage wise
PCOSTORPW = Project Cost Overrun
PCODE= Project Code

III. Data Collection and Analysis

All it represents whether the cost/time overrun occurs or otherwise, the data related to highway projects have been assembled and analyzed in this work. The details related to highway projects have been gained from only National Highway Authority source has been accumulated and analyzed in this work an. However, the result of this work could also be applied to other infrastructure projects in Pakistan. Therefore, in its present context, the findings should only be applied to highway infrastructure projects in Pakistan. It may be noted that some of the research project data is related to socio/geographical condition and contracting climates that may have varied from time to time during the analysis period.

The Study of the analysis of cost and time overruns factors holds an important value for the betterment of the present system and can be used as a helpful tool to diagnose trouble spots in construction activities and to pinpoint areas in highway construction projects where the greatest improvement can be obtained by taking care of such dependent variables (Fig. 2).

General Form of Multiple Regression Model Equation

$$Y=\beta_0 +\beta_1X_1 +\beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10} + \epsilon$$

Where, Y is the value of the Dependent variable i.e. predicted Project Cost Overrun Percentage wise (PCORPW) and X_1- X_{10} are independent variables that is the variance in explaining Y;

y	=	β_0	+	β_1X_1	+	β_2X_2
Predicted PCORPW	=	-6.898	+	0.186*DPSR	+	0.199*FCR

+	β_3X_3	+	β_4X_4	+	β_5X_5
+	0.100*SPR	+	0.165*TR	+	0.248*AR

+	β_6X_6	+	β_7X_7	+	β8x8	+
+	0.136*SI/C	+	0.105*SC	+	0.012 *CER	+

β_9X_9	+	$\beta_{10}X_{10}$	+	ϵ
0.079*NAEM	+	0.188*FM		

B_1-β_{10} are the Slopes (Beta coefficient) for X_1-X_{10} the independent variables those are explaining the Variance in Y i.e. Predicted Time overrun Percentage wise (PTORPW).

Whereas, β_0 (Beta) is the Constant or intercept, β_1 is the Slope (Beta coefficient) for X_1= DPSR- Design, Planning and Scheduling related Problems, β_2 is the Slope (Beta coefficient) for X_2=FCR- Financial Constraints related Problems, β_3 is the Slope (Beta coefficient) for X_3=SPR- Social Problems related Factors, β4 is the Slope (Beta coefficient) for X_4=TR- Technical Factors, β_5 is the Slope (Beta coefficient) for X_5=AR- Administrative Factors, β_6 is the Slope (Beta coefficient) for X_6=SI_D- Scope increase or change factors, β_7 is the Slope (Beta coefficient) for X_7=SC- Specifications change factors, β_8 is the Slope (Beta coefficient) for X_8=CER- Cost Escalation related factors, β_9 is the Slope (Beta coefficient) for X_9=NAEM - Non availability of materials or equipment related factors and β_{10} is the Slope (Beta coefficient) for X_{10}= FM - Force majeure related factors.

Similarly

Y is the Dependent variable, i.e Predicted value of Project Time over Runs percentage wise (PTORPW)

Y	=	β_0	+	β_1X_1	+	β_2X_2
Predicted PCORPW	=	0.414	+	0.205*DPSR	+	0.190*FCR

+	β_3X_3	+	β_4X_4	+	β_5X_5
+	0.167*SPR	+	0.172*TR	+	0.219*AR

+	β_6X_6	+	β_7X_7	+	β_8X_8
+	0.235*SI/C	+	0.214*SC	+	0.049*CER

+	β_9X_9	+	$\beta_{10}X_{10}$	+	ϵ
+	0.122*NAEM	+	0.101*FM		

IV. Result

The analysis of actual data of 131 road construction projects shows delay and cost overruns are significant and in 82 projects and there is a road construction project for the state holders responsible for construction of road related projects. The delay and cost overruns play a vital role in the determination of the success rate of such projects. It is imperative to identify and address the construction features making the project run over and above the planned cost and competition responsible for such overrun in cost and time are also required to and make accountable.

The dependent construction features of delay and cost overrun now been used in the regression development research for cost over runs and time over runs separately and the independent values have been captured in term of percentage cost and time over run. In order to develop economic model liner regression has been carried out by using Microsoft Excel software

and for carrying out comparison between the predicted and the actual values of percentage cost and time over run.

The predicted values worked out by the help of regression models and hence it is concluded that the proposed cost overrun and time overrun models are accurate with a probability of 95%.This accuracy level of prediction obtained in the form of project cost and duration in the form of equations are the same as actually worked out in the monitoring reports and through the use of models.

V. Conclusions

The time and cost run over are very critical features for determination of success of project. The economic models developed may play a major role in the prediction of likelihood of cost over runs and delays in road construction projects. The developed economic model shall support decision makers to keep an eye while undertaking such endeavors and it shall also be beneficial for contractors and other stake holder for making corrective measures to avert cost and time over runs in construction project on various stages in the life of a project.

As a result of this work following conclusions are made.

1. The first accomplishment was the identification of construction factors responsible for cost run-over and delays in construction projects. The purpose has been achieved by detailed literature review and study of monitoring reports of 131 mega road construction projects.
2. The second achievement of this research was to evaluate the impact of identified causative factors on the schedule delay and cost over runs on road related construction projects. Among the ten identified causative factors, the factors of Administrative Reason (AR), Design, Planning and Scheduling Related (DPSR), Technical Reasons (TR) and Force Majeure (FM) were the most significant factor causing cost and time overruns. The Cost Escalation Related (CER) reasons have been found to have the least amount of impact on cost increase and delays.
3. In the third achievement, causes were ranked according to the ability to impact and it was observed that factors of Administrative Reason (AR), Design, Planning and Scheduling Related (DPSR), Technical Reasons (TR) and Force Majeure (FM) were the most significant factors in cost and time overruns. It was also noted that Cost Escalation Related (CER) had the least impact on cost increase and delays and had maximum contribution to cost over-run.
4. In the fourth achievement cost and time over-runs models have been made by using regression techniques. This was done by inputting causative factors as dependent variables and to develop independent variables i.e. cost and time over-run, model equations respectively.
5. In the fifth achievement, the results obtained through use of these equations have been compared with the real values for verification and perfection of the models.

The models developed by use of MS Excel software as a result of this research, can be utilized by the decision makers for minimizing cost and time over-runs in the road construction projects effectively.

VI. Novelty

There are very few organizations present in Pakistan which have developed organized data of road construction related projects. This data can actually be used or analyzed. Despite deploying our best efforts, the credible data showing details required to analyze cost and time over-runs factors could not be fetched from all the public organizations including MOP other than NHA. Therefore, the case studies selected were from the organization NHA only. However, the findings of the research are equally beneficial for other R & D organizations of Pakistan.

VII. Future Research Guidelines

The proper knowledge of management and its practical implementation in an organization and its fruitful effects can be determined and associated with R&D performance by observing the factors underlined in this work. The R&D performance of the first phase can be measured through knowledge management and then by its results. A data of this work can be stored for historical picture and prove to be a foundation stone for future advancement in this research. All grand organization in Pakistan must benefit from the knowledge and implementation of management techniques.

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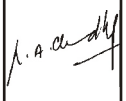
2	Muhammad Abbas Choudhary Department of Electrical Engg. NAML Univ., Mianwali, Pakistan	Proposed topic, Design of studies, related to paper, Verification of statistical analysis and interpretation of results etc.	
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Section D

COMPUTER/SOFTWARE/ TELECOMMUNICATION/ COMPUTER SCIENCE

Video Analytics Framework for Automated Parking

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***Abstract*-**In this research work we proposed secure parking framework based on video analytics for human activity recognition and user interaction through smartphone application. We used machine learning algorithms for human activity recognition using smart camera. Algorithms were used to process the parking lot video to extract meanings form human activities while mobile phone application was used to communicate with the user. Image registration algorithm marked incoming and leaving vehicles to keep track of available parking bins. Activities happening in the parking area e.g. human-vehicle interaction, human-human interaction, parking, entering and exiting the parking lot were recognized using support vector machine classification on space time features representation of the scene. In order to train and test the activity identification algorithm we used real world video dataset VIRAT (1.0). Video analytics algorithms were embedded into smart camera hardware. Video backup was maintained at backend surveillance server.

***Keywords*-**Smart Camera, Video Analytics, Vehicle Surveillance, Human Activity Analysis

I. INTRODUCTION

Security and surveillance of parking lot is common requirement in urbanized areas. Various automated solutions have been proposed and installed in parking lots. These parking lot management solutions are based on motion sensors, acoustic sensors, passive infrared sensors and radar sensors technology [i]. Video surveillance cameras are installed to monitor these parking lots. Human operators keep watch on parking lot through video surveillance console and look for activities happening in the parking lot. This paper presents framework based on video analytics in smart camera and mobile phone application for security and surveillance of vehicles in parking lots as shown in Fig. 1.

The video processing system proposed in this research consist of smart cameras, mobile phone applications and videos surveillance servers. A smart camera has its own processing unit built into the camera module to perform video analysis. Furthermore these cameras have communication capabilities to interact with video server as well. The processor in smart camera can be programmed on different algorithms for analysis of visual data. A video server stores the video archive and the human activity models as back end repository. Smart cameras are major advancement in camera technology. Vision based parking management is most convenient choice for parking management as we usually have video surveillance infrastructure in almost every urbanized parking facility. In contrast with mounted sensor array based systems video based system is more flexible and easy to scale. It can be modified to fit in various geometrical configurations and environmental conditions [ii]. Although, advantages of using video sensing are evident there are some inherent challenges attached to use of cameras. Changing lighting conditions, inclement weather, fog, shadows, vehicle projection and contrast are a few of

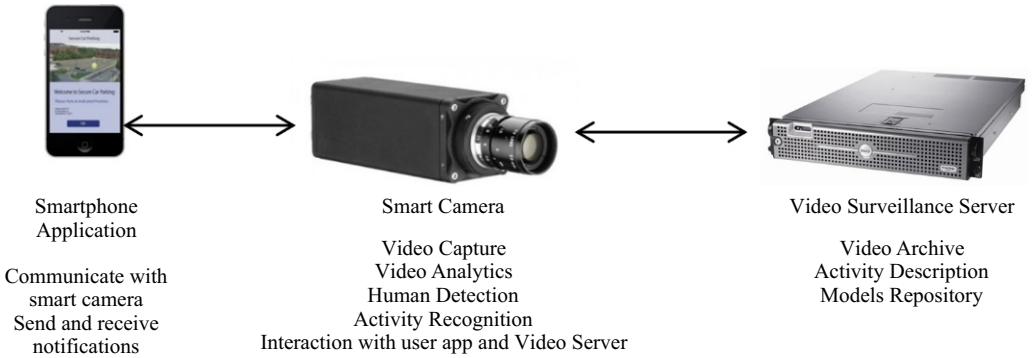

Fig. 1. System diagram of the proposed framework with details of modules

many challenges that can affect the performance of detection process. Camera motions under strong winds can also affect the performance. The geometry of the parking area can also pose a challenging effect (Fig. 2) and cause occlusion leading to misclassification of events.

Fig. 2. Examples realistic parking scenes from VIRAT dataset reference [xx] depicting light variations, shadow and projection variations.

Upon arrival at parking lot the incoming vehicle is monitored and registered to the vehicle database. The smart camera sends notification to the user smart phone app indicating the nearest available parking bin (Fig. 3).

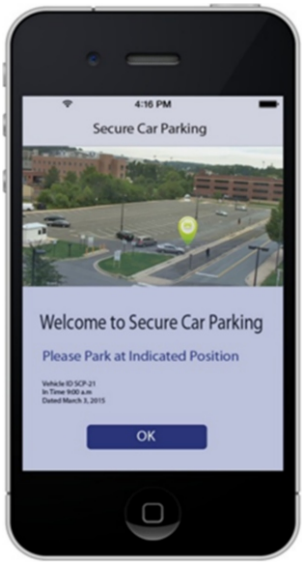

Fig. 3. Smartphone app indicating first available parking bin for driver of the vehicle.

This research work presents a novel approach for parking lot management using video analytics for human action and interaction. This work applies region localization feature extraction mechanism in order to simplify the future processing. For activity detection, BoW representation of STIP descriptors has been used in SVM based multi classifier. This mechanism is less complex and requires minimal classifier training. This method works directly on presented features and generates activity classes. For evaluation of proposed techniques we used VIART large scale activity dataset. VIRAT data set contains videos depicting real world environmental constraints the nature of activities in these videos makes this data set extremely challenging. For validation of obtained results "leave one out cross validation" scheme was used and classification accuracy up to 91% was achieved. In next section we have mentioned some work related to incorporation of video analytics for parking lot management.

II. Literature Review

Video analytics for activity recognition is the process of automatically identifying the activities of interest in a video segment. By definition high-level or complex events are long-term object interactions that happen under certain spatially and temporally dynamic settings in a scene. Usually complex activities are categorized into two classes instructional and social activities [iii]. The former includes procedural videos (e.g., "parking a vehicle", "changing a vehicle tire", "opening a vehicle trunk"), while the later includes social activities (e.g., "birthday party", "conversation").

One class of methods makes use of motion trajectories to represent actions based of target tracking as in [iv] and [v]. Another type of approaches uses background subtraction to obtain a sequence body contours to model actions [vi]. In more recent times action recognition is carried out using local spatio-temporal features which are computed over the detected spatio-temporal interest points (STIPs). These features were used to characterize the video sequence and the classification was carried out using a bag-of-word (BoW) approach [vii]. Methods for motion segmentation were also used before local feature based methods [iii].

A. Visual Feature Representation

Features are the backbone of visual content analysis. A good feature presentation is supposed to be robust against light and scale variations. This makes possible the recognition of same class of video possible under different conditions. We have two vital sources of information that can be utilized in this process. First one is visual appearance information; this is about the objects present in the scene and scene settings. The second one is the motion information pertaining to the mobility of the objects and camera.

Feature representations like scale invariant features transform (SIFT) and histogram of oriented gradient (HOG) are known as 2D feature representation schemes. They are easy to compute and have low computational complexity [viii]. These features have proven remarkably successful in presenting distinguishable visual discriminations in videos.

Their accuracy further improves in the videos in which we do not have rapid inter frame transitions [iii]. Parking lot videos are perfectly suitable to be categorized as this type of videos thus the HOG feature extractors are excellent choice as feature descriptors. For videos with rapid inter frame transition it is required to pick selective frames out of overall video sequence if not all frames are to be used. An optimal key frame selection criterion is yet to be discovered. It is usually the practice in research to pick key frames uniformly [iv]. Since these features include no temporal information they are unable to provide any motion information which was a very important requirement in video analysis. These lead scientists to device a spatio-temporal feature representation like [ix]. The work of [v] presented the use of local and global reference points to model the motion of dense trajectories, this lead to a comprehensive representation of location and motion. This representation proved to be a more robust, and also was able to infer the relationships among moving objects

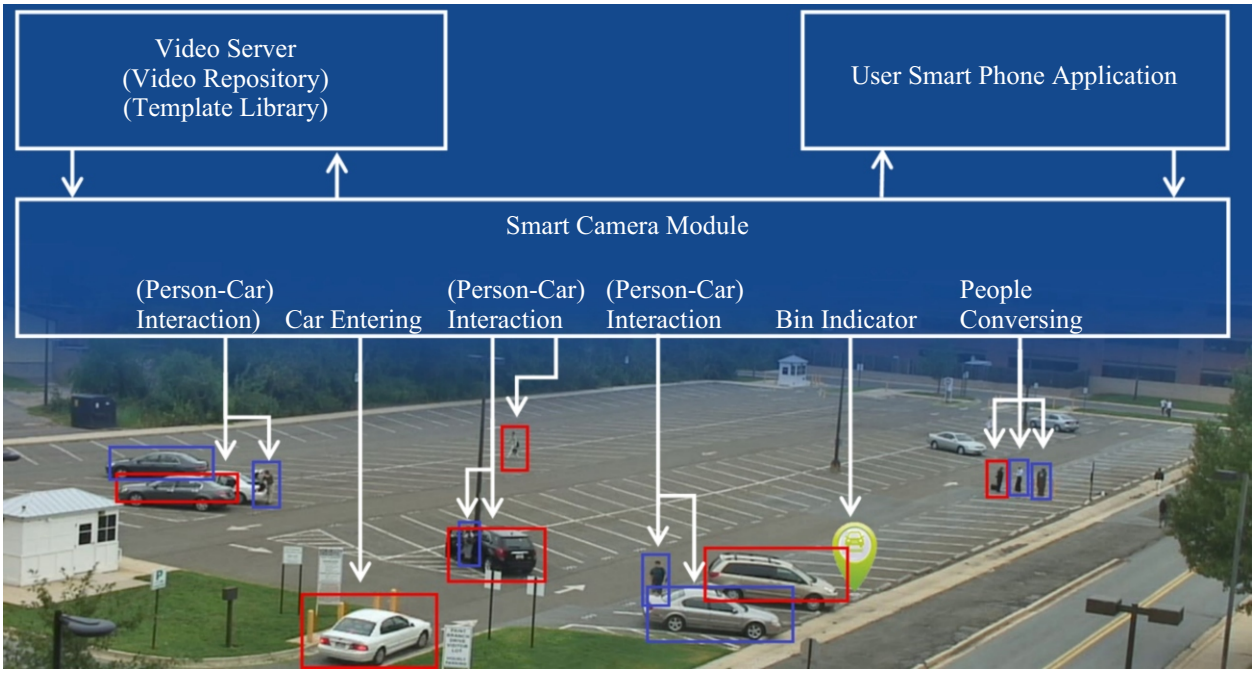

Fig. 4. The proposed activity recognition framework in process. Smart camera registers parking lot and sends captured videos to surveillance server. Smart phone app receives notification from smart camera. Human activities are analyzed in smart camera processing unit.

B. Activity Recognition methods

Once the scene is represented using features activity recognition process can start. There are various classifiers people have used in order to identify activities in videos. Activity classification is a typical machine learning process. A collection of training videos were used for model training and test videos for model verification. There were direct classification methods as well but their ability to classify highly structured activities was limited. Process of understanding deep semantic structure present in complex activities requires more structured approach [x]. For example the event "changing a vehicle tire", consists of semantically base level categories like as "holding a tire", "person using wrench" and "person jacking car". A bag of words representation breakdowns information into a feature vector direct classification carried out over this does not explain this semantic structure. This lead the researchers to the discovery of more efficient semantic analyzer for complex activity classifier. These models were successfully applied for the recognition of complex activity recognition. Reference [xi] proposed the usage of syntactic context free grammar SCFG based scene representation approach for complex event recognition. This approach was used in integration with a real time activity monitoring system to demonstrate its usefulness. In a similar manner, [xii] came up with the use of CFG, to represent an event as time based processes consisting of poses, gestures, and sub-events. A slight modification of this idea was used by [xiii]. They attempted to detect events happening in parking lot using attribute grammar posing additional conditions upon existing production rules

III. Materials and Methods

As depicted in Fig. 4 the proposed video analytics infrastructure used smart camera for video processing. The input video frames were processed every time

there was a change in visual information in the scene. The object detection algorithms were used to detect the objects of interest and marked the areas in video for further processing. The activity recognition algorithms were used to process the given regions to identify types of activities found (Fig. 5). Following is the detailed discussion on algorithmic approach used in this paper.

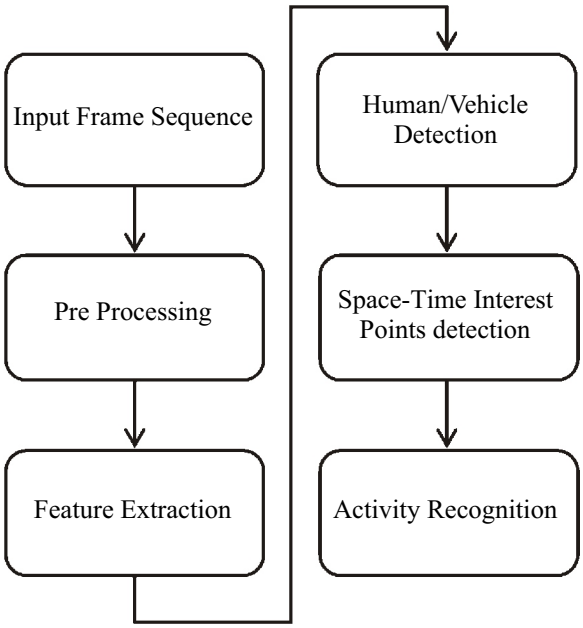

Fig. 5. Process diagram of the activity recognition method

A. Foreground Segmentation

In order to acquire foreground presentation of the object background subtraction approach was used. As the system used current frame ***I*** and subtract background frame ***B*** from it then pixel by pixel threshold is used to determine a pixel's being background or foreground as in Eq.(1).

$$| I_t(x,y) - B_t(x,y) | > T \quad (1)$$

The threshold ***T*** is predefined threshold value. The result of background subtraction is a binary map that shows presence of foreground objects in terms of region blobs (Fig. 6). There were some noisy areas in the image which could lead to false representation of foreground in terms of small blobs. A sizing filter was used to eliminate the blobs of sized too small than estimated object size. Since the background is also prone to change with respect to visual appearance it was updated dynamically using the method mentioned in Eq.(2).

$$B_{t+1} = \alpha I_t + (1-\alpha) B_t \quad (2)$$

This first order running average adaptive filter [xiv] used for background estimation with value of $\alpha=0.05$ as the learning rate. Every moving object was marked by a bounding box defining the boundary of the object. These bounding boxes were then used for feature extraction in subsequent steps.

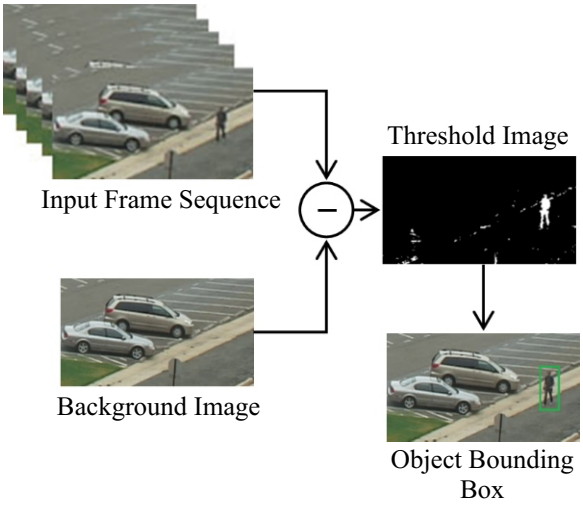

Fig. 6. Foreground extraction and area of interest localization

B. Feature Extraction

In order to have a clear human form we used a slight modification of the feature descriptor presented by [xv]. Combining edge orientation histograms and SIFT techniques into more robust descriptor as [vi] propose. We evaluated the object appearance and shape using local intensity gradient distributions, (Fig. 7). To represent the scene using histogram of oriented gradients (HOG) we resized the original bounding box to 128x64 pixels size as shown in Fig. 7. Then resized image was divided into 128 cells each having 8x8 pixels. A histogram of gradient direction was computed for each cell. With a gradient direction of -90o to 90o each histogram was quantified into 9 bins. To reduce the effect of illumination variation on the image we carried out the local contrast normalization.

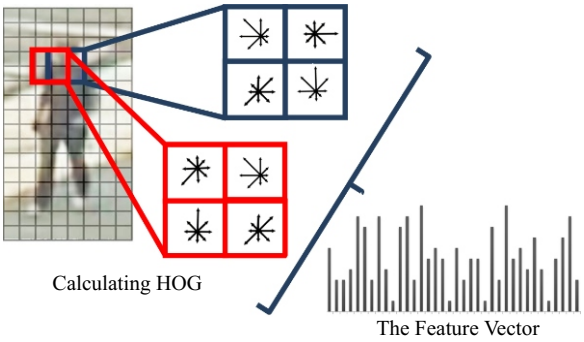

Fig. 7. Histogram of Oriented Gradients and Feature Vector Extraction

Local contrast normalization was achieved by

grouping the cells into overlapping blocks. This left us with a single block of 2x2 cells and any two neighboring blocks have 2 cells in common due to overlapping arrangement. A feature vector 36 elements was constructed using histogram of each block. The content is represented by a feature vector of dimensions 36x105.

C. Vehicle vsHuman Classification

Using the feature vectors obtained in the previous segment an SVM was employed to determine whether the moving object was human or a vehicle. SVM classification was chosen because of its properties to generalize well even in higher dimensional space and it required less training samples. We used to go through the SVMs for a two-class classification problem on similar lines as mentioned in [xvi]. Given a training set $S=\{(x_1,y_1),\ldots,(x_n,y_n)\}$ where feature vector $x_i \in R^d$ and label $y_i \in \{1, -1\}$ the goal of SVM was to construct a hyperplane to maximize the margin while minimize a the misclassification error. The optimal separating hyperplane $w^*.x+b^*=0$ was found under the following constraints as given in Eq.(3):

$$\min_{w,b,\xi} \frac{1}{2} w.w + C \sum_{i=1}^{n} \xi i \qquad (3)$$

Subject to $yi(w.xi + b) \geq 1 - \xi i,\ \xi i \geq 0, i = 1, \ldots, n \geq 0, i = 1, \ldots, n.$ where C refers to the penalty parameter that was used to control the tradeoff between the margin and the misclassification errors $\xi = (\xi 1, \xi 2, \ldots, \xi 3)$. This became a quadratic programming problem which was solved by Lagrange multipliers. Given the decision function $f(x) = w*.x + b$ the Eq.(4) gave the posterior class probability as given below:

$$P(y = 1|x) \approx \frac{1}{1 + exp\,(Af(x) + B)} \qquad (4)$$

Most appropriate setting of parameters (A,B) was obtained from the training data as reported by [xvii]. Once the humans and vehicles were segmented out in a video frame activity recognition methods were used to identify the ongoing activities as discussed in following section.

D. Parking Lot Activity recognition

In order to recognize human activity in the parking area we used the similar approach as one mentioned in [xviii]. We calculated a bag of features representation from previous section. The spatio-temporal interest point descriptor STIP [xix] was used for bag of words (BoW) collection(Fig. 8). This Bow representation was used in two class SVM in order to classify an activity. As given in Eq.(5) two-class SVM, the decision function for a feature vector **x** of a test video had the following form as given by Eq. 5.

$$f(\mathbf{x}) = \sum_i \alpha_i y_i K(\mathbf{x_i}, \mathbf{x}) - b \qquad (5)$$

$K(\mathbf{x_i}, \mathbf{x})$ was the output of the Gaussian kernel function for the features of ith training video $\mathbf{x_i}$ and its test sample $\mathbf{x}$; y_i was the event class label of $\mathbf{x_i}$; α_i was the learned weight of the training sample $\mathbf{x_i}$; and b was a threshold parameter. For the feature descriptors presented in (BoW) manner, it has been learned that χ^2 Gaussian kernel is more suitable defined as below

$$K(\mathbf{x}, \mathbf{y}) = e^{-\rho d_{\chi^2}(\mathbf{x},\mathbf{y})} \qquad (6)$$

$$d_{\chi^2}(\mathbf{x}, \mathbf{y}) = \sum_j \frac{(x_j - y_j)^2}{(x_j + y_j)} \qquad (7)$$

In Eq.(7) $d_{\chi^2}(\mathbf{x},\mathbf{y})$ was the distance between samples **x** and **y**. The performance of SVM classification was subject to a few parameters, ρ is the most important of them found in the kernel function. Data distribution itself gave a hint for proper parameter selection. Cross-validation mechanism was used to evaluate the range of parameters to choose the best one

IV. Results

To test and validate our proposed method for activity recognition, experiments were performed on VIRAT benchmark dataset [xx]. VIRAT is used for large scale event detection: In our experiments we used the Release 1.0 of the dataset which was publish in the CVPR'11 activity recognition challenge as well. It has 128 videos released as test videos where total 6

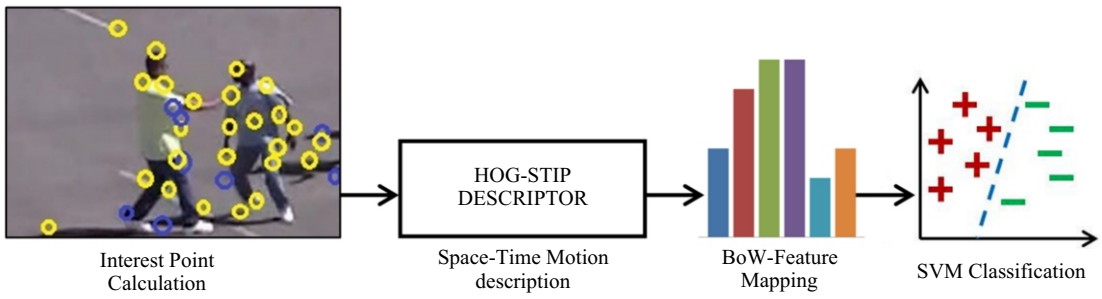

Fig. 8. Interest point calculation and activity classification using SVM

different scenes are present, three same scenes like in training set with three additional scenes Fig. 3. These videos were captured at 1080px720p by fixed mount high definition camera. Size of human shape found in this data set ranged 20-220 pixels; this made 222% of the heights of video screen with average being about 9%. Results of human detection algorithm are given in Table I, along with performance comparison of proposed human detection with state of the art methods [xxi] and [xxii] is given in Table II. The proposed activity recognition model was trained and tested for seven different types of human activities on VIRAT 1.0 data set videos. Later on these trained models were tested using parking lot videos from smart camera as well. The results of activity recognition process are given in Table III.

TABLE I
RESULTS OF PROPOSED HUMAN DETECTION ALGORITHM IN DIFFERENT TEST VIDEOS

	Video Description	Number of Humans Present	Humans detected	Missed Detections	False Detection
1.	Indoor parking video	130	123	7	12
2.	Outdoor parking	210	199	11	19
3.	Corridor	160	151	9	14
4.	Bus Stop video	250	239	11	8
5.	Street surveillance video	300	288	19	18

TABLE II
PERFORMANCE COMPARISON OF HUMAN DETECTION METHODS ON PARKING LOT VIDEOS

	Video Content Description	Proposed Method	(Montabone and Soto, [xxi])	(Khan and Saeed, [xxii])
1.	People walking by	82.5%	80.6%	77.8%
2.	Group of people standing	80.1%	79.0%	75.5%
3.	Person entering vehicle	79.3%	77.2%	76.8%
4.	Person leaving vehicle	81.5%	78.7%	77.9%

TABLE III
RESULTS OF ACTIVITY RECOGNITION ALGORITHM ON PARKING LOT VIDEOS

	Activity Description	Activities Present	Activities Detected	% Accuracy
1.	Vehicle entering parking area	80	73	91.3
2.	Vehicle leaving parking area	80	72	90.0
3.	Person entering vehicle	75	65	86.7
4.	Person leaving vehicle	75	67	89.3
5.	Person loading into vehicle	33	25	75.8
6.	Person opening trunk	26	19	73.1
7.	Person-person interaction in parking area	45	37	82.2

A user opinion survey was conducted to gauge the usefulness of the proposed solution. A person participating in this survey had to own a car and a smart phone with internet connectivity with our application installed. A group of parking lot users comprising 250 persons from different age groups took part in this survey. After a period of one month of usage of our parking lot management there were over 6000 interactions with the smartphone application. At completion of one month of usage the participant were asked a variety of questions regarding their experience with the system. The survey questionnaire comprised of questions about user interface, ease of access and utility of the proposed system. The outcome of user survey is shown in Fig.9.

V. CONCLUSION

Based on test results and user opinion survey findings it is concluded that video analytics and mobile phone based parking lot management system offered reliable parking solution. This framework is capable of providing seamless automated parking facility which is appreciated by vehicle owners as well as parking security staff. The proposed system automated the existing parking management system by keeping all the in/out information and parking status of vehicles. In the meanwhile it helped to facilitate the parking

security department by automatically identifying the human activities in the area. This system also saves a considerable number of vehicle miles inside parking lot area by efficiently allocating the parking place for incoming vehicle thus eventually contribute to lower fuel consumption. User behavior identification for parking patterns in large scale parking lot videos would be an interesting future extension of this work.

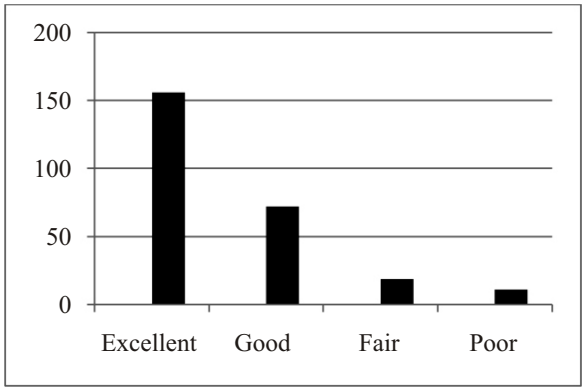

Fig. 9. Results of user survey on utility of the proposed system

VI. Acknowledgments

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Authorship and Contribution Declaration			
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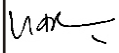
2	Dr. Hafiz Adnan Habib Bravo (2nd Author)	Proposed topic, Critical Review, Revision of results, methodology and quality insurer	

Software-based Internet Traffic Classification and Prioritization to Improve Network Performance in Multimedia Broadband Networks

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***Abstract*-**Rapid development in multimedia broadband applications in the last decade has led towards higher bandwidth demand, which has resulted in quality of service issues for business critical applications. Researchers have suggested internet traffic classification and prioritization as a solution to the problem but still the complexity of available solutions is a fertile research area. In this paper, traffic classification and prioritization was performed using FreeBSD (v8.1) operating system for a small and medium enterprise network, the system and network performance results are presented for optimum performance conditions. Though researchers have worked on open source systems for traffic classification but the computation of impact of classification on system and network performance, and to suggest optimum performance conditions is still a fertile research area. The implementation is done by using FreeBSD (v8.1) IP Firewall (IPFW), pipes and queues, on an Intel 3.0 GHz machine and the results are presented for critique review and discussion. The key challenges faced and open issues are also discussed for future research.

***Keywords*-**IP Firewall (IPFW), Deep Packet Inspection (DPI), Internet Service Provider (ISPs), Serial Line Internet Protocol (SLIP), Quality of Service (QoS)

I. INTRODUCTION

Network congestion is among the key challenges faced by different Internet Service Providers (ISPs), aggravated further by inefficient utilization of link capacity and peer to peer applications that eat up the entire bandwidth. Present solutions are based on rate limiting different users by classifying internet traffic via their application and usage patterns. An intrusion detection system [i-ii] also works on the principle of Internet traffic classification and it is used to prevent DDoS (Distributed Denial of Service) attacks. The pre-requisite for Internet traffic classification is packet inspection. However strict privacy policies and heavy network load coupled with high processing and infrastructure requirement for deep packet inspection have made it difficult to implement. The researchers have responded to this difficulty by working out different methods of internet traffic classification, which are based on statistical characteristics of different traffic flows without performing deep packet inspection. There are number of packet scanning applications which are implemented across different networks and they are capable of doing packet inspections like SNORT [i], Bro [ii] and Linux L-7 (Layer-7) filter. SNORT and Bro are two mostly used Intrusion detection systems, whereas Layer-7 filter is an application for application layer protocol analysis, which makes packet classification based on application layer data. Traffic classification helps to ensure network security, to filter malicious traffic flows and to offer billing solutions as per application requirement. It is one of the key requirements for Internet Service Providers (ISPs) to perform usage based billing by deploying an efficient but low cost solution which not only allocates available bandwidth based on nature of application but also ensures Quality of Service (QoS) for business critical applications [iii].

We conducted analysis of internet traffic of Pakistan Largest multimedia and broadband service provider (Pakistan Telecommunication Company Limited) with over 1.5 Million broadband customers across Pakistan, and the traffic was studied for the period June 2014 to December 2014 at PTCL core aggregation sites in Lahore and Islamabad and the analysis shows that 20% of the available bandwidth was consumed by Peer to Peer (P2P) applications; the top applications which consumed major part of overall bandwidth are shown in Table I. These P2P applications create network congestion and for optimum utilization of network bandwidth all such applications need fair sharing of available bandwidth. For these reasons researchers are working on different traffic classification techniques; which can help to classify network traffic into different traffic flows and to allocate bandwidth as per nature and priority of the

Application.

TABLE I
BROADBAND TRAFFIC CLASSIFICATION BASED ON TYPE OF PROTOCOL

Protocol type	% Bandwidth Utilization
Bit Torrent UTP	20.10%
Other TCP Protocol	11.70%
Bit Torrent	10.00%
UDP	8.90%
Bit Torrent Encrypted	7.00%
Flash Video	6.50%

The rest of the paper is organized as follows: Section-II covers literature review in this area; Section-III covers the methodology and approach. Section-IV covers implementation and system design, Section-V covers results and comparison analysis, Section-VI concludes the paper with discussion on key results achieved and future scope of work.

II. LITERATURE REVIEW

A detailed survey work has been done by Nguyen and Armitage [iv] that covers detailed work up to 2008. Most of the researchers have suggested internet traffic classification by using Machine Learning Algorithms. W. Li & A. W. Moore suggested machine learning approach based on Naive Bayes & C4.5 decision tree [v-vi] algorithms, which accurately classify the internet traffic by collecting different features at the start of internet traffic flow. Zander, Sebastian, Thuy Nguyen & Grenville Armitage [vii] used machine learning for dynamic identification of different internet traffic using their statistical characteristics. Nguyen, Thuy TT, Grenville Armitage, Philip Branch, and Sebastian Zander [viii] also used machine learning technique to analyze interactive IP traffic. In Internet traffic the P2P applications consumes most of the bandwidth and Sen, Subhabrata, Oliver Spatscheck & Dongmei Wang [ix] worked on identification of P2P traffic using application level signatures and designed online filters that were able to track P2P traffic with accuracy and robustness. But, W. Jiang & M. Gokhale [x] suggested that computation complexity of internet traffic classification using statistical approaches based on machine learning [xi] could be high, and due to the their complexity, it is not practical for the Internet Service Providers (ISPs) to deploy them in their networks. W. Jiang & M. Gokhale [x] implemented Locality Sensitive Hashing (LSH) on FPGAs for real time traffic classification and Z. Li, R. Yuan & X. Guan [xii] used pattern recognition methods for traffic classifications. The researchers also worked on some other techniques for internet traffic classification like Moore, Andrew W, and Denis Zuev [v] used Bayesian analysis techniques for Internet traffic classification and they achieved 90% accuracy on training data of different applications.

Most recent researches cover detailed working to avoid network congestion and bandwidth optimization that may not be available to different applications due to DDoS attack [xiii] or due to poor management of available bandwidth. Johnson & Christopher L [xiv] described key requirements for effective bandwidth management and implemented bandwidth management by executing the limits from socket layer to protocol layer for each application. In order to guarantee agreed service levels to business customers there are systems available to handle required content delivery and to handle differentiated business services [xv] and to ensure that agreed service levels are delivered to business customers without any major impact on their services. To handle differentiated services a plethora of different techniques including buffer management, packet scheduling etc have been worked out by different researchers and they have concluded over the time that traffic classification is the key feature of all QoS enabled architectures [iii], which are implemented by different multimedia and broadband service providers. Carbone, Marta, and Luigi Rizzo [xvi] studied detailed features of dummy net link emulator when operated under different operating systems and suggested the required operating conditions to run an emulator for the desired accuracy of results. Nussbaum, Lucas, and Olivier Richard [xvii] did comparative analysis of link emulators, but all such emulators were not tested for real time live environment where internet traffic and packet queuing is performed. But it is different from our work, in that authors have not computed the impact of traffic classification and prioritization on system performance. In this paper, we are trying to contribute in terms of evaluation of system and network performance and suggesting optimum operating conditions while optimizing the available bandwidth.

III. RESEARCH METHODOLOGY & APPROACH

In FreeBSD, packets were read through ethernet interface and packet inspection was carried by using 4-tuple packet characteristics; i.e *source IP, source port, destination IP, and destination port.* The implementation block diagram is shown in Fig.1 and the detailed working of each block has been described as under

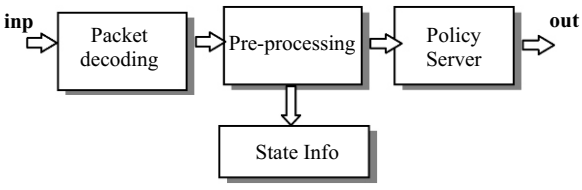

Fig.1. Implementation block diagram

A. Packet Decoding and Preprocessing

In FreeBSD operating system, IPFW (IP firewall) is user interface for controlling firewall; whereas the packets entered (depending on source and destination address) the firewall from different places in the protocol stack. The traffic which was passing through the firewall was compared against all the rules in the rule set according to the configured rule-number, order permitted and in the order of insertion of the packet. Once the match was found then the packet was treated according to the matching rule.

The incoming packets were read by **ether_demux()** function and afterwards the traffic was passed to **ether_input()** function for packet processing [xviii] to upper layers as shown in Fig. 2. The mapping of different OSI layers for **network code** in FreeBSD [xviii] is shown in Fig. 3 which shows how the traffic was captured from physical layer till the application layer process was invoked to handle the traffic. In this paper, we used the simplistic approach with lesser computations to capture and to identify the traffic and thus minimizing load on network resources.

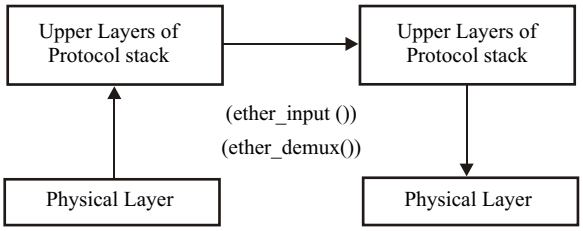

Fig. 2 Packet flow from physical layer to application layer

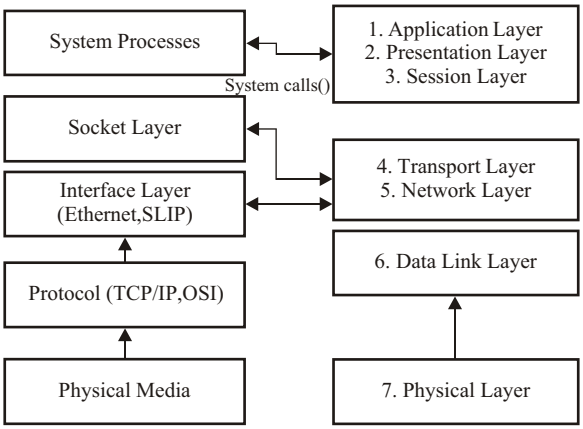

Fig. 3 FreeBSD-Network Code Mapping with OSI Layers

A. Traffic Policing

After the identification of different applications, they were passed from two objects i.e. pipe and a queue to rate limit and prioritize as per available bandwidth. The objects which were configured were pipes; the pipe control the link with certain delay and bandwidth, and traffic was further passed to the scheduler; afterwards the packets were passed to the queue with configured queue size and loss rate. As packets arrived out of ipfw, they were transmitted over the configured outgoing link. The traffic flow diagram from different pipes has been shown in Fig.4. The key variables for a pipe are

queue size
link bandwidth
network end to end delay

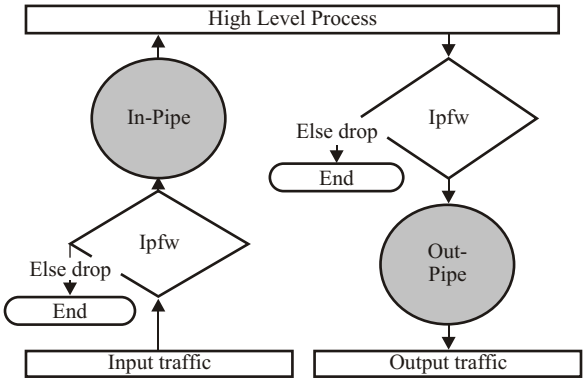

Fig. 4. Flow Diagram for In & Out traffic

IV. Implementation & System Design

The implementation network topology is shown in Fig. 5. The FreeBSD server has two network interfaces **fxp0** and **fxp1**. The **fxp0** was connecting inter network devices whereas **fxp1** was connected to the public internet. Internet traffic classification and prioritization has been done through FreeBSD server which was working as a policy server for internet traffic.

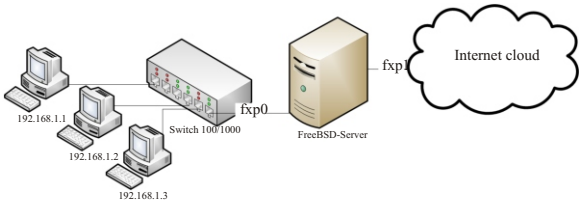

Fig. 5 Network Topology

Following options were enabled in FreeBSD kernel configuration to enable dummynet.

IPFIREWALL ; to enable IP firewall
IPFIREWALL_VERBOSE; to enable firewall output
IPFIREWALL_VERBOSE_LIMIT; to limit firewall Output
DUMMYNET ; to enable dummynet operation
HZ ; to set the timer granularity

In order to enable firewall rules, following were added to ***/etc/rc.conf*** file, the code is mentioned in below Fig. 6.

```
# vi /etc/rc.conf
firewall_enable= "YES"
firewall_loggin= "YES"
firewall_script= "/usr/local/etc/ipfw.rules"
#ipfw.rules will contain the complete listing of
rules
; After saving the basic firewall configuration the
firewall services are started as under
# service ipfw start
```

Fig. 6. Code to enable firewall

A. Reading Input Traffic

The data at each interface ("**fxp0"** in our case) was being held at ***ifnet*** structures, which were connected in a linked list form and following were some of the key ifnet functions [xix] which were used to handle the internet traffic.

```
if_init          ; To initialize the interface (fxp0)
if_start         ; To initiate transmission of packets
if_output        ; To queue outgoing packets
if_ioctl         ; To Interface ioctl function
```

All incoming packets were read and handled by following functions

a) ether_input() & ether_demux () ; to read input traffic and to add or remove headers
b) ipntr- Interrupt to identify nature of application as per defined priority

B. Pipe Configuration

In order to measure results, we configured pipe no 10 & 11 for the client machine **192.168.1.1**. We configured following output rate and input rate for client machine 192.168.1.1.

(1) pipe no. 10 was configured for maxim output rate of 2500 Kbps with delay of 5 ms.
(2) pipe no. 11 was configured for maximum input rate of 512 Kbps with delay of 15 ms.

The configuration steps and code for client machine 192.168.1.1 has been mentioned in below Fig. 7.

```
# cd /etc
# vi ipfw.ruleset
ipfw add 00005 allow all from any to any via
fxp0
; allowing all traffic to inner network interface
# Output pipe 10 and input pipe 11 were
configured for outgoing and incoming traffic for
host 192.168.1.1
ipfw add 110 pipe 10 out 192.168.1.1
ipfw add 220 pipe 11 in 192.168.1.1
# client 192.168.1.1 was restricted to output rate
of 2.5Mbps and input rate of 0.5Mbps
ipfw pipe 10 config bw 2500Kbit/s delay 5ms
ipfw pipe 11 config bw 512Kbit/s delay 15ms
# save and exit file
:wq!
```

Fig.7. pipe configuration code for client 192.168.1.1

C. Network Applications and Prioritization

We implemented UDP traffic priority over TCP traffic using wf2q+ (Worst case weighted fair queuing). The results were measured by originating the test traffic from these machines. The prioritized traffic passed through the Interface "fxp0", which was acting as a gateway for all the applications. The traffic prioritization code is shown in Fig.8.

```
# vi ipfw.ruleset
ipfw add 00017 sched 10 config type wf2q+
ipfw queue 5 config weight 20 sched 10
ipfw queue 6 config weight 10 sched 10
ipfw add 00018 queue 5 out proto udp
ipfw add 00019 queue 6 out proto tcp
# save and exit file
:wq!
```

Fig.8. Priority configuration for tcp and udp traffic

TCP and UDP test traffic was generated at 200 kilo packets per second (packet size as 64 bytes) from client 192.168.1.1 towards yahoo server (IP 76.13.28.70) and we used Wireshark (v.1.10.2) to capture internet traffic [xx-xxi], the Timestamp sent and its echo reply time moving average was used to measure RTT. The results are shown in Table IV.

V. Results & Performance Analysis

In order to measure the results, TCP and UDP traffic was generated traffic from client machine 192.168.1.1; the system performance, i.e. CPU and memory utilization was measured by using vmstat. The packet sizes were kept 64 bytes and 256 bytes whereas the packet rate was varied from 10 Kilo packets per second to 400 Kilo packets per second. The results achieved are shown in Table II and Table III. The results show that when traffic classification was performed, the system utilization remained upto 50% but as we go above 500 kilo packets per seconds, the system utilization increased substantially, i.e. reaching upto 75%. The CPU utilization at different packet rates is shown in Fig. 9.

TABLE II
CPU Load of Core 0 Depending on Packet Rate, Packet Size and Sampling Rate

Packet Rate (kilo packets/s)	Core 0 CPU Load (%age) with 64 bytes packet size	Core 0 CPU Load (%age) with 256 bytes packet size
10	5	6
100	14	17
200	26	28
300	36	37
400	42	48

TABLE III
MEMORY UTILIZATION DEPENDING ON PACKET RATE, PACKET SIZE AND SAMPLING RATE

Packet Rate (kilo packets/s)	Memory Utilization (%age) with 64 bytes packet size	Memory Utilization (%age) with 256 bytes packet size
10	5	7
100	15	19
200	23	29
300	37	39
400	44	54

Looking at the CPU utilization, 500 kilo packets per second is the maximum supported packet rate while working under current system conditions. Similarly, the memory utilization also increased as packet size was increased and it is shown in Fig.10. It was observed that memory utilization was slightly higher as compared to the CPU utilization due to queuing implementation effect. The system performance results show that FreeBSD (v8.1) dummynet can be a good candidate to be part of multi-service traffic classification system but its major limitation is to filter out encrypted traffic with maximum packet rate of 500 packets per seconds. The results measurements were taken on an Intel 3.0 GHz machine with 4 GB RAM and in order to analyze queuing impact, the traffic priority was implemented for TCP and UDP traffic.

The bandwidth throttling and optimization results for client 192.168.1.1 are shown in Fig.11 and Fig.12, the client 192.168.1.1 traffic was passed through configured pipe number 10 and 11. The traffic usage of client 192.168.1.1 was captured and is shown in Fig.11 and Fig.12. In Fig.11 and Fig.12, the X-axis is representing time (hours) and Y-axis is representing the download rate in bits per seconds (download rate). The Fig. 8 shows that the download rate of client 192.168.1.1 was reaching to 4Mbps and such peer to peer high download rate would impact other customer's experience.

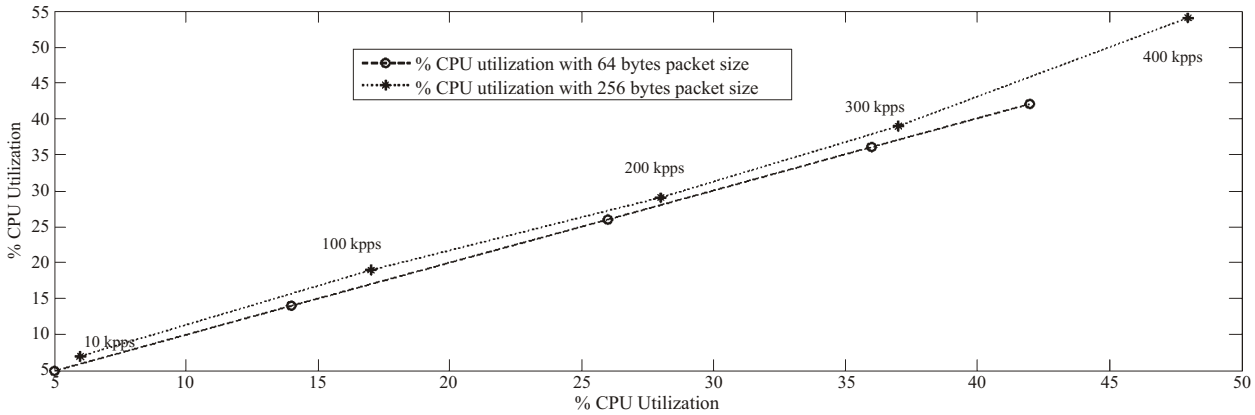

Fig. 9. CPU (Core 0) Utilization for packet size of 64 bytes and 256 bytes

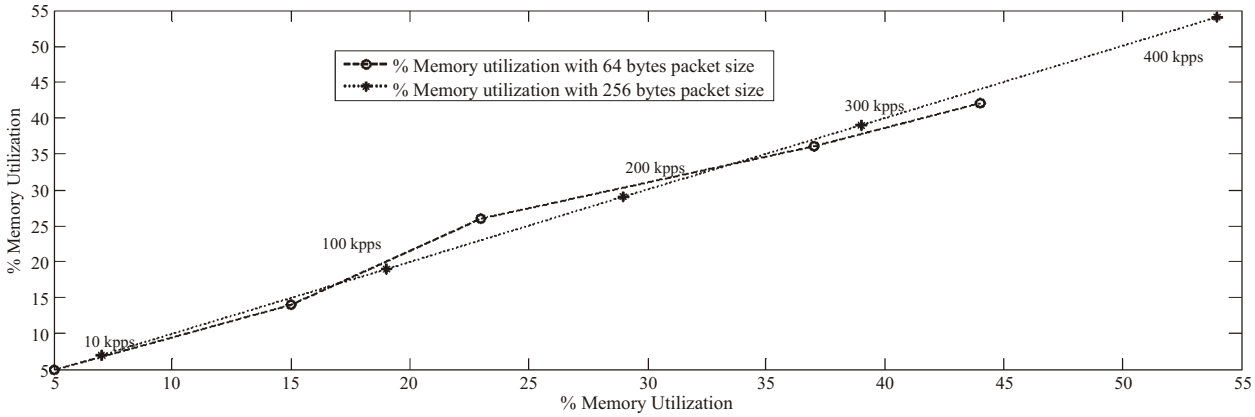

Fig. 10. Memory Utilization for packet size of 64 bytes and 256 bytes

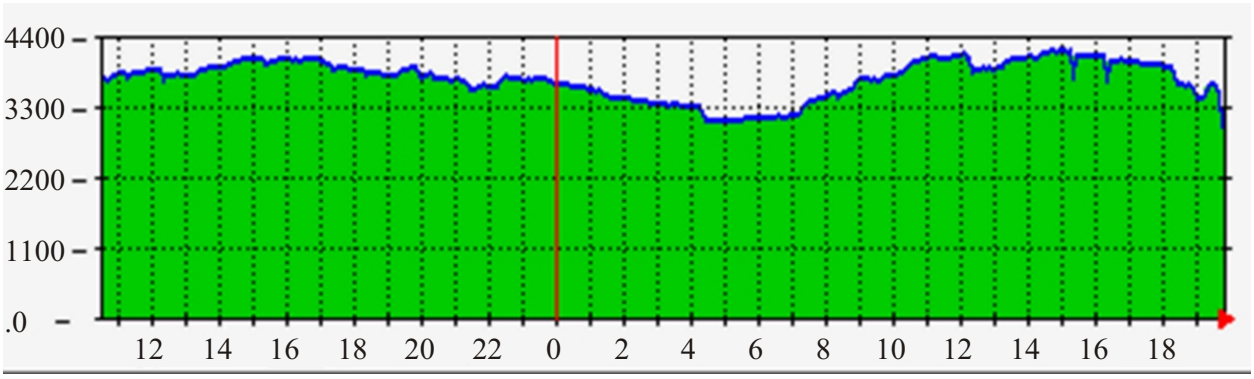

Fig. 11. Traffic pattern before applying rate limitation

The Fig.12 shows total traffic of client 192.168.1.1 during different hours of the day and it shows that whenever the traffic of client 192.168.1.1 tried to exceed 2500Kbps, it was rate limited to 2500Kbps for uniform allocation of available bandwidth. Thus bandwidth allocation was made uniform for all the clients. To test the traffic prioritization, TCP and UDP traffic was prioritized and their results are shown in Table IV. The results were quite encouraging with 10% higher throughput with 1% lesser packet loss was achieved for UDP traffic in comparison to TCPtraffic.

TABLE IV
TRAFFIC PRIORITY IMPLEMENTATION

Application	TCP	UDP
Throughput (%age)	80	90
Packet Loss (%age)	3	2
Kpps (Kilo Packets per Seconds)	**200**	**200**

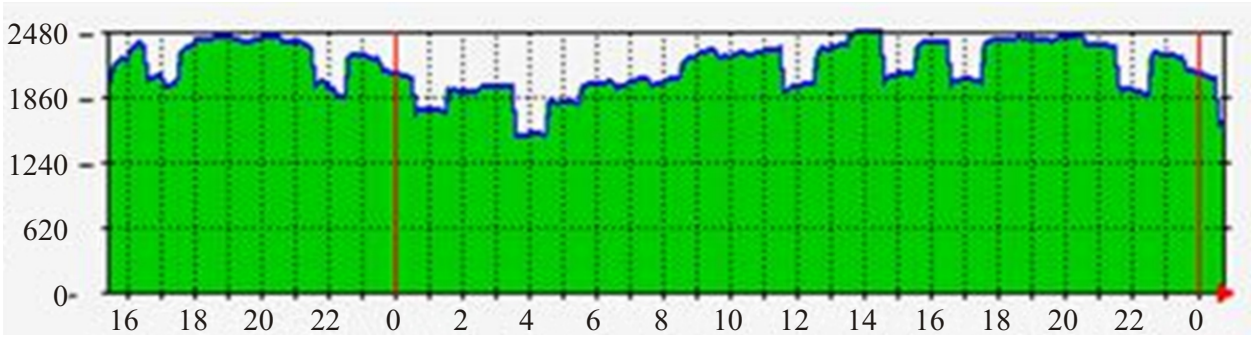

Fig. 12. Traffic pattern after applying rate limitation

VI. CONCLUSIONS

In this paper we have presented an overview of system and network performance while implementing network bandwidth optimization using FreeBSD (v8.1) operating system. Though deep packet inspection is among the available solutions but for Internet Service Providers; solution complexity, cost, network load (utilization) and legal requirements are major constraints towards DPI (deep packet inspection) implementation. In addition to the default features of FreeBSD (v8.1) operating system, we were able to rate limit, classify and prioritize different network flows as per their nature and priority to ensure Quality of Service (QoS) for business critical applications. We presented different system level measurement results and showed the system behavior by varying packet rate and packet size of different applications. Although FreeBSD (v8.1) is a mature operating system and is used by different mid-sized service providers for the optimization of network bandwidth, but still system and network performance under different set of operating conditions to get optimum results is a fertile research area.

This paper will help researchers to evaluate further FreeBSD operating system for the implementation of network security, which can be an area of further work for the researchers. Moreover, we plan to do extended comparison of our suggested technique against other classifiers.

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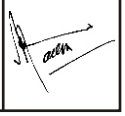
1	Mr. Naveed Akhtar	Proposed topic, basic study Design, Literature review, methodology and manuscript writing	
2	Prof. Dr. Muhammad Kamran	Referencing and quality insurer	

A Security Model for SaaS in Cloud Computing

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***Abstract*-**Cloud computing is a type of computing that relies on *sharing computing resources* rather than having local servers or personal devices to handle applications. It has many service modes like Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS), Infrastructure-as-a-Service (IaaS). In SaaS model, service providers install and activate the applications in cloud and cloud customers access the software from cloud. So, the user doesn't have the need to purchase and install a particular software on his/her machine. While using SaaS model, there are multiple security issues and problems like Data security, Data breaches, Network security, Authentication and authorization, Data integrity, Availability, Web application security and Backup which are faced by users. Many researchers minimize these security problems by putting in hard work. A large work has been done to resolve these problems but there are a lot of issues that persist and need to overcome. In this research work, we have developed a security model that improves the security of data according to the desire of the End-user. The proposed model for different data security options can be helpful to increase the data security through which trade-off between functionalities can be optimized for private and public data.

***Keywords*-**Pay-As-You-Go Model, Cryptography, SaaS Security, Cloud Computing.

I. INTRODUCTION

Internet has been strongly involved in computing world so as to fulfill its modern requirements; it is approaching towards Cloud Computing. A set of different shared networks that use internet technologies to interconnect different networks and also present and deliver distinct computing services and resources to several users, clients, service providers, organizations, academia and business etc., sparing users heavy expenditures is called Cloud Computing.

Cloud Computing architecture provides the services of its miscellaneous associating computing resources and networks to its different users, clients, service providers, organizations, academia and businesses through its service delivery models [i]. There are four deployment models in cloud computing which are Private cloud, Public cloud, Community cloud and Hybrid cloud. There are some service delivery models in cloud computing like Software as a Service (SaaS), Platform as a Service (PaaS), Infrastructure as a Service (IaaS) and Everything as a Service (XaaS).

SaaS is a software deployment model where applications are remotely hosted by the application or the service provider and made accessible to customers on demand, over the Internet. The SaaS model provides the customers sizable benefits, such as ameliorated operational efficiency and decreased costs. SaaS is rapidly rising as the dominant delivery model for fulfilling the necessities of enterprise IT services. However, most enterprises are still disagreeing with the SaaS model due to deficiency of visibility about the way their data is stored and secured [i].

Many researches provide different security models and contribute their efforts to resolve the security issues and problems in SaaS model but there are lots of issues that need to be overcome to improve the security level. These security issues are Data security, Data breaches, Network security, Backup, Authentication and Authorization, Web application security, Availability and Data integrity.

Our study is based on SaaS security issues aiming at Data security in this research. As it is already discussed that the SaaS is floating over PaaS and PaaS on IaaS, so in somehow the security related with SaaS is interconnected with both of underneath layers, eventually more responsible security is the security of SaaS. A high degree of integrated functionality is given by the SaaS model but minimum customer control or extensibility is presented by it. On a lower level the PaaS due to its relatively lower degree of abstraction provides relatively greater customer control and greater extensibility. More power and customer control over security is offered by IaaS, the lowest bed as compared to PaaS or SaaS [ii].

We are going to elaborate a summary of Cloud Computing infrastructure and its associated services, Issues in SaaS model and existing solutions in section 2. And we will also explain our proposed security model for SaaS and block diagrams in section 3.We will discuss a case study which justifies our proposed model with Encryption and Decryption process in section 4. Finally, we will conclude our work in section 5.

II. Literature Review

With the computing characteristics of cloud computing, the server deals with various issues associated with safeguarding of data which is the prime asset of the user. In [vii] M. R Faheem explains the latest issues of cloud computing connected to its services for data solidarity and web browsing etc. On security issues along with data hosting and services provided in Cloud Computing, a comprehensive study has been applied in literature [ix, iii]. The requirements of control on related threats and exposures in cloud computing is taken by generic design principles [iv].

In [v], author admires Cloud computing for its possibilities abstracted hardware, generally personalized, platform-agnostic, cheap and QoS promised etc. Our effort (attempt) of different literature studies moves our attention towards NIST definition.

The National Institute of Standards and Technology (NIST) defines Cloud Computing in its Special Publication 800-145 i.e., "*Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction* [vi]*.*"

A. Cloud Computing Infrastructure

Cloud Computing contains four deployment models and three service models.

Four deployment models are as follow:

Private Cloud

If a cloud is used by organizations that may operate on its own and manage it by itself or by a third party and it may substain exclusive or inclusive of a premise is called private cloud.

Community Cloud

If a cloud is offered to one or more organizations colligated to a specific community that may be owned, operated and managed by the community itself or a third party it may sustain exclusive or inclusive of a premise is called community cloud.

Public Cloud

If a cloud is offered to general public that may be owned operated and managed by an organization, government or a business community or it may subsist in the provider's premise is called public cloud.

Hybrid Cloud

An integrated combination of some separate clouds i. e., two or more Private, Public and/or community clouds colligating for load balancing and efficient data portability.

Three Service Models are as follow:

Software as a Service (SaaS)

In this model cloud provider provides various kinds of Software applications on-line through internet e.g., different software, online running applications, e-mail applications, web browsing applications etc., are provided to clients using them without superseding the lower tier infrastructure.

Platform as a Service (PaaS)

This is lower layer of SaaS in which application deployment capabilities are provided to a provider. The applications developed byprogramming languages, libraries, services etc., can be deployed but control over lower infrastructure is restricted.

Infrastructure as a Service (IaaS)

In this model consumer provides a limited control over lower tier infrastructure like configuration setting, memory management, and network resources etc.

These service delivery models conjointly form a layered architecture as shown in Fig-1. SaaS model is the outer core of the infrastructure which enables applications servicing and it resides on PaaS layer. PaaS model is the central core of the infrastructure which enables deployments services of applications and it dwells on IaaS layer. IaaS model is the lower bed of the infrastructure which consists of the services of system, networks and hardware resources.

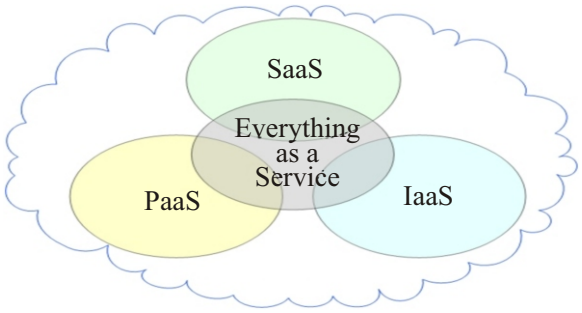

Fig. 1. Service Delivery Model of Cloud Computing

B. Security Issues of SaaS

An analysis of efforts of different authors on some security matters of Cloud Computing as vulnerabilities, warnings, procedures, security standards, data security, certainty, security requirements and SaaS, PaaS, IaaS security are issued by Hashizume et al. In [ix] our study is based on SaaS security issues aiming at Data security in this research. As it is already discussed that the SaaS is floating over PaaS and PaaS on IaaS, so in some regard the security related with SaaS is interconnected with both of underneath layers, eventually more responsible security is the security of SaaS. A high degree of integrated functionality is given by the SaaS model but minimum customer control or extensibility is presented by it. Beneath it the PaaS due to relatively

lower degree of abstraction provides relatively greater customer control and greater extensibility. Greater power or customer control over security is offered by IaaS the lowest bed as compared to PaaS or SaaS [ii].

Data is the key feature to be kept secure for almost all the users, either solitary or from an organization's platform. The user is dependent to its cloud provider in SaaS in regard of security concerns because user's data is stored in data center at provider's proximity. Certainly, other user's data is also stored there. So, there is a probability of mixing of irrelevant data with enterprise data if a SaaS provider is related with a Public Cloud Service. In addition the cloud provider might replicate the data in case to obtain high availability and rapid access of data at multiple locations on the globe. So un-awareness of placements of user's data causes the lack of control that involves an un-guaranteed situation in the SaaS model [viii].

This case may create another problem that if a user wants to remove his data, he does not know where it is stored and while trying a removal action, it is removed from all the locations where it was duplicated by provider at time of storing. Software applications and databases are moved by cloud computing services to enlarge data centers where the dependability of management services is not aspiring. This activity generates many security problems and issues [x]. The privacy of a user data from other users is the responsibility of the provider In the SaaS model.

By definition, for the cloud customer, new software applications are substituted with old ones periodically or sporadically. So for accomplishment of a successful data migration, the protection or enhancement of the security functionality (along with portability of applications) issued by the legacy application must be concentrated by the provider.

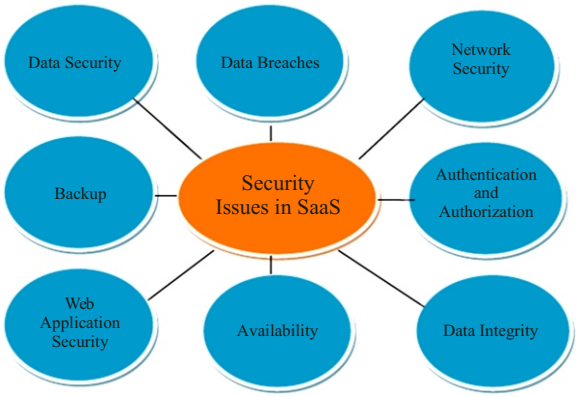

Fig. 2. Security Issues in SaaS

III. Related Work

In [xi] Prashant Srivastava, et al., proposed a structural design that works as a proactive model to handle the progressively more security problems in cloud computing. Their proactive methodology creates a detailed cloud policy and according to this policy, client identifies the suitable service provider which satisfies the client's security requirements. Security is continuously monitored by the security cloud. Inform security measures are taken by the client when there is any violation in cloud security policy

In [xii] Eman M. Mohamed, et al., introduced Enhanced Data Security Model for Cloud Computing which is divided into three layers. The first layer authenticates the user by using OTP (One-Time-Password) technique. The second layer performs encryption on user's data, and protects the user's privacy by using one symmetric encryption algorithms. Also allow protection from user. Finally, they implemented this software in the Amazon EC2 Micro instance and obtained positive results.

In [xiii] Steven Y. KO, et al., proposed a Hybr Ex (Hybrid Execution) model for securing data privacy in cloud computing. This model uses partitioning of data and computation as a way to provide confidentiality and privacy of data. Also they discuss how this model is one specific execution requirement, Map Reduce over Big table.

In [xiv] H. Raj, et al., present a resource isolation technique which enables the deployment of VMs (Virtual Machines) with isolation enhanced SLAs (Service Level Agreement). They propose to deploy many of such VMs in the ownership of different independent SPs (Service Providers) under the decisions of the RM (Resource Manager) of the CIP (cloud Infrastructure Provider). They claim about Security of data during processing.

TABLE I
Proposed Model vs Previous Model

Attribute	Proposed Technique	Previous Technique
Cypher length	Moderate	Bigger
Effective	More Effective	Less Affective
Complexity	Less complex	More Complex
Memory	Takes Shorter memory	More memory Required
Processing	Takes less processing	Takes more processing
Cypher	ASCII, Binary and Decimal	Usually Binary

IV. Proposed Model

In SaaS, organizational data is often processed in plain text and is stored in data center of the cloud. The main responsibility of security of the data falls on the shoulders of SaaS provider while storing data in the data center and its management as well. Our approach

to secure data is based upon making responsible both parties i.e, the user and the provider. We believe due to this approach high security of private and enterprise data will be achieved. There are three different levels of security that are available in this model. These security levels are named as level-1, level-2 and level-3. Client has the data of different nature so client's data can be secure with different level of security based on the desire of client. Level-1 is lowest and level-3 is highest security level.

In level-1, client simply authenticates by password and stores the data on the behalf of service provider's security technique. In level-2, client encrypts data by using algorithm-1 technique. In level-3, client secures his/her most private data by using algorithm-2 method and then sends to service provider.

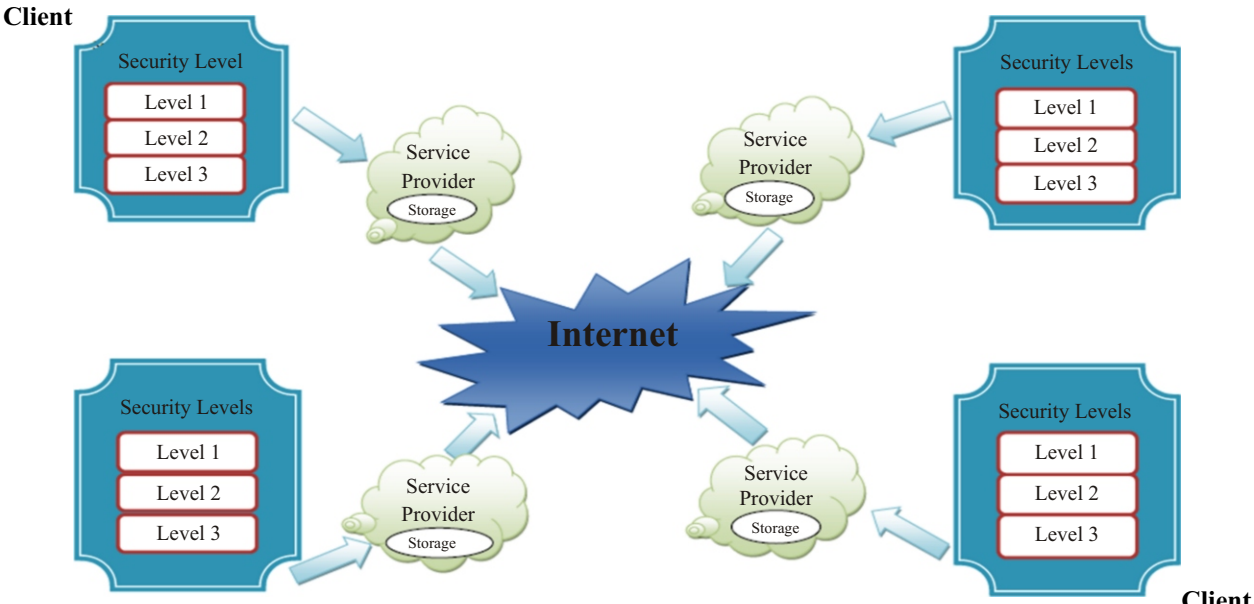

Fig. 3. Proposed Data Security Model

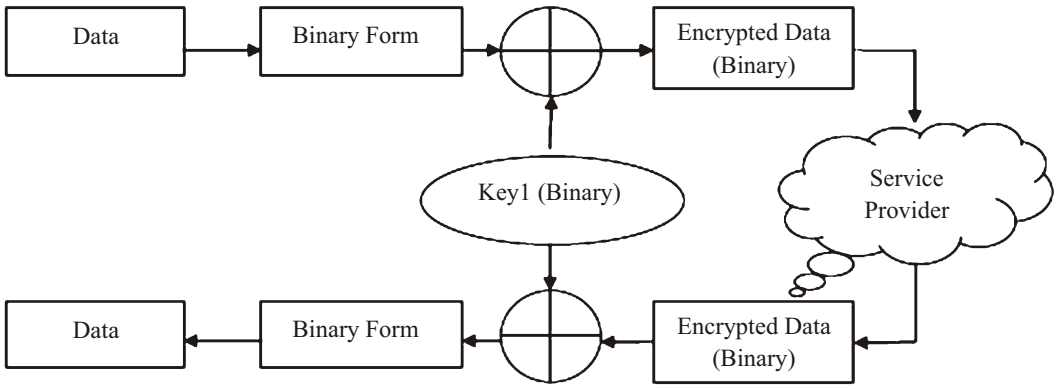

Fig. 4. Block Diagram of security level-2

Level-2 (Encryption)

Step 1. "Convert data into Binary form by using ASCII values."

For letter "H" its ASCII value is "72" and Binary form of "72" is "01001000"

Step 2. "Select the binary key"

It can be any 4-digit binary key which repeats two times while performing operation on 8-digit binary value. Here, binary key is "1010".

Level-2 (Decryption)

Step 1. "Select the binary key"

Key is same which is used for encryption that is "1010".

Step 2. "Perform XOR operation on binary data by using selected key"

Binary encrypted data is "11100010" and key is "10101010". After taking XOR operation output value is "01001000".

Step 3. "Perform XOR operation on binary data by using selected key"

Binary converted data is "01001000" and binary key is "10101010". After taking XOR operation output binary data is "11100010".

"11100010" is the output encrypted binary data.

Step 3. "Convert Binary form into original data by using ASCII values."

For binary value "01001000", its ASCII value is "72" which is equal to alphabet "H".

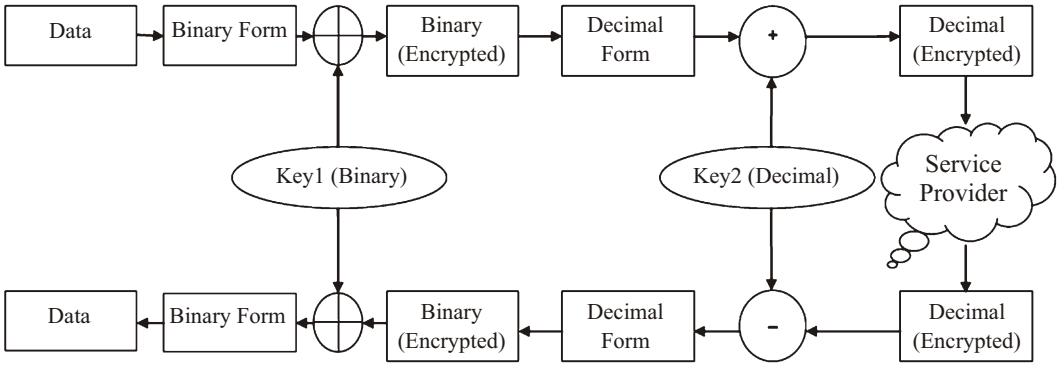

Fig. 5. Block Diagram of level-3 security

Level-3(Encryption)

Step 1. "Convert data into Binary form by using ASCII values."

For letter "H" its ASCII value is "72" and Binary form of "72" is "01001000"

Step 2. "Select the binary key"

It can be any 4-digit binary key which repeats two times while performing operation on 8-digit binary value. Here, binary key is "1010".

Step 3. "Perform XOR operation on binary data by using selected key"

Binary converted data is "01001000" and binary key is "10101010". After taking XOR operation output binary data is "11100010".

"11100010" is the output encrypted binary data.

Step 4. "Convert binary encrypted data into Decimal form"

Decimal form of binary encrypted value **"11100010"** is "226".

Step 5. "Select the decimal key"

It can be any decimal value so here we take "323" as a decimal key.

Step 6. "Perform Addition operation on decimal data by using selected decimal key"

Decimal converted value is "226" and decimal key is "323". After taking addition operation output decimal data is "549".

"549" is the output encrypted decimal data.

Level-3 (Decryption)

Step 1. "Select the decimal key"

Key is same which is used for encryption that is "323".

Step 2. "Perform Subtract operation on decimal data by using selected key"

Decimal encrypted data is "549" and key is "323". After performing subtraction operation output value is "226".

Step 3. "Convert decimal data into binary form"

Binary form of decimal value **"226"** is "**11100010"**.

Step 4. "Select the binary key"

Key is same which is used for encryption that is "1010".

Step 5. "Perform XOR operation on binary data by using selected key"

Binary encrypted data is "11100010" and key is "10101010". After taking XOR operation output value is "01001000".

Step 6. "Convert Binary form into original data by using ASCII values."

For binary value "01001000", its ASCII value is "72" which is equal to alphabet "H".

V. Case Study

In this case study, we perform Encryption and Decryption process for Level-2 and Level-3 security by following algorithm-1 and algorithm-2 respectively and compare the results.

The original Data is "HELLO"

Level-2

(Encryption Process)

"Data = HELLO"

TABLE II
LEVEL-2 ENCRYPTION FOR "HELLO"

Character	ASCII	Binary	Key1	XOR Operation
H	72	1001000	1010	11100010
E	69	1000101	1010	11101111
L	76	1001100	1010	11100110
L	76	1001100	1010	11100110
O	79	1001111	1010	11100101

"Encrypted data = 11100010111011111110011011100110111100101"

(Decryption Process)

"Encrypted data = 11100010111011111110011011100110111100101"

TABLE III
LEVEL-2 DECRYPTION FOR "HELLO"

Encrypted Data	Key1	XOR Operation	ASCII	Data
11100010	1010	1001000	72	H
11101111	1010	1000101	69	E
11100110	1010	1001100	76	L
11100110	1010	1001100	76	L
11100101	1010	1001111	79	O

"Data = HELLO"

Level-3

(Encryption Process)

"Data = HELLO"

TABLE IV:
LEVEL-3 ENCRYPTION FOR "HELLO"

Data	ASCII	Binary	Key 1	XOR	Decimal	Key 2(k2)	(k2+D)
H	72	1001000	1010	11100010	226	323	549
E	69	1000101	1010	11101111	239	323	562
L	76	1001100	1010	11100110	230	323	553
L	76	1001100	1010	11100110	230	323	553
O	79	1001111	1010	11100101	229	323	552

"Encrypted Data = 549562553553552"

(Decryption Process)

"Encrypted Data = 549562553553552"

TABLE V
LEVEL-3 ENCRYPTION FOR "HELLO"

Enc. Data	Key 2(k2)	Decimal	XOR	Key 1	Binary	ASCII	Data
549	323	226	11100010	1010	1001000	72	H
562	323	239	11101111	1010	1000101	69	E
553	323	230	11100110	1010	1001100	76	L
553	323	230	11100110	1010	1001100	76	L
552	323	229	11100101	1010	1001111	79	O

"**Data = HELLO"**

VI. RESULTS

Here, we discuss the favorable factors of proposed model as compare to previous security models as we mention in Table I.

Effective: There are number of security models which are used to encrypt data but the techniques used by these models require lot of processing, memory and also complex algorithms. The proposed technique also performs cryptography but it requires less processing, less memory and easy steps to perform encryption. Therefore, the proposed security model is more effective as compare to previous security models.

Complexity: In this proposed model, each level (2, 3) uses only two keys to encrypt the plain text. These keys use binary and decimal languages which are easy to understand for machine as well as human. Due to these simple and effective keys the proposed technique is less complex as compare to previous security models.

Memory: The level-3 converts the binary data which is the result after binary key encryption into decimal digits. The decimal digits need less memory for storage as compare to other languages which is used in old security models. Therefore the encrypted data of proposed model consumes less memory as compare to previous models.

Processing: The proposed model only performs XOR operation on binary and decimal data for data encryption. XOR operation is the basic operation which is easy to process for machine. So, the proposed technique requires less processing as compare to previous models.

VII. CONCLUSION

Although cloud computing is a versatile environment of heterogeneous and distributed networks which provides services to several customers and enterprises to share heterogeneous networks, resources and software online using internet technologies. In this work we have concluded that numerous threats of security and vulnerabilities have been arisen with the development and advancement in such a complex, huge meshed, word-wide distributed infrastructure. Till now many researchers have contributed to secure the users from these issues by providing different techniques, encryption and signatures etc., but complexities increases due to the tradeoff between different issues and functionalities inherited in this domain. In this paper, we proposed a security model which has three different levels and each level has its own algorithm. Client has data of different types so client can secure data according to required security level.

In our Future Work we are focusing to work for a flexible model of services which can offer an optimum situation for the availability of encrypted data i.e., lower-level of trade-off between security functionality and availability.

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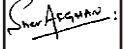
	Author-s Full Name	**Contribution to Paper**	
1	Mr./Dr./Prof. Alpha (Rizwan Abbas)	Proposed topic, basic study Design, methodology and manuscript writing	
2	Mr./Dr./Prof. Bravo (Dr. Amjad Farooq)	Data Collection, statistical analysis and interpretation of results etc.	
3	Mr./Dr./Prof. Charlie (Sher Afghan)	Literature review & Referencing and quality insurer	

A Survey of Recommender Systems and Their Application in Healthcare

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***Abstract*-**The technology advancement in E-commerce have flooded enormous amount of data in the cyberspace. There exist a dire need of proposing effective solutions to filter all the relevant data among the huge pool of disorganized data for users to select the most suitable item among the available items collection. Recommender Systems facilitates the users in selection of items, products or information of users' interest from a large amount of data available on the cyberspace. Recommender systems uses data mining techniques along with prediction algorithms to accomplish the task of providing recommendations. The proposed research work presents a comprehensive survey on existing state-of-the-art recommender systems. This paper presents the classification of recommender systems among content-based, collaborative, demographic, knowledge-based, and hybrid techniques. The proposed work focuses on providing a comprehensive overview of the recommender systems in healthcare. We have proposed a hybrid recommender system for healthcare. The reported results of our proposed system is also presented. This paper also presents the comparison of the proposed system with existing state-of-the-art.

***Keywords*-**Collaborative filtering, Content based filtering, Demographic, Hybrid recommender system, knowledge-based recommendation,

I. INTRODUCTION

The information available in the cyberspace has increased enormously in last few decades. Different strategies have been developed to assist the selection of information of interest. The recommender systems helped, in providing affordable and quality recommendations, by automating these strategies.

People have to make their choices in daily life like what products to buy, which news to read, which music to listen and which movies to watch etc. Mostly they rely on the suggestions of friends and family. The oldest version of recommender system is "Word-of-mouth" where people ask others to suggest. This method is used by most people when they made a decision e.g. to buy a product. Recommender System is a relatively new area as compared to other information systems. The recommender system was not a separate field, initially, and its roots can easily found in information retrieval and management sciences. It emerged as an independent research area at the end of 19th century and its popularity has dramatically increased in recent years [i-ii].

Recommendation techniques have been used in various domains such as health, entertainment, e-commerce, sports, media etc. This paper provides a comprehensive overview of the recommender systems in healthcare industry. Recommender systems are widely used in health care industry now-days to provide better health services to patient and also facilitate doctors and hospital staff to make decisions. The practice of recommendation techniques in health care demands to consider distinct requirements as compared to other domains like e-commerce. We have developed a hybrid recommender system for healthcare. The reported results of the proposed recommender system is also presented in this survey paper. The statistical comparison of the proposed system with existing state-of-the-art systems is also presented. The proposed survey paper presents a critical analysis of the existing recommender systems specifically in health care. This paper elaborates the usage of recommender systems in health care domain, which mainly focus on providing the most suitable recommendations of doctors and hospitals to patients. The key factors of hospital selection is also investigated. Finally, this survey paper provides useful suggestions that can help in improving the quality of recommender systems in health care industry.

II. DEFINITION OF RECOMMENDER SYSTEM

Recommender system has been defined in many different ways. According to reference [iii] a recommender system is operated by providing recommendations as an input from the user which is aggregated and directed to appropriate recipient. Reference [iv] defines recommender system which can predict the items of user interest based on previous record. Another variant of recommender system presents a subjective nature of recommendations which provide personalized recommendations to various users according to personal interest of any item among the large pool of items collection. The factors of individualization and user interest discriminate the recommender systems from various search engines and information retrieval (IR) systems. [v].

III. Classification of Recommendation Techniques

The recommender systems are usually classified in the following categories such as content-based, collaborative, knowledge-based, demographic-based and hybrid which are based on input and background data as well as the algorithm used to generate the recommendations. The classification of recommendation techniques is depicted in Fig. 1. User is the source of input which feeds the input to the recommender system. The output in the form of various recommendations are provided by the recommender system. The recommendations are provided to the user based on his/her interest for any given domain. The recommender system process all the information available in the form of background data before the start of recommendation process [ii, v].

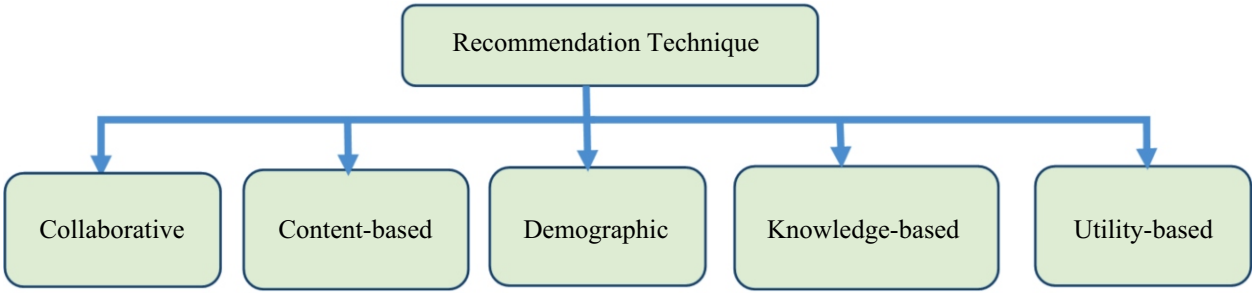

Fig. 1. Classification of Recommendation Techniques

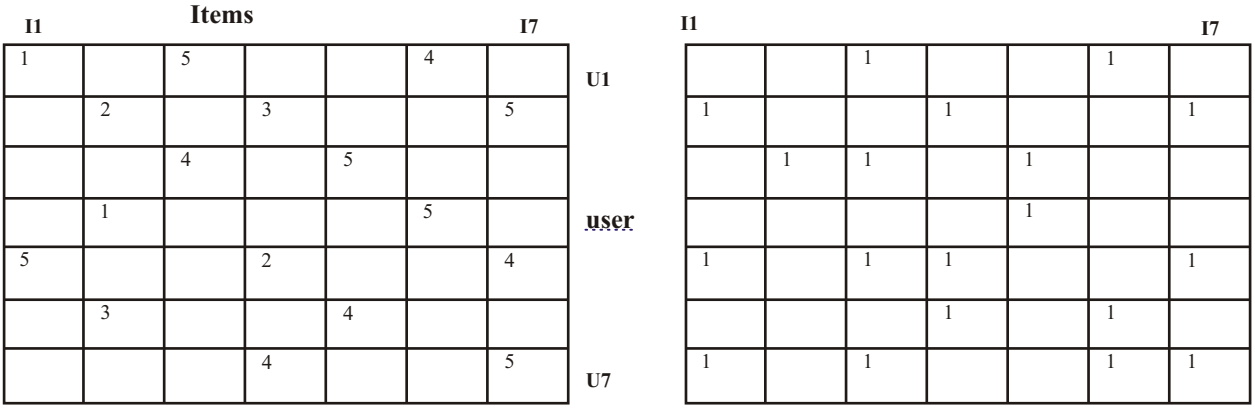

Fig. 2. An examples of user-item matrices for a dataset of seven items and seven users. Values in matrix are explicit user rating (left) or implicit user activity (right) [vii]

A. *Collaborative Recommender Systems*

The term collaborative was first used in tapestry filtering system, which provided assistance to the user to annotate documents. These annotated documents were requested by other users. Collaborative filtering (CF) is probably the most popular class of recommendation algorithms. Although collaborative filtering technique is only a decade old but its roots can be found in something that humans are doing for centuries [vi]. It usually tries to automate the "word-of-mouth" recommendation.

Collaborative filtering uses the information gathered from many users about their interests or preferences, and provide the required predictions regarding any particular user by utilizing this information. CF algorithms mostly require three inputs to make predictions [vii].

i. Active participation of user
ii. Easy way of representing users' interest to system
iii. Algorithms to match people with similar interests

One of the renowned corporation using the collaborative filtering is Amazon. The Amazon website acquires an explicit input from the user to rate an item on a subjective scale of 1 to 5. The information can also be gathered, implicitly, by analyzing and collecting various information such as monitoring the user purchase history, time spent on any webpage, or download contents etc. The collected information is represented in the form of a matrix as shown in figure 2. The majority of cells are empty because a user do not purchase or rate all of the available items. CF algorithms operate on these user-item matrix to predict the missing values.

CF algorithms can be categorized broadly into following two categories.

1) Memory-based collaborative filtering

Memory-based collaborative filtering are popularly known as lazy recommendation algorithms. The actual computational effort, in predicting a user's interest in a particular item, is deferred until a user requests for recommendations [vii]. These algorithms are easy to implement and are primarily deployed in commercial recommender systems like Amazon [ix], firefly and Group Lens [x].

Memory-based collaborative filtering introduces numerous challenges. For example, if the number of users who have provided the ratings for items is lesser as compared to the items in the dataset, than the calculated similarity values would not be reliable [ix-x].

User based top-N recommendation algorithm identify similar users to active user using vector-space model or pearson correlation technique. Each user is treated as a vector and similarity is calculated between vectors followed by the aggregation of the corresponding rows of similar users in user-item matrix. It identifies a set of items purchased by these users along with purchase frequency. User-based algorithms then suggest top N items that are not purchased by the active user [ix, xi].

Item based top-N Recommendation algorithms initially computes a set of most similar items to each items depending upon similarity. A collection of items representing the candidates of recommendations is created, recommendation, by captivating the union of most similar items and eradicating the items that has been already purchased by the user. The resulting collection would be recommended items in ascending order [ix].

2) Model-based collaborative filtering

Model-based collaborative filtering focus on developing various models by using machine learning techniques on the training data to find patterns. These techniques predict the output on real data [viii] to provide the recommendations. Therefore, most of the work is performed during training phase and that's why they are also known as eager recommendation algorithms.

B. Knowledge based Recommender Systems

The purpose of all personalized recommender systems is to figure the items of interest for a particular user. Content based algorithms perform this task on the basis of interests of a user represented as text. Collaborative filtering algorithms perform this task on the basis of behavior of active user and other similar users. The knowledge-based recommender systems use the knowledge about user preference, item properties and criteria of recommendation. These techniques allow algorithms to reason about the relationship between user and items which is helpful in preventing the generation of useless recommendations [xix-xx].

The collaborative filtering system are not very useful in case of smaller base rating. The accuracy is also very sensitive to the number of rated items that can be associated with a particular user. These factors result in "ramp-up" problem. A large amount of information about users' habits is necessary to generate recommendations accurately. A sufficient number of rated items are necessary for systems to be useful. The knowledge-based recommender systems do not suffer from this "ramp-up" problem as they are independent on user ratings. This independency increases the efficiency of knowledge-based recommender systems [xxi].

C. Content-based recommender systems

Content based recommender systems recommend items on the basis of user profile and description of item. The recommendations are provided to the user according to the past user preferences similar to any item. The system investigates and analyzes the description of items rated by the user in past and creates a profile of user based on the features of those rated items. The recommendation approach matches the user profile and item features which results in the judgment of a user's interest in that particular item category [xv-xviii]. An approach to use content based filtering to provide recommendations is profile centric matching. This approach collates all the data assigned to the user into user profile. The purpose of aggregation is to capture the user interests. Similarly, item profile collates all the metadata assigned to items by users in the training set. A ranking list is created by matching active user profile with the items profile for similarity. The removal of items that are already in user profile provides the final recommendation list [xxii].

D. Demographic Recommender Systems

Demographic recommender systems categorize the users according to their personal information and recommend items based on the demographic classes. It combines the ratings of all users from a particular demographic nook and provides recommendation to the user from that place [xii-xiii]. This has been made obvious from research that results of a study, conducted for a particular population, cannot be used to draw conclusion for another population if user sample differs too much. Demographics and user characteristics significantly affect the recommendations [xiv]. A recommender system proposed for tourism categorizes the tourists according to their demographic information and recommend places based on the demographic classes. It assumes that the tourists from same category have same preferences. The recommendations generated by using demographic recommendation strategy are not very accurate [xxiii].

E. Hybrid Recommender Systems

Hybrid recommender systems integrates multiple recommendation techniques to improve the overall prediction of recommendation systems [xii]. Different approaches can be used to build a hybrid recommender system. One way is to combine separate recommender techniques. In this case we have two different scenarios. First, we can combine the recommendation generated by individual recommender systems to create a final recommendation [xxiv]. Second, we can use a recommender system that gives better results in a particular scenario. The selection criteria for this scenario is the application of some quality metric for recommendation. For example DailyLearner system selects the recommender system on the basis of confidence of recommendations. Another criteria is to select a recommender system with more consistent recommendations. [xxv]

IV. Recommendation Systems in Healthcare

The use of recommender system in health care is increasing with the passage of time. The availability of internet connection allows organizations and users to maintain and access health related data online. The

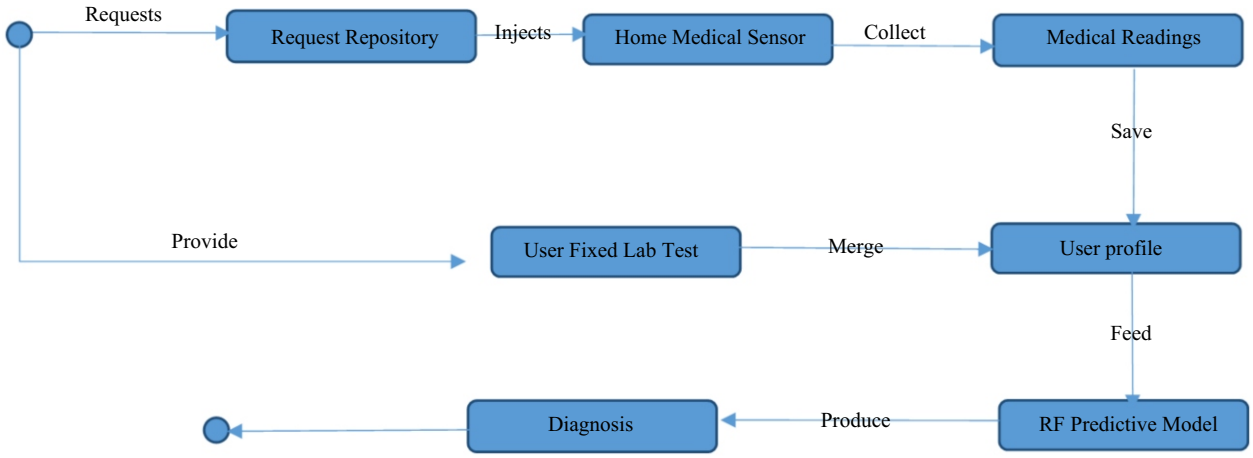

Fig. 3. Scenario of diagnosis prediction [xxviii]

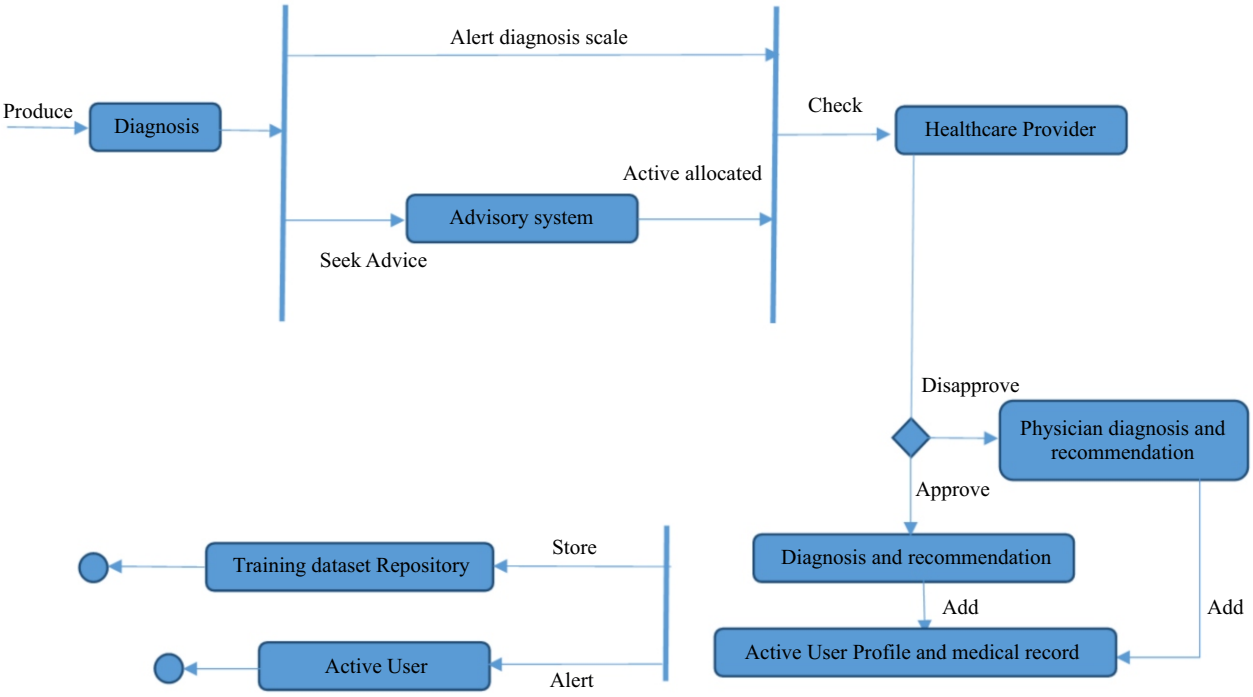

Fig. 4. Medical Advices Recommendation [xxviii]

patients are getting mature in accessing health related data online. Recommender system usage has enabled users to access information more accurately.

The use of context based health information tailored for individuals assist patients to be autonomous in controlling their health data. The Wikipedia articles can be a very good source of information as it allows users to search articles in much better way than other search engines because of its structured knowledge base. The relatedness can be improved further by computing relevance with the help of graph [xxvi].

An algorithm has been developed to improve the performance of Shanghai Medical League Appointment Platform [xxvii]. This algorithm creates a doctor performance model based on the reception and appointment situation. It creates a patient preference model based on the current and historical reservation choices. It uses time sharing mechanism to reserve doctors. Weights are assigned to four sub-criteria to evaluate the performance of the doctor. The evaluation criteria has been designed according to the following equation as shown in eq. 1.

$$R = 0.0476 \text{ x } C + 0.2857 \text{ x } D + 0.0833 \text{ x } E + 0.5833 \text{ x } F \quad (1)$$

It creates patient preferences model based on the selection of department and preferred hospitals, which helps in accurate recommendation. The doctor recommended by this algorithm are divided into four grades. This effectively resolves the problems of doctor's information overload and reservation imbalance.

Considering the complexity of medical data represented by multidimensional, large noisy and/or missing data, it's a challenge to provide accurate medical recommendation. The chronic disease diagnosis [xxviii] provides an accurate prediction of disease risk and medical advices recommendation. It is based on a hybrid model using unified collaborative filtering and multiple classification. The provision of accurate and efficient recommendations facilitate the patients in controlling their chronic diseases. The recommendation of medical advices is based on the collaborative filtering hypothesis “external user and items”.

The patient's diet plays an important role in controlling and curing the disease. Reference [xxix] provides a service to recommend the suitable diet to patients which assist in the prevention and better management of cardiovascular disease. It considers the consequential signs and family history in addition to basic information about disease and patient's food preferences. The Diet Management uses sensors to collect the vital indicators and predict the patient's present health condition by analyzing these indicators. It solves the problems faced by conventional recommendation services by recommending diet as a daily service.

Collaborative Assessment and Recommendation Engine (CARE) [xxx] uses CF techniques to predict the amount of risk for a patient to sustain a disease. It considers the medical history of the patient with the record of other similar patients. It uses the vector similarity and inverse frequency techniques to predict the users as similar to the active user and possible diseases that active patient can incur. The prediction is further refined by including temporal factor, which allows it to discriminate the chronic from an occasional occurrence of disease.

Clinical recommender system for nursing plan creation [xxxi] uses correlation among diagnosis, outcomes and interventions to create plans. It uses both traditional association-rule measure to rank items as well as the novel measures of information value to anticipate the selections, which might be helpful in improving the quality of rankings in future. Unlike the commercial recommender systems, all the items are important and must be selected by nursing staff for their plans. It is necessary to exploit both dimensions, strength and confidence, in order to provide accurate and useful recommendations.

Mobi Day [xxxii] is a personalized context aware mobile service integrated into information system of a hospital. It supports patients to complete their tasks in a day hospital scenario. It provides personalized information to user by exploiting the contextual data like patient's current location and also history of message reading behavior. The architecture consists of a server component that generate messages and a client running on patient mobile device. It monitors the user message reading and questionnaire filling behavior to identify right user-context for future messages. It uses RFID techniques instead of GPS and WIFI to enhance the precision.

Reference [xxxiii] presents a recommender system that assist patients in selecting an appropriate doctor. This system uses fuzzy linguistic and fuzzy text classification methods to rank doctors depending upon their skill level and associated degrees related to that skill. It process the requirements of patient by using the available record. Empirical results are used for indication of patient's satisfaction with the recommended doctors. This system rely on patients to rank doctors. This dependency effects the accuracy of this recommender system which makesit difficult to provide accurate patient profile.

Shown in TableI is the comparative analysis of existing medical recommender systems. The recommendation approach used by each of the existing work is presented in Table I.

TABLE I
COMPARISON OF RECOMMENDER SYSTEMS DEVELOPED FOR HEALTHCARE

Platform	Content-based	Collaborative	Knowledge-based	Context aware	Fuzzy linguistic and text classification
Doctor Appointment platform [xxvii]	✓				
Chronic disease diagnosis [xxviii]		✓			
Diet recommendation service [xxix]	✓		✓		
Collaborative assessment and recommendation engine (CASE) [xxx]	✓				
Clinical recommender system for nursing plan [xxxi]			✓		
MobiDay [xxxii]			✓	✓	
Recommender system for doctor selection [xxxiii]					✓

V. PROPOSED HYBRID RECOMMENDER SYSTEM

A hybrid recommender system for healthcare is proposed and discussed in this survey paper. This section elaborates the methodology of the proposed medical recommender system.

A. Identification of key Factors to measure Hospital Quality

The identification of key factors for hospital quality are very critical for designing an efficient medical recommender system. We have identified a list of factors that are vital in measuring the quality of services provided by any hospital. These factors are usually considered by patients in making decision about hospital selection. Table 2.depicts the identified factors in the proposed approach. These factors affect the patient's perception of hospital quality. The survey conducted by HCAHPS covers all these factors that are identified in the literature review. We conducted a survey among patients from different hospitals and requested them to rate the hospital quality based on these factors, on a subjective scale of (1 to 4), where 1 represents “not recommended” and 4 represents “always recommended”. The survey was based on the questions from HCAHPS survey. The proposed system presents a novel weight-based approach to calculate the overall rating of hospitals, which differs from HCAHPS technique.The proposed weight-based approach uses distinctweights for each factor. The numeric rating of each factor provided by patient is multiplied by its corresponding weight and the aggregate of these represents the overall rating of the hospital. The calculation of rating is presented in eq. 2.

$$\boldsymbol{Rating}\ (\boldsymbol{R}) = {\textstyle\sum_{i=1}^{n} \boldsymbol{Wi\,Pi}} \Big/ {\textstyle\sum_{i=1}^{n} \boldsymbol{Fi}} \qquad (2)$$

Where
Wi= weight of factor 'i’
Pi= rating of factor 'i' provided by patient.
Fi=Maximum rating for factor 'i’

Equation (2) is used to calculate the normalized rating of each hospital provided by each patient. This rating (R) is used to find the average rating of each hospital as shown in eq. (3).

$$\boldsymbol{Aggregate\ Rating} = {\textstyle\sum_{i=1}^{n} (\boldsymbol{Ri})} \Big/ \boldsymbol{n} \qquad (3)$$

Equation (3) provides an aggregate rating of a particular hospital.

Where
Ri=individual rating of hospital
n= total number of ratings for hospital

TABLE II
IMPORTANT FACTORS CONSIDERED BY PATIENTS

Sr.	Factor
1	Doctors communication
2	Nurses communication
3	Staff behavior
4	Pain control procedures
5	Medicine explanation
6	Guidance during recovery at home
7	Surrounding cleanliness
8	Quietness in patient surrounding

The overall rating of each hospital is normalized before using it to generate recommendation for patient.

B. Weight Calculation for Identified Factors

To find the accurate weights for each quality factor used in rating calculation for hospital, we conducted another survey among doctors from different hospitals. We asked them to rate each factor for its significance in measuring the quality of the hospital. A subjective ranking criteria on a scale of (1 to 5) is provided the users to rate each factor. 1 represents "not important" and 5 represents "very important". These ratings are used for calculating the weight for each factor mentioned in Table 1. Shown in Table 3is the listing of each factor and its corresponding weight used in calculating overall rating of the hospital.

TABLE III
WEIGHT CALCULATED FOR EACH FACTOR

Sr.	Factor	Weight
1	Doctors communication	0.25
2	Nurses communication	0.20
3	Staff behavior	0.15
4	Pain control procedures	0.14
5	Medicine explanation	0.10
6	Guidance during recovery at home	0.10
7	Surrounding cleanliness	0.02
8	Quietness in patient surrounding	0.04

Factor weight computation criteria is shown in eq. (4).

$$\textbf{\textit{Factor weight}} = \sum k(D,k) \Big/ \sum_{i=1}^{n} k \qquad (4)$$

Where k is the rating value which can be from 1 to 5 and **(D, k)** is the number of doctors who gave **k** rating to this factor. The weight in eq. (5) is normalized by dividing it by the sum of weight of each factor. These weights are used to compute the overall rating of each hospital after calculating the weight for each factor.

C. Patients Similarity

The foundation of generating recommendation is to find the patients similar to active user. A simple strategy is employed in order to accomplish the recommendation procedure. The active user provides a condition to visit the hospital of his choice. The system tracks and identifies the record of other patients who suffered from the same condition. The similarity index between patients is computed according to the criteria mentioned in eq. (5).

$$S(P,P') = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n} S_c(Pc_i, P'c_j)}{m*n} \qquad (5)$$

Where **m** and **n** is the number of conditions listed in patient **P** and **P′** profile respectively. $\mathbf{S(Pc_i, P'c_j)}$ is the measure of similarity between conditions $\mathbf{c_i}$ and $\mathbf{c_j}$ and it is calculated as shown in eq. (6).

$$S_c(Pc_i, P'c_j) = log\frac{P}{Pc_i} \qquad (6)$$

Where **P** is the total number patients and $\mathbf{Pc_i}$ represent the number of patients having the similar condition/symptoms as mentioned in their profile.

C. Recommendation Criteria

A hybrid approach is used to provide a customized recommendation for a particular user. Top-n collaborative filtering is used to acquire a list of hospitals that are highly rated by similar patients. Location based filtering is employed to further refine this list. The hospital which is nearest to patient's current location is preferred.

The active patient provides a condition for hospital visit. A list of hospitals providing the user required services is acquired and presented to user. The proposed system ranks any hospital at the top of recommended hospitals list in case if the user has rated that hospital with good ratings in the past. A list of top rated hospitals is generated by meeting the criteria of similarity index with the active user. The rating of each patient is weighted by meeting the similarity index with active patient. The distance of each hospital from current location is calculated and hospitals are arranged in ascending order of distance with reference to patient's location. The orthodromic distance metric is used to compute the distance between the user and hospital. Unlike commercial recommender systems for movies, music and articles, where some features of item can easily be ignored, each factor is considered in rating calculation.

VI. FUTURE TRENDS

The modern day technology and recent advances in information technology have motivated the researchers to proposed effective solutions to process and analyze massive data available in the cyberspace efficiently. Recommender systems have been developed by the researchers from time to time to provide accurate and reliable recommendations to the users. The researchers across the globe are looking for innovative ways to improve the efficiency of recommender systems. The future trends can be divided into two categories. The first category include concepts, which are under development [xxxiv]. Some of the most highlighted concepts in this category are listed below.

i. Integration of social media for efficient data collection.
ii. Use of body sensor for collecting vital indicators of patient.
iii. Using available information to optimize and personalize the medicine prescription.

The second category of trends focus on less explored research areas such as big data. The featured concepts in this category are as follows:

i. Use of Big Data and artificial intelligence to make decisions related to treatment.
ii. Incorporating decision making ability in microscopic robots. It will facilitate in data collection process.

VII. Conclusion

This paper provides a comprehensive overview of existing recommender systems with more focus on health care systems. The recommender systems are classified into content-based, collaborative, demographics, knowledge-based, and hybrid categories. The critical analysis of the existing recommender systems in each of these categories are elaborated in detail. The proposed research work mainly focuses on the discussion of recommender systems for healthcare. Existing approaches for recommender systems in health care industry are also discussed in detail. The open challenges are raised and recommended suggestions are provided in the proposed work. The recommendation techniques in healthcare domain are thoroughly investigated and suggested improvements are recommended as well. For e.g, some of these techniques facilitate patients directly by recommending a diet plan for them while others provide services to assist the users to acquire appointment from doctors effectively. These recommender systems can be merged to improve the quality provided by the health care industry.We have developed a hybrid recommender system for healthcare. The proposed technique for medical recommender system is discussed in detail. Future trends in recommender systems are also examined and open problem areas are identified with recommended suggestions.

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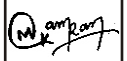
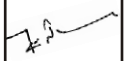
Authorship and Contribution Declaration			
	Author-s Full Name	**Contribution to Paper**	
1	Mr. M. Kamran (Main/principal Author)	Literature survey, Design, methodology, statistical analysis and interpretation of results and manuscript writing	
2	Mr. Ali Javed (2nd Author)	Proposed topic, Data Collection, manuscript writing and manuscript review	

Model-based Version Management System Framework

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Abstract-In this paper we present a model-based version management system. Version Management System (VMS) a branch of software configuration management (SCM) aims to provide a controlling mechanism for evolution of software artifacts created during software development process. Controlling the evolution requires many activities to perform, such as, construction and creation of versions, identification of differences between versions, conflict detection and merging. Traditional VMS systems are file-based and consider software systems as a set of text files. File-based VMS systems are not adequate for performing software configuration management activities such as, version control on software artifacts produced in earlier phases of the software life cycle. New challenges of model differencing, merge, and evolution control arise while using models as central artifact. The goal of this work is to present a generic framework model-based VMS which can be used to overcome the problem of tradition file-based VMS systems and provide model versioning services.

Keywords-Software Configuration Management, Version Management System, Model Diff, Model Merge, Evolution Control, Model-Based VMS

I. INTRODUCTION

To develop large software projects (in which more than one person participate), it essentially needs the efficient management of software artifacts created during software development. In the absence of controlled management, the software products that the industry has turned out can be delivered much later than scheduled, may cost more than anticipated and would have been poorly design and documented [xi]. Version management system (VMS) aims to provide a controlling mechanism to such problems. VMS deals with controlling the evolution of software systems. Controlling the evolution requires many activities to perform, such as, construction and creation of versions of the software artifacts, performing **model diff** activity (i.e., the identification of differences between versions), conflict detection, and merge activity (i.e., combining two or more versions) [i].

With the advent of modern software development methodologies, such as model driven engineering (MDE), models become first-class artifacts. Therefore, performing VMS activities on models are essential; however, existing file-based VMS systems are not adequate for performing such activities on models. Fundamentally, the main reason of inadequacy of existing systems, such as Subversion [x], is due to the fact that these systems are file-based and consider software artifacts as a set of text files having no relations. In contrast, models are graphs with nodes being complex entities and arcs (relations) containing a large part of model semantics. File-based tools use textual or structured data to represent models at fine-grained level. This representation is not suitable for diff and merge operation of models due to several reasons. For instance, in MDE, software documents are not only text files, but also consist of diagrams such as different types of UML diagrams. These diagrams are often stored as XMI formats, such as a class diagram might be represented by a few lines of text in the file. The order of these sections of text is irrelevant in a file and the CASE tools can store the sections representing classes or other diagram elements in arbitrary order. To a large extent, the order of text lines and their layout is immaterial for diff and merge operations on models. Therefore, applying diff and merge operations at the level of plain text would hardly produce meaningful results. Therefore, the goal of this paper is to develop a generic fine-granular model diff solution for class and activity diagrams of the unified modeling language (UML). The model diff deals with comparing the two versions to detect the differences and matches between them. It is an important and challenging task in the MDE. The traditional VCS systems are text-based systems and are not designed to operate adequately on models. Therefore, in this paper we propose an approach that handles the model structures adequately.

The goal of this work is to develop a generic framework to deal with the issues of model diff, merge and evolution control activities in model-based VMS system. At a fine-grained level we represent our models as graph structures, which is an intermediate representation based on graph theory. The diff, merge and evolution control activities are performed at the level of graph structures, whereas versioning activities should remain at textual or structural representation,

such as XMI-files. By doing so, on one hand we are getting the advantages of reusing the traditional VMS systems for versioning purposes and on other hand we avoid the problems associated with textual or structured representation when performing the rest of the activities. Evolution control mechanisms are defined based on intra & interlink dependencies between models element. The innovative aspects of the approach are generality, traceability between models element through intra & interlink dependencies, definition of evolution control mechanism and reusability of existing VMS systems.

The organization of this paper is as follows: Section 2 describes the related work. Section 3 presents the main components of our framework. Section 4 describes reference architecture. Finally a short conclusion and future work is given in the last section.

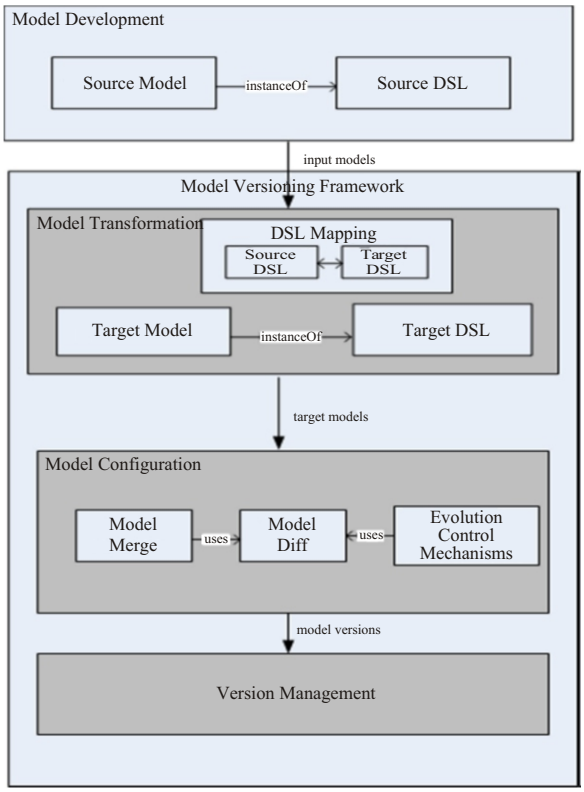

Fig. 1. Model-based SCM Framework

II. Related Work

Many solutions to model-based SCM exist in literature. In this section we will describe the existing solutions. Alanen and Porres in [xiii] discuss the difference and union of models in the context of a version control system. Three meta-model-independent algorithms are given that calculate the difference between two models, merge, and calculate the union of two models. However, these algorithms crucially rely on the existence of a universally unique identifier for each model element. The output produced by the approach is in form of a sequence of edit operation while in our approach the results are brought back into a model which is more comprehensible for understanding. The approach also does not detect shifting of elements between models and detect shift operation as delete-add operation. Ohst et al. [ix] address the problem of how to detect and visualize differences between versions of UML documents, such as, class or object diagrams. The approach assumes that each model element has a unique identifier which is used for model comparison. For showing the differences between two documents the unified document is used which contains the common and specific parts of both base documents; the specific parts are highlighted. EMF Compare [xiv] is an open source tool used EMF technology project to compare models in EMF. It is realized by a package of Eclipse plugins that overwrite Eclipse's standard comparing behavior. EMF Compare uses a generic algorithm for model comparison. The comparison is performed in two-phases: In the first phase the match engine tries to find similar elements and creates a match model. Based on this model the difference engine is used to generate detailed information about the differences of certain model elements. A difference model is the result of the second phase. Both match and difference model are EMF models and therefore can be treated like any other model. As compared to our approach the diff and match model produced by EMF Compare cannot be converted to graphical representation as done in our approach. Furthermore, EMF Compare also suffers from the sensitivity issue of layout or order changes. A detailed empirical comparison of our approach with EMF Compare is already given in Section 4 which shows the performance efficiency of our approach. Xing et al. [xv] presented an automated UML-aware structural-differencing algorithm, UML Diff. UML Diff is an algorithmforautomatically detecting structural changes between the designs of subsequent versions of object-oriented software. It takes as input two class models of a java software system, reverse engineered from two corresponding code versions. The approach uses a language-based matching criterion and identifies corresponding entities based on their name and structure similarity. If two objects have same name, they are identified as equal, if not, their structural similarity is considered, computed from the similarity of names and other criteria specific of the considered entity type. Kelter et al. [xvi] presented a generic algorithm SiDiff which uses an internal data model comparable with a simplified UML meta-model. A diagram is extracted from an XMI file and is represented as a tree consisting of a composition structure. In this approach the model elements are characterized by the elements they consists of, the difference algorithm starts with a bottom-up traversal at the leaves of the composition tree. The approach uses

a signature-based matching criterion. The Pounamu approaches presented in [v] describes a generic approach for diff and merge via a set of plug-in components. Plug-ins is developed for the meta-CASE tool Pounamu which support version control, visual differencing and merging. The approach uses operation-based method for difference computation which results in the dependency of the tool in which diagrams are edited, contrary to our approach which uses State-based approach. The approach uses a universal ID (uid)-based matching criteria. Also the approach lacks detection of the shifts operation.

Existing approaches in the area of model-based VMS usually deal with only one specific kind of model e.g. workflow [viii] or class diagram [ix, vi], in contrast, our approach is generic and not dependent on any specific model. The approach presented in [vii] performs diff/merge on structured data, i.e., XMI. As stated earlier such representation is not suitable for these activities, we use graph structure for diff/merge operations to avoid problems of textual representation. The approach presented in [iv, iii], is based on operation-based conflict detection & resolution. All edit operations that are executed on the diagrams are logged by the editor tool and used for conflict resolution, thus the approach is dependent on editor tool. We presented a state-based approach which is independent of editor tools since logging of edit operations is not required. To the best of our knowledge the only approach that addresses the issue of evolution control is given in [ii], however the evolution control is based on the attributes' properties while in our approach it is based on interlink information. Furthermore, the existing approaches, with the exception of [v], don't reuse the traditional VMS tools, while we argue that existing VMS tools should be reused for versioning purpose.

III. Model-Based VMS Framework

Keeping the issues of file-based VMS systems this paper provides a generic model-based VMS framework, which aims to overcome the challenges faced by existing systems when dealing with models as central artifact. Following are the components of our proposed framework:

a. Model development
b. Model transformation
c. Model configuration
   i. Model diff
   ii. Model merge
   iii. Evolution control
d. Version management
e. Graph structure DSL

Below is the description of these components.

A. Model Development

The Model Development module deals with modeling issues, such as the development of source models conforming to source DSL using a model editor. As a source models we are using MOF-compliant domain specifics languages (DSLs), such as unified modeling language (UML), ECore. A source model conforming to source DSL is transformed into target model conforming to target DSL in Model Transformation module. A developer can load a source model from the repository rather than developing a new one.

B. Model Transformation

The Model Transformation module deals with model-to-model transformation. At a fine-grained level we represent our models as graph structures. In Model Transformation module the configuration manager first establishes mappings between the source and target DSLs.

The mappings are the transformation rules defined for the sake of transforming a source model into a target model. Transformation between a source model into the target model is based on the mapping rules defined by the configuration manager.

C. Model Configuration

The Model Configuration module deals with Model Diff, Model Merge, and Evolution Control Mechanisms. Below we give a brief description of these tasks.

1) Model Diff

The Model Diff deals with model differencing. Model differencing is the process of comparing two models for the purpose of identifying mapping (similarity) and differences between them. It is an essential activity in many model development and management practices [ix]. For example, model differentiation is needed in a model versioning system to trace the changes between different model versions to understand the evolution history of the models. Model comparison techniques and tools may help to maintain consistency between different views of a modeled system. Furthermore, model differentiation can also be applied to assist in testing the correctness of model transformations by comparing the expected model and the resulting model after applying a transformation rule set.

When comparing two models, model mappings define those entities that represent a single conceptual entity in the compared models, while the unmatched entities represent model differences [ix].

2) Model Merge

The Model Merge deals with model merging. Model merging denotes the process of combining n alternative versions a1, . . . ,an into a consolidated version a, usually, n = 2. Different variants developed more or less independently from some common

ancestor are sometimes needed to be combined into one common version. The merge process consists of the following three main steps:

Versions comparison: The process of comparing derived versions with the base version.

Conflict detection and resolution: The process of identifying the conflicted elements and resolving the conflicts either manually or automatically.

Merging: The process of combining two or more versions into a consolidated version.

The comparison process of versions are described in the previous subsection Model Diff. We reuse the results of Model Diff in merge activities. We identified different merge cases in order to differentiate the conflicted and non-conflicting cases. Based on merge cases we establish our merge policy. The result of diff comparison will be analyzed according to the merge policy and possible actions are categorized into add, delete, include changed etc. The desired action then will be performed. The process of merging cannot be completely automated [xix]. Manual interaction is required in case of conflict detection. A conflict usually occurs if the same element of a model is modified in parallel. In case of conflict the conflicted elements will be identified. A manual interaction will be required to resolve the conflict. Finally the merge operation will be performed and the merge diagram will be obtained.

3) Evolution Control

The goal of MDE is to perform Software Engineering (SE) activities only on models, however, in reality models and files coexist and will have to be managed together in a consistent way. As identified in [ii, xii] this situation requires the definition of new evolution paradigms for software projects that consist of a mixture of models and files. The Evolution Control deals with defining a policy for creating a new version, defining version granularity, defining intralink and interlink information. The assumption is that software development consists of a set of different kinds of models and the interlink information between these models. Such models include analysis and design models, test models, and implementation models. These models may possibly be created using different development tools in a heterogeneous environment. For traceability & synchronization between these models one needs to identify intra & interlink dependencies between different model elements. In our framework, we first define the concepts of intra & interlink dependencies between model elements. Based on intra & interlink information we define the concept of evolution control policy. In this regard this module addresses the issue of traceability and evolution control mechanisms in model-based VMS systems.

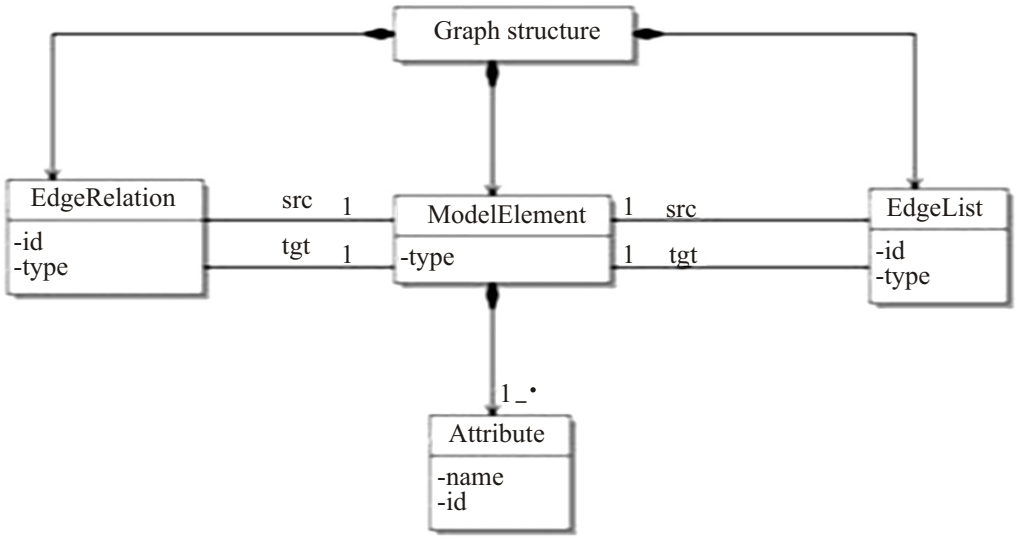

Fig. 2. DSL of Graph structure

D. Version Management

In traditional VMS approaches versioning, diff, and merge activities are performed on structured data such as XMI. In versioning, a version model defines the items to be versioned, the common properties shared by all versions of an item, and the deltas. It defines whether a version is characterized in terms of the state it presents or in terms of some changes relative to some baseline. It selects a suitable representation for the version set (e.g. version graph), and it also provides operations for retrieving old versions and constructing new versions. Each version has relationship to the next and previous versions. Versions are queried or created by transactions. These include both read-only and read-write transactions, such as update, history, check in, checkout etc made by the user. Although traditional

VMS tools do not provide good support for model diff, merge, and evolution control activities however they do so for versioning. Therefore, in our approach we reused them for versioning purposes.

E. Graph Structure DSL

An abstract view of the proposed framework is given in figure 1 which depict the relation of input models and proposed framework. The inputs of the framework are graphical models such as UML models. We call the input model as source domain specific language (DSL). The source models are transformed into target models which are the instances of graph structure which is our target DSL. Below we describe our graph structure DSL.

A model can be represented in three different ways [vi], a) the graphical representation, i.e., the diagram itself, b) the persistence representation e.g. XMI, and c) intermediate representation e.g. syntax tree or graph structure. The graphical representation is the coarse-grained while the other two are fine-grained representations. In our approach, at a fine-grained level we represent models in an intermediate representation, i.e., graph structures. A metamodel of graph structure is given in Fig. 2. It consists of Model Element, Edge Relation, EdgeList and Attribute. Model Element represents the set of entities in the model, Edge Relation represents the relationships or associations within the model, EdgeList is a relationship used to connect all entities in the graph structure. Finally, Attribute represents all the possible features of model elements. With this metamodel, we can represent any kind of model at fine-grained level.

IV. Reference Architecture

Fig. 3 shows the reference architecture of our proposed framework. There are six main components and a repository. The components are Model Editor, XMI/GS Converter, Merger, Diff Comparator, EPControler and Versioning System. XMI/GS transforms them into graph structures and vice versa. The graph structures of different versions are inputs to the DiffComparator. The Diff Comparator performs model diff by comparing the graph structures and produces diff result in the form of matched and unmatched elements. The output of the DiffComparator, i.e., The diff result is input to both the Merger and EPControler component. Merger analyzes diff result based on the merge policy and performs a three-way merge. The EPContorler manages the evolution control based on diff result and intra & interlink information. Finally, the Versioning System is the reusable component of existing VMS systems and responsible for managing versions.

V. Conclusion

This paper presents a generic framework for model diff, merge and evolution control activities in model-based VMS systems. Graph structure can be used to represent any kind of model either domain specific or UML models. The presented framework is generic in a sense that it is neither dependent on any specific tool nor on any specific model type. Furthermore, these existing approaches do not consider reusability of existing file-based VMS systems and in most of the cases evolution control mechanisms are also missing. In this work at conceptual level, we proposed a model-based VMS framework that can be used to developed model-based VMS systems. As a future work, the implementation and evaluation of the architectural components, i.e., XMI/GS converter, Merger and EPController will be performed.

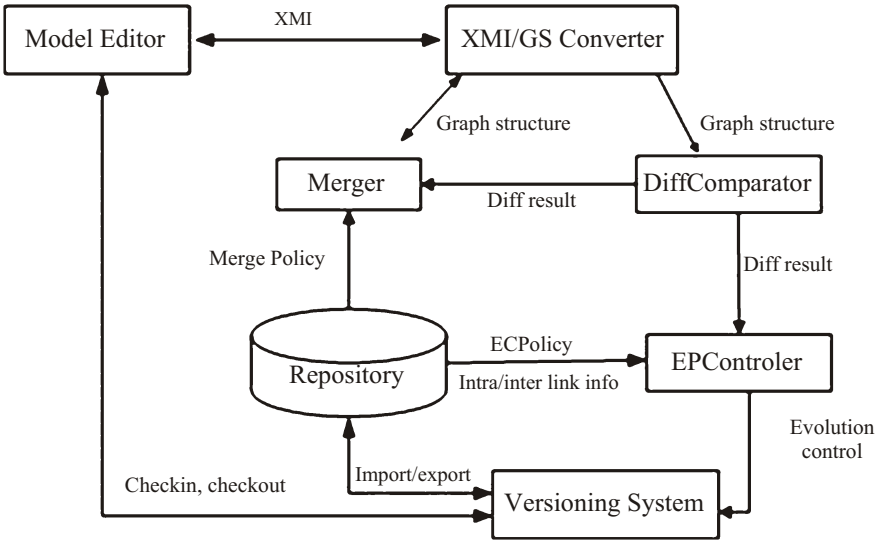

Fig. 3. Reference Architecture

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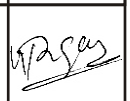
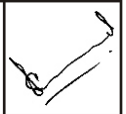
1	Dr. Waqar Mehmood (Main/principal Author)	Proposed topic, basic study Design, methodology and manuscript writing	
2	Mr. Arshad Ali (2nd Author)	Literature review	
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