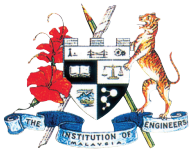

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THE THIRTIETH PROFESSOR CHIN FUNG KEE MEMORIAL LECTURE

Presented at Webinar on 17th October 2020

Ir. Academician Emeritus Professor Tan Sri Dato' Dr Chuah Hean Teik
Hon FIEM, FASc, FIET, FIEEE

Dr Chuah Hean Teik graduated with a BEng (First Class Honours), MEngSc and PhD in electrical engineering, all from University of Malaya, Malaysia. From July 1988-April 1997, he was on the faculty of the Electrical Engineering Department of the University of Malaya. From March-Nov 1994, he was a Fulbright Scholar at the Wave Scattering Research Centre, University of Texas at Arlington, USA. From May 1997–Jan 2008, Dr Chuah was a Senior Professor at the Multimedia University (MMU), during which he held various posts as Vice President (R&D and Academic Development), Dean of Engineering, and Director of Research. From June 2001-Jan 2008, he also assumed the duty of the Penang State Government Professor of ICT in MMU. He was President of Universiti Tunku Abdul Rahman (UTAR) in Malaysia from 2008-2019. He is also a Consultant Professor to Northwestern Polytechnical University, Xian, China.

His research interests include microwave remote sensing and applied electromagnetics. He has authored/co-authored more than 260 papers in international journals and conferences. Dr Chuah has received many awards locally and internationally. Among them include the Professor Chin Fung Kee Gold Medal for Engineering Management in 1986, the inaugural Young Engineer Award by the Institution of Engineers, Malaysia in 1991; 1990 Young Scientist Award at the 23rd General Assembly of the International Union of Radio Science (URSI) at Prague, Czechoslovakia; 1993 Young Scientist Award at the 24th General Assembly of URSI at Kyoto, Japan; 1995 Young Scientist Award (Industrial Sector) by the Malaysian Ministry of Science, Technology and the Environment; 1999 Malaysian Toray Science Foundation Science and Technology Award for his contributions in the area of microwave remote sensing; 2002 Sterling Award from the Sterling Group of Universities (research-based universities in UK with engineering faculties) for his services to promotion of engineering profession; 2011 IET Malaysia Outstanding Achievement Award; Rotary Charity Foundation of Kuala Lumpur Research Gold Medal 2012 for excellence in original research and significant achievement in the field of electrical engineering; 2014 Distinguished Engineer Award by IEM Penang Branch, 2016 Taiwan Professional Education and Culture Medal for his contribution towards education and cultural exchange between Malaysia and Taiwan, 2017 Exemplary Leaders Award (Education Category) by The Federation of Hokkien Associations of Malaysia; 2017 Outstanding Engineering Achievement Award by the ASEAN Federation of Engineering Organisations; and the 2018 Distinguished Honorary Mentor Award by Myanmar Engineering Council. In collaboration with Malaysian Centre for Remote Sensing, his research team working on "Paddy Monitoring and Yield Prediction System using Remote Sensing and GIS Technologies" won a Gold Medal at the 2003 Malaysian Science and Technology Expo, and a Gold Medal at the 32nd International Exhibition of Inventions at Geneva in 2004. For his significant contribution in engineering profession, he was awarded Honorary Doctor of Engineering by MMU in August 2013. He was inducted into the IEM Engineering Hall of Fame in 2019 for his outstanding professional achievements and

contribution to the country, IEM and the engineeirng profession. He is recipient of 2019 FEIAP Engineer of the Year, and 2019 WFEO Medal of Excellence in Engineering Education.

Dr Chuah is an eminent technical leader. He is currently the President of ASEAN Academy of Engineering and Technology (AAET), Past President of the Federation of Engineering Institutions of Asia and the Pacific (FEIAP) from 2011-2015, and current Chairman of FEIAP Standing Committee on Engineering Education. Dr Chuah was the President of IEM (2009-2011). He is a Senior Fellow of the Academy of Sciences, Malaysia (ASM); Hon. Fellow of the ASEAN Federation of Engineering Organisations, IEM, and Myanmar Engineering Society; a Founding Fellow of the AAET and The Academy of Engineering and Technology of the Developing World; Fellow of the Remote Sensing & Photogrammetry Society, UK; the Institution of Engineering and Technology, UK; the Institute of Electrical and Electronics Engineers, USA; and the Electromagnetics Academy, USA. He is also a Professional Engineer in Malaysia, a Chartered Engineer with the Engineering Council, UK; an APEC Engineer, International Professional Engineer and ASEAN Chartered Professional Engineer; and Hon. Member of the Golden Key International Honour Society. Dr Chuah serves as reviewer for technical papers submitted to international journals such as Progress in Electromagnetics Research (PIER) Journal, and IEEE Trans. Geoscience and Remote Sensing. He is currently a member of the Disciplinary Committee Panel under the Advocates and Solicitors' Disciplinary Board, Malaysia, the Malaysian Engineering Accreditation Council (EAC) and the Civil Aviation Authority of Malaysia; was a Council Member of the Malaysian Qualifications Agency (2008-2012) and ASM (2007-2011, 2014-2016). He also serves in Technical Committee or Advisory Committee of a few regional and international conferences and symposia.

In recognition of his valuable services and contributions, he was conferred an Order of Chivalry, Darjah Setia Pangkuan Negeri, which carries the title "Dato", by the Governor of Penang in July 2005, and conferred the Panglima Setia Mahkota Award, which carries the title "Tan Sri", by the Yang DiPertuan Agung of Malaysia in September 2019.

EDUCATING FUTURE ENGINEERS: CHALLENGES AND OPPORTUNITIES

(Date received: 25.11.2020/Date accepted: 08.12.2020)

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ABSTRACT

In this paper, various trends and challenges facing the world are discussed. These include urbanization and inequality in wealth distribution, clean air and clean water, food distribution, energy, global warming and climate change, old and new diseases and aging population, as well as physical-space and cyber-space security. The new Digital Revolution or commonly known as 4th Industrial Revolution causes anxiety in the industry, academia and society as we are uncertain of the future of our jobs and what new disruptive technologies are coming. The author also gives USA and Malaysian examples of challenges and limitation in STEM education. To tackle the challenges, we require new ideas and inventions which will only be possible with excellent knowledge workers. A brand new set of technology breakthrough will require different skill sets, particularly on STEM skill sets, in the engineering workforce. Good engineering workforce (engineer, engineering technologist and engineering technician) is considered as the driver for the success of any nation in this globalized world. The paper also touches on the challenges faced by future engineers vis-à-vis globalization and mobility of engineers; and what skills young engineering graduates should acquire to face the challenges. In the opinion of the author, what is important now is for the educators to train future graduates who can embrace life-long learning and professional skills with strong basic fundamentals of natural sciences and engineering, and who are ready-to-evolve rather than graduates who are just ready-to-market as many of the graduates will be entering a whole new and unknown sea of employment. Values and ethics should also not be forgotten in educating future graduates. In particular, three IC's are advocated for our future graduates: Integrity & Competence, Integration & Communication, and Internationalization & Cooperation.

Keywords: Engineering education, skill set for engineering workforce, STEM education, mobility of engineers.

1.0 INTRODUCTION

Ir. Professor Tan Sri Dato Dr Chin Fung Kee is one of the most respected and outstanding civil engineers in Malaysia, both in engineering practice and also in engineering research and education.[1] He is a renowned leader in geotechnical and structural engineering. He played a key role in the development of engineering education, research and practice in the country. Professor Chin completed his secondary education at the Bukit Mertajam High School and was awarded a Straits Settlements Scholarship at Raffles College, Singapore where he obtained a First Class Diploma in Arts. Then he was awarded a Queen's Scholarship in 1949 to study Civil Engineering at the Queen's University in Belfast. At Belfast he won the Foundation Scholarship in Civil Engineering and the Belfast Association of Engineers Prize. In 1952, Prof. Chin graduated with First Class Honors in Engineering and proceeded to complete his Master's at the same University while working as an assistant lecturer. In 1954 Professor Chin returned to Malaya and served as an engineer with the Drainage and Irrigation Department before joining the University of Malaya in 1955 as Lecturer, Senior Lecturer and finally a full Professor.

Prof. Chin (who was a senior lecturer then) played a major role in the formation and development of the Faculty of Engineering, University of Malaya, Kuala Lumpur. The Government of Malaya then decided to offer an endowment to any department/faculty which was prepared to move to Kuala Lumpur "lock stock and barrel" from Singapore. Prof. Gray (who was professor of civil engineering then) together with Prof. Chin agreed to take up the offer and was asked to see the Prime Minister of Malaya, YTM Tunku Abdul Rahman Putra. With the approval of the Tunku, an allocation of RM1.5 mil endowment was given to the Faculty for its development. Under the stewardship of Prof. Chin, the project went on full swing to build the Faculty of Engineering in early 1958; assembling the then existing government designs of buildings already constructed for the new Faculty of Engineering buildings at Lembah Pantai. The buildings were completed in a record time of four months, in time for the engineering courses to commence in October 1958 without any break in the moving of the Faculty to Kuala Lumpur "lock, stock and barrel". Professor Chin's great achievement in UM Faculty of Engineering, attained through the collective effort of both staff and students, was to build up in a

short period of a few years, a degree which attained international recognition. A pass in engineering degree from the University of Malaya was readily accepted by British, Australian and American Universities for postgraduate studies which normally required a good honors degree. There was reluctance and decline by senior engineers to be posted as the State Engineer in Penang in the early 60's. One non-UM trained engineer agreed to accept the post on condition that he could have three UM engineering graduates as his assistants. This speaks volumes of the confidence on the quality of UM engineering graduates those days.

Prof. Chin was acting Vice Chancellor of University of Malaya for seven years and for a period he was concurrently the Professor and Dean of Engineering, Deputy and Acting Vice Chancellor. He retired as Emeritus Professor in 1973 and joined Jurutera Konsultant (SEA) Sdn. Bhd. Prof. Chin was an outstanding engineer in geotechnical, structural and hydraulic engineering and is always remembered for his leading role in the design and construction of the first Penang Bridge, the Penang KOMTAR building foundation rectification work and many other important projects such as the North-South Expressway.

Professor Chin's significant contributions benefited the engineering fraternity nationally, regionally and internationally and his success was recognized worldwide. Prof. Chin passed away in 1990 and in recognition of Prof. Chin's outstanding achievements and contributions, the Prof. Chin Fung Kee Memorial Lecture was inaugurated in 1991 and jointly organized by The Institution of Engineers, Malaysia (IEM) and the Engineering Alumni Association of the University of Malaya. Also a Prof. Chin Fung Kee Gold Medal was established in UM to recognize the top engineering student with the best result in the final year common subject on Management (and later was changed to award for the best engineering graduate).

The author had the honour to be invited by the Organizing Committee to deliver the 30th Prof. Chin Fung Kee Memorial Lecture. The author presented his lecture on 17, October, 2020 and this paper is a write-up on his presentation. This paper is an updated version of the author's paper entitled "Developing Engineering Work Force, Designing a Better Future" presented at the 3rd Chiam Teong Tee Memorial Lecture in March 2019.[2] Incidentally Mr. Peter Chiam Teong Tee was also a student of Prof. Chin and was encouraged by Prof. Chin to teach at UM in 1963, and was also the Dean of Engineering in 1973.

The author received his education all from Malaysia, starting from primary education to PhD. He was honoured to be a recipient of the Professor Chin Fung Kee Gold Medal in Management subject in University of Malaya during his final year electrical engineering course. In this paper, the author shares his experience as a researcher, educator and engineer in Malaysia. The paper also attempts to explain the technological revolutions in human civilization and the global trends in the Digital Revolution. Various challenges and trends in the globalized world are discussed, particularly population increase, urbanization, energy, clean air and clean water, inequality in wealth, food distribution and environmental issues. The new Digital Revolution requires a brand new breed of engineers, technologists and technicians. As there will be many disruptive technologies, and new jobs will be created while many old jobs will become obsolete, engineering education must be reviewed. The industry, academia and society are in anxiety as the technological advancement is progressing and changing so fast that no one can really anticipate what new technologies are coming. The author proposes that engineering education should aim to train "ready-to-evolve" graduates rather than "ready-to-market" graduates so that they are able to adapt to changes and new technologies in future. Thus, it is imperative to prepare the young generation with solid science, mathematics and engineering principles based on natural laws. They will need a strong foundation to be self-learners and to be able to keep abreast with the new technologies throughout their careers. At the same time, it is also important for us to educate our future engineers and technologists to be responsible, ethical and professional.

The author presents the trends in tertiary education, the USA and Malaysian scenarios in Science, Technology, Engineering and Mathematics (STEM) education. There is an urgent need to promote STEM education among the young children even as early as primary or lower secondary school level as there is a decline in the number of upper secondary school students taking Science subjects. The author also presents the skill sets and emerging clusters of professionals for 2022 by the World Economic Forum. He also proposes what professional bodies like the IEM can do to help the government, the Ministry of Education and the institutions of higher learning to train future engineers. Future engineers are expected to deal with complex problems, providing solutions which are novel and innovative. Mobility of the engineering workforce is another important issue that the author discusses in the paper, particularly for engineering services. For mobility, it is necessary for the engineering degree programmes to be recognized regionally and globally. It is also necessary for practicing engineers to attain experience which is of substantial equivalence to their counterparts worldwide. The author also proposes 3 IC's for the engineering profession: Integrity and Competency; Integration and Communications; and Internationalization and Cooperation. If every engineer carries with him/her these 3 IC's, the author is sure that the engineering profession will be highly regarded by the society and all engineers will be able to contribute to humanity as what Professor Chin Fung Kee had done.

2.0 AUTHOR'S EXPERIENCE IN MALAYSIA

The author takes pride in being a 100% made in Malaysia engineer. He completed all his primary, secondary and tertiary education (from degree to PhD) in Malaysia. He started with his primary education in a Chinese school, Hu Yew Siah, in Penang. He then continued with his lower, higher secondary education and sixth form study in Chung Ling High School in Penang. In 1986 he completed his four year electrical engineering degree programme in the Electrical Engineering Department of University of Malaya. Then he proceeded to complete his master's degree by research in 1988 while working as a tutor in the department. After completing his Master's, the author was actually awarded full scholarship from University of Cambridge UK, University of California San Diego, and University of Texas at Arlington to pursue his PhD degree. However, family circumstances stopped him from going overseas. Thus he decided to stay back in Malaysia. In 1988 he started his career as a lecturer in the Electrical Engineering Department of UM while pursuing his part time PhD programme in the same department. The author is very fortunate to have both his Master's and PhD projects supervised by Professor Tan Hong Siang, another

renowned electrical engineering professor in UM. The author completed his PhD in 1992 after publishing eight international journal papers based on his PhD work. Then he continued to teach and conduct research in UM, before he was offered as a full Professor and founding Dean of Engineering of the first private university in Malaysia, Multimedia University. The author spent 11 years in MMU as the Dean, Director of Research and later as Vice President (Academic and Research & Development). In 2008-2019, the author was appointed as the President of Universiti Tunku Abdul Rahman. As a Malaysian trained engineer and as an educator in Malaysia, the author learnt a few things which he would like to share.

While he was doing his research projects in late 80's and early 90's in UM, research funding was scarce and difficult to get. He only managed to obtain a total of RM10,000 for 3 years under the Vote F grant in UM. Thus he could not afford expensive equipment nor a super workstation to work on his project. Both his supervisor and he decided on a theoretical project on multiple scattering mechanisms in random media for application in microwave remote sensing. The formation of the problem based on High-order Renormalization Method ended up with a 36-fold integral equation. He did not give up but persevered and finally managed to solve the equation until the last 6-fold integration which he had to resort to numerical technique using the available computing facility in the laboratory then – an IBM 8088 computer. Yet they managed to produce results which are able to match with experimental data available in the literature. While he was solving his theoretical problem at Master's level, after about four months, he re-formulated what his PhD supervisor did during his sabbatical leave in USA in 1980. The author detected an error in the original solution based on Second-order Renormalization Method provided in a published paper by his PhD supervisor and his co-researcher in USA. The author went to see his PhD supervisor Prof Tan. Instead of questioning the author, Prof Tan was quick to admit there was a mistake and encouraged the author to quickly submit a paper to IEEE Transactions on Geoscience and Remote Sensing with the right solution. The paper corrected the error in the Second-order Renormalization Method and further included the solution the author proposed based on High-order Renormalization technique (the 36-fold integral solution!). His solution was able to produce simulated radar backscatter results which could match with the experimental data in the field, for both the co- and cross-polarizations. The author learnt from his supervisor that to move the frontier of knowledge, we must be open minded and accept that our own students could know more than ourselves in certain aspects – that is what advancement of knowledge and research is all about. The author's favourite quote to all his undergraduate and postgraduate students and colleagues is: "If a person can only work when given everything under the sun, he is just mediocre. If a person can perform within constraints, he is a real achiever". One must have the commitment, passion and right attitude in doing one's job. It is not the method that is important, it is how we apply the method to solve problem and to find a solution which has not been done before. Another lesson he learnt is about being humble and do not look down on anyone, even your own student.

While serving as a lecturer in the Electrical Engineering Department, the author was assigned different subjects to teach: Field Theory, Electromagnetics, Quantum Mechanics, Machine Theory, Microprocessor, Communication Theory, Electronics, Engineering Mathematics, Instrumentation and Control. He never objected. The best way to learn is to teach. When we teach, we shall push ourselves to learn what we do not know and we shall continue to know a subject better and in greater depth. Thus another of his favourite quote is "Learning never stops: Keep learning new knowledge". Don't just simply complain. Whatever we learn now, even if it appears to be not useful, it will enhance our knowledge. For example, many electrical engineering students now argue why they should learn thermodynamics which appears to be not relevant to an electrical engineer. But engineering problem is now more and more multi-disciplinary. Our knowledge on Laws of Thermodynamics, for example, will make sure we do not aim to design and produce a perpetual motion machine! Also many engineering students feel it is a waste of time to learn accounting and management, but we must remind ourselves that engineers are expected to be good project and resource manager – both in technical and financial aspects.

The author spent his sabbatical leave in University of Texas at Arlington in 1994 for a period of nine months as a Fulbright Scholar. During that period, he was involved in a research on electromagnetic wave scattering in random dense media. His interaction with co-researchers in USA enhanced his belief that it does not matter where one graduates from. It is the attitude, the desire to continue learning, the ability to work with others with cultural intelligence and the right mindset that will differentiate between a successful person and a failure.

3.0 DIGITAL REVOLUTION AND ENGINEERING EDUCATION

3.1 Waves of Technological Revolution

Over the past few centuries, human civilization has gone through several major technological revolutions (see Figure 1), starting with the first phase of the Agricultural Revolution in the Middle Ages. One significant implement during this period was the heavy plough, which could plough deep and turn over the heavy fertile clay soils in Northern Europe. Economies and cities grew and prosperity came along. Another phase of the Agricultural Revolution came in the 1700s and it brought great changes in the way farming was done. The technological advancements via mechanization had eased the work of farming while scientific methods allowed for the improvement of crop yields and livestock.

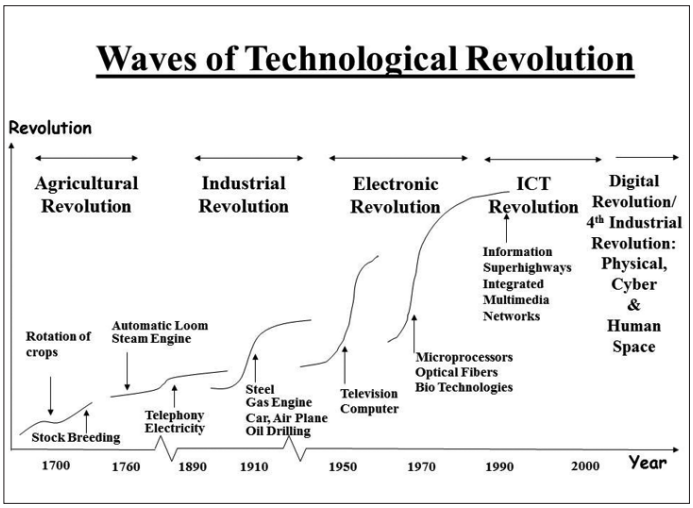

Figure 1: Waves of Technological Revolution

During the Industrial Revolution which took place in the late 18th century, the economy began to shift towards industrial and machine manufacturing. The invention of the steam engine was crucial in the Industrial Revolution. Goods were mass produced in factories, moving away from the home-based, hand-made industry. The mass production of goods led to the cheaper prices of goods. The mushrooming of factories during this period brought about drastic social, economic and environmental implications.

The Electronic Revolution, which heralded the coming of the Information Age, began in the late 1940's and 1950s. It marked a technological shift from analog and mechanical to digital. The invention of the transistor in 1947 paved the way for the computers and supercomputers that we use today. We began to enjoy telephones, televisions and computers. The Information and Communications Technology (ICT) Revolution, which started in the 1990s and which is still on-going, relies on the foundations built during the Electronic Revolution. It alters the way we communicate and also the way we generate, process and share information. The ICT Revolution affects almost all aspects of our daily lives, bringing profound effect to humankind.

The next wave of revolution, which is happening now as the ICT Revolution begins to spread across wider economy sectors, will see technologies being embedded in societies and even human bodies in whole new ways. Many call this the Fourth Industrial Revolution. However, the author would like to call it the Digital Revolution as it not only affects the Industry, but cuts across all sectors. Also, one should not forget about the First Revolution (The Agricultural Revolution). The Digital Revolution brings about advanced robotics and autonomous transport, artificial intelligence and machine learning, advanced materials, biotechnology and genomics. It is all set to transform our way of life and also way of work – at an exponential rate.

As we take a deeper look into the time frame of these technological revolutions, we will realize that the time span for each wave of technological revolution is becoming shorter and shorter. This means that technology is changing at a faster and faster pace. It is crucial that we should take heed of this development lest we are drowned by the technological waves.

3.2 Widening Trends and World Challenges in the Globalized World

We now stand at the unfolding of a technological revolution that has the immense power to affect all aspects of our lives. The changes are taking place at an unprecedented pace and no slowdown is in sight.

About 20 years ago, the pace of the already globalized world was accelerated by a new transformative creation – the Internet. Geographical borders melted away and the world evolved into a borderless global village. Due to recent advancements in transport and also technology, the effects of globalization are even more profound. The economic event of one nation will have ripple effects in another remote nation across the globe. This presents opportunities for the initiated. We are not looking at local market itself, but regional and world markets.

Things are becoming miniature in size and advanced in features. As technology becomes more and more advanced, the functions of multiple electronic devices begin to converge towards a single one. For example, the radio, television and personal computer merged into a small smartphone in our hands. Fast forward ten years, affordable mobile communication and devices put communication and the Internet into the hands of billions of people anytime, anywhere – whether for business or play. With web and mobile applications, people can get almost anything, from computers, T-shirts and phone covers to food and transport – all in a personalized manner. For example, one can order via the internet one's own designed T-shirt and it can be custom-manufactured by an AI-controlled machine and delivered to your door step within a few days. With seamless information and communication technology in hand, we have become better informed and thus, our expectations begin to grow.

As technology advances, the cost of doing things has been greatly brought down by the increased effectiveness of processes. Technological breakthroughs and progress have basically pointed to one thing: the power of knowledge.

As at April 2020, the world population stood at 7.7 billion, and counting. By the year 2050, it is estimated that it could reach more than 9 billion. The population growth has been so rapid that it will most definitely pose serious social and economic challenges. It calls for greater efforts in meeting the basic needs for food, clean water, energy, housing, decent work, healthcare and education.

The challenges faced by a world which plays host to more than 7 billion inhabitants are aplenty. The global wealth report published by Credit Suisse in 2017[3] highlighted the widening gap between the have's and have-not's where the globe's richest 1% own half of the world's wealth.

As a whole, the global population becomes more urban. In 2010, 50.5% or 3.5 billion people lived in cities. The rising level of urbanization will reach 84% in North America and 64% in Asia by 2050. In Malaysia, it is projected that by 2050, our population will reach 42 million and 86% of the population will be concentrated in urban areas.

With the increase in human population, human activities, which are the major contributors to the air pollution problem plaguing the world, will increase in tandem. Air pollution – the biggest environmental risk to human civilization – causes one in nine deaths.[4] Other shocking statistics on fatalities linked to air pollution include the following:

- 6.5 million people die annually due to poor air quality including 4.3 million due to household air pollution
- 52 million years lost or lived with disability annually caused by lower respiratory infections due to household or ambient air pollution, including second-hand tobacco smoke
- 32 million years life lost or lived each year with disability due to chronic obstructive pulmonary diseases as a result of household air pollution and workers' exposure
- By 2030, ground level ozone pollution will reduce staple crop yields up to 26 per cent

As the world continues to grow and progress, a lot of people are still without access to clean and safe water.[5] In 2015, 2.1 billion people were without safely managed drinking water services – that is, they had no access to improved water sources located on premises, available when needed, and free from contamination. Those people included:

- 1.3 billion people with basic services, meaning an improved water source located within a round trip of 30 minutes
- 263 million people with limited services, or an improved water source requiring more than 30 minutes to collect water
- 423 million people taking water from unprotected wells and springs

- 159 million people collecting untreated surface water from lakes, ponds, rivers and streams

In a world where we intend to produce enough food to feed everyone, 821 million people – one in nine – still go to bed on an empty stomach each night. Even more – one in three – suffer from some form of malnutrition.[6] Ironically, as people go hungry every day, around a third of the world's food is lost or thrown away each year. We waste 1.6 billion tons of food annually, worth about $1.2 trillion dollars.[7]

As the earth plays host to more and more inhabitants, the big question arises, "Will the earth's resources be able to sustain this population boom?" We have already seen clear signs of the environment bearing the brunt of it. The U.S. Energy Information Administration's latest International Energy Outlook 2017 (IEO2017) projects that world energy consumption will grow by 28% between 2015 and 2040, and three-quarters of the world energy consumption through 2040 will still come from fossil fuels.[8] In Malaysia, the energy consumption has increased almost three-fold from 17,728 ktoe in 1993 to 51,584 ktoe in 2013 while the energy consumption for petroleum products increased from 13,075 ktoe in 1993 to 29,190 ktoe in 2013.[9]

The increased consumption in fossil fuels will cause an upward trend in greenhouse gas emission resulting in the increase in global temperature. According to the Earth Policy Institute 2010 Report, from 1880 to 1970, the Global Average Temperature increased 0.03°C/decade. In fact since 1970, it has increased 0.13°C /decade. 2/3 of the increase of 0.8°C happened in the last 40 years. This will cause sea levels to rise and change the amount and pattern of precipitation, and we have to brace ourselves for the coming of more natural disasters. On 26 December 2004, a magnitude 9.3 temblor struck the undersea off the west coast of Sumatra creating a massive tsunami that left an estimated death toll of between 230,000 to 280,000 in 14 separate countries in its wake. In 2011, East Africa was hit with the worst drought in 60 years and in November of the same year, Thailand experienced its worst flooding in half a century.

Improvements in healthcare have vastly contributed to the increase in life expectancy. As of 2018, the average life span of a Malaysian was estimated at 74.7 years; in 2000, it was 72.2 years. We have to come to terms with the fact that Malaysia is heading towards an aging nation. The United Nations Economic and Social Commission for Asia and the Pacific's 2016 population data sheet shows that in 2016, Malaysians aged 60 and above comprised 9.5% of the population. This is projected to increase to nearly a quarter of the population (23.5%) by 2050.[10] Nevertheless, does living longer means having a better quality of life? Well, not necessarily. While the rates of infectious diseases may have gone down, various National Health and Morbidity surveys show the worrying continuous upward trend of the number of those afflicted with lifestyle/non-communicable diseases such as diabetes, hypertension, obesity and cancer.[10] This will add more stress to the country's healthcare system as it struggles to take care of the increasing number of aging and ill patients. Ultimately, the overall cost of healthcare will go up.

In 1940's and 1950's, Tuberculosis (TB) was considered as number one cause of death in Malaysia. With the introduction of National TB Control Programme in 1961, and with vaccination and good medical treatment, TB has not been a treat anymore since the 90's. However, as public awareness of TB dwindled away and with presence of illegal immigrants who did not seek treatment for fear of actions being taken against them by the authorities, TB has now resurfaced as a contagious disease killing about 1500-2000 lives annually in Malaysia.[11] A National Strategic Plan for TB Control's goal of making Malaysia TB-free by 2035 has been in place by the Ministry of Health. Thus we must not overlook the possibility of coming back of old diseases. The recent highly infectious and deadly COVID19 is an example of new diseases and its effects on the world are unprecedented. No country is an island in this global village. We may initially think it was just confined to a country, but very soon we realize that every corner of the globe is affected. The extent of the spreading of the virus, the health care pressure, the shortage of medical supplies and equipment especially personal protective equipment due to lock down of cities and movement control by different countries, the closing down of businesses, the melting down of the stock markets etc are some of the consequences of such a new disease. Thus we need to be more well prepared for such emergency cases and international collaboration is certainly required to tackle such cases.

As the cyber world plays a bigger role in people's lives, cybercrimes are also on the rise. Data-destroying software, ransomware, network attacks and data thefts are becoming commonplace nowadays. Large corporations and governments are not spared from suffering massive data and consequential financial losses. E-mail and mobile phone scams have resulted in identity thefts and system frauds. Besides financial losses, there are increasing instances where cybercrimes unfold into real physical-world harms. Stalking, harassing and blackmailing, cyber-bullying, online romance scam and fake news are some of the examples.

3.3 The Digital Revolution (Fourth Industrial Revolution)

The winds of change have been constantly blowing and we are now staring right into the advent of a Fourth Industrial Revolution as indicated by how technologies are emerging and impacting our lives. The author would like to call it the Digital Revolution instead of the Fourth Industrial Revolution. This is to register the fact that we should not miss the First Revolution – The Agricultural Revolution. The Digital Revolution is built on previous Revolutions, particularly the Electronic and ICT Revolutions with the development of digital systems and communication, and rapid advances in computing power. In this Revolution, we will see technologies being embedded within societies and even human bodies in whole new ways. It will bring about advanced robotics and autonomous transport, artificial intelligence and machine learning, advanced materials, biotechnology and genomics, transforming our way of life and also way of work.

The Digital Revolution will affect our job or career in ways that are unprecedented. It is predicted that over one-third of the skills that are considered important in today's workforce will change. Current skills will become obsolete and new skills that are previously unheard of will leap into centre stage. "The Future of Jobs" Report published in 2016 by the World Economic Forum[12] highlighted that digital technologies, combined with other socio-economic and demographic changes, will transform labour markets in the next five years, leading to a net loss of over 5 million jobs in 15 major developed and emerging economies.

Two million new jobs will be created in the digital industrial and services sectors while 7 million jobs will be lost in traditional industrial and service sectors. It is also predicted that 65% of children entering primary school today will ultimately end up working in completely new job types that do not exist yet.

Various countries have adopted national initiatives in response to this Digital Revolution in order to propel their countries ahead of looming competition as in the following chart:

Initiatives by Various Countries for Digital Revolution

- **Industrie 4.0 of Germany**
- **Reindustrialisation of USA**
- **New Industrial of France**
- **Rejuvenation Plan of Japan (Building Society 5.0 by 2050)**
- **China**
  "Internet Plus" Action Plan;
  Big Industry Country 2015;
  Made in China 2025;
  Primary Industry Power 2025;
  Medium Industry Power 2035;
  Leading Industry Power 2045
- **Manufacturing 4.0, Korea**

Figure 2: Initiatives by Various Countries for Digital Revolution

3.4 Education – The Driver in Digital Revolution

At the core of an innovative and productive high income economy is its human capital. Education, and thus human capital development, will need to train inquisitive and creative minds to tackle the growing global challenges and uplift the standard of living. Education can be the catalyst of change and innovation, and the driver for economic growth.

As the number of institutions of higher learning and programmes offered increase, the quality and standard of the programmes have become more critical and there is a need for some kind of quality control or assurance. Quality assurance needs to be done to ensure that the graduates produced by the institutions of higher learning are indeed competent and able to compete not only in the local scene, but also in the international arena.

Solid financing goes a long way in sustaining the well-being of institutions of higher learning. Due to the rise of overall living costs and budget cut by government on education, there arises the pressing need to adjust the tuition fees accordingly. Nevertheless, institutions of higher learning need to strike a balance between maintaining their existence and avoiding higher education being exclusive to people from higher income groups. This is where new technology such as e-learning can come into play to address the rising cost of education.

Faced with constant disruption of the labour market and the fast pace of change, we need to ensure that our engineering and technical education is broad and diversified enough to tackle future trends. Extra focus and effort should be put into Technical and Vocational Education and Training (TVET) to prepare graduates for the real world of work. It is indeed a challenge for institutions of higher learning to tailor curricula that cater well to the demands of industries or employers in order to enhance the employability of their graduates. And it is crucial for the institutions of higher learning to continue generating fresh ideas and keep on innovating in all aspects, from programme design to delivery.

To allow students from all walks of life equal access to higher education, an understanding of the underlying concerns and the setting up of an efficient student loan/aid system have to be in place.

When all the issues surrounding higher education are properly addressed, only then will the institutions of higher learning be well poised to produce graduates who are ready to take on the task of contributing to the nation and propelling it forward.

3.5 The U.S. Experience

In 2005, the U.S. realized that their competitiveness in the global economy was declining in comparison to some rising Asian countries such as China, Singapore and South Korea largely due to globalization. The U.S. National Academies was then commissioned by the U.S. Congress to study the phenomenon and to offer recommendations. The result – a report entitled "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future" identified the areas that are in dire need of revamps, which include the knowledge capital, human capital, and the existence of a creative ecosystem. During that period of time, the facts and statistics in higher education and research in U.S. showed a worrying trend. Financial allocations for higher education and research were significantly lower than those rising Asian countries. A huge portion of the doctoral degrees were awarded to foreign students. Also, more than a third of the workforce with PhD qualifications in the fields of science and technology were foreign born. Moreover, it was found that a third of U.S. students with initial intention to major in engineering ended up switching their majors before graduation. In fact, they found that the interest in science and engineering had been dwindling in the prior decade.

3.5.1 The U.S. Experience Revisited 2010

Five years later, the follow-up report entitled "Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5" made even more startling discoveries. In 2009, U.S. consumers spent significantly more on potato chips than energy research and development – $7.1 billion versus $5.1 billion. 51% U.S. patents were awarded to non-U.S. companies. Federal funding on research in physical sciences fell by 54% in 25 years after 1970, while engineering funding declined 50%. Even more worrying was the fact that 69% of U.S. public school students in the 5th-8th Grade were taught Mathematics by teachers without a degree or certificate in Mathematics while 93% of U.S. public school students in the 5th-8th Grade were taught Physical Sciences by teachers without a degree or certificate in Physical Sciences.

3.6 Engineering Education in Malaysia

An engineering personnel is a person with an analytical mind who can think logically and provide solutions based on fundamental principles of natural laws. The engineering workforce is the prime mover behind nation building. As Malaysia develops into a knowledge-based and innovation-driven economy, it is crucial that we continue to strengthen our engineering education and stimulate the growth of the engineering population. Currently, Malaysia still lags behind developed countries such as France, Germany, Canada and United Kingdom in terms of engineer-

population ratio. It is estimated that the ratio for Malaysia now stands at about 1:150 and the targeted ratio by 2020 is 1:100.

As at April 2020, there were 56 institutions of higher learning (17 public and 39 private) offering 270 active accredited engineering programmes in Malaysia. In 2017, enrolment in engineering programmes only made up about 20% of the overall enrolment in degree programmes. The ratio of male to female engineering enrolment was about 1:0.68 (see Figures 3-5).

Current Scenario in Malaysia:

1. **Total Number of IHL's with Engineering Degree Programmes (April 2020):**
   - **17 Public**
   - **39 Private**

   offering 270 active accredited programmes

2. **Total Number of Engineering Disciplines: 28**

2017 (IHL's)	Engineering, Manufacturing and Construction (% of Overall Degree) (Male:Female)
Intake	33409 (17.8%) (1:070)
Enrolment	122932 (20.3%) (1:0.68)
Output	27142 (20.3%) (1:0.74)

Source: EAC & Higher Education Statistics 2017, MOHE

Figure 3: IHL's with Engineering Degree

Current Scenario in Malaysia

Statistics of Bachelor Degree Students in Public Universities 2017

	Bachelor Degree (M:F)	Science-based (M:F)	Engineering, Manufacturing & Construction (M:F)
Intake	96483 (1:1.77)	49027 (1:1.37)	23669 (24.5%) (1:0.88)
Enrolment	332023 (1:1.77)	168873 (1:1.36)	83792 (25.2%) (1:0.86)
Output	79725 (1:1.94)	39356 (1:1.51)	19092 (23.9%) (1:0.94)

Source: Higher Education Statistics 2017, MOHE

Figure 4: Statistics of Degree Students in Public Universities 2017

Current Scenario in Malaysia:

Statistics of Malaysian Students in Private Institutions of Higher Learning 2017

	Total (M:F)	Degree (M:F)	Estimate of Engineering, Manufacturing & Construction (%) (M:F)
Intake	222315 (1:1.10)	91033 (1:1.09)	~9740 (10.7%) (1:0.39)
Enrolment	565852 (1:1.08)	274787 (1:1.06)	~39140 (14.2%) (1:0.39)
Output	149857 (1:1.25)	54120 (1:1.15)	~8050 (14.9%) (1:0.40)

Source: Higher Education Statistics 2017, MOHE

Figure 5: Statistics of Malaysian Students inPrivate Institutions of Higher Learning 2017

Every year in Malaysia, about 230,000 students graduate from institutions of higher learning. Shockingly, one out of five graduates remain unemployed, with the majority being degree holders. These graduates make up 35% of those who are unemployed. The reasons boil down to the following:[13]

- Asking for unrealistic salary/benefits (66%)
- Choosy about the job/company (58%)
- Poor character, attitude or personality (58%)
- Poor command of English (52%)
- Poor communication skills (49%)

Institutions of higher learning have to be responsive and rethink how best to train and prepare engineers to answer the challenges posed by the fast paced, competitive, and global environment of the 21st century. As a start, emphasis should be placed on strengthening the fundamentals of engineering where solutions to most complex problems can be designed.

A wholesome engineering education should also focus on nurturing engineers who have the ability to think logically and analytically and make wise decisions or propose constructive and practical solutions based on fundamental principles of engineering. Also, engineering students should have the insatiable thirst for knowledge and the institutions of higher learning should steer them towards the path of knowledge exploration and self-development. No man is an island and engineering students would do well to have linkages to social networks that provide them the avenues for discourses and exchanges of ideas and information.

Institutions of higher learning should provide engineering students with greater experiential preparation to work under constraints. Instead of being brought down by constraints, engineers should be inspired by them as most of the time, they may well be the building blocks that hold the key to creativity and innovation.

As Albert Einstein once said, "Everybody is a genius. But if you judge a fish by its ability to climb a tree, it will live its whole life believing that it is stupid". Thus the institutions of higher education must allow the academic staff more flexibility in delivering of the curriculum to the students, making full use of the flexibility inherent in online technologies.

Admittedly, engineering education may at times be viewed in a 'not-so-positive' light. When it comes to engineering education, people always think that it is tough, boring and too technical with simply too many problems that need to be solved. This misconception is something that needs to be tackled and managed right from the early stages if Malaysia is to achieve its targeted engineer-population ratio.

3.7 Main Challenges in Malaysia

Efforts to increase the engineering workforce in Malaysia may well be an uphill task. For example, statistics showed that in 2014, only about 21% of students in upper secondary schools chose to study in science subjects, and this is one of the main contributors for the shrinking engineering workforce in Malaysia. It has also been the current trend for school leavers to rush for degree courses only. This has left a great void for technicians at diploma levels.

An analysis of the Science, Technology, Engineering and Mathematics (STEM) enrolment among students in Malaysia shows a worrying trend. In 2012, a total of 441,883 students enrolled in Form 1.[14] However, in 2016, only 48.6% of those

students continued on in STEM streams (23.7% in science, 8.8% in vocational and 16.1% in technical streams). It showed a leakage of 17,755 students in Form 3 and another 34,037 in Form 5. And after the Form 5 *Sijil Pelajaran Malaysia* (SPM) examination, in 2017, only 19.8% of the students managed to continue on in Matriculation, Form 6 and Vocational College in STEM. This was only 8.5% of the Form 1 enrolment in year 2012 (see Figure 6)!

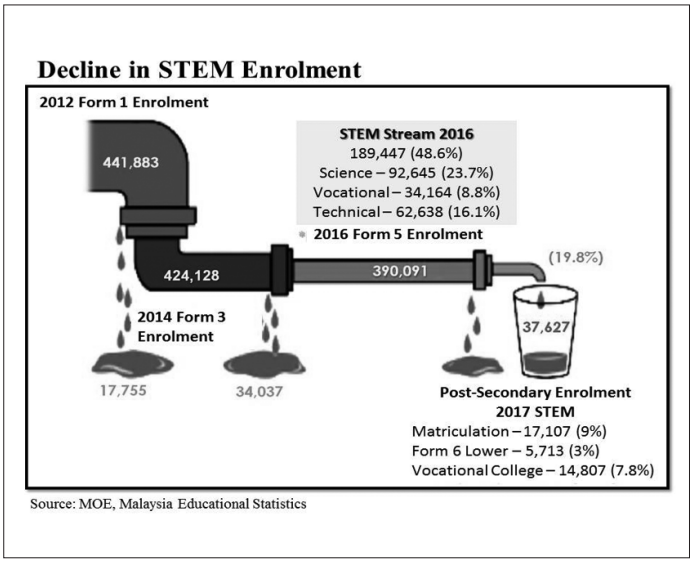

Figure 6: STEM Enrolment in Malaysia

The teaching profession seems to have lost its past glory and social status, and it has been quite a challenge to get qualified and experienced teachers and lecturers to teach and guide future generations of engineering students. To add on to the challenges faced by engineering education, top down governance mechanism in schools and institutions of higher learning has more often than not restricts freedom for innovation.

As Malaysia moves towards a knowledge-based digital economy, its requirement for a bigger pool of highly skilled engineering workforce will naturally increase. This has led to the increased demand for higher education, and consequently, to cater to the increasing demand, the number of institutions of higher learning will also increase, leading to keen competition and the constant struggle for survival. We must ensure quality of education is not compromised.

In this era of globalization and internationalization where everyone and everything become more and more interconnected and interdependent, it is imperative that institutions of higher learning take on a global approach and explore new emerging areas. Not only that, they should also strive to enhance their graduates' employability by equipping them with skills fit for this globalized world while guiding them towards building a global human network for healthy exchanges, collaboration, and support.

3.8 Future Job Trends

Based on a survey of trends expected in the 2018-2022 period in 20 economies and 12 industry sectors, the following five important findings are reported:[15]

(i) The focus, adoption and applications of automation (including AI), robotization, digitization and big data analytics will vary across different industries (see Figure 7).

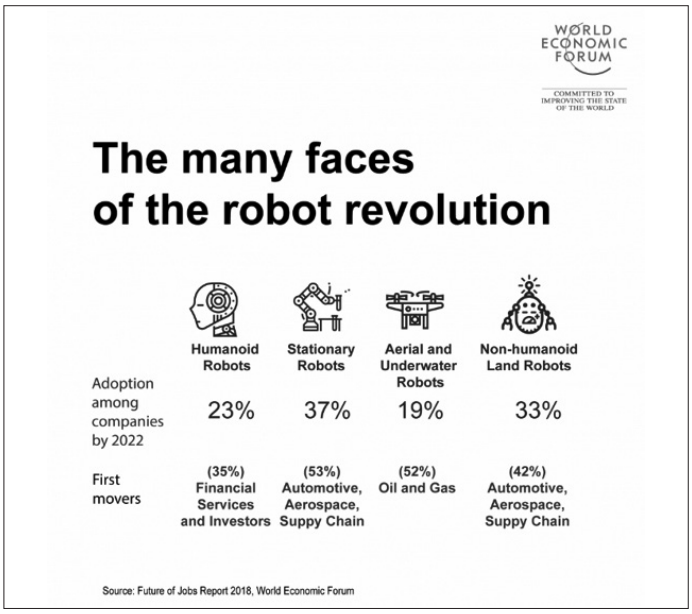

Figure 7: Many Faces of the Robot Revolution (Image from Future of Jobs Report 2018, World Economic Forum)

(ii) Though there is a major disruption in job market, there will be a net positive outlook for jobs – by 2022, emerging occupations will grow from 16% to 27%, while jobs affected by technological obsolescence will decrease from 31% to 21%. In short, 75 million current jobs will be displaced, while there will be 133 million new jobs emerging (see Figure 8). Jobs that require innovation, people and culture, and human touch will continue to grow while those clerical and mundane and repetitive jobs will be replaced with robots.

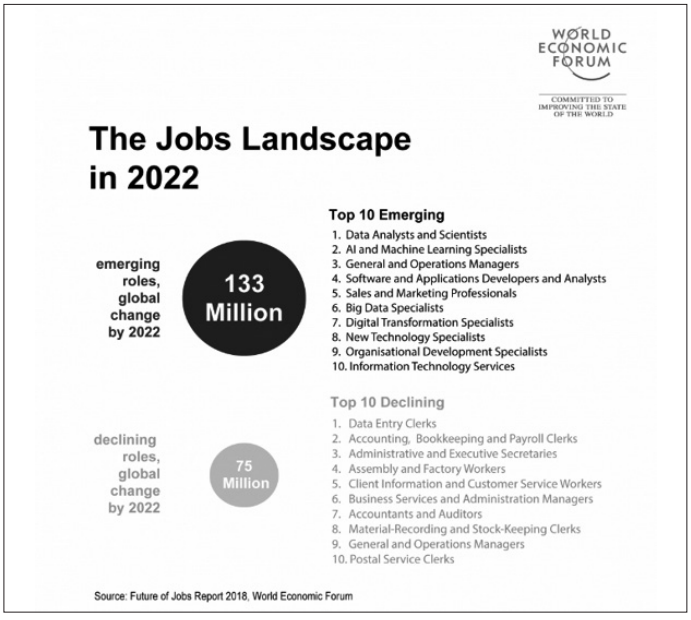

Figure 8: Job Landscape in 2022 (Image from Future of Jobs Report 2018, World Economic Forum)

(iii) There is a rapid shifting in the division of labour between humans and machines/algorithms – currently only about 29% of the total task hours are performed by machines or algorithms; while 71% are by humans. By 2022, it is expected to be 58% by humans and 42% by machines/algorithms (see Figure 9).

(iv) New skill sets are demanded by the new job scopes – there will be a significant shift from core skills of about 58% to workplace skills of 42% by 2022. The workplace skills include analytical thinking, active and self-learning, creativity, originality and taking initiative, negotiation and persuasion, cognitive flexibility, complex solving, leadership, emotional intelligence as well as social and cultural intelligence (more details in Section 3.10).

(v) Life-long learning is a necessity. Learn, unlearn and re-learn will be the trend. Re-skilling and Up-skilling will be the key factor for survival of management and companies. It is estimated that employees require 101 days of re-training and up-skilling for the period up to 2022.

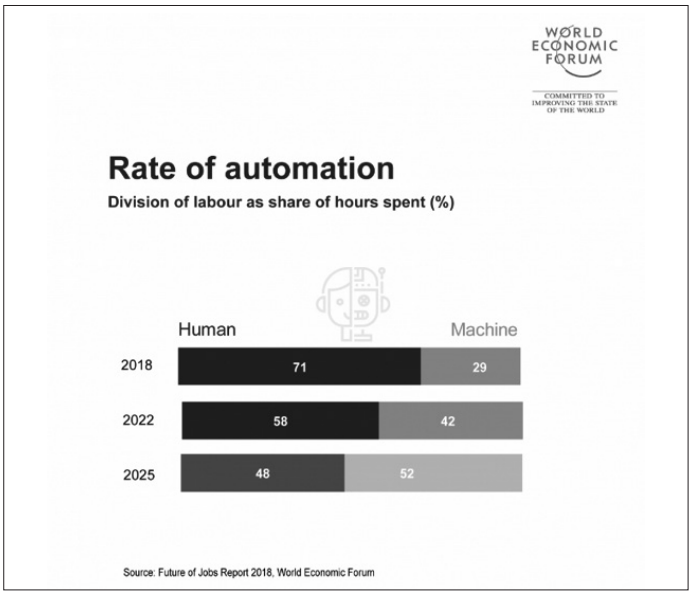

Figure 9: Division of Labour between Human and Machine (Image from Future of Jobs Report 2018, World Economic Forum)

3.9 Clusters of Professionals in 2020-2022

As job landscape will change due to the disruptive technologies in the Digital Revolution, there will be emerging clusters of jobs. From the World Economic Forum 2020 report "Jobs of Tomorrow: Mapping Opportunity in the New Economy"[16] (see Figure 10), some key findings include:

(i) Seven key professional clusters are emerging in tandem with demand of professionals of the future who require both "digital" and "human" skills. These are: Data and AI; Engineering and Cloud Computing; People and Culture; Product Management; Sales, Marketing and Content; Care Economy; and Green Economy.

(ii) It is estimated that in 2020, the featured 7 professional clusters will represent 506 out of every 10,000 job opportunities; and 715 out of every 10,000 job opportunities by 2022.

(iii) Based on the World Economic Forum's 2018 Future of Jobs Report, a total of 133 million new jobs will be created over the 2018–2022 period. Then using the survey done for the report in 2020, the seven emerging professional clusters are estimated to create 1.7 million new jobs in 2020, and growing to 2.4 million jobs by 2022. From 2020-2022, 37% of projected job opportunities will be in the Care Economy; 17% in Sales, Marketing and Content; 16% in Data and AI; 12% in Engineering and Cloud Computing; 8% in People and Culture and 1.9% in Green Economy.

(iv) Within the high-volume jobs, the following are the highest growth professionals: Artificial Intelligence Specialists, Medical Transcriptionists, Data Scientists, Customer Success Specialists and Full Stack Engineers. Within the lower-volume jobs, the highest growth is in Landfill Biogas Generation System Technicians, Social Media Assistants, Wind Turbine Service Technicians, Green Marketers and Growth Hackers.

	Number of Opportunities (per 10000)	
Professional Clusters	2020	2022
Data and AI	78	123
Engineering and Cloud Computing	60	91
People and Culture	47	58
Product Development	32	44
Marketing, Sales and Content	87	125
Care Economy	193	260
Green Economy	9	14

Figure 10: Emergence of Clusters of Professionals of the Future, 2020-2022[16]

From these studies and reports, engineering profession is no exception as far as future jobs are concerned. New emerging technologies require us to train our students with new technical skill sets. In addition, human skills are also important and should not be overlooked.

3.10 Top Skills Required for Future Graduates

Based on Annual Meeting of the New Champions (2018) by Vesselina Stefanova Ratcheva and Till Leopold, World Economic Forum,[15] the following ten skills will take centre stage come 2022 as shown in the following chart:

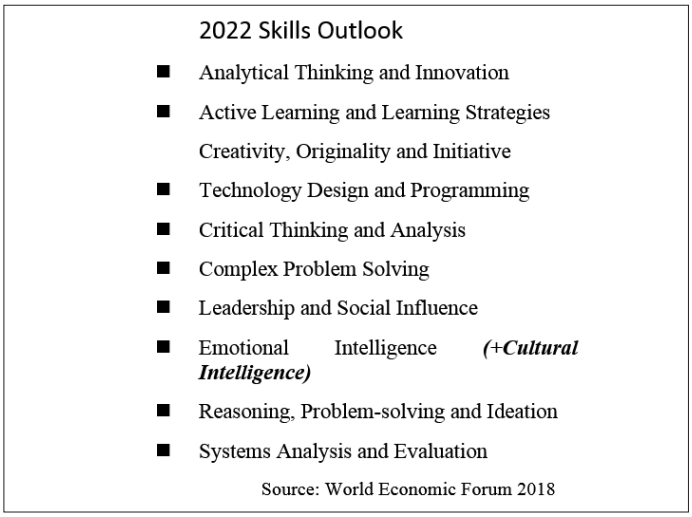

Figure 11: Top 10 Skills Required in 2022

If we take a close look at the skills outlook, we would realize that mere memorizing of facts and information is no longer sufficient for our future graduates. We need to train students with analytical, logical and critical mind, self-learners with

creativity and innovativeness. The future graduates need to have leadership skills and must be pro-active. They need to be able to provide practical solutions in a more wholesome manner. With rapid technological changes that we are experiencing, problems and challenges will take on a more complex outlook, and solving them will require a different or new approach.

In addition to technical and professional skills, it is imperative that future graduates also master certain general skills. Social skills seem to occupy one of the prime spots. In the ten skills for future graduates listed in the "10 Trends – Transformative changes in higher education" published by the British Council in June 2017 (see Figure 12),[17] social intelligence is one of the top three skills that future graduates should possess. Social intelligence is all about building relationships and finding one's way around social environments. The author also thinks that cultural intelligence is going to be an important skill set. We are going to deal with different people from different countries, with different religious beliefs and cultural backgrounds. Malaysians do have an advantage due to our multi-ethic, multi-cultural, multi-lingual and multi-religious environment. We must capitalise on our strength so that we can perform in this globalized environment.

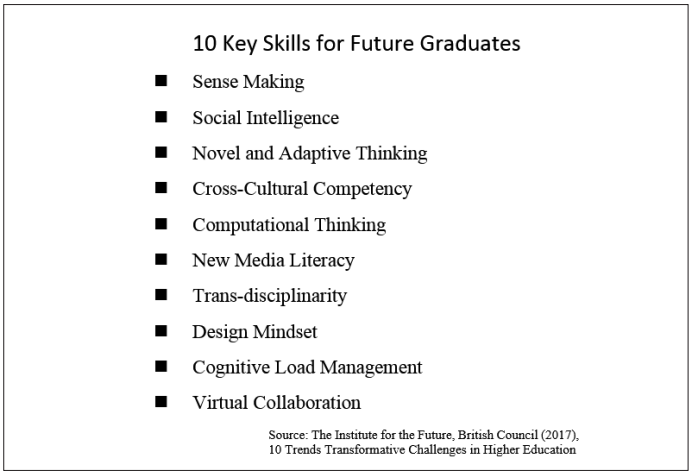

Figure 12: 10 Skills for Future Graduates

3.11 Ready-to-Evolve Graduates – A Proposal

The advent of the Digital Revolution has brought along a frenetic sweeping change that makes the task of predicting the future requirements of jobs almost utterly impossible. When industrial development is progressing much faster than the academia, the academia and the society in general are in anxiety. We are not sure of the future technologies, and neither are we sure what kinds of graduates are required by future job markets. Faced with this, institutions of higher learning should realign themselves to produce graduates who are highly flexible and adept in working with new paradigms. Future graduates should be trained to be "ready-to-evolve" in line with evolving labour market requirements. As such, high priority should be given to the solid fundamental of engineering sciences such as mathematics, material sciences, electromagnetics, thermodynamics, dynamics and kinetics in the first two years of the engineering programmes. Additionally, in the first two years, while training students on the basics, more engineering application examples should be incorporated into lectures. As technology changes, more elective options should be introduced for students in the third and fourth years, and the Faculty should have the flexibility to review, introduce and remove these elective options as and when the need arises. At the same time, the training of skill sets should be integrated into lectures/tutorials. There is also a need for a soft skills certificate system as an added incentive for students to develop and enhance their soft skills. Additionally, students should be encouraged to participate in exchange programmes within Malaysia and internationally on a credit transfer basis to gain a broader perspective and outlook, and a deeper understanding of other cultural and global issues. While technological training is important, tertiary education must also not forget the very basic of education: training a wholesome and ethical individual who will be useful for the society. Thus ethics and professionalism, the ability to work as a team, social responsibility to our society and good universal values must be imparted onto the students as a social norm. The author always shares with his colleagues and students: "the harm that a highly educated person will bring to the society, if he is not ethical, is going to be much more than an uneducated person".

3.12 Complex Problem Solving Skills

One of the important engineering graduate attributes expected by engineering programmes under the Washington Accord is that the graduates must have complex problem solving skills. There are different understanding and interpretation of this requirement.

Real life problems are not just scientific nor technical in nature. They encompass different aspects, from technical to environmental, to social and economic; from scientific to financial and cost-effectiveness of solutions. Many a times, there may not be definable problem boundary, and it may involve confusing and contradictory factors, interdependent elements, cognitive flexibility and compromise between what is best and what is available, what is ideal and what is practical and affordable, and conflicting stakeholder views or interest. There maybe a few optimal solutions, and some of which have not existed or tested before. Thus it needs a person's creativity and innovativeness, discretionary judgement, negotiation and leadership skills to come up with best possible practical solution which is acceptable by the stakeholders at the material time.

Take for example, the designing of a dam. An engineer needs, for example, to calculate the water flow and pressure, and work on the engineering design based on latest code of standards and by-laws. This is not considered complex problem solving if he/she is only looking at it from a technical aspect. However, if the engineer takes into consideration the efficiency of the dam design, the environmental impact of the dam on natural habitat, the social economic impact on local community, the financial sustainability of the project, as well as compromise between development and conservation of nature, then the engineer is considered to have engaged in a complex problem solving process.

Institutions of higher learning could have more open-ended and contemporary problems incorporated into the assignment, integrated design projects and final year projects. This kind of complex problem solving skills requires scientific, technical and engineering knowledge, which are acquired via lecture, tutorial, laboratory and field work, individual and group assignment. It also involves many other professional and social skills such as decision making and sound judgement based on facts and

figures, negotiation skills, management and communications skills, cultural and emotional skills, which need to be acquired via extra-curricular activities, social and society activities, and life-long training.

3.13 What is Next After Covid19?

Recent Covid19 pandemic has made institutions of higher learning to start switching to various on-line teaching platforms during the Movement Control Order in Malaysia. Change of mindset is necessary in the mode of delivery of lectures/ tutorials to our students. We need to look into a new norm for dissemination of knowledge and for teaching and learning. However, we cannot over simplify the effectiveness of online teaching and learning. We need to study the advantages, disadvantages and challenges in such a new norm. For examples:

(i) The speed and cost of the internet in different parts of Malaysia
(ii) Would the students be able to concentrate on online delivery method? And if so the optimum period of focus and attention.
(iii) Efficiency and effectiveness of such learning modes
(iv) Interaction of students with course-mates and instructors
(v) Group discussion and assignment
(vi) Assessment tools to judge attainment of learning outcomes by students
(vii) Laboratory experiments and field work. This should not simply be substituted by computer simulation work as we need to train engineering students with practical and field experience.
(viii) Recreational and social activities by students. This should not be downplayed as it forms a very important part of our tertiary education. We need to train wholesome graduates.
(ix) Human-networking for students, not only between classmates and course-mates, but also with peers in other faculties. After all, a major part of our tertiary education is to allow students to build their character and personality and to work with others.

3.14 Working with Industries and Professional Bodies

Institutions of higher learning should forge mutually beneficial collaborations with industries and professional bodies. Being at the forefront of technology, the industries and professional bodies are in a position to provide institutions of higher learning a better understanding of the latest and future technological trends and human resource needs.

Industrial attachment in industry plays an important part in any education curriculum as it allows students to gain hands-on experience in applying their learnt knowledge and skills in a real working environment. It is also beneficial for the industry as the students carry fresh ideas and quality assistance with them. These students could also be valuable human assets for the industry in future. As an encouragement for closer collaboration with industries and professional bodies, academic staff members from institutions of higher learning with work or projects undertaken with industries and professional bodies should be granted sabbatical leave.

Undoubtedly, the industries and professional bodies have an integral role to play in engineering education and it will only make sense if the curriculum development takes into consideration the inputs from industries and professional bodies as after all, they are in a position to know better the knowledge and skills that an engineer should possess. Additionally, professionals in industries could share their knowledge and experience by giving guest lectures in institutions of higher learning and join forces to conduct R&D activities for a better outcome.

Last but not least, academic staff members from institutions of higher learning could also share their knowledge and research outcomes with the industries for continual professional development of the practicing engineering personnel.

Stakeholders such as the Institution of Engineers Malaysia (IEM), the industries and the Ministry of Education Malaysia (MOE) should work hand in hand in nurturing competent and ready-to-evolve graduates. Each IEM branch could form an Advisory Committee to interact with institutions of higher learning within the State while IEM volunteers could be in the Advisory Committee of MOE to review the engineering, technologist and diploma programmes. At the same time, MOE should also work closely with IEM to promote Science, Technology, Engineering and Mathematics at school level.

4.0 MOBILITY OF ENGINEERING WORKFORCE

Globalization and internationalization through international trade, relations and treaties have set aside what once was an immobility of labour and capital between or among nations. More than ever, barriers to international trade have been considerably lowered through international agreements. This is also true for cross-border engineering works and services. According to industry analysts, demand for engineering services grew substantially across most sectors and geographies through 2010, with only about 10% of the world's work being based in the U.S. and other developed countries, versus about only 40% back in the 1990's. So what does this entail for the engineering workforce? As the maxim goes, "*With prosperity comes opportunity*". For engineers, now would be the perfect opportunity to soar and spread their wings globally.

4.1 Modes of Services

The General Agreement on Trade in Services (GATS) which came into effect in January 1995 is a multilateral agreement which covers international trade in services. The GATS has created a borderless world for professionals, and engineers can take advantage of the vast opportunities offered under GATS to expand the reach of their professional services beyond their local scenes. The following are the four modes of supplying services under the GATS:[18]

4.1.1 Mode 1: Cross-Border Supply

Cross border supply covers the flows of services from one jurisdiction into any other jurisdiction. A user in economy A receives services from abroad via telecommunications or postal services. Such supplies may include market research report, tele-medical advice, distance training or engineering consultancy.

4.1.2 Mode 2: Consumption Abroad

A consumer moves into another jurisdiction to obtain service. The consumers (Nationals of A) move abroad as tourists, students or patients to consume the respective services in Nation B, for example.

4.1.3 Mode 3: Commercial Presence

The service supplier of one jurisdiction, through commercial presence, supplies services in the territory of any other jurisdiction. The service is provided by a locally established affiliate, subsidiary, or representative office of a foreign-owned and controlled company. Examples include banks, hotel groups, construction companies, universities, etc.

4.1.4 Mode 4: Presence of Natural Persons

Persons of one jurisdiction enter the territory of any other jurisdiction to supply a service. A foreign national provides a service within an economy as an independent supplier (e.g., consultant or health officer) or employee of a service provider (e.g., consultancy firm, hospital, or construction company).

4.2 Global Mobility of Engineering Workforce

For the development of a nation, we need many engineers – for infra and info structure development, for development of creative systems to improve human lifestyles, for proper management of natural resources, etc. The kind of engineers we require should not only excel in a particular nation, but they must also be competent and must stay competitive regionally and globally.

We live in a borderless world brought about by regional integration, technological advancements, a free world ideology and borderless enterprises. This setup presents new opportunities and challenges to the engineering sector. To tap these opportunities, the mobility of the engineering professionals becomes crucial.

In the 21st century and beyond, engineering professionals need to work as a team to solve problems and improve the quality of life for humanity. This is a global effort not confined to a particular country or economy. It is therefore important for us to develop not only regional, but also international agreements on accreditation of engineering programmes. This will be a necessary step for mutual recognition of substantial equivalence of engineering education to fulfil the basic academic requirements for mobility of engineering personnel.

Within the globalization setup, various cross-border understandings/agreements for the mobility of engineering professionals have been established. Examples of such understandings/agreements are as follows:

- Previously known as the Engineers Mobility Forum (EMF), the International Professional Engineers Agreement (IPEA) is a multi-national agreement between engineering organizations in the member jurisdictions which creates the framework for the establishment of an international standard of competence for professional engineers, and then empowers each member organization to establish a section of the International Professional Engineers Register.
- The APEC Engineer Agreement is an agreement in place between a number of APEC countries for the purpose of recognizing "substantial equivalence" of professional competence in engineering. APEC countries can apply to become members of the agreement by demonstrating that they have in place systems which allow the competence of engineers to be assessed to the agreed international standard set by the APEC Engineer agreement.
- Formerly known as the Engineering Technologists Mobility Forum (ETMF), the International Engineering Technologist Agreement (IETA) allows for the mutual recognition of the substantial equivalency of standards establishing the competency for practicing engineering technologists.
- Agreement for International Engineering Technicians (AIET) allows for the mutual recognition of the substantial equivalency of standards establishing the competency for practicing engineering technicians.

Nearer to home, the formal establishment of ASEAN Economic Community in December 2015 paves the way for a fully integrated ASEAN with 622 million people and a combined GDP of US$2.6 trillion. In the regional landscape, engineering is one of the active service sectors in the ASEAN economic integration. In fact, the signing of the Mutual Recognition Arrangement (MRA) on Engineering Services in December 2005 by the ASEAN Economic Ministers reflected a shared interest between the governments and the engineering community in ASEAN to improve and enhance the competitiveness of engineering services quality as well as facilitating the free flow of engineering professionals within the region. Under the MRA, an engineering professional who is a national of an ASEAN member country and who possesses the required qualifications and experience may apply for inclusion in the ASEAN Chartered Professional Engineers Register (ACPER) and accorded the title of ASEAN Chartered Professional Engineer (ACPE). The Engineering Register set up under these various international forums and agreements is an engineer's gateway to trade liberalization in professional services.

5.0 THREE IC's – ANOTHER PROPOSAL

In his Presidential Address of the Institution of Engineers Malaysia in 2010,[19] the author proposed that in order to thrive in this fast advancing global market, engineers need to constantly keep three IC's in mind. The first IC is Integrity and Competency; the second IC is Integration and Communications; and the third IC is Internationalization and Cooperation.

5.1 Integrity and Competency

Integrity is consistency between one's action, values, methods, measures and principles. The value of a person is defined by the knowledge in the mind, the worth of the character and the principles upon which he/she builds his/her life. Handling ethical dilemmas and making ethical decisions are important parts of being a professional. Engineering is a profession that has specialized knowledge, the privilege of self-regulation, and a responsibility to the public. As engineers, it is important that we maintain a high ethical standard as the decisions we make will have a direct impact on society. It is the awareness of these heavy responsibilities and obligations that lies at the professional code of conduct and ethics that govern the engineering profession. In the practice of the profession, engineers must adhere to high principles of ethical conduct on behalf of the public, clients, employers and the profession.

Engineers must be competent to provide professional service and advice in order to protect the safety, health and welfare of the public. In such a technically complex field, new discoveries and changes in practice occur frequently. Engineers need to fully equip themselves to thrive in this competitive world. Engineers will have to be equipped with the highest standards of R&D skills, keep abreast with global

technological trends, be strategic thinkers and planners and develop market driven services and high-tech products/ systems.

5.2 Integration and Communication

The world is becoming increasingly integrated by information systems, economic markets and political and social issues. These pose challenges that are growing in complexity and transcend specific disciplines and are driving the emergence of multidisciplinary and interdisciplinary thinking. Thus, it is imperative that engineers master an overwhelming array of technical knowledge.

As we move towards a more knowledge-based and innovation-driven economy, engineers too will move beyond being technically equipped, towards obtaining an even wider range of expertise, such as in research and development, consulting, regulatory knowledge, leadership, management, etc. Thus inter- and multidisciplinary approaches are becoming more prevalent in engineering.

To operate successfully in a multidisciplinary environment, it requires a broad intellectual perspective. Equally important is the ability to manipulate information into knowledge as well as understand and communicate across disciplines. Similarly, engineers are tackling multifaceted problems that require solutions beyond the reach of any single discipline. Thus, much of the work will involve teams of people from different disciplines and in some cases, from different locations around the world. It is imperative that engineers are able to collaborate and work in multidisciplinary and multicultural teams as well as communicate well in order to be effective in engineering itself.

The engineer's ability to communicate, both in writing and orally, will determine the chances of being successful as an engineer and advancing his/her career. Technical expertise alone is not sufficient if the engineer is not able to communicate useful information to colleagues, supervisors and clients, and to express his views and opinions convincingly.

5.3 Internationalization and Cooperation

Globalization, characterized by the increase in international trade, mobility of labour and capital, as well as borderless communication, presents new opportunities and challenges for the engineering sector. It opens up boundless opportunities in the mobility of technical expertise within the region and the global community. Engineers should aim at achieving engineering excellence not only in their home countries, but also contribute to the development of the region and the world. Local professional engineers should look beyond national boundaries and create winning partnerships with foreign professionals and high technology industry leaders abroad. Cooperation and smart partnership, capitalizing on strength of each other, is the key to conquer regional and world markets.

6.0 CONCLUSION: WHAT WE COULD DO COLLECTIVELY

Different stakeholders in Malaysia such as the education institutions, industries, society and policy makers have to come together and work hand in hand to strengthen engineering education in order to develop a strong engineering workforce.

For a start, institutions of higher learning should strive to gain accreditation and professional recognition for their programmes. Such accreditation and professional recognition provide those programmes with international recognition, and create benchmarks against the global standards in the respective fields. Setting standards for programmes will follow naturally as standards will serve to ensure the continuity of the accreditation and professional recognition. At the same time, they provide the necessary assurance and confidence to prospective students, graduates, employers, graduate schools, licensing agencies and government.

With the current communication technology, the ability for educators to share experiences exists on a scale never before possible. Experience and knowledge sharing is a great avenue for solving complex cross-regional problems. We should also encourage the networking of people with similar interest such as among students or educators, so that their projects and goals are more exciting and encompassing. Consequently, the energy level and success rate would be higher.

It would be too late for students to be interested in STEM the day they step into institutions of higher learning. Their interest in STEM should be cultivated during their early days in school. Therefore, a fair amount of effort should be invested in going back to schools to promote STEM and to share the relevance of STEM education to young students in primary and lower secondary levels.

The word "engineer" brings up different impressions in different people. We should improve the image of engineers by showing more real examples of people in the engineering field, rather than leaving it to archetypes in movies and fictions. Wrong expectations may not be a good thing for motivation. People in the engineering community, be they educators, students or working professionals, should be more vocal in speaking up in order to be leaders and trend setters in their own fields. After all, they are the ones who know well where innovation can lead to. ■

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AN EXPERIMENTAL INVESTIGATION ON VEHICULAR BLOCKAGE EFFECT ON THE MAXIMUM SMOKE TEMPERATURE IN TUNNEL

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ABSTRACT

Researchers are motivated to study tunnel fires because of the increasing number of large-scale incidents in urban tunnels. When a fire occurs, most likely there are vehicles which get stuck in the tunnel. The stuck vehicles act as additional barriers against the flow of smokes. The effect of blockages on the maximum temperature of smoke which has not received considerable attentions in most of the previous investigations, is studied in this research. A set of scaled-down experiments was performed in a model tunnel [3 m (length) × 0.6 m (width × 0.96 m (height)]. The variables in this section are ventilation velocity, heat release rate (HRR) and blockage percentages. Gasoline was used as fuels in rectangular pools to generate a heat source. The influence of blockage percentages on the maximum smoke temperature beneath the ceiling has been investigated by improving the model of maximum smoke temperature published earlier by Li using local velocity near the fire source. This analysis reveals that the modified model of maximum temperature, which considers the effect of vehicular obstacles, could estimate experimental results with greater accuracy.

1.0 INTRODUCTION

One of the most effective ways to alleviate the ever-increasing traffic volume and congestion is constructing urban tunnels where automobiles, vans, buses, motorcycles, and trucks could travel pass congested urban areas or hills. In recent years, the significant increase in the number and the total length of tunnels contributed to several catastrophic fire incidents in tunnels and tremendous damage to properties and lost of lives around the world. Therefore, many researchers and fire safety engineers have studied fire characteristics in tunnels usually equipped with a ventilation system to understand the risks involved. Maximum smoke temperature beneath the ceiling is an important issue for fire safety engineering because of its influence on the tunnel structure which could be damaged when exposed to the relatively high temperature. In addition, the activation of sprinkler and ventilation systems installed in tunnels is related to this parameter. Consequently, it is worthy to study the maximum smoke temperature under the tunnel ceiling to improve the safety level in the tunnels. There are different factors, including the tunnel geometry, longitudinal ventilation velocity, and the heat release rate (HRR) of the fire source. Such knowledge has been studied by researchers widely and several empirical equations have been proposed to estimate the maximum temperature of hot gases under the ceiling. The first researcher who proposed a model for the maximum temperature in tunnel fires was Kurioka [1]. He carried out experimental tests to study fire characteristics including the maximum temperature and flame tilt angle in a tunnel. The various cross-sectional shapes under longitudinal ventilation were utilized. The following dimensionless empirical model of the maximum temperature rise based on the dimensionless heat release rate and the Froude number was derived:

$$\frac{\Delta T_{max}}{T_a} = \gamma \left(\frac{Q^{*2/3}}{Fr^{1/3}} \right)^{\varepsilon}, \tag{1}$$

where

$$\begin{cases} \gamma = 1.77, \varepsilon = 1.2 & \text{for } \left(\frac{Q^{*\frac{2}{3}}}{Fr^{\frac{1}{3}}} \right) < 1.35, \\ \gamma = 2.54, \varepsilon = 0 & \text{for } \left(\frac{Q^{*\frac{2}{3}}}{Fr^{\frac{1}{3}}} \right) \geq 1.35, \end{cases} \tag{2}$$

$$Q^* = \frac{Q}{\rho_a T_a C_p g^{1/2} H^{5/2}}, \tag{3}$$

and

$$Fr = \frac{V^2}{gL}. \tag{4}$$

According to this formula, when the fire is relatively small, the maximum temperature increases with the 2/3 power of the fire HRR, while it decreases with the 2/3 power of the longitudinal ventilation velocity. On the other hand, when the fire is relatively large, the maximum temperature does not vary with these two parameters.

Hu *et al.* [2] compared Kurioka's model by full-scale tunnel fire tests. Although they only confirmed the first part of Kurioka's model, good agreement was observed with the latter. They carried out twelve experiments in total, two experiments in a large-scale tunnel and ten experiments in full scale tunnels. Variations of this study were the fire size, tunnel section geometry, and ventilation velocity. They concluded that:

1. The maximum smoke temperature beneath the ceiling was higher for larger fire sizes, but it decayed faster while traveling down the tunnel.
2. The smoke temperature of upstream backlayering flow decreased with increasing longitudinal ventilation velocity.
3. A comparison between the upstream and backstream smoke temperature revealed that although the smoke temperature for the upstream backlayering was higher near fire source; it decreased much faster while traveling away from the fire than that of the downstream flow.

Smoke diffusion characteristics were analyzed by Wang [3] experimentally and theoretically. A formula developed for maximum smoke temperature under the condition that ambient air velocity existed. Li [4] presented a theoretical analysis to correct the Kurioka's model as it gives an infinite estimation of the maximum smoke temperature when the longitudinal ventilation approaches zero. An axisymmetric fire plume theory was used, and the dimensionless ventilation velocity was the basis of dividing the maximum excess gas temperature into two regions. According to their theoretical analysis and experimental data, which the necessary empirical coefficients are obtained from them, the following equation was presented:

$$\Delta T_{max} = \begin{cases} \dfrac{Q}{u r^{\frac{1}{3}} H_d^{\frac{5}{3}}} & \text{for } u' > 0.19 \\ \dfrac{17.5Q}{H_d^{5/3}} & \text{for } u' \le 0.19 \end{cases} \quad (5)$$

where

$$u' = {}^{u}/_{u^*}, \quad (6)$$

and

$$u^* = \left(\frac{Q_c g}{r \rho_a C_p T_a}\right)^{1/3}. \quad (7)$$

Li *et al.* [4] also evaluated the experimental results by comparing data from one model-scale test and two full-scale tests. Li *et al.* found a good agreement between the model-scale tests and the other tests. Since Equation 1 is useful for only small fires where the flame does not impinge the ceiling, Li and Ingason [5] continued their experiments and improved their model (Equation 5) to obtain a new model. They concluded that the maximum temperature is dependent on the combination of relevant parameters to an upper limit and then remains constant.

Kashef *et al.* [6] carried out reduced-scale experiments and derived two formulas to predict the ceiling temperature. However, Kashef *et al.* [6] did not discuss the effect of tunnel configuration on smoke diffusion characteristics.

Recently, ceiling maximum temperature and its longitudinal decay in case of tunnel fire were obtained and studied in [7] where the tunnel has a horseshoe shape. The major result of this study proves the results of previous investigations where the maximum smoke temperature beneath the ceiling is proportional to the terms of ${}^{Q^{2/3}}/_{H_d^{5/3}}$. Gao *et al.* [7] proposed modified equations for maximum smoke temperature rise beneath the ceiling and longitudinal temperature decay. Their experimental data had a good agreement with numerical simulations, the differences between experimental and numerical results were less than 7.5%. It should be notified that the present results need to be verified with more full-scale simulations.

The previously discussed models for measuring the maximum smoke temperature considered tunnel fires without blockage effect. However, in most actual tunnel fires, vehicles are usually stuck in the tunnel. A vehicle plays the role of an obstacle in the longitudinally ventilated tunnel, which will impact on local velocity around the fire source remarkably. Consequently, the tunnel fire characteristics such as the burning rate, the smoke flow pattern, and the temperature will be affected.

To examine the effect of blockages as well as their distance to the fire source on the maximum smoke temperature, Hu *et al.* [8] carried out an experiment in a longitudinally ventilated tunnel [8]. A modification coefficient considering the impact of blockage-fire distance was added and then, a global model including both the blockage ratio and blockage-fire distance was developed as in Equation 8. The maximum temperature decreased and then approached a constant value (similar to that with no blockage) with an increase in blockage-fire distance.

$$\Delta T_{max} = \begin{cases} \dfrac{Q}{\left[\frac{A - A_{blkg}}{A} + \frac{A_{blkg}}{A}\left(0.3\,{}^{d_b}/_{\bar{H}}\right)\right] V r^{\frac{1}{3}} H_d^{\frac{5}{3}}} & \text{for } u' > 0.19, d_b < 3.3\bar{H} \\ \dfrac{Q}{V r^{\frac{1}{3}} H_d^{\frac{5}{3}}} & \text{for } u' > 0.19, d_b \ge 3.3\bar{H} \\ 7.5\dfrac{Q^{2/3}}{H_d^{5/3}} & \text{for } u' \le 0.19. \end{cases} \quad (8)$$

Ceiling temperature distribution and smoke diffusion distance in a tunnel equipped with natural ventilation and with a train blockage have also been investigated [9]. This is very important as many times, urban tunnel are congested; researching in such an arrangement is more meaningful. The dimensionless smoke temperature and a constant value, which was different for investigated different tunnels in this article [9], were used to derive the reference temperature in the fire section. Shafee and Yozgatligil [10] studied the effect of blockage ratio and found out that blockages caused the temperature along the tunnel ceiling to increase significantly.

However, few studies have considered the effect of tunnel blockage ratio on the maximum temperature under the ceiling in tunnel fires. Motivated by past studies, this study focuses on the effect of tunnel blockage ratio on the maximum temperature of hot gases under the ceiling in tunnel fires. Data from experimental fire tests in tunnels with considerable blockage ratios are used. By analyzing these experimental data, previous models will be modified by introducing a factor that accounts for the blockage effect.

2.0 EXPERIMENTAL STUDY

2.1 Experimental Set-Ups

The first step in the experimental setup to obtain reliable and

qualify results is constructing the right model which can provide the acceptable similarities between the scaled model and the full-scale tunnel. However, the thermal inertia of the involved material, turbulence intensity, and radiation are not explicitly scaled, and the uncertainty due to the scaling is difficult to estimate, the general nature of the buoyancy-driven flows generated by a fire is not dependent on the scale [11]. The dynamic similarity between the scaled model and real model is related to preserving non-dimensional parameters such as the Froude, the Reynolds, and the Richardson numbers. Since it is not possible to preserve all mentioned numbers in most cases, the main goal is the preservation of the Froude number as the latter is the ratio between inertia and buoyancy forces and the Froude scaling model is used to build this scaled model [12]. The Froude number in this analysis in the same as in Equation 4. The scaling relationships for key parameters, velocity, and HRR, based on the preservation of the Froude number are as follows:

$$V_m = V_F \sqrt{\frac{L_m}{L_F}}, \tag{9}$$

$$Q_m = Q_F \left(\frac{L_m}{L_F}\right)^{5/2}. \tag{10}$$

In equations 9 and 10, subscript *m* is allocated for the model and *F* is for the full-scale tunnel. A review on a variety of approaches on similarity analyses, backlayering conditions including the effect of blockages, inclination, and the location of the fire source can be found in an earlier literature survey [13].

In this study, the Froude scaling method was used to build the model tunnel 1:50 scale of the Resalat Tunnel, Iran. The Resalat Tunnel is 150 m long and a diameter of 5.13 m. This expressway connects east to the west of Tehran, Iran. Based on the scaling ratio and method, the length of the tunnel, *L*, was scaled geometrically. The investigated model was 3 m long (*x* coordinate), 0.6 m width (*y* coordinate), and 0.95 m high (*z* coordinate). Fig. 1 shows the drawing of the model tunnel. Tunnel origin located 164 cm away from the right end of the model. The tunnel cross-section area was rectangular. All surrounding walls except half of one sidewall, the ceiling, and the floor of the tunnel were constructed by 25 mm - thick fireproof boards. Ten mm thick tempered glass in half of one sidewall of the tunnel provides the capability of smoke movement observation.

A ventilation fan with 1 kW power and an airflow capacity of 8400 cfm was installed at the left end of the tunnel (upstream section) to generates the longitudinal ventilation. Ventilation velocity was controlled and calibrated by varying the voltage by Toshiba frequency inverter VF-S11. One honeycomb mesh and two metal mesh screens made of wire were installed within a galvanized steel box and connect the three-phase fan and the main tunnel to provide a uniform and straighten flow.

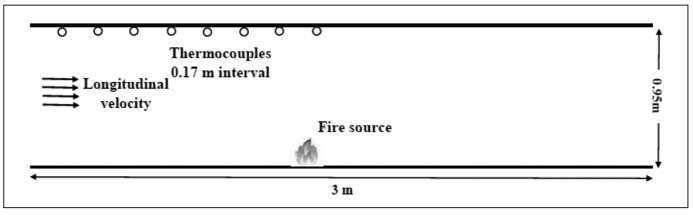

Figure 1: Schematic side view of the model tunnel

A detailed description of the experimental set up can be found in an earlier article [14].

2.2 Heat Release Rate

Real tunnel fires were simulated by pool fires in this study. The fuel was gasoline and square vessels were used as fuel containers and later as burners during fire. There were three different vessel dimensions i.e. 8, 10, and 13 cm square. Each pool was 2 cm deep and filled with a fuel height of 1 cm. The mass burning rate is used to calculate the heat release rate. Since gasoline needs a lot of oxygen in case of complete combustion, the mass burning rate increases with the ventilation velocity for fuel-controlled fires and the rate approaches a constant value for well-ventilated fires. There is no blockage between the fuel source and the fan which explains the easy access of oxygen into the core of the fuel and well-ventilated fire. However, $\dot{m}_f$ and Q are varied with time and ventilation velocity, based on the empirical relationship presented by Burgess [15], the burning rate with constant value is predicted in the function of pool diameter:

$$\dot{m}_f = \dot{m}_\infty \left(1 - e^{-k\theta D}\right), \tag{11}$$

where $\dot{m}_\infty$ is the burning rate of an infinite diameter pool fire. In Equation 11, k is the coefficient of radiative emission, and θ is the mean beam-length corrector. The HRR was determined by the burning rate [16] and can be calculated using Equation 12;

$$Q = \dot{m}_f a H_T, \tag{12}$$

where H_T is the heat of combustion of the gaseous combustibles when it is oxidized completely at ambient condition and a is burner area.

These sizes of pools produce simulated fires with heat release rates of 2.21 MW, 4.22 MW, and 8.98 MW in a typical tunnel. These fire sizes correspond to fires of approximately 39-160 MW in a tunnel with a diameter of 5.13 m when the Froude scaling model is used.

2.3 Measuring Instruments

The temperature of hot gases beneath the tunnel ceiling was detected by using one array of eight K-type stainless-steel sheathed thermocouples of 0.3 mm diameter. A K-type thermocouple is a precise and reliable instrument for continuous measurements providing the temperature range of -250 °C to 1260 °C. Thermocouples were placed 1 cm below the tunnel ceiling with 17 cm intervals in the centerline of the ceiling. The first thermocouple, T1, was fixed above the fire source and the other seven thermocouples, T2 - T8, were installed after T1 between the origin and the fan section (Fig. 1).

The main part of the data collection system was the Arduino Mega 2560 microcontroller. The signal from a K-type thermocouple should be digitized before sending it to a microcontroller. Therefore, the MAX6675 amplifier was used to measure the output of a K-type thermocouple, to perform cold-junction compensation, and to provide the result to the Arduino via an SPI interface.

2.4 Vehicular Blockages

Experimental tests with different sizes of blockages were carried out to simulate the influence of vehicles. The vehicle

models consisted of three sizes, representing a sedan, a bus, and a truck. The dimensions of the sedan were 0.38 m (L) × 0.15 m (W) × 0.12 m (H), for the bus: 0.54 m × 0.17 m × 0.21 m, and for the truck: 0.61 m × 0.19 m × 0.20 m (Table 1). This represents a 1:12 model of typical vehicles. The purpose of this dimension (1:12 scale) was to examine the effect of different cross-sectional occupancy percentages of the tunnel cross-sectional area rather than to simulate conditions close to actual conditions. Nevertheless, further investigations are needed to explore the behavior of the smoke flow in conditions close to real scenarios for safe and efficient design of tunnel fire. The vehicular blockages were placed on one, two, and three lineups to simulate a tunnel with various lanes of vehicles. Typically, 3 to 15% of the tunnel cross-sectional area was occupied by the model vehicles. Table 1 summarizes the blockage ratio of all scenarios.

Table 1: Blockage ratio of various scenarios in this study

Scenario	Vehicles	Lanes occupy	Blockage ratio
1	Sedan	1	3.4%
2	2 Sedans	1-3	6.8%
3	Sedan-Bus	1-3	9.6%
4	Bus-Truck-Sedan	1-3	12%
5	Bus-Truck-Sedan	1-2-3	15%

3.0 RESULTS AND DISCUSSION

Before studying the effect of blockages on the maximum smoke temperature, the influence of blockages on smoke flow behaviors and values which are used in different parts of this study needs to be determined first. When the blocking area percentage increases, the cross-section area of the tunnel decreases leading to the rise of local velocity at the vicinity of the fire source. As a result, the inertial force with respect to buoyant force enhances and then the Froude number rises. This phenomenon and less entrained air because of it causes more heat convection and radiation and the acceleration of the discharge rate of fire smoke. This also affects smoke characteristics, i.e. the maximum smoke temperature to decrease.

When there is no obstacle in the tunnel, the ventilated air diffuses to the entire tunnel and the concentration of the ventilation flow does not change along the tunnel. However, with the existence of blockages in the tunnel, the tunnel cross-sectional area becomes smaller. When the fire source is located at the centerline and the blockage is positioned at the side lanes, local velocity will be larger when the ventilation air reaches the fire source to preserve continuity (Equation 14). In other words, velocity is inversely proportional with the cross-sectional area. Parameters below are defined to estimate the local velocity:

$$\text{Tunnel blockage ratio } (\alpha\%) = \frac{A - A_{blkg}}{A}, \tag{13}$$

where A is the tunnel cross-sectional area and A_{blkg} is the blockages cross-sectional area. The blocking percentage is defined as:

$$\text{Blockage percentage } (\varphi\%) = \frac{A_{blkg}}{A}. \tag{14}$$

The existence of blockages causes that local ventilation velocity in the vicinity of the fire source V_{local} to change through the changes of the cross-sectional area as the following equation:

$$V_{local} = {}^{V}/_{\varphi} = {}^{V}/_{(1-\alpha)}. \tag{15}$$

3.1 Influence of Vehicular Blockages on Maximum Smoke Temperature

The behavior of fire-induced flow changes when blockages occupy part of the tunnel cross-sectional area because of the effect obstacles on the longitudinal velocity in the vicinity of the fire and downstream section. The bigger blockage causes higher local velocity which in turn, the discharge rate of smoke is increased and the capability of ventilation to release the heat produced by the fire accelerates [4].

In other words, the maximum smoke temperature, which depends on ventilation velocity, changes with the latter. Table 3 illustrates the effect of blockage ratio on example cases with the same HRR and ventilation velocity.

Table 2: Three examples of the influence of blockages on maximum smoke temperature

Ventilation velocity (m/s)	HRR (kW)	φ%	Maximum smoke temperature (°C)
0.1	2.21	0% 6.8% 9.6%	45.8 45.0 43.0
0.8	2.21	0% 6.8% 12%	36.8 36.0 34.5
2.9	4.22	0% 6.8% 12%	37.8 37.0 35.5

In this section, first, the model presented by Li *et al.* [4], who studied the maximum temperature in a tunnel without blockages, is evaluated by the experimental results of this study in the presence of blockages (Fig. 2). As shown in Fig. 2, Li's model cannot estimate the maximum temperature rise within acceptable errors. Therefore, Equations 5 are amended by using V_{local} (ventilation velocity in the vicinity of the fire source) instead of V and are now represented in Equations 16. Fig. 3 compares the experimental results of the maximum smoke temperature with predictions by modified Li's model considering the blockage ratio (Equation 16). The black line presents modified Li's model considering the blockage ratio. It is shown that there is a good agreement between the model predictions and experimental results (Fig. 3) and they are close enough to the measured values which means that the amended Li's model could estimate the maximum smoke temperature in the presence of obstacles. In addition, at low ${}^{Q}/_{V_{local}r^{1/3}H_d^{5/3}}$, ΔT_{max} is below the black line and at high ${}^{Q}/_{V_{local}r^{1/3}H_d^{5/3}}$ is above the black line.

$$\Delta T_{\max} = \begin{cases} \dfrac{Q}{V_{local} r^{\frac{1}{3}} H_d^{\frac{5}{3}}} & \text{for } V' > 0.19 \text{ and} \\ \dfrac{17.5Q}{H_d^{5/3}} & \text{for } V' \le 0.19, \end{cases} \tag{16}$$

where

$$V' = {V_{local}}/{u^*}, \quad (17)$$

and

$$u^* = \left(\frac{Q_c g}{r\rho_0 C_P T_a}\right)^{1/3}. \quad (18)$$

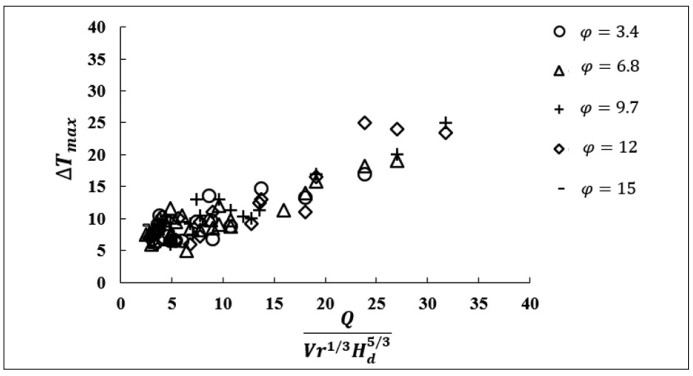

Figure 2: Comparison of Li's model (Equations 5) predictions with experimental results for different tunnel blockage ratio

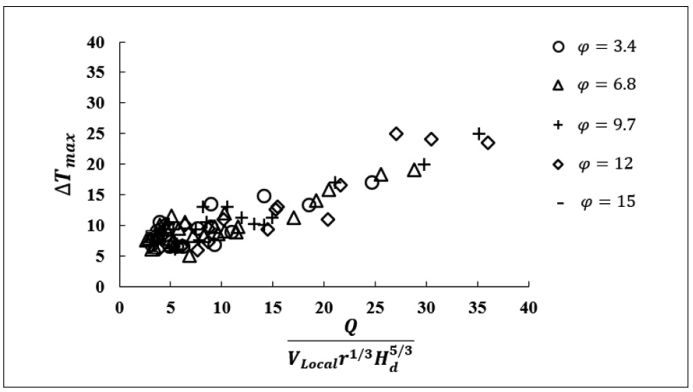

Figure 3: Comparison of modified Li's model (Equations 16) predictions with experimental results for different tunnel blockage ratio

4.0 CONCLUSION

This work investigates the influence of blockages on the maximum temperature of hot gases beneath the ceiling in case of a tunnel fire. A 1:50 reduced scale tunnel with 3 m × 0.6 m × 0.95 m (length × width × height) dimensions was employed to carry out a series of experiments with different fire heat release rates, longitudinal ventilation velocities and blockage percentages. Real tunnel fires were simulated by gasoline pool fires in this study. Temperatures were detected by using one array of eight K-type stainless-steel sheathed thermocouples. The vehicle models consisted of three sizes, representing sedan, bus, and truck. 3 to 15% of the tunnel cross-sectional area was approximately occupied by the model vehicles. Experimental results of this study show that the maximum smoke temperature decreases in the presence of blockages due to the effect of them on local velocity. Moreover, the measured values were compared with previous model proposed by Li which do not consider the blockage influence. When the blockage is placed upstream from the fire source, due to its hinder of the local ventilation flow from directly reaching the fire source region, the maximum gas temperature beneath the ceiling cannot estimate Li's model correctly. Therefore, a modification model with V_{local} instead of V was developed, which is shown to collapse maximum temperature predicted and measured values. Still, further thermal experiments are recommended in order to find the most appropriate and suitable correlations for both low and high ${Q}/{V_{local}r^{1/3}H_d^{5/3}}$. Moreover, the scaled tunnel model can be further improved to study a wide range of several scenarios.

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INVESTIGATION OF THRESHOLD ENERGY, ABSORPTION COEFFICIENT AND THERMAL LOADING IN GLASS IONOMER CEMENT LASER REMOVAL

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ABSTRACT

***Purpose**: Various kinds of lasers have been developed for the diagnostic and operative application. In dental restoration, the laser is used for removal of remaining dental material. The main benefits of laser applications are patient comfort and pain relief. The primary concern in laser application is a better result for the specific area applied compared to the traditional method. Quality result of laser irradiation could be promised with appropriately controlled laser parameter. Thus, this work aims to determine laser energy threshold, absorption coefficient, and thermal loading of glass ionomer cement (GIC) through the application of Beer-Lambert's law to enhance the use of Nd:YAG laser in the restorative dental application.*

***Method**: 132 tooth samples were collected from the Advanced Medical and Dental Institute, Universiti Sains Malaysia. All the tooth sample were drilled and filled up with GIC dental material. Spectron Pulse Nd:YAG Laser System, SL-805G (1064 nm) was used to irradiate all the samples with various parameter applied; laser energy, number of shots and beam size, thus the depth of GIC removal was obtained.*

***Results**: Graph of depth GIC removal against laser energy, was plotted for each number of shots, and beam size that considered in measuring the average of GIC removal efficiency. As a result, the general ET, α, and γ were obtained at 46.82 mJ, 10.79 mm-1 and 505.18 mJ mm-3 respectively.*

***Conclusion**: These results were recommended as the best estimation of laser depth penetration into GIC dental material.*

Keywords: Glass ionomer cement, Laser removal, Nd:YAG laser, Thermal decomposition

1.0 INTRODUCTION

Laser, the acronym of light amplification by stimulated emission of radiation, is a coherent and monochromatic source of electromagnetic radiation with wavelength ranging from the ultraviolet to the infrared range [1, 2]. Lasers have wide-ranging applications in different materials processing [3, 4]. The introduction of laser in dentistry, in the 1960s, by Miaman [5], has led to continuous research in the various applications of lasers in dental practice.

The laser has an ability of precise control of the material and at what rate energy is deposited [6-8]. From that, to achieve desired material modification a proper selection of laser processing parameter is needed. A spatial intensity of laser profile used in controlling the deposited energy to the desired region [9]. At the point when light strikes the surface of the materials, some portion of the light will be reflected, and the rest will be transmitted into the material [10]. The reflection process is due to the discontinuity in the real index of refraction. Besides, the reflectivity of the given material will rely upon on the frequency of the light source through the dispersion relation of its index of refraction[10, 11]. Besides, surface reflectivity depends on the temperature of the material through the changes in the permittivity, band structure, plasma oscillation or material phases [6, 12]. In the case of small scale or structured materials, additional optical resonance is required for improved absorption or reflection due to the details of the photon-electron interaction.

Laser absorption process will occur depending on the type of material and also on several different parameters used [6, 8, 13]. In general, photons will be coupled into the available electronic or vibration states in the material and it will depend on the photon energy. In insulators or semiconductors, the absorption of laser is likely to occur through resonant excitations like transitions of valence bands electrons to the conduction band or within the band [14]. The excited electronic states transfer their energy to lattice photons. Photons with energy below than material bands gap will not be absorbed.

The response of the materials can be classified as a result of raised in temperature. The temporal and spatial evolution of the

temperature field inside a material given by the heat equation [6, 15]. The details of the material response will depend on the material system and the laser processing conditions. The materials will respond, and it will be the function of the local material heating and cooling rate. Maximum temperatures reached and all of which can be determined from the solution to the heat equation for the given irradiation conditions. The transient pool of molten material on the surface will occur if the energy deployed is above the threshold of melting [16-18].

To enhance the removal of glass ionomer cement (GIC) dental material and to limit the risk of the tooth damage and health implications, the important factors identified to these issues must be addressed. Laser removal of GIC material can only promise great quality results if the operational process parameters, for example, laser energy (E), number of pulses (N), beam size (BS) and any related factors are appropriately controlled [19].

The information of how far a laser beam is absorbed by GIC surface is intrinsically influenced by laser wavelength (λ), laser energy(E), beam size (BS) and repetition rate (RR). This information is essential for effectiveness, quality, and its efficiency of GIC laser removal process in the dental application. Increasing of E will increase the removal efficiency of GIC dental material. However, there should be a maximum depth of GIC thickness that can be reached by increasing the E until all the GIC had been removed. In addition, E is needed to ablate GIC material and depending on the threshold energy (E_T) of GIC material and N of the laser.

Thus, this study aimed to investigate the E_T, α and γ over GIC dental material irradiated by Nd:YAG laser. Beer-Lambert law was applied to obtain the results from the plotted graph.

2.0 MATERIAL AND METHODS

2.1 Tooth Sample Preparation

A total of 132 tooth samples was obtained from hospital and private dental clinics around Bertam, Penang Malaysia. The permission to collect human teeth and to conduct this study human ethic has been obtained from the Human Research Ethics Committee of Universiti Sains Malaysia. Only healthy and non-erupted human incisor tooth was collected in this study.

Deciduous incisors that were chosen, without obvious decay or sign of fluorosis, fractures or fillings. After exfoliation or extraction, the teeth were stored in a 0.2% thymol solution to prevent desiccation of dental tissues. In order to minimize variability, tooth samples collected must be approximately the same in dimension. The teeth were then transported to the Craniofacial and Biomaterial Laboratory to be cleaned and stored. During tooth transport, all extracted teeth were placed in a well-built container with a secure lid to avoid any leakage.

All tooth samples were cleaned from gross debris and visible blood for educational purposes. Besides that, the tooth samples were required to be maintained in a hydrated state. The tooth samples were gently brushed with a soft brush and finally rinsed with water to eliminate all gross debris and visible blood. Next, the tooth sample was stored in a chiller at 5°C in 0.2% thymol solution before the dental drill test was conducted. Also, all the guidelines for handling the extracted tooth were fulfilled.

Lastly, all these tooth samples were drilled to obtain a hole of 2 mm diameter with 2 mm depth using a round shape bur handpiece dental drill and filled with GIC (3M ESPE Ketac Molar Aplicap, GI) material before being irradiated with certain laser parameters as shown in Table 1. Each parameter was repeated three times. Thus, the total number of 132 samples was performed in this study.

Table 1: Laser parameters considered for 0.5mm and 1mm BS with varies in laser Energy, Number of shots and Repetition rate

Sample number	Number of shots	Beam sizes (mm)	Laser energy (mJ)	Repetition rate, RR (Hz)
1	5	0.5	100	0.08
2	10	0.5	100	0.17
3	20	0.5	100	0.33
4	30	0.5	100	0.50
5	40	0.5	100	0.67
6	50	0.5	100	0.83
7	5	1	100	0.08
8	10	1	100	0.17
9	20	1	100	0.33
10	30	1	100	0.50
11	40	1	100	0.67
12	50	1	100	0.83
13	5	0.5	130	0.08
14	10	0.5	130	0.17
15	20	0.5	130	0.33
16	30	0.5	130	0.50
17	40	0.5	130	0.67
18	50	0.5	130	0.83
19	5	1	130	0.08
20	10	1	130	0.17
21	20	1	130	0.33
22	30	1	130	0.50
23	40	1	130	0.67
24	50	1	130	0.83
25	5	0.5	160	0.08
26	10	0.5	160	0.17
27	20	0.5	160	0.33
28	30	0.5	160	0.50
29	40	0.5	160	0.67
30	50	0.5	160	0.83
31	5	1	160	0.08
32	10	1	160	0.17
33	20	1	160	0.33
34	30	1	160	0.50
35	40	1	160	0.67
36	50	1	160	0.83
33	5	0.5	200	0.08
34	10	0.5	200	0.17
35	20	0.5	200	0.33
36	30	0.5	200	0.50
37	40	0.5	200	0.67
38	50	0.5	200	0.83
39	5	1	200	0.08
40	10	1	200	0.17
41	20	1	200	0.33
42	30	1	200	0.50
43	40	1	200	0.67
44	50	1	200	0.83

2.2 Operating Principle

Nd:YAG laser system Spectron Laser System, SL-805G, the US with a maximum energy output of 1300 mJ and a pulse duration of 6 ns is used. In this study, a set-up of Nd:YAG laser system irradiation was developed. The GIC filling material of the tooth was perpendicularly irradiated as shown in Figure 1. A pinhole laser beam was used to remove the unwanted multiple order energy peaks and bypass the central maximum of the diffraction pattern known as a Gaussian beam. Meanwhile, the addition of the focusing lens allows the adjustment of the size of the beam needed for the irradiation procedure.

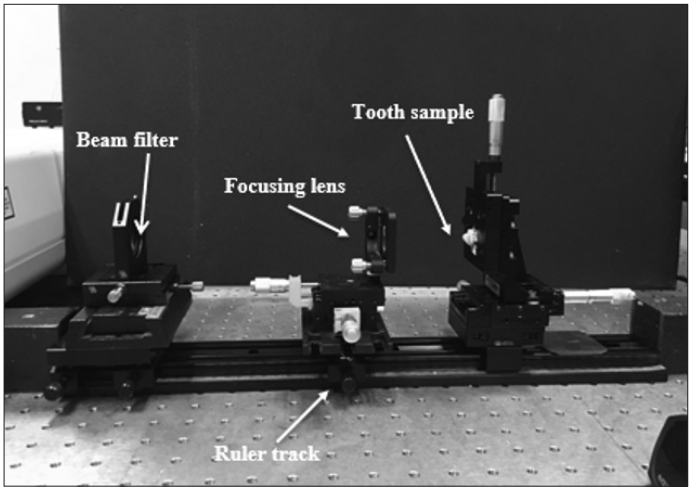

Figure 1: Experimental set-up for laser glass ionomer cement removal on tooth sample

2.3 Sample Analysis

Bowers Micro-Gauge 2 Point Bore Gauge, Camberly England designed particularly for the precise measurement of bores from 0.01 mm to 10 mm. This gauge was used to analyze 132 irradiated crated depths to obtain the depth thickness and diameter of laser penetration (*d*). For this study, depth versus laser energy graph was plotted for each beam size and number of shots. Hence, the ϵ of GIC dental material can be determined by measuring its inclination of the fitted linear graph. The best laser energy threshold, E_T for GIC dental material was selected from the interception of a fitted linear graph of ϵ with their X-axis. This can be described by using Beer-Lambert. Graph depth, d versus Laser energy, *E* was plotted to derive a general E_T for GIC dental material from the interception of the fitted linear graph with the X-axis.

3.0 RESULTS AND DISCUSSIONS

By plotting a graph of variation removal GIC depth versus the changes in laser energy as shown in Figure 2 and Figure 3, E_T can be easily established from the interception of the fitted linear line of the x-axis.

According to Figure 2 and Figure 3, only one linear line shows the interception at X-axis which was referred to the E_T of the GIC dental material. From the graph, the minimum energy required to remove GIC dental material was at 48.62 mJ for pulse Nd:YAG laser with 0.5 mm beam size and 10 number of shots. The selection of a E_T was based on the linear line that intercepts certain laser energy and the *E* that intercept at the X-axis should be greater than zero.

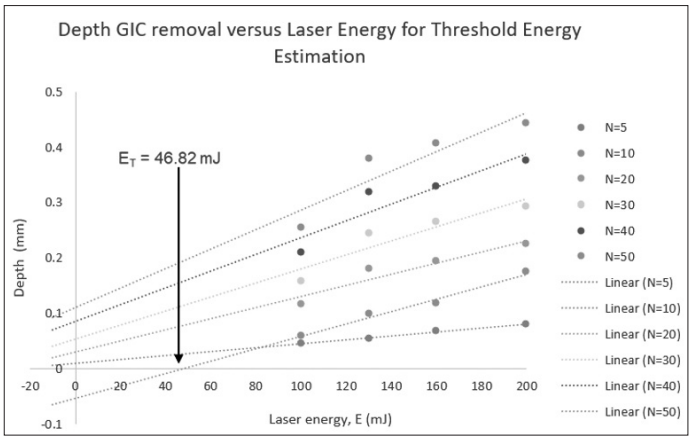

Figure 2: Fitted linear graph of GIC dental material for 0.5 mm beam size

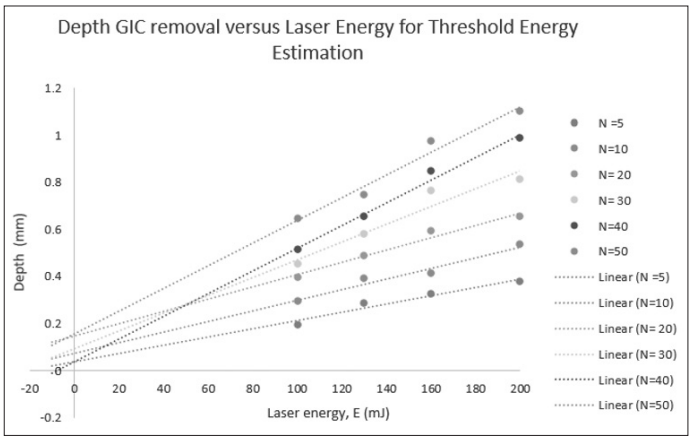

Figure 3: Fitted linear graph of GIC dental material for 1 mm beam size

Based on Figure 2, the E_T indicated the general threshold energy for GIC dental material. The linearity of the data points shown in Figure 2 further validates the use of the approach for the examination of continuous wave (CW) lasers.

Since the energy deposition profile will be governed by the optical absorption coefficient, α (mm^{-1}), then the depth, *d* of material removed is given by Beer-Lambert's law:

$$d = \frac{1}{\alpha} \ln\left(\frac{E}{E_T}\right) \quad (1)$$

Where E_T is the threshold value of the laser energy for GIC material removal occurs [20], α is the absorption coefficient (mm^{-1}). Equation (1) is the absorption coefficient of incident radiation by the plume of removed GIC dental material.

As demonstrated by the works of Schmidt *et al.* [21] and Andrew *et al.* [20], the simple form of Equation 1 can be rearranged as follows:

$$\alpha = \frac{\ln\left(E/E_T\right)}{d} \quad (2)$$

By introducing the ablation depth, d and the corresponding value of laser energy, for each data point into Equation (2), it is possible to calculate the absorption coefficient of Nd:YAG laser radiation into the surface of the GIC dental material under the actual experimental conditions.

The thermal loading, γ (mJ mm^{-3}) of GIC dental material laser removal can be found based on Equation (3).

$$\gamma = \frac{E_T}{\alpha} \quad (3)$$

The material that has been evaporated and removed from the surface of the component known as material ablation. This material is removed upon laser impact. Hence, the GIC removal mechanism begins after the absorption of laser intensity to the GIC exceeds the ablation threshold of the material as shown in Equation 1 above.

It is concluded that GIC tooth sample of 0.5 mm coupled with 10 pulses gives the best result to estimate the optimum efficiency of GIC dental material removal. After identifying the value of E_T, at a certain depth, an α and γ were determined.

When GIC removal at 0.1 mm depth and its corresponding laser energy of 137.73 mJ, the general value of α and γ can be obtained, as shown in Table 2. Then, the removal efficiency of GIC material can be determined as shown in Table 3.

Table 2: Summarization of general E_T, α and γ for GIC dental material

Energy (mJ)	Depth (mm)	Threshold Energy, E_T (mJ)	α (mm^{-1})	γ (mJ mm^{-3})
137.73	0.1	46.82	10.79	505.18

Table 3: Removal efficiency of GIC material for N=10 and beam diameter of the laser was 0.5 mm

Energy (mJ)	Depth (mm)	Fluence (mJ mm^{-2})	GIC removal efficiency, ϵ (mm^2 mJ^{-1})
100	0.0588	56338.03	1.04 x 10^{-7}
130	0.0988	29411.76	3.35 x 10^{-7}
160	0.1185	7222.22	16.4 x 10^{-7}
200	0.1739	3448.28	50.60 x 10^{-7}

The removal efficiency is determined based on the volume of GIC removed with a certain amount of laser energy and the number of laser shots. From the results, the highest ϵ for GIC is 50.60μ mm^2 mJ^{-1}, as shown in Table 3.

From the literature, threshold energy, E_T of GIC materials will be reduced by increasing laser energy, E with increasing the ϵ [22, 23]. During this analysis, the results show significant effects in the laser threshold energy, E_T with the increase of the laser energy while remaining with the same number of shots.

The results gave a positive effect in increasing the laser energy, where the average removal efficiency, (ϵ) was also increased, as shown in Table 3. Figure 2 and Figure 3 clearly show that the crater depth was linearly developed into the GIC samples as energy increased. Higher laser energy caused higher thermal energy to dissipate at the GIC target area for the process of thermal decomposition, thus increasing the ϵ of the unwanted layer.

4.0 CONCLUSION

This study concludes that the E_T, α, and γ were obtained at 46.82 mJ, 10.79 mm^{-1} and 505.18 mJ mm^{-3}, respectively. The GIC removal efficiency, ϵ in GIC removal, depends on the function of laser parameters sort of laser energy, beam size, number of pulse and repetition rate. Furthermore, the mechanism of the photothermal and photochemical process contributes to the ϵ. The physical and chemical factors of GIC material and laser beam characteristics play a role in the absorption coefficient efficiency onto regions of interest (ROI) as well. Hence, the optimum operation of laser parameters should be applied to achieve the best efficiency in removing GIC using a laser.

In conclusion, this analysis reveals the interaction characteristics of GIC material laser irradiation in terms of threshold energy, E_T (mm^{-2} mJ), absorption coefficient, α (mm^{-1}) and thermal loading, γ (mJ mm^{-3}). This research proves that the effectiveness, quality and efficiency of GIC removal process can be obtained by using Spectron Nd:YAG laser System, SL-805G with a proper selection of laser parameter.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper. ■

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DEVELOPMENT OF A COMPREHENSIVE MODEL FOR EROSION AND SEDIMENT CONTROL TOWARDS GOOD WATER GOVERNANCE: UKM CAMPUS AS A WATERSHED MODEL

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ABSTRACT

This study was carried out to develop a whole ecosystem-based erosion and sediment transport control management system of UKM Campus Watershed which is a sub-basin of Langat River Basin catchment. This is done through the development of an Erosion and Sediment Control (ESC) model for the UKM campus watershed that includes localised technology, information and communication system, as well as awareness and community participation for the greening and rehabilitation of UKM Campus. The management system was developed to give a strong participatory element and to ensure that the model will be placed into a user friendly context to make data input and model operation simple for stakeholders with limited resources and training in the use of the models. The application of hydromulching (bioengineering technology) is adopted as part of the ESC study by using the local components to recover most landslides occurred in UKM Campus. It is also as an option where the post-landslide restoration works involving conventional civil designs are costly and sometimes not practical at remote sites. Therefore (due to cost constraints), the remoteness of the sites and low risk to lives and property, bioengineering was the option taken for erosion control, slope stabilization and vegetation establishment. The study successfully developed the local hydro mulching (bio engineering technology) product for erosion and sediment control of UKM campus watershed by using the local components to recover most landslides issues in UKM Bangi Campus. The study also developed the integrated information and communication system for the campus community of UKM in order to raise awareness and to increase participation of UKM Campus stakeholders in minimising the erosion and sedimentation issues. The integrated information and communication system is coordinated under the Integtrated Water Resources Management (IWRM) Research Group of UKM, which also monitor and evaluate the erosion and sediment transport within the UKM campus.

Keywords: Erosion and Sediment Control, Water Governance, Watershed Model, Hydromulching, UKM Campus

1.0 INTRODUCTION

Erosion is one of the common phenomenon that can be happened in any tropical region, including Malaysia. Malaysia which is located near to the equator, being hot and wet throughout the year with annual rainfall average of 2,400 mm per year and the average temperature of 27°C, being exposed to rainfall and runoff, some of construction activities and uncontrolled land disturbance, high scale of deforestation, are among factors that lead to the erosion and sedimentation issues. In Malaysia, erosion or slope failure commonly related to rapid development of land. The development includes changing forest cover area to other development such as agriculture, urbanization, industrial, infrastructure and also residential that would mismanaged the slope become non environmental friendly and causing slope failure (Jaafar *et. al.* 2011).

There are several factors related to this slope failure i.e (i) the occurrence of heavy rain for a long period of time, (ii) changes in the nature of the earth through geomorphologic processes, (iii) the plane of rock discontinuities and (iv) the erosion of soil by the action of rain water and runoff (Komoo 1985; 1986). Generally, landslide is associated with the movement of rocks, debris and soil down a group. Moving water is the major agent of erosion where rain carries away bits of soil and slowly washes away rock fragments (Cruden 1991; 1996).

The same situation is also occurred in UKM Campus, which has facing series of issues related to erosion and sedimentation, slope failure and landslides. The effect has been in obvious water quality and quantity deterioration in a UKM Watershed due to severe siltation and sedimentation. Sediment is always the number one pollutant in waterways, where siltation and nutrients have entered and flowed into the rivers system, and UKM is no exception. There is a need to develop a whole ecosystem-based erosion and sediment transport control management system for UKM Campus Watershed.

This study focused on the soil erosion causes, effective erosion control designs and techniques for fast greening of bare

slope faces. In addition, there is the unsuitability of conventional hard-engineering solutions (e.g. concrete revetments) in blending in with the landscape in a campus or institutional environment like the UKM. Bioengineering solutions will not only be green in appearance, but in the long term may be cheaper to maintain due to the flexibility of vegetation in following ground level movements as compared to hard concrete structures. The monitoring and evaluation system for erosion and sediment transport within the UKM Campus will also need to be done in supporting the ongoing study.

2.0 EROSION AND SEDIMENT CONTROL

Erosion defined as the detachment, entrainment, and transport of soil particles from ongoing land development and construction areas by the rainfall and runoff activities (DID, 2011). Erosion occurs in form of mass movement of soils and debris down a slope, and starting with raindrop splash. At the onset of runoff sheet, water collects into small rivulets, which may erode very small channels called rills (Dilley *et. al.* 2005). Soil particles can be transported over a short distance (such as the splash from a raindrop impact), or a longer distance (to the bottom of the slope, or into a water conveyance) before being deposited. The transportation and deposition process is called sedimentation.

Erosion and sedimentation are natural processes. These processes occur daily, on all land, as the result of wind, and water. However, human activities can make it happen more quickly than under natural conditions. Destruction of soil is caused by abiotic factors, the activity of which is attributable to mechanical action, and is called "mechanical erosion." Erosion also includes chemical action, which is connected with the mechanical action of water, and is referred to as "chemical erosion" or "corrosion" (Zachar 1982).

The natural processes can be divided into geological erosion and also accelerated erosion. Geological soil erosion tends to bring the earth's surface to a uniform level. The first phase of this process is weathering which is essentially physico-chemical in nature. This leads to simplification of substances through disintegration and is aided by certain biological influences causing further disintegration. The process leads to the development of complex soil bodies with definite physical, chemical and biological properties. Therefore, as a part of geological process, erosion takes place through various weathering processes. While accelerated Erosion under cultivation, the land experiences a lot of pressure from outside and consequently the balance between vegetation cover and climate is disturbed. Thus, removal of surface soil by natural agencies takes place at a faster rate than it can be built up by soil forming process. Erosion occurring under these conditions is referred to as accelerated erosion. Its rate and magnitude are higher than those in normal geological erosion (Montgomery, 2007).

Soil erosion is a common geomorphological process in the tropic area and managing it is a constant challenge (Jaafar *et. al.* 2011). There are many impacts of soil erosion towards environment especially on soil quality, air quality and also water quality. Organic matter is a small fraction (2% to 4%) of soil mainly present on the soil surface. Organic matter contributes to productivity through its effect on the physical, chemical, and biological properties of the soil. Erosion gradually depletes organic matter and decreases soil productivity. When organic matter is lost, soils tend to lose their physical structure. The degradation of soil structure makes the soil hard, compact and cloddy. The soil aeration, water-holding capacity and permeability are also decreased. Decreased aeration means less oxygen available for plant roots to grow. Decreased water availability also means less water available for healthy plant growth. When soil permeability decreases, less water will soak into the soil and more will run-off. Beneficial organisms that suppress disease and break down organic residues will not function well due to reduced oxygen and water in soil. This in turn will reduce nutrient storage and supply abilities of the soil.

While air quality have a major impact on human and animal health when the soil particles blown by the wind into the air. Particles suspended in air by wind are easily inhaled and accumulate in lung tissues causing major respiratory problems. Concentrated levels of windblown particles can also reduce visibility and increase the risk of automobile accidents. Impacts of erosion on water quality sediment deposition in lakes and rivers will increase water turbidity making it difficult for light to penetrate the water. This causes problems for aquatic plants that need sunlight for photosynthesis. Sediments are also rich in nutrients such as phosphorus and nitrogen. These nutrients promote the excessive growth of algae. This process is called eutrophication. Areas of excessive algae growth, called algae blooms, deplete oxygen in the water resulting in the death of aquatic animals from lack of oxygen (Chislock *et al,* 2013).

Sedimentation defined as the build-up (aggradation) of sediment on the land surface or the bed of receiving waters. Sedimentation leads to the rising of bed levels contributing to increased floods levels and escalates the destruction of aquatic habitats and fisheries. It is a dynamic process and is dependent upon the geomorphic and hydraulic characteristics of the drainage system and the nature of the receiving water body (DID, 2011). The deposited sediment tends to remain in place sometimes for short periods of time, where subsequent rainstorms flush the sediment downstream and sometimes for very long times, the later being the case in estuaries and lakes. Sediment tends to be transported in pulses depending on the flow characteristics of the drainage systems. There are primarily eight basic principles of Erosion and Sediment Control (ESC) described in MSMA guideline by DID (2010) i.e. (1) Minimizing Soil Erosion; (2) Preserving Top Soil & Other Assets; (3) Access Route & Site Management; (4) Runoff Control & Management; (5) Earthwork & Erosion Control; (6) Sediment Prevention Control; (7) Slope Stabilization; and (8) Site Maintenance.

Erosion control is the process of reducing erosion by wind and water. Sometimes, engineers simply install structures to physically prevent soil from being transported. Gabions are huge wire frames that hold boulders in place, for instance. But this mitigation would exceed ten to twenty years depending on the gabion structure. Erosion control can also be done by physically changing the landscape. The plant could help to anchor the soil to the area, preventing erosion. Trees and plants hold soil in place. When people cut down the forests or plow up grasses for agriculture or development, the soil washes away and blows more easily. Water also rushes over exposed soil rather than soaking into it, and that will cause flood.

3.0 STUDY AREA AND RESEARCH METHODOLOGY

3.1 Study Area

The study on the development of a comprehensive model for erosion and sediment control is done at UKM Campus which is

seen as a watershed model for a bigger catchment area of Langat River Basin of Malaysia. UKM Campus Watershed is a sub-basin of Langat River Basin, which is currently identified as one of the UNESCO-IHP Hydrology for the Environment, Life and Policy (HELP) Basins out of 91 catchments from 67 countries in the world since 2004. HELP (Hydrology for Environment, Life and Policy) is a cross cutting and transdisciplinary initiative of the UNESCO led by the International Hydrological Programme (IHP) with objectives to deliver social, economic and environmental benefits to stakeholders through sustainable and appropriate use of water by directing hydrological science towards improved integrated catchment management basins and also implementation of research in collaboration between scientists, managers and stakeholders (UNESCO, 2004). In order to makesure the Langat River Basin to be promoted to an Operational or Demonstration HELP Basin, it is important to conduct a more systematic and holistic study, using multisectoral and multidisciplinary approach, and therefore the study conducted under this project will also be focused on the transdisciplinary initiative and comprehensive approach for managing UKM Campus watershed which taking into account the scientific, bio-engineering and social components. This is among the reason why we need to manage the UKM Campus Watershed properly and take necessary actions to mitigate the ecosystem degradation related issues (especially those which related to erosion and sediment control) in UKM to be occurred, beside UKM Campus itself is located at the centre part of Langat River Basin. By seeing & treating a UKM campus as a watershed model, only then we can better manage and act, as well as able to measure the catchments progress (UKM Campus Watershed) towards good water governance which implementing the HELP philosophy and long-term sustainable development within the river basin concept harmonisingly.

UKM Campus is located in humid tropical zone with nearly constant temperature throughout the year and high annual rainfall. These elements expose to geomorphological agent actions that capable to higher the potential of landslide at slope area. The annual average temperature is 23.3°C while total amount of rainfall is 175.9 mm per year recorded in UKM Station Meteorological Department in 2012. Bangi area, where UKM Campus is located, is divided by three geology structures which are alluvium, granite and metasediment (Komoo 1984). In UKM Bangi Campus context, metasediment rock is dominant that consist of meta-argillite type which is fine-grained and meta-arenit which is coarse-grained (Muda & Komoo 1984). The combination of both rocks effected erodibility level that lack of cohesive and potentially disintegrate easily towards soil surface and sub-soil surface layer. Soil type in UKM Bangi Campus are from Munchong-Seremban series, which categorized in tropeptic subgroup. This soil is fragile, easily broken and easily absorbed water and also contain of 42.5% clay. The combination of all these features gives early indicator to slope failure around UKM Bangi Campus.

There are several series of landslides events in UKM Bangi Campus identified since May 2012 as shown in Figure 1 and 2. Landslides occurred in the UKM Bangi Campus driven by three main factors, i.e (i) slope vulnerability of materials engineering aspects associated with the low level of soil erodibility, (ii) accumulation of excessive ground water occurred for a long time, and (iii) very less preventative measures against the slope and surface slope to encourage further erosion events (Komoo 1987).

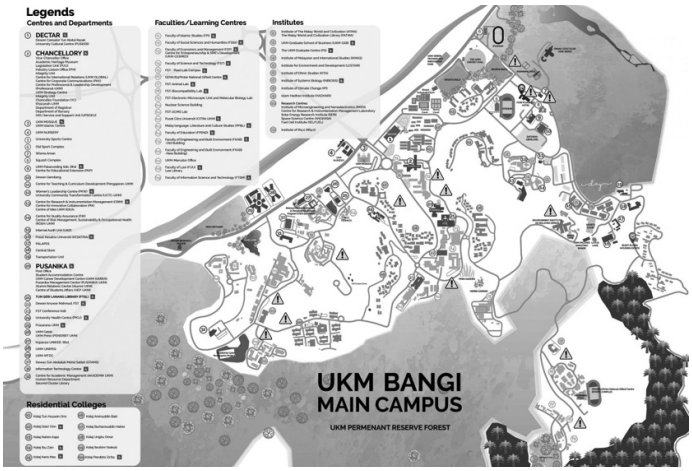

Figure 1: Landslide Locations in UKM Bangi Campus (shown by using warning signages)

Figure 2: Landslides occurred in UKM Bangi Campus

Slope failures in UKM are also influenced by soil properties. Some of these slopes were through appropriate mitigation approach and others are become worst without any big action plan taken (Jaafar *et. al.* 2011). There is just a preventive action such as by putting the plastic canvas linen to cover it, but it only for a short period of time because the linen is easily torn. The composition of the soil texture was dominated by sand and silts which are significantly influenced the level of the erosion. This has shown that several problematic slopes that have not yet been mitigated should be rehabilitated immediately to avoid any possibility of large scale landslide occurrence in the future (Huat *et. al.* 2008).

UKM Campus is developed very fast recently, with many new buildings development in the campus, and also renovation of number of old buildings. These involved huge of land clearing area, some land use changed area, as well as lots of engineering and construction works during the developments. The process is also taking some times. Whenever heavy rain comes, soil erosion and sediment transport will be occurred by surface runoff and deposited downstream to the detention ponds, i.e into Alur Ilmu (Small Canal within UKM Campus) and also into University Lake (UKM Lake near Faculty of Engineering and Built Environment of UKM). Sediment accumulates in detention ponds and impounded water bodies over time that will affect their chemical, physical and also biological processes (Heal e*t. al.* 2006). Detention ponds provide three basic functions that are as flood control, water quality enhancement and also ecological and aesthetic value. Continued accumulation and deposition of sediments may lead to the deterioration of water quality and the migration of pollutants through sediments (Shamsuddin *et al,* 2012). When this is happened, the excessive suspended sediment settled in the detention pond and may affect the detention pond function (Figure 3 & 4).

Figure 3: Erosion and sediment issues at Alur Ilmu UKM

Figure 4: Erosion and sediment issues at University Lake of UKM

The same condition has also affected the UKM Campus watershed and its University Lake, which acted as a detention pond for the University. However, the lake is currently not functioning anymore due to the sediment that being transported from the landslides and erosion into the lake through drainage system which casued by rapid development activities in the UKM Campus. The sediment eroded from erosions, suspended solid and any materials in the detention pond should be removed to ensure the detention pond work effectively. Lots of works and initiatives need to be done to makesure the sediment that being transported from those erosions can be minimized in order to makesure the detention pond functioning as before.

This is why and where Erosion and Sediment Control (ESC) need to be done urgently in UKM through application of bio-engineering technology as part of the ESC study. It is also as an option where the post-landslide restoration works involving conventional civil designs are costly and sometimes not practical at remote sites. Therefore (due to cost constraints), the remoteness of the sites and low risk to lives and property, bioengineering was the option taken for erosion control, slope stabilization and vegetation establishment.

3.2 Research Methodology

The initiative to counter the impact of Erosion and Sediment in UKM is done through the development of an Erosion and Sediment Control (ESC) Model for UKM campus watershed that includes localised technology, information and communication system, as well as awareness and community participation for the greening and rehabilitation of UKM Campus (Figure 5 & 6) to achieve these following objectives:

a) To develop a local hydro mulching (bio engineering) technology for erosion and sediment control of the UKM campus watershed.
b) To develop an integrated information and communication system for the campus community of UKM in order to raise awareness and to 'buy-in' the involvement of all stakeholders
c) To monitor and evaluate the erosion and sediment transport within the UKM Campus.

The management system is also being developed to give a strong participatory element and to ensure that the model will be placed into a user friendly context to make data input and model operation simple for stakeholders with limited resources and training in the use of the models.

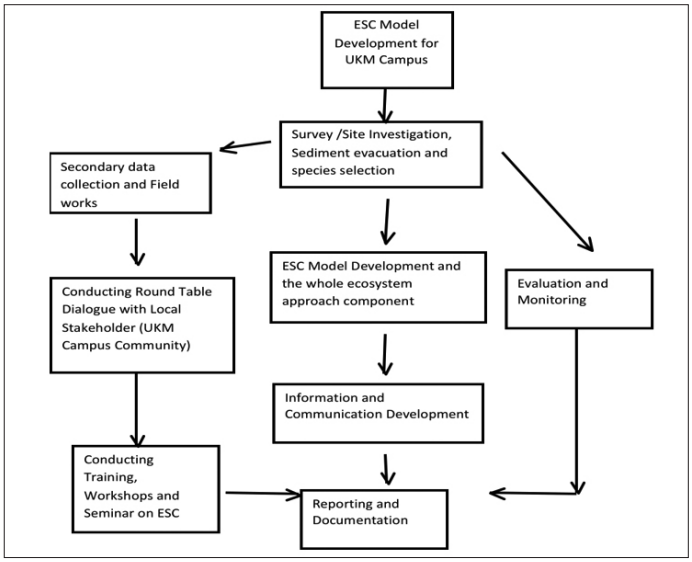

Figure 5: Research Framework of Development of ESC Model for UKM Campus

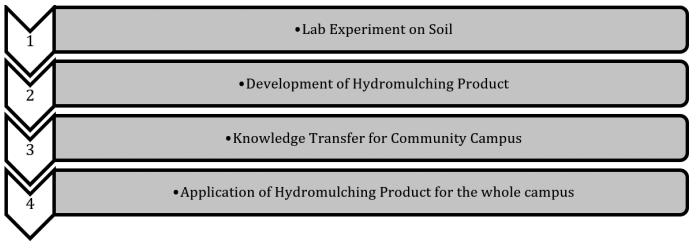

Figure 6: Sequences of erosion and sediment control activities within UKM Bangi Campus

4.0 RESULTS AND DISCUSSION

4.1 Development of Local Hydromulching Product

The application of hydromulching (bioengineering technology) is adopted as part of the ESC study by using the local components to recover most landslides occurred in UKM Campus. It is also as an option where the post-landslide restoration works involving conventional civil designs are costly and sometimes not practical at remote sites. Therefore (due to cost constraints), the remoteness of the sites and low risk to lives and property, bioengineering was the option taken for erosion control, slope stabilization and vegetation establishment.

It is found that there are plenty of bare soils exposed to erosion and excessive sediment transport in UKM, there is no Mulching method and approach currently practiced in UKM. The typical grass cutting in UKM are also too close to the ground, mostly poor and lack of buffer zones, and very much exposed to erosion and sedimentation issues without any preventive and

mitigation action being undertaken. Figure 7 shown plenty of bare soils exposed to erosion and sedimentation in UKM.

Figure 7: Some pictures showing plenty of bare soils exposed to erosion and sedimentation in UKM Campus

Mulching is one of the methods used for effective management of erosion and landslides. Mulching is a method of closing the exposed soil with no ground cover plants using organic materials, sawdust, rice husk and also coconut husk as a fibres. Apart from reducing the impact of the effects of rain, mulch also acts as a holder of the grass roots, retain soil moisture, increasing the permeability of the soil and prevent fertilizer from passes out due to rain (Moradi *et al* 2012).

Hydro mulching is one alternative to traditional planting or sowing seeds. Hydro mulch that will be produced is a process that uses the cultivation of seeds and hydro fluid as the main ingredient. While other materials such as fibre, latex and organic fertilizer as by-products. Mixed materials will be embedded in a tank that is connected to the machine which then will be applied to the exposed slopes.

In UKM, the local hydromulching product is being developed by using the local materials from gardening and trees cutting waste, which has processed in form of green compos product. It will then be generated as hydromulching product that is processed by using a Hydromulching Machine owned by UKM since 2013 (Figure 8). The hydromulching product is produced as an approach to prevent the slope in the future with plant growth.

Figure 8: Hydromulching Machine in UKM

Once sprayed, the mixture of wet fiber will create a strong bond between the land will protect seeds from other factors such as sunlight, wind and erosion. When the seeds begin to germinate, the fibre will begin to decompose above compounds will be supplied nutrients to the soil. Fiber used in the method of hydro mulch can increase soil moisture levels and thus the seeds will speed up germination rate (Parsakhoo *et al* 2018). Figure 9 shown Hydromulching product sprayed on to soil to cover open slope area that is also produced in UKM under this study.

Figure 9: Hydromulching product sprayed on to soil to cover open slope area to be produced in UKM

After hydro mulching material is applied through a hose to the surface of the slope, it will be green in colour that is similar to the germination of seeds within a period of four to five weeks depending on weather conditions. The green color will fade in a few days before the seeds will begin to germinate. Hydro mulching materials to be produced is based on a formula of practice by a company in Santa Barbara, California with 60% of fibre, 30% of organic fertilizer, 5% of the seeds and the rest is a mixture of latex, water and organic dye green colour. Plants provide protective cover on the land and prevent soil erosion by slow down water as it flows over the land (runoff) and this allows much of the rain to soak into the ground; plant roots hold the soil in position and prevent it from being washed away; plants break the impact of a raindrop before it hits the soil, thus reducing its ability to erode; plants in wetlands and on the banks of rivers are of particular importance as they slow down the flow of the water and their roots bind the soil, thus preventing erosion (Ramphele & McDowell 1991).

The loss of protective vegetation through deforestation, over-grazing, ploughing, and fire makes soil vulnerable to being swept away by wind and water. In addition, over-cultivation and compaction cause the soil to lose its structure and cohesion and it becomes more easily eroded. Erosion will remove the top-soil first. Once this nutrient-rich layer of soil is gone, few plants will grow in the soil again. Without soil and plants the land becomes desert-like and unable to support life - this process is called desertification. It is very difficult and often impossible to restore desertified land.

4.2 Development of Integrated Information and Communication System in UKM

An integrated information and communication system is developed in UKM for the campus community in order to raise awareness and community participation of all stakeholders for the greening and rehabilitation of UKM Campus. Since the project is focusing on UKM Campus, therefore campus community is the main target group which involving all students, academics, staffs, management, contractors, suppliers, and other related parties in UKM. The knowledge regarding erosion and sediment control should be transferred in order to make the campus community aware with their surroundings. Sometimes people are not really aware about their environment and surroundings because they thought it is not part of their job or responsibility, but more to campus management. Initiative to make them aware and responsible is necessary and urgently needed. This is also being undertaken through various awareness and public participation or community engagement programmes such as campaign, dialogue, workshop, carnival and competition.

Under this study, the round table dialogue (RTD) with the campus community on water resources management in UKM Campus was held in 2012 as an initiative to bring together the

campus top management, lecturers, researchers, staffs and students from various faculties, research institutes, and residential colleges in UKM, as well as private entities that have direct involvement with UKM in the development and daily business activities such as contractors, developers, suppliers and cafeteria owners in UKM. The main objectives of this RTD is to identify issues and challenges on water resources management and development within UKM Campus, to increase awareness and campus community participation in water resources management, to develop a communication system and knowledge transfer within UKM Campus and also create better problem solving initiative. During RTD, many issues related to water resources management have raised and discussed, especially on water resources pollution that caused by erosion and sediment around UKM Bangi Campus.

A special workshop on development of ESC guideline has also conducted in 2013 as continuation of above RTD on Water Resources Management within campus community. This is also as an initiative to develop a comprehensive manual and guideline to overcome erosion and sediment issues in UKM Campus (as a main suggested output from previous RTD). The objectives of the workshop are to identify issues related to erosion and sediment control in UKM and to propose comprehensive guideline for erosion and sediment control to be applied in UKM Campus. During the workshop, a draft of Guideline on Erosion and Sediment Control in UKM Campus has produced and currently in the process of final editing to be published. The guideline is planned and designed to be simple and easily understood by all and to be practically practiced in daily life or businesses.

Other than that, campaign is one of the best way to increase community participation. Knowledge could transfer more easily in order to change their behaviour and perspective with the awareness towards their environment. Campaign and special event focusing on ESC and especially on Hydromulching product is still in planning to makesure campus commmunity will be aware on ESC related issues and on how to prevent it to be happened again in the future and mitigate the impacts on human and environment. It will also to disseminate information and extend knowledge about our product i.e hydromulching to protect the slope from erosion and sediment.

5.0 CONCLUSIONS AND RECOMMENDATIONS

This study successfully developed the local hydro mulching (bio engineering technology) product for erosion and sediment control of UKM campus watershed by using the local components to recover most landslides issues in UKM Bangi Campus. By applying this hydro mulching product, it will protect the soil erosion and control the production of sediment being transported from the landslide. Hence, the detention pond in UKM act as a good watershed model by minimized the amount of sediment deposited.

This study also developed the integrated information and communication system for the campus community of UKM in order to raise awareness and to increase participation of UKM Campus stakeholders in minimising the erosion and sedimentation issues. The integrated information and communication system is coordinated under the Integtrated Water Resources Management (IWRM) Research Group of UKM, which also monitor and evaluate the erosion and sediment transport within the UKM campus.

Some recommendations under this study included following basic actions to be undertaken especially for construction of new buildings in UKM, for rehabilitation of UKM ponds (Alur Ilmu and University Lake) and for maintenance activities in UKM. These will enable erosion and sediment control (ESC) to be effected in future. The proposed actions address present shortcomings in the overall approach and overcome perceived limitations in budgeted allocation for buildings and ponds, which has always been quoted as the reason for ESC measures not being implemented in the past few years. The proposed guides for new building construction in UKM are described as follow:

1. *Fit the building to the site (not the site to the building)*
   This frequently neglected measure alone can be the single biggest contributor to solving the bulk of erosion and sediment problems during earthworks stage. What this means is that the architect should be clearly instructed right at the beginning to fit the building to the terrain – it being mostly hilly in UKM, and minimize "cut and fill" i.e. earthworks. Most of past problems in ESC during building construction stem from the design requiring a flat platform for the building (i.e. fitting the site to the building) which had to be carved out from the hill at the site. A building which utilizes cascading platforms following the contours of the site will minimize earthworks.
2. *Require an ESCP for the site (the ESCP must be fully implemented and monitored by competent Inspectors)*
   An ESCP (erosion and sediment control plan) is mandatory under the new Regulations to EQA 2012 which is expected to come into force soon. At the minimum, in case of a small building, this means simple plans which show how the erosion and sediment from the earthworks during construction stage, will be controlled. All other buildings will have to have proper ESCPs prepared by a "competent person" i.e. a certified CPESC (certified professional in erosion and sediment control).
3. *Incorporate the latest BQ from PWD (All BQs for all future Building Contracts must contain provisions for ESCP and BMPs to be used in ESC)*
   The latest "technical instruction" from the Public Works Department (PWD) includes in the Bill of Quantities (BQ) for the contract, items for ESC which need to be costed for by the contractor. As such therefore, the contractor has every reason to implement the ESCP, knowing that they will be fully paid for every BMP (best management practice) implemented. This is in contrast to the present situation where the contractor tries every trick to avoid implementing them as they are extra costs to the contractor.
4. *Promote awareness at all levels (contractors, consultants, clients)*
   There is a need to train all supervisory personnel from Department of Development Management of UKM in ESC, preferably all supervising engineers from Department of Development Management of UKM should be certified as CPESC. There is also a need to require maintenance and landscape contractors to attend an ESC course.

During this study, proposed actions for the University Lake rehabilitation and restoration are also identified which included the rehabilitation of UKM ponds with ESCP (adding flocculants, pumping/excavate-out sediment, put in BMPs to control erosion & sediment) and restoration of Pond Ecology (water's edge vegetation, wetlands).

Last but not least, the proposed actions for maintenance activities in UKM are identified as follow:

1. Reform Maintenance Practices (Cutting to 2 in. (50 mm) only)
2. Change methodology for Grass Planting in UKM and Malaysia at whole

3. Develop a cheap, local version of BFM – can be easily sprayed on to eroding slopes to promote vegetative cover (Introduce Mulching for flower beds & Bare soil)

Once implemented, the agenda for UKM sustainable campus and UKM campus as a comprehensive watershed model for erosion and sediment control towards good water governance will be achieved, with the participation and involvement of all campus community at all levels.

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