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IGCES 2008
International Graduate Conference on Engineering and Science 2008
School of Graduate Studies
Universiti Teknologi Malaysia

23-24 December 2008
Johor Bahru, Malaysia
and sincere greetings to all

It gives me great pleasure to welcome all the speakers, participants and distinguished guests to the International Graduate Conference on Engineering and Science (IGCES) 2008 at Universiti Teknologi Malaysia. I trust that you will find the IGCES 2008 informative and interesting, and hope that numerous scientific discussions will be deliberated and friendship will bloom as well.

Universiti Teknologi Malaysia is among the top universities in Malaysia which focus on research-driven activities especially in science and engineering fields. The variety of research activities are multi-disciplinary in nature, extending across faculties and departments, often crossing traditional subject boundaries. Thus, this conference is initiated to provide opportunities for the young researchers to gain invaluable experience and useful insights on issues pertinent to their areas of specialization. In addition, this conference also aims to enhance the contribution and strengthen the role of the graduate scholars in responding to various issues and challenges facing graduate education.

I would like to take this opportunity to express my utmost gratitude to the International Advisory Committees, all the Reviewers and the Organizing Committee for their relentless effort and undivided attention in ensuring the successful implementation of the conferences. Last but not least, my sincere appreciation to all the sponsors and all those involved in making this seminar possible.

Thank you.
WELCOME ADDRESS from

Professor Dr. Mohd. Ibrahim Seeni Mohd.
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School of Graduate Studies
Universiti Teknologi Malaysia

Professor Dr. Rose Alinda Binti Alias
Dean (Engineering)
School of Graduate Studies
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It is indeed a pleasure to welcome you to the International Graduate Conference on Engineering and Science 2008. To our overseas participants, welcome and I wish you a pleasant stay in Malaysia and may this conference be a rewarding experience for you.

I wish all the participants a successful conference with the hope that the findings gathered and resolutions agreed would contribute towards building a bridge between the scientific community and policymakers for continuous improvement and excellence.

I would like to take this opportunity to express my sincere appreciation and gratitude to the organizers of the International Graduate Conference on Engineering and Science 2008 for their commendable effort in organizing and conducting the conference and also to the co-organizers and speakers as well as participants for their distinctive role in making this conference a success.

Thank you.
MESSAGE from

Aulia Sayuti
The Chairman of IGCES 2008 Organizing Committee

السلام عليكم ورحمة الله وبركاته
and sincere greetings to all

It is great pleasure to welcome out colleagues from all over the world to attend 1st conference in Universiti Teknologi Malaysia Skudai Johor Bahru

The 1st International Postgraduate Conference on Engineering and Science 2008 (IGCES 2008) has been organized by School of Graduate Studies and Postgraduate Student Society. Actually this IGCES is the continued of RPCES (Regional Postgraduate Conference on Engineering and Science) in 2006. It will be an opportunity for international community, academics, scientist, and engineers to present and to exchange much ideas and their progress in researches. In line with educational process, this technical conference is designed to promote tremendous researches, enhance the skill in paper writing and oral presentation. All the excellent papers and experiences gained in this conference will be much valuable to increase the quality of research and technology achievement. This year’s around 399 abstract papers had been reviewed and 218 abstract papers from 15 countries are accepted for the conference proceeding.

Three keynote speakers are invited in the plenary session after opening ceremony. These distinguished speakers are the Vice-Chancellor of Universiti Teknologi Malaysia, Rector of Institut Teknologi Bandung and Rector of Institut Teknologi 10 Nopember Surabaya. Oral session will be held during conference will be focusing on all aspect in engineering and science especially those who works on research of Energy, Chemical, Mechanical Engineering, Education Technology, Electrical and Communication, Bio-medical and Bio-technology, Computing and Information Technology, Architecture Engineering, Civil Engineering, Applied Physics and Nano Technology, Business and Management, Petroleum Engineering, Fundamental Science.

The organizing committee, colleagues, and friends who have been working behind the scenes deserve special mention too. Without their unfailing cooperation, hard work and dedication, this event would be simply not been possible. The organizing committee sincerely hopes that the IGCES 2008 will be a truly memorable experience for all participants.

Finally, we encourage you to explore the beautiful sights of Johor Bahru and Malaysia during your stay.
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Universiti Teknologi Malaysia, Malaysia

Assoc. Prof. Dr. Nurly Ghofar,
Universiti Teknologi Malaysia, Malaysia
LIST OF PAPERS

A. Energy

A.1 EXTRACTION OF FUEL FROM MUNICIPALITY SOLID WASTES

A.2 Feasibility study of hybrid Wheel Desiccant Dehumidification Cooling Systems in Malaysia
Author: 1. Salman Khosravi 2. T.M.indrea Mahlia 3. Y.H Yau

A.3 Performance Evaluation of Air Mixed and Displacement Ventilation System for Office Room
Author: 1. Bambang Iskandriawan

A.4 Marine Current Energy Extraction System Using a Fuzzy Logic Controlled Buck-Boost DC-DC Converter

A.5 A map of wind and solar resources for the Nangroe Aceh Darussalam province - Indonesia: A perspective of a preliminary modeling of hybrid renewable energy system for urban water supply (HRESUWS)

A.6 A further development of implementation program of hybrid renewable energy system for urban water supply (HRESUWS) in Indonesia: A designing of long term research program
Author: 1. Ahmad Taufik 2. Barony Herdiarto

A.7 INVESTIGATION OF EFFECT GAP RATIO IN SAVONIUS TURBINE FOR VERTICAL AXIS MARINE CURRENT TURBINE (VAMCT) USING CFD PROGRAM
Author: 1. DEDY TRIAWAN SUPRAYOGI

Author: 1. Emishaw Dandena Iffa 2. A.Rashid A Aziz

A.9 Production of Biodiesel from Jatropha Oil (Jatropha Curcas) in Pilot Plant
Author: 1. Tint Tint Kywe 2. Prof Mya Mya Oo

B. Mechanical Engineering

B.1 CIP- LBM SCHEME FOR THE SIMULATION OF NATURAL CONVECTION IN ENCLOSURE WITH LOCALIZED HEATING
Author: 1. MOHD ROSDZIMIN ABDUL RAHMAN 2. NOR AZWADI CHE SIDIK

B.2 STUDY OF FLOW PATTERN AROUND TWO CYLINDERS IN TANDEM ARRANGEMENT
Author: 1. Mohd Rody Mohamad Zin 2. Nor Izwadi Che Sidik

B.3 Kinetics of CO2 Corrosion with Acetic Acid in Turbulent Flow Conditions
Author: 1. Martin Fatah 2. Mokhtar Ismail

B.4 Concept Modeler: A Computer Aided Conceptual Design Tool
Author: 1. Dereje Engida Woldemichael 2. Fakhirudin Mohd Hashim

B.5 Recognizing intersecting volumetric features from a design-by-feature solid model
Author: 1. Mohammad Hayasi

B.6 Analysis of Product Disassemblablility using the Disassembly Evaluation Chart Methodology
Author: 1. Wiwiek Fatmawati 2. Ariffin Abdul Razak

B.7 Simulating the Current Performance and the Use of Dispatching Rules in an Automotive Part Manufacturing Company
A Comparative Study of Energy Management Strategies for Plug-In Hybrid Electric Vehicle

Microstructural Study on 8YSZ and NiCoCrAlY Thermal Barrier Coating Due To High Temperature Oxidation
Author: 1. Lukman Noerochim 2. Bagus Primadianto

The Performance of Valveless Pulse Combustor Using Gaseous Fuel

DIFFUSIVE THERMAL INSTABILITY IN PREMIXED FLAME
Author: 1. AHMAD FAIZ MAT ZIN 2. MAZLAN ABDUL WAHID 3. ROSNAIDAH BAHSAN

Multi axial behavior of natural fiber reinforced composite for prostheses application

Framework of End-of-life Product Disassembly Analysis
Author: 1. Feri Afrinald 2. Muhamad Zameri Mat Saman 3. Awalluddin Mohamad Shaharoun

DESIGN OF AN INTELLIGENT PIG FOR OFFSHORE PIPELINE MAINTENANCE
Author: 1. Kresnajaya Prasetia Pancakarsa 2. Fakhirudin Mohd Hashim

Design and Construction of 4 axis Computer Numerical Control (CNC) Milling Machine
Author: 1. Aung Zaw Htun

PROGRAMABILITY AND SIMULATABILITY OF HOLONIC WORKFORCE MANAGEMENT SYSTEM FOR LABOR-INTENSIVE MANUFACTURING WITH CASE STUDY
Author: 1. LIM YONG CHING

A proposed critical factor for effective implementation of quality engineering tools and techniques in malaysian and indonesian automotive industries
Author: 1. Nilda Tri Putri 2. Sha’ri Mohd. Yusof

INTERFACIAL REACTIONS BETWEEN Sn-Ag-Cu LEAD-FREE SOLDERS
Author: 1. SALIZA AZLINA OSMAN 2. ALI OURDJINI 3. SITI RABIA TULL AISHA IDRIS

EFFECT OF SOLDER VOLUME AND PAD AREA ON INTERMETALLIC COMPOUNDS FORMATION DURING SOLDERING BETWEEN Sn-4Ag-0.5Cu AND IMMERSION SILVER FINISH
Author: 1. SITI RABIA TULL AISHA IDRIS 2. ALI OURDJINI 3. ASTUTY AMRIN 4. SALIZA AZLINA OSMAN

Child Model Size and Mesh Refinement Effect to the Result Accuracy of Sub Modeling Technique in Finite Element Analysis
Author: 1. OJO KURDI 2. Roslan Abd Rahman 3. Mohd Nasir Tamin

LAYOUT REDESIGN WITH USING CLUSTERING APPROCHES TO OPTIMIZE CONTAINERS HANDLING PROCESS
Author: 1. Andre Sugiyono

RING TEMPERATURE ON PROPANE FLAME LIFT-UP

The Influence of Ring on Flame Height and AFR Of Flame Lift-up Phenomenon; An Experimental Study

ANALYTICAL INVESTIGATION OF BIOFUEL BLENDS SPRAY AND ATOMIZATION
CHARACTERISTICS IN PRESSURE SWIRL ATOMIZERS

B.25 Combustion Characteristics of Palm Shell Fuel in Fluidized Bed Combustion
Author: 1. Rosyida Permatasari 2. Muhammad Nazri jaafar

B.26 Disturbance Rejection Control of a Disk Brake System to Reduce Vibration and Noise

B.27 Taguchi Method: Influence of Different Dielectrics in Machining SKD 61 with Electrical Discharge Machining (EDM)

B.28 Effect of Thermal Aging and Absorbed Hydrogen on Fatigue Crack Growth Behavior of Welded A516 Steel
Author: 1. Muhammad A Khattak 2. Mohd N Tamin

B.29 Application of Full Factorial Experiment in Designing an ANN-based Control Chart Pattern Recognizer
Author: 1. Ibrahim Masood 2. Adnan Hassan

B.30 Developing an effective method to successful implementation of ISO 9000:2000 regarding to the usage of quality tools

B.31 Supplier evaluation method based on process capability and price analysis with CPMPC chart

B.32 Initial Study on Flow Behaviour Around Four Circular Cylinders With Different Reynolds Number by Using Lattice Boltzmann Scheme
Author: 1. H. M. Faizal 2. C. S. N. Azwadi

B.33 LAMINAR FLOW THROUGH A DOUBLE ELBOW GEOMETRY WITH LATTICE BOLTZMANN NUMERICAL METHOD
Author: 1. N. M. Akmal 2. C. S. N. Azwadi 3. M. S. Zuhairi

B.34 SIMULATIONS OF TWO BUBBLES RISE IN CAVALITY WITH LATTICE BOLTZMANN METHOD
Author: 1. Muhamad Zuhari Sulaiman 2. C. S. N. Azwadi 3. N. M. Akmal

B.35 Study On The Effect Of Stent Strut Parameters in Aneurysm Model To Blood Flow Behavior
Author: 1. Mohamad Mazwan bin Mahat 2. C. S. N. Azwadi

B.36 Vibration Control of a Hand model using Active Force Control with Piezoelectric Actuator

B.37 Tool Wear and Tool Life Performance of TiAlN Coated Carbide Cutting Tools when Turning Hardened Cold Work Tool Steel

C. Electrical and Communication

C.1 ANFIS AND ANN COPARISIM FOR STATIC SECURITY ASSESSMENT
Author: 1. ibrahim saeh 2. ibrahim saeh 3. Azhar Kurdeen

C.2 Numerical Simulation of Two - Dimensional Thermal Oxidation of Silicon

C.3 HSDPA Mobile Broadband Communication Model for Data Correction in Network-RTK of GPS Satellite Navigation Systems
Author: 1. Arief Marwanto 2. Tajul Ariffin Musa
C.4 Performance Comparison between Smooth-Windowed Wigner-Ville Distribution and the Adaptive Optimal Kernel Method

C.5 Secure Digital Communication System

C.6 Analysis of Sub-packet Interleaving for Multipath Fading Channels
Author: 1. Abd Rahim Mat Sidek 2. Ahmad Zuri Sha'ameri

C.7 CROSS LAYER DESIGN OF COGNITIVE RADIO MB-OFDM SYSTEMS

C.8 New OADM Design for Next Generation Passive Optical Network and its Protection

C.9 Voltage Control System Design for Micro Hydro Power Generation based on Fuzzy Logic Approach in Order to Improve Voltage Profile of Alternative Power Generation

C.10 Electronic Devices Thermal Analysis and Optimization Using Genetic Algorithm
Author: 1. FATIMAH SHAM ISMAIL 2. RUBIYAH YUSOF

C.11 Indian mackerel on Target Strength Measurement
Author: 1. SUNARDI SUNARDI 2. JAFRI DIN 3. ANTON YUDHANA 4. RAJA BIDIN

C.12 PERFORMANCE IMPROVMENT OF HIGH SPEED DOWNLINK PACKET ACCESS (HSDPA) BASED ON TRAFFIC SCHEDULING TECHNIQUE
Author: 1. Ida Wahidah 2. Sofia Naning

C.13 The Comparison of Conventional and Modified Dielectric Barrier Discharge Chamber to Produce Lower Power Consumption for Ozone Gas Generation

C.14 Hardware Design for Low Cost Auditory Brainstem Response (ABR) Machine

C.15 Automatic Computerized Audiometric System

C.16 Semi-automatic Design of Two-hidden Layer Feedforward ANN for Predicting Grid-PV System Output
Author: 1. SHAHRIL IRWAN SULAIMAN 2. TITIK KHAWA ABDUL RAHMAN 3. ISMAIL MUSIRIN

C.17 DYNAMIC MODEL OF A TWO LINK FLEXIBLE MANIPULATOR
Author: 1. Moh. Khairudin 2. Zaharuddin Mohammed

C.18 APPLYING AN EXPERT SYSTEM AS AN EARLY DETECTION OF CERVICAL CANCER ON WEB BASED
Author: 1. Frida Kusumawati 2. Eko Handoyo

C.19 Non-Linear System Identification of Gaseous Pilot Plant at UTP
Author: 1. Hurriyatul Fitriyah

C.20 PERFORMANCE ANALYSIS OF WLAN IEEE 802.11E FOR TCP-UDP TRAFFICS WITH USING ADAPTIVE ADMISSION CONTROL MECHANISM
Author: 1. Rendy Munadi 2. Laila Yulia 3. R.Rumani M
C.21 Implementation of Arithmetic Logic Unit Design Based on Hardware Description Language (Verilog)  
Author: 1. May Phyo Thwal

C.22 TRANSLATION BETWEEN MICROPROGRAMMED CONTROL AND HARDWIRED CONTROL  
Author: 1. Aye Thi Ri Wai

C.23 Finite Difference Approach for Nonlinear Parameter Update on Fixed Radial Basis Function Network’s Learning Method  

C.24 Performance Evaluation of Decision Tree Algorithms For Flow-Based Network traffic classification  
Author: 1. Sulaiman Mohd Nor 2. Abuagla Babiker Mohammed

C.25 Information Fusion for Terrain State Feasibility Assessment based on Maximum Score of the Total Sum of Joint Probabilities Method  

C.26 Anti Jamming Transceiver Design by Using Advanced Free-Jamming Frequency Channel Selection Method  

C.27 An Analysis of Turtle Hearing Capability to Design TED (Turtle Excluder Device)  

C.28 System Performance Analysis for 150 km SCM/WDM Radio over Fiber  
Author: 1. Arief Marwanto 2. Sevia Mahdaliza Idrus

C.29 Wired and Wireless Technology For Transmission Line and Substation Protection Scheme  
Author: 1. Hamzah Eteruddin 2. Abdullah Asuhaimi

C.30 Application of ATmega8535 Microcontroller as Partial Discharge Detector  
Author: 1. Abdul Syakur 2. Iwan Setiawan 3. Darjat Fahrudin H. Prastowo

C.31 CAPACITY AND QUALITY IMPROVEMENT IN THE WCDMA SYSTEM EMPLOYING SMART ANTENNA  
Author: 1. Tito Yuwono

C.32 Design and Build Water Temperature and level controlling At silk worm Cocoon Boiler  
Author: 1. Tito Yuwono

C.33 Performance Analysis of a 2.4 GHz ISM-Band Wireless LAN in Indoor Wireless Communication Link  

C.34 High Efficient Coupling Using Fiber-Tapped Micro Lens in Single Mode Step Index Fiber Link  

C.35 Vulnerability Analysis of Oil Dependence for Electricity Supply in Indonesia  
Author: 1. Muhammad Eri Wijaya 2. Bundit Limmechokchai

C.36 A Tightly Coupled Hardware for FPGA-based Embedded Elliptic Curve Cryptosystem in GF(2m)  
Author: 1. Arif Irwansyah 2. Mohamed Khalil Hani

C.37 Simulation of Improved Direct Torque Control Scheme for Permanent Magnet Synchronous Motor Drives  
Author: 1. Tole Sutikno 2. Auzani Jidin

D. Computing and Information Technology
D.1 VIRTUAL ENVIRONMENT OF THE HAJJ
D.2 DEVELOPMENT OF AN INTELLIGENT COMPUTER VISION SYSTEM FOR AUTOMATIC RECYCLABLE WASTE PAPER SORTING

D.3 Text-Independent Speaker Identification By Artificial Neural Network Model Using Resilient Backpropagation Method
Author: 1. Soo Yee Cheang 2. Abdul Manan Ahmad

D.4 Implementation of FPGA Based Sobel Edge Detection Operator
Author: 1. Indra Yasri

D.5 APPLYING NATURAL LANGUAGE PROCESSING IN DEVELOPING SPLIT PATTERN OF LATIN CHARACTER TEXT DOCUMENT ACCORDING TO LINGUISTIC KNOWLEDGE OF WRITING JAVANESSE SCRIPT
Author: 1. EMA UTAMI 2. JAZI EKO ISTIYANTO 3. SRI HARTATI 5. AHMAD ASHARI

D.6 Building Knowledge Base Using C4.5 Algorithm
Author: 1. Enny Itje Sela

D.7 Optimal FEC Block Size for Media Streaming Over Internet
Author: 1. Omar Almomani 2. Suhaidi Hassan

D.8 A Review on Soft Computing in Image Enhancement Techniques: Neural Network, Genetic Algorithm, and Fuzzy Filters
Author: 1. Nur Zahrati Janah 2. Baharum Baharudin

D.9 Double Simulated Annealing Model for Mapping of Graphs to Single-Row Networks
Author: 1. Ser Lee Loh 2. Shahraruddin Salleh 3. Nor Haniza Sarmin

D.10 Using artificial intelligent techniques for meteorological forecasting: A Review
Author: 1. Ahmad shahi 2. Dr. Rodziah Atan 3. Associate Prof. Dr. Md. Nasir Sulaiman

D.11 Maturity Classification of Papaya Based on Two-Color Processing
Author: 1. Musa Mokji 2. Kamal Zharif

D.12 HUMAN ACTIVITIES CLASSIFICATION IN FAR FIELDS SURVEILLANCE SYSTEMS USING INTELLIGENT SYSTEMS
Author: 1. ALTAHIR ABDALLA ALTAHIR MOHAMMED 2. Vijanth S. Asirvadam 3. Patrick Sebastian

D.13 A review of QoS-aware routing protocols in Vehicular Ad hoc Networks

D.14 Problem Recognition Technique for Maintenance Modelling with Special Reference to Incomplete Data

D.15 Online Mobile Medical Records In Obstetrics-gynecology Subsystem
Author: 1. Anung Prastyo Pribadi 2. Eko Handoyo

D.16 A Data Mining Approach for Business

D.17 A new approach for Fingerprint Authentication

Author: 1. Retna Arliana 2. Eko Handoyo
D.19 **Mapping of OWL Context Ontology onto Z Notation**  
**Author:** 1. Bayu Erfianto 2. Ahmad Kamil Mahmood 3. Abdullah Sani Abdu Rahman

D.20 **ANALYSIS IMPLEMENTATION BANDWIDTH MANAGEMENT IPDSLAM FOR ACCESS VPN IP SERVICE**  
**Author:** 1. I Gede Astawa 2. Rendy Munadi 3. Sony Sumaryo 4. M R. Rumani

D.21 **Stakeholder Analysis for Malaysian Herbs Industry**  
**Author:** 1. Yunura Azura Yunus 2. Azizah Abdul Rahman 3. Noorminshah A. Iahad

D.22 **THE FEASIBILITY OF DEVELOPING COMPONENT-BASED SPEECH RECOGNITION APPLICATIONS IN MALAYSIA**  
**Author:** 1. Hong Kai Sze 2. Eric Tiong Chew Siong 3. Lee Bee Seah 4. Wan Timun 5. Chu Kean Fatt

D.23 **MULTI-SCALE COLOR IMAGE ENHANCEMENT USING CONTOURLET TRANSFORM**  
**Author:** 1. M. H. Asmare

D.24 **Protein Interaction Networks for Protein Function Prediction: A Review**  
**Author:** 1. Afnizanfaizal Abdullah 2. Safaai Deris 3. Hany Alashwal

D.25 **Optimized Fuzzy Cluster of E-Documents Using Validity Index**  
**Author:** 1. Lailil Muflikhah 2. Baharum Baharudin

D.26 **Implementation of Online Examination System Using Mobile Agent**  
**Author:** 1. Moe Moe Aye 2. Mie Mie Thet Thwin

D.27 **Comparison of Techniques for Estimating the Accuracy of Classification Methods**  
**Author:** 1. Aidel Basri 2. Baharum Baharudin 3. Brahim Belhaouari Samir

D.28 **Effectiveness of Pruning to Increase Efficiency and Accuracy in Decision Tree**  
**Author:** 1. Aidel Basri 2. Baharum Baharudin 3. Brahim Belhaouari Samir

D.29 **IPv6 Multi Generated Address for Enterprise Wireless Local Area Network**  

D.30 **IMPACT OF APPLICATION ADVERTASING AT INTERNET AND MARKETING WITH E-MAIL TOWARD PROCESSING INFOARMATION AND BUYING DECITION OF CONSUMER**  
**Author:** 1. Mujiyana Mujiyana 2. Mohammad Abdul Mukhyi

D.31 **Object Identification by Using Combination of Neural Network and Information Fusion**  

D.32 **performance evaluation of Malaysian University Website**  
**Author:** 1. Handaru Jati

D.33 **Off-Line Cursive Character Recognition Based on Hybrid Statistical Features**  
**Author:** 1. Amjad Rehman Khan 2. Fajri Kurniawan 3. Dzulkifli Mohamad

D.34 **Study On Reduced Support Vector Machines And Its Application In Ozone Level Detection**  
**Author:** 1. SANTI WULAN PURNAMI 2. SP RAHAYU 3. ABDULLAH EMBONG

D.35 **DESIGNING A WEB BASE ELECTRONIC MEDICAL RECORD IN STAYED NURSING INSTALLATION**  
**Author:** 1. Moh. Muttaqin 2. Eko Handoyo

D.36 **A LANGUAGE TO REPRESENT SECURITY POLICY FOR MULTI-AGENCY HEALTH INFORMATION SYSTEM**  
**Author:** 1. Intan Najua binti Kamal Nasir 2. Azween Abdullah
D.37 **Assessing the amount of erosion and sediment yield in watershed level using Geomorphology & EPM model**  
Author: 1. A. Haghizadeh 2. L. Teang shui

D.38 **Collaborating Text and Image Features for Building Decision Tree of Diagnose Problem**  

D.39 **Software Plagiarism Detection Using Code-Group Approach**  
Author: 1. Imam Much Ibnu Subroto 2. Ali Selamat

D.40 **A Review of the PBL integration into E-learning System**  

D.41 **Knowledge Dissemination Overview**  

D.42 **PARALLEL PROCESSING IN NEURAL NETWORK FOR PATTERN RECOGNITION**  

D.43 **Page 1 Combination Cryptography with EL-Gamal and Steganography with LSB for Data Text Security**  
Author: 1. Titin Sri Martini 2. Esti Suryani 3. Tuessi Ari Purnomo

D.44 **A New Dynamic Strategy on Portals for Managing ERPs as a Semi Distributed ERP Approach**  
Author: 1. MIR SHAHRIAR EMAMI

D.45 **Identification of Human Counterproductive Behavior Using Text Analysis Method**  

D.46 **Wireless Security: A Review of Researches Achievement today**  

E. **Civil Engineering**

E.1 **APPLYING QUALITY FUNCTION DEPLOYMENT APPROACH IN THE BUILDING LAYOUT DESIGN PROCESS**  
Author: 1. MUHAMAD AZANI YAHYA 2. Aniza Binti Ibrahim

E.2 **The Significant of Financial Management to Contracting Firms in Malaysia**  

E.3 **Comparison of Partial Strength Connection between Extended and Flush End-Plate Connections Using Built-Up Beam Sections**  

E.4 **Prioritizing The Maintenance of Pipeline**  
Author: 1. Silvianita Silvianita

E.5 **WATER PERMEABILITY OF MICRONISED BIOMASS SILICA CONCRETE**  
Author: 1. SURAYA HANI ADNAN 2. PM DR. YEE LOON LEE 3. DR. ISMAIL ABDUL RAHMAN 4. DR. HAMIDAH MOHD SAMAN 5. MIA WIMALA SOEJOSO

E.6 **GEOTECHNICAL CENTRIFUGE PHYSICAL MODEL OF REINFORCED CLAY SLOPE**  

E.7 **Hydrodynamics Study of Artificial Mangrove Root System (ArMS)**  
Author: 1. Hooi Bein Goh 2. hadibah Ismail

E.8 **An Over view of a Three-dimensional finite difference method (FDM) swelling behavior in tunnels**  
E.9 Comparison of Steel Portal Frame Analysis Based on Elastic and Simple Plastic Theory  

E.10 Effect of Development Condition on River Basin Response (A Case Study on Kayu Ara River Basin, Malaysia)  
Author: 1. Sina Alaghmand 2. Rozi bin Abdullah

E.11 BREAKING WAVE ENHANCED TURBULENCE IN A SEMI-ENCLOSED WATER BODY  
Author: 1. Purwanto Bekti Santoso

E.12 Conceptualization for Design of Earthquake Resistant High-rise Building in Myanmar  
Author: 1. Toe Toe Win

E.13 OPERATIONAL PERFORMANCE OF HARMONI TRANSFER POINT OF THE JAKARTA BUS RAPID TRANSIT SERVICE  
Author: 1. Leksmono Suryo Putranto

E.14 CONSIDERATION OF FRACTURES AND CAVITIES IN KARST TERRAIN BY USING GEOFLEX ELECTROMAGNETIC TECHNIQUES  

E.15 Effect of Packing Factor for SCC Mix Design  
Author: 1. YOYOK SETYO HADIWIDODO 2. SABARUDIN MOHD

E.16 LABORATORY INVESTIGATIONS ON SHEAR STRENGTH OF ORGANIC SOILS AND PEAT REINFORCED WITH CEMENT COLUMNS  

E.17 Stabilization of Subgrade Soil by using of Oil Palm Fruit Ash (OPFASH)  

E.18 SLIDEABLE CONNECTION FOR PRECAST CONCRETE FRAME SUBJECT TO INCREMENTAL STATIC LOAD  
Author: 1. Lim Jee Hock 2. Ahmad Baharuddin Abd Rahman 3. A. Aziz Saim

E.19 Treatment of pharmaceutical wastewater using thermophilic UASB reactor  

E.20 REDUCTION OF SUSPENDED SOLIDS FROM WASTEWATER BY COMBINED MAGNETIC FIELD - ELECTROCOAGULATION PROCESS  
Author: 1. Moh Faiqun Niam 2. Fadil Othman 3. Johan Sohaili

E.21 ADAPTATION OF SUSTAINABLE LIVING CONCEPT IN MALAYSIA  

E.22 THE CORRELATION BETWEEN TEXTURE DEPTH, PENDULUM TEST VALUE AND ROUGHNESS INDEX OF VARIOUS ASPHALT SURFACES IN MALAYSIA  
Author: 1. Suleiman Arafat yero 2. Rosli Mohammed Hainin 3. Haryati Yacoob

E.23 The Performance of Stabilized Road Base Material with Oil Palm Fruit Ash (OPFASH) as Additive  

E.24 On Street Parking and internal urban transportation  
Author: 1. Amirmahmood GhaFFARI

E.25 EVALUATION OF MARSHALL PROPERTIES OF ASPHALT CONCRETE MIXTURES WITH AGGREGATE GRADATIONS DESIGNED USING BAILEY METHOD  

E.26 DETERMINATION OF MIXING AND COMPACTING TEMPERATURES FOR HOT MIX ASPHALT
E.27 Utilization of Compressed Sugi Dowels to affect the performance of Wood Floor System

E.28 Beam to Column Partial Strength Composite Connections Using Trapezoid Web Profiled (TWP) Sections

E.29 Tsunami Run-Up on a Vegetated Coastal Slope - A Literature Review and Future Study
Author: 1. Nor Eliza binti Alias

F. Business and Management
F.1 Factors, Advantages and Disadvantages of Internet Financial Reporting: An Exploratory Study
Author: 1. Mohd Noor Azli Ali Khan 2. Noor Azizi Ismail

F.2 Component Commonality for Quality and Lead Time Uncertainties in Manufacturing

F.3 A Proposed Manufacturing Performance Measures for Malaysian Automotive Small and Medium-sized Enterprises (SMEs)
Author: 1. Elita Amrina 2. Sha'ri Mohd. Yusof

F.4 INFLUENCE OF ADVERTISING PROGRAM IMPLICATION VIA INTERNET AND MARKETING VIA E-MAIL AGAINST ADVERTISING INFORMATION PROCESSING AND ALSO ITS IMPLICATION AGAINST PURCHASING DECISION TO SAN MIGUEL INDONESIA Ltd., (Studi cases IN DEPOK - BEKASI REGIONS)

F.5 ANALYSE DISGRUNTLED OF CUTOMER : APPROACH OF BALANCED SCORECARD (case study in PT. HYUNDAI of CAR INDONESIA)
Author: 1. Nurul Fadillah 2. Mohammad Abdul Mukhyi

F.6 IMPACT OF FOOD INDUSTRY APPLICATION ADVERTASING AT INTERNET AND MARKETING BY E-MAIL TOWARD PROCESSING INFOARMATION AND BUYING DECITION
Author: 1. Mujiyana Mujiyana 2. Mohammad Abdul Mukhyi

F.7 A Review of the Relationship between Drivers of Organizational Innovation and Innovativeness in Malaysian House-building industry
Author: 1. Mohammed kamaruddeen Ahmed 2. Nor Aini Yusof 3. ILias Said

F.8 Telecommunications privatization in developing countries towards jointing the WTO
Author: 1. Hoda Ghaffari

F.9 The role of knowledge management in innovation
Author: 1. Iraj Imani 2. Farhad Shirani

F.10 Virtual Environments Innovation and R&D Activities: Management Challenges

G. Fundamental Science
G.1 Surface Morphology and Lateral Distribution of Self-assembled In0.5Ga0.5As Nanostructures Grown on GaAs (100) Substrates

G.2 Capacitated Arc Routing Problem With Time Window in Solid Waste Operation
Author: 1. Mohammad Fadzli Ramli 2. Assoc. Prof. Dr. Zuhaimy Ismail

G.3 Effect of excess MgO molar ratio in Crystallization and Phase Evolution of cordierite synthesized by crystallization of glass method using talc and kaolin
G.4 The 3D FcRM Modeling in Miles Per Gallon of Cars

G.5 Determination of organophosphorus pesticides by hollow fiber liquid-phase microextraction prior to liquid chromatography

G.6 Mixing in hydraulically controlled exchange flows

G.7 Parameterisation OF NEUTRON Spectra (TRIGA Reactor) for Neutron Activation Analysis without MULTIELEMENTAL Standard

G.8 An Integral Equation Method for Conformal Mapping of Triply Connected Regions onto a Disk with Circular Slits
Author: 1. Ali H. M. Murid 2. Laey-Nee Hu

G.9 The Nonabelian Tensor Square of One Family of A Bieberbach Groups with Point Group C2
Author: 1. ROHAIDAH HJ MASRI 2. NOR’AINI ARIS 3. NOR HANIZA SARMIN 4. ROBERT F. MORSE

G.10 Technical development of Instrumental Neutron Activation Analysis (INAA) based on ko method at The National Nuclear Agency of Indonesia
Author: 1. Nursama Heru Apriantoro 3. Ahmad Termizi Ramli

G.11 Simple Analysis Technique to Determine Lewis and Bronsted Acid Sites of Solid Catalysts

G.12 The Mechanism of Generation of Protonic Acid Sites Originated from Hydrocarbon Over Pt/So42 dropdown_ZrO2

G.13 Performance Of Holography Interferometer Based On Optical Reconstruction As Alternative Dental Imaging For Artificial Tooth Morphology

G.14 Role of Brönsted Acid Sites on Propane Aromatization

H. Chemical Engineering
H.1 THE USAGE OF EMPTY PALM FRUIT BUNCH (EPFB) AS THE SUBSTRATE FOR THE CULTIVATION OF PLEUROTUS OSTREATUS

H.2 ANN Models for Determining Bio-Gasoline’s Octane Number based on the Input Data Conditions
Author: 1. ABDUL WAHID 2. BAMBANG HERU SUSANTO

H.3 Theoretical studies on the morphological and electrical properties of blended PES/SPEEK nanofiltration membranes using different sulfonation degree of SPEEK
Author: 1. Woei Jye Lau 2. Ahmad Fauzi Ismail

H.4 Preparation of porous polysulfone hollow fiber membranes via a phase inversion method using glycerol as an additive
Author: 1. AMIR MANSOURIZADEH
H.5 Characterization and Potential Use of Crude Glycerol
Author: 1. Mahadhir Mohamed 2. Rubyatul Adawiyah Samsudin 3. Ramli Mat

H.6 CLONING OF CHITINASE, CHT1 GENE FROM TRICHODERMA VIRENS UKM-1
Author: 1. Nazihah Ab Hamid 2. Rosli Md. Illias

H.7 CONSTRUCTION OF WATER ELECTROLYZER FOR SINGLE SILCE O2/H2POLYMER ELECTROLYTE MEMBRANE FUEL CELL
Author: 1. May Zin Lwin 2. Mya Mya Oo

H.8 EFFECT OF MANGANESE DIOXIDE FILLING ON THE PROPERTIES OF POLYANILNE/MULTI-WALLED CARBON NANOTUBES POLYMERIZED BY IN-SITU

H.9 Synthesis and Characterization of Cobalt Carboxylates

H.10 Calcium and Strontium Sulfate Scale Formation Due to Incompatible Water
Author: 1. Amer Badr Bin Merdhah 2. Abu Azam Mohd Yassin

H.11 Optimal Electricity Generation Mix with Carbon Dioxide Constraint

H.12 Effect of some environmental factors on hydrogen production by Rhodobacter sphaeroides NCIMB 8253

H.13 Development of Non-woven Filter Media from Lignocellulosic Fiber for Pretreatment of Palm Oil Mill Effluent

H.14 Manufacture of Alkyd Resin from Dehydrated Castor Oil
Author: 1. Nway Nay Hlaing 2. Mu Mu Htay

H.15 Preparation of Zeolite NaY Catalyst for Petroleum Cracking
Author: 1. Nway Nay Hlaing 2. Mu Mu Htay

H.16 CO2 Removal from Biogas Using Carbon Nanotubes Mixed Matrix Membranes

H.17 BENDING BEHAVIOR OF TIMBER BEAMS STRENGTHENED USING GLASS FIBRE REINFORCED POLYMER
Author: 1. Yusof Ahmad 2. Abd Latif Saleh

I. Education Technology
I.1 WAT: A WEB-BASED ADAPTIVE TESTING APPARATUS

I.2 INDUSTRIES’ PERCEPTION ON UTM CHEMICAL ENGINEERING INDUSTRIAL TRAINEES

I.3 A Contextual Case-Based Engineering Mathematics Teaching Strategies to Facilitate the Development of Creative and Critical Thinking to Undergraduate Civil Engineering Students

J. Permeability of cancellous bone
Author: 1. Ardiyansyah Syahrom 2. Mohammed Rafiq Abdul Kadir
J.2 Molecular cloning, insertion and transcription confirmation and expression study of bromelain gene from Ananas comosus.
Author: 1. NURUL AZIRA ISMAIL 2. AZURA AMID

J.3 "Organic and Inorganic Compounds Characterization Study of Urinary Calculi "

J.4 Cloning of Family 11 Xylanase Genes from Locally Isolated Aspergillus fumigatus RT-1 and Expression in Escherichia coli
Author: 1. SOO YEE TEE 2. ROSLI MD ILLIAS

J.5 A Similarity of Sobel And Prewitt Edge Detection for Cell Counting Simulation Of Human Blood Cells Using MATLAB

J.6 The Effect of Leptin in TCM-199 Medium on the Expression of Cdc25A Protein in Oocyte Resulted from In-vitro Maturation

J.7 IDENTIFICATION OF HYPOCHOLESTEROLEMIC PEPTIDE IN FERMENTED SOYMILk STERILIZED
Author: 1. Fatma Zuhrotun Nisa

J.8 Construction of Signal Peptide Based Expression Vector
Author: 1. Noor Faizah Ismail 2. Prof. Madya Dr.Rosli Md.Illias 3. Dr.Salehhuddin Hamdan

K. Architecture Engineering
K.1 Landowners Attitude Affecting Land Supply Constraint for Redevelopment of Indigenous Lands
Author: 1. Djurdjani Wardaya 2. Ismail Omar 3. Asiah Othman

K.2 ANALYSIS OF AIR MOVEMENT AND VELOCITY IN HIGH-RISE BUILDING WITH ENCLOSED ATRIUM, SQUARE LAYOUT, AND NATURAL VENTILATION: Model Simulation Using Wind Tunnel
Author: 1. Apif M. Hajji 2. Dian Ariestadi

K.3 A CONCEPT TOWARDS NEGOTIATION SUPPORT
Author: 1. FARIDA MURTI 2. CHRISTIONO UTOMO

L. Applied Physics and Nano Technology
L.1 Variables Effects on Temperature Distributions for Coupled Single Mode Optical Fibers

L.2 Ferroelectric and Conductivity Properties of Bi0.5-xNa0.5-yKyRExTiO3 (RE= La, Sm and Gd) Lead-Free Piezoelectric Ceramics in MPB Area
Author: 1. Lukman Noerochim 2. Madirechi B. Suresh 3. Chen-Chia Chou

L.3 VERTICAL MOSFET FOR NANOMETER SCALE DEVICE
Author: 1. Munawar A. Riyadi 2. Ismail Saad 3. Razali Ismail

L.4 DETECTION OF THERMAL DEFORMATION ON ARTIFICIAL TOOTH USING HOLOGRAPHIC INTERFEROMETRY SINGLE EXPOSURE TECHNIQUE

M. Petroleum Engineering
M.1 Mechanistic Prediction Models of CO2 Corrosion
Author: 1. Yuli Panca Asmara

M.2 THE EFFECT OF PETROPHYSIC PROPERTIES TO THE COMPRESSIONAL AND SHEAR WAVE
VELOCITY IN CARBONATE ROCK
Author: 1. Jarot Setyowiyoto

M.3 Sulfonation of Petroleum Base Oils with Development of the Emulsifiers
Author: 1. A. M. Elgellal

M.4 Experimental Investigation of a Viscous Surfactant and Surfactant Flooding to Enhanced Oil Recovery
Author: 1. O. Arjmand
Prioritizing the Maintenance of Pipelines

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Abstract

Pipelines are the most economical tools for conveying the fluid substances on mass scale to larger distances. But there have been a number of tragic incidences happened those have brought some unwanted consequences. In order to minimize the failure, it is required to clearly understand the failure mechanism, governing factors and the data to be analyzed in order to determine the extent of failures. This research is based on Analytical Hierarchy Process (AHP) to determine the probability of pipeline failure that would be useful in the pipeline industry. To perform the AHP approach, pipelines located at Kertih West Malaysia have been chosen as case study.

Keywords : AHP, Pipeline, Failure

2. Objective and Scope of Study

The main objectives of this research are:
• To identify the greatest risk factors involved in failure of pipeline network system by applying the efficient analytical approach.
• To prioritize the maintenance of pipeline system based on risk analysis.

3. Literature review

The term pipe is defined as a closed conduit, usually of circular cross section. It can be made of any appropriate material such as steel or plastic. The term pipeline refers to a long line of connected segments of pipe, with pumps, valves, control devices, and other equipment/facilities needed for operating the system. It is intended for transporting a fluid (liquid or gas), mixture of fluids, solids, fluids-solid mixture. Offshore pipelines can be classified as follows [3] :
• Flow lines transporting oil and/or gas from satellite sub sea wells to sub sea manifolds;
• Flow lines transporting oil and/or gas from sub sea manifolds to production facility platforms;
• Infield flow lines transporting oil and/or gas between production facility platforms;
• Export pipelines transporting oil and/or gas from production facility platforms to shore;
• Flow lines transporting water or chemicals from production facility platforms, through sub sea injection manifolds, to injection wellheads.

Transportation of products by pipeline is a risk because there is some probability of the pipeline failing, releasing its contents, and causing damage (in addition to the potential loss of the product itself). The most commonly accepted definition of risk is often expressed as a mathematical relationship:

\[ \text{Risk} = (\text{event likelihood}) \times (\text{event consequence}) \]
As such, a risk is often expressed in measurable quantities such as the expected frequency of fatalities, injuries, or economic loss. Monetary costs are often used as part of an overall expression of risk; however, the difficult task of assigning a dollar value to human life or environmental damage is necessary in using this as a metric [4].

Risk analysis is about developing an understanding of the risk. It provides an input to decisions on whether risks need to be treated and the most appropriate and cost-effective risk treatment strategies. Risk analysis involves consideration of the sources of risk, their positive and negative consequences and the likelihood that those consequences may occur. Factors that affect consequences and likelihood may be identified. Risk is analyzed by combining consequences and their likelihood. In most circumstances existing controls are taken into account [9].

Risks are by nature subjective, so to analyze their potential of contributing to a failure, the AHP developed by Saaty (1980), is used here. This technique allows subjective and objective factors to be considered in risk analysis and also provide a flexible and easily understood way to analyze subjective risk factors. It is a multiple criteria decision-making technique that permits the active participation of those involved, and provides managers a rational basis on which to make decisions. [5].

In the AHP, a problem is structured as a hierarchy. This is then followed by a process of prioritization, which is involves eliciting judgments in response to questions about the dominance of one element over another when compared with respect to a property. In this process, the decision maker carries out simple pair wise comparison judgments which are then used to develop overall priorities for ranking the alternatives. The AHP both allows for inconsistency in the judgments and provides a means to improve consistency [6].

In the pair wise comparison method, criteria and alternatives are presented in pairs of one or more referees (e.g., experts or decision-makers). It is necessary to evaluate individual alternatives, deriving weights for the criteria, constructing the overall rating of the alternatives and identifying the best one.

Table 1 shows the scale of judgments and their definitions [7]. After scales of judgment have been identified for all levels of the hierarchy, matrices are constructed for each level starting from the top of the hierarchy.

Table 1. Analytical hierarchical process scale of judgements

<table>
<thead>
<tr>
<th>Intensity of Importance</th>
<th>Definition</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
<td>Two elements contribute equally to the property.</td>
</tr>
<tr>
<td>3</td>
<td>Moderate importance of one over another</td>
<td>Experience and judgment slightly favor one element over the another.</td>
</tr>
<tr>
<td>5</td>
<td>Essential or strong importance</td>
<td>Experience and judgment slightly strongly favor one element over the another.</td>
</tr>
<tr>
<td>7</td>
<td>Very strong importance</td>
<td>An element is strongly favorable and its dominance is demonstrated in practice.</td>
</tr>
<tr>
<td>9</td>
<td>Extreme importance</td>
<td>The evidence of favoring one element over another is of the highest possible order of affirmation.</td>
</tr>
<tr>
<td>2, 4, 6, 8</td>
<td>Intermediate values between two adjacent judgments</td>
<td>Compromise is needed between two judgments</td>
</tr>
</tbody>
</table>

One begins with a matrix A of real numbers, representing the pair wise comparison of the importance of the elements of one level in H (hierarchy) with respect to one element of the next higher level and the solution of the equation:

\[ A \mathbf{w} = \lambda_{\text{max}} \mathbf{w} \]

where \( \lambda_{\text{max}} \) is the largest eigenvalue of the matrix, \( \mathbf{w} \) is the weight. The consistency index \( CI \) is given by:

\[ CI = \frac{\lambda_{\text{max}} - n}{n - 1} \]

The ratio of \( CI \) to the average \( RI \) for the same order matrix is called the Consistency Ratio (CR). A Consistency Ratio of 0.10 or less is considered acceptable.

\[ CR = \frac{CI}{RI} \]

where ‘\( RI \)’ is the average value of ‘\( CI \)’ for a random matrices using the Saaty’s scale [7]. CR is a normalized value, because is divided by an arithmetic mean of a random matrices consistency indexes (\( RI \)).
Table 2. Random index for a several matrix dimensions [7].

<table>
<thead>
<tr>
<th>n</th>
<th>1-2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>0.00</td>
<td>0.58</td>
<td>0.90</td>
<td>1.12</td>
<td>1.24</td>
<td>1.32</td>
<td>1.41</td>
<td>1.49</td>
</tr>
</tbody>
</table>

4. Methodology

The methodology to carry out this analytical research is demonstrated in the following flowchart (Fig. 1).

Comprehensive lists of factors that can cause pipeline failure were obtained from literature [3, 4, 8]. And the list need to be reviewed by pipeline engineers in order to identified the probability of pipeline failure. The hierarchical structure in this research consist of four level which are level 1 is the goal, level 2 is criteria (risk factors), level 3 is sub-factors and level 4 is alternatives (Fig. 2).

![Flowchart of Research Working Process](image)

Figure 1. Research working flowchart

5. Results

The application of prioritizing the maintenance of pipeline is at Kertih West Malaysia. The thesis research was presented and feedback was collected from the experts. There are 8 pipeline engineers involved in discussion and interview to carry out the problem.

Table 3. The characteristic of pipeline

<table>
<thead>
<tr>
<th>Pipeline ID</th>
<th>Material Pipe</th>
<th>OD (mm)</th>
<th>WT (mm)</th>
<th>ID (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipeline 1</td>
<td>5LX-60</td>
<td>610</td>
<td>14.3</td>
<td>581.4</td>
</tr>
<tr>
<td>Pipeline 2</td>
<td>5LX-60</td>
<td>762</td>
<td>17.1</td>
<td>727.1</td>
</tr>
<tr>
<td>Pipeline 3</td>
<td>5LX-60</td>
<td>762</td>
<td>17.1</td>
<td>727.1</td>
</tr>
</tbody>
</table>

The Analytical Hierarchy Process (AHP) structure is developed to identify the probability of failure (PoF) and consequence of failure (CoF). The risk factors that can cause failures as identified by the pipeline engineer of the organization under study are the following:

a. Internal Corrosion: internal corrosion due to fluid composition and improper chemical treatment of fluid
b. External Corrosion: external corrosion due to damaged coating and damaged anodes and defect from construction
c. Internal Erosion: internal corrosion due to flow characteristic and pipeline design e.g. angle and number of bends
d. External Impact: impacts from dropped objects, fish bombing
e. On Bottom Stability: seabed movement and loss of weight coating
f. Free Span: seabed scouring, pipeline on bottom instability and seabed undulations

To find the risk of pipeline the next step was to determine the consequence of failure, which can identify the impact on a range of stakeholders and the assets. The Analytical Hierarchy Process (AHP) structure also developed to identify the consequence of pipeline failure. The hierarchical structure of consequence in this area consist of four level which are level 1 is the goal, level 2 is criteria (factors), level
3 is the sub factors and level 4 is alternatives (see Fig.3).

Analytic Hierarchy Process frameworks for CoF are:

1. Economic Consequences due to repair cost and business loss
2. Safety Consequences due to product transported and manning on installation
3. Environmental Consequences due to pollution and pipeline size

**Figure 2. Hierarchical structure of probability**

**Figure 3. The Hierarchical structure of the consequence**
5.1. Result of the Analysis of the Analytical Hierarchy Process

### Table 4. Probability of the risk factors

<table>
<thead>
<tr>
<th>Major Factor</th>
<th>Probability</th>
<th>Sub factor</th>
<th>Probability</th>
<th>Pipeline 1</th>
<th>Pipeline 2</th>
<th>Pipeline 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Corrosion</td>
<td>0.417</td>
<td>Fluid Composition</td>
<td>0.278</td>
<td>0.039</td>
<td>0.093</td>
<td>0.147</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improper Chemical Treatment of Fluid</td>
<td>0.139</td>
<td>0.033</td>
<td>0.029</td>
<td>0.077</td>
</tr>
<tr>
<td>External Corrosion</td>
<td>0.107</td>
<td>Damage Coating</td>
<td>0.053</td>
<td>0.017</td>
<td>0.014</td>
<td>0.022</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Damage Anodes</td>
<td>0.033</td>
<td>0.005</td>
<td>0.007</td>
<td>0.021</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Defect from Construction</td>
<td>0.021</td>
<td>0.003</td>
<td>0.005</td>
<td>0.012</td>
</tr>
<tr>
<td>Internal Erosion</td>
<td>0.191</td>
<td>Flow Characteristic</td>
<td>0.048</td>
<td>0.007</td>
<td>0.012</td>
<td>0.028</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pipeline Design</td>
<td>0.143</td>
<td>0.043</td>
<td>0.077</td>
<td>0.023</td>
</tr>
<tr>
<td>External Impacts</td>
<td>0.138</td>
<td>Impact from Dropped Objects</td>
<td>0.092</td>
<td>0.018</td>
<td>0.029</td>
<td>0.045</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fish Bombing</td>
<td>0.046</td>
<td>0.015</td>
<td>0.012</td>
<td>0.019</td>
</tr>
<tr>
<td>On Bottom Stability</td>
<td>0.067</td>
<td>Seabed Movement</td>
<td>0.050</td>
<td>0.009</td>
<td>0.013</td>
<td>0.027</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Loss of Weight Coating</td>
<td>0.017</td>
<td>0.008</td>
<td>0.005</td>
<td>0.003</td>
</tr>
<tr>
<td>Free span</td>
<td>0.081</td>
<td>Seabed Scouring</td>
<td>0.044</td>
<td>0.007</td>
<td>0.013</td>
<td>0.024</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pipeline On Bottom Instability</td>
<td>0.017</td>
<td>0.004</td>
<td>0.004</td>
<td>0.009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Seabed Undulations</td>
<td>0.019</td>
<td>0.004</td>
<td>0.005</td>
<td>0.011</td>
</tr>
<tr>
<td>Probability of failure of various Pipeline</td>
<td></td>
<td></td>
<td>0.217</td>
<td>0.317</td>
<td>0.466</td>
<td></td>
</tr>
<tr>
<td>Ranking</td>
<td></td>
<td></td>
<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

### Table 5. AHP output of CoF kerih pipeline

<table>
<thead>
<tr>
<th>Major Factor</th>
<th>Consequence</th>
<th>Subfactor</th>
<th>Consequence</th>
<th>Pipeline 1</th>
<th>Pipeline 2</th>
<th>Pipeline 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic</td>
<td>0.249</td>
<td>Repair Cost</td>
<td>0.062</td>
<td>0.009</td>
<td>0.027</td>
<td>0.027</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Business</td>
<td>0.187</td>
<td>0.037</td>
<td>0.075</td>
<td>0.075</td>
</tr>
<tr>
<td>Safety</td>
<td>0.157</td>
<td>Product</td>
<td>0.118</td>
<td>0.011</td>
<td>0.026</td>
<td>0.041</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manning</td>
<td>0.039</td>
<td>0.026</td>
<td>0.026</td>
<td>0.026</td>
</tr>
<tr>
<td>Environment</td>
<td>0.594</td>
<td>Pollution</td>
<td>0.297</td>
<td>0.042</td>
<td>0.127</td>
<td>0.127</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pipeline Size</td>
<td>0.297</td>
<td>0.042</td>
<td>0.127</td>
<td>0.127</td>
</tr>
<tr>
<td>Probability of failure of various Pipeline</td>
<td></td>
<td></td>
<td>0.164</td>
<td>0.409</td>
<td>0.428</td>
<td></td>
</tr>
<tr>
<td>Ranking</td>
<td></td>
<td></td>
<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

### Table 6. The pairwise comparison respect to goal

<table>
<thead>
<tr>
<th>Factors</th>
<th>Internal Corrosion</th>
<th>External Corrosion</th>
<th>Internal Erosion</th>
<th>External Impacts</th>
<th>On Bottom Stability</th>
<th>Free Span</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Corrosion</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>0.417</td>
</tr>
<tr>
<td>External Corrosion</td>
<td>1/4</td>
<td>1</td>
<td>1/2</td>
<td>1/3</td>
<td>3</td>
<td>2</td>
<td>0.107</td>
</tr>
<tr>
<td>Internal Erosion</td>
<td>1/5</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>0.191</td>
</tr>
<tr>
<td>External Impacts</td>
<td>¼</td>
<td>3</td>
<td>1/3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>0.138</td>
</tr>
<tr>
<td>On Bottom Stability</td>
<td>1/3</td>
<td>1/3</td>
<td>1/2</td>
<td>½</td>
<td>1</td>
<td>½</td>
<td>0.067</td>
</tr>
<tr>
<td>Free span</td>
<td>1/3</td>
<td>1/2</td>
<td>1/3</td>
<td>½</td>
<td>2</td>
<td>1</td>
<td>0.081</td>
</tr>
<tr>
<td>Consistency Index</td>
<td>0.137</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Random Index</td>
<td>1.24</td>
<td></td>
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<tr>
<td>Consistency Ratio</td>
<td>0.11</td>
<td></td>
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</tr>
</tbody>
</table>
The above results obtained from the pipeline engineers. Pipeline engineers express the judgments into numerical values on a scale of 1 to 9 (Table 1). Elements at each level of hierarchy are compared with each other in pairs with their respective “parents” at the next higher level. As an example, the pair wise comparison values of the major categories of failure are shown at table 5.

Results of the pair wise comparison for the first level of the hierarchy as shown on table 3 indicate that the highest contributes to the likelihood of pipeline failure is internal corrosion with 41.7%, the second highest likelihood causing a pipeline failure is internal erosion with 19.1%, the third highest is external impact with 13.8%, and the other factors are external corrosion10.7%, free span 8.1%, on bottom stability 6.7%.

The results of the pair wise comparison at the sub factors level of the hierarchy show the probability that a major factor will be the result of one of the sub factors. For example, the result of major factor show that internal corrosion is 41.7% that would be due to the sub factors which are fluid composition 27.8% and improper chemical treatment of fluid 13.9%.

From the analysis of consequence of failure, it was determined that the highest probability i.e. 59.4% will have significant impact on environment. There are two sub factors those are pollution and pipeline size, both of them will contribute equally with a consequence 29.7%, each respectively.

<table>
<thead>
<tr>
<th>Weight of Priority</th>
<th>Risk Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.10 - 0.20</td>
<td>1</td>
</tr>
<tr>
<td>0.21 - 0.40</td>
<td>2</td>
</tr>
<tr>
<td>0.41 - 0.60</td>
<td>3</td>
</tr>
<tr>
<td>0.61 - 0.80</td>
<td>4</td>
</tr>
<tr>
<td>0.81 - 1.00</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 7. Risk score

Table 8. Risk matrix

<table>
<thead>
<tr>
<th>Category of Risk</th>
<th>Range of Risk Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Risk</td>
<td>21 – 25</td>
</tr>
<tr>
<td>Medium to High Risk</td>
<td>16 – 20</td>
</tr>
<tr>
<td>Medium Risk</td>
<td>10 – 15</td>
</tr>
<tr>
<td>Low to Medium Risk</td>
<td>6 – 9</td>
</tr>
<tr>
<td>Low Risk</td>
<td>1 – 5</td>
</tr>
</tbody>
</table>

Table 9. Risk category of pipelines

<table>
<thead>
<tr>
<th>Name</th>
<th>Probability</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight Rank</td>
<td>Risk Score (0-5)</td>
</tr>
<tr>
<td>PLN 1</td>
<td>0.133 3</td>
<td>1</td>
</tr>
<tr>
<td>PLN 2</td>
<td>0.191 2</td>
<td>1</td>
</tr>
<tr>
<td>PLN 3</td>
<td>0.276 1</td>
<td>2</td>
</tr>
</tbody>
</table>
6. Conclusion

The objectives of this paper are:
1. To identify the greatest risk factors involved in failure of pipeline network system. Based on the analysis Internal Corrosion would be the major factor involved in probability of failure and the highest consequence will be impact on the environment.
2. To prioritize the maintenance of pipeline system based on risk analysis. The result shows that the three pipelines fall into low risk. In order to prioritize for maintenance is pipeline 2, pipeline 3 and pipeline 1.

7. Reference