Sri Lanka Association for the Advancement of Science

SLAAS

78th Annual Sessions

Part II

Presidential Addresses

PROCEEDINGS OF THE
78TH ANNUAL SESSIONS

2022

Sri Lanka Association for the Advancement of Science

Proceedings of the 78th Annual Sessions

11 – 16 December, 2022

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ISSN: 1391-0248

2022 December

Sri Lanka Association for the Advancement of Science
Vidya Mandiraya,120/10 Vidya Mawatha, Colombo 07, Sri Lanka
www.slaas.lk

Edited by: *Theshini Perera, Editor*
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This publication is sponsored by the National Science Foundation

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General President's Address

Effective Science Communication for an Informed Society

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Introduction

Science is generally defined as the intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experiment (Oxford Dictionary 2022). Since the development of modern scientific discourse a few centuries back, objectivity gradually gained prominence surpassing superstition and intuition. Still both superstition and intuition prevail in decision making at individual as well as institutional level in many communities. Furthermore, value placed on those two factors over application of scientific method runs through a rollercoaster trajectory across time and space, more evident in nations, cultures and communities considered to be economically underprivileged than those which have gained economic stability. The above possibly explains the root causes of the economic stability itself and implicates the vicious cycle of wrong decisions leading to, and entangled in, economic stability with no visible exit.

Science provides a sense for people to understand their surroundings and helps them to think beyond what they see. Even if they choose not to learn science, consciously or unconsciously they cannot alienate from science in daily life. Knowingly or unknowingly, they engage in scientific process in carrying out their daily activities. Those who are hardliners, defending influences of supernatural powers, believe in non-scientific explanations and propagating such discourse also benefits from outcomes of science and scientific thinking. Furthermore, they benefit from scientific discoveries and technologies resulting from scientific processes. Thus, science is for masses and ownership needs to be transferred to the public.

Role of Scientists

The role of scientists is twofold; generate evidence and communicate same to the public and advocacy for decision making and enhancing awareness of the public to embrace informed choices. Hence, a scientist needs to be clear on the distinctions among science; bad science, pseudo-science and no science. This is of utmost importance as forecast by Carl Sagan three decades back when he noted, "I worry when the millennium edges nearer, pseudo-science and superstition will seem year by year more tempting, the siren song of unreason more sonorous and attractive". It is disheartening to see how misinformation is leading the way over and above evidence-based information, not uncommon to be originated by the "scientists" themselves, particularly due to use of science in an inappropriate manner or propagating pseudo-science for their own personal advantages. This was clear during the covid pandemic across the globe and moreover in Sri Lanka in recent times related to organic agriculture.

Science is the use of scientific method (pre observations, hypothesis, experiment, results and conclusions) to find regulative connections between our sensual experiences. However, one can portray conclusions based on biased results or results that are cherry picked to support a favoured hypothesis as science. The distinction between science and "bad science" is gray, and is thus mostly beyond the comprehension of decision makers as well as the public (Goldcare 2008). However, "pseudo-science", a collection of beliefs or practices mistakenly regarded as being based on scientific method, is more tempting. The proponents of pseudo-science keep on searching vague arguments to support their hypothesis and silently retreat when overwhelming evidence convinces people that the idea is falsified (Oxford Dictionary 2022). Pseudo-science attracts politicians for diverse reasons; the belief that they resolve difficult issues, instantly and alternatively, to promote nationalism and ideologies or subscribe to those who maintain similar ideas. The real culprits are the ones qualified as professionals who propose pseudoscience to the lawmakers because of ignorance, self-interest or to gain undue advantage (Tennakone 2002). The passage of time clears the distinction of science and pseudo-science for the public; however, on most occasions irreversible damage is done.

An area of study that is not scientific, especially one that is not a natural science or a social science, that is not an object of scientific inquiry is "non-science". In a complex situation where science through non-science is present in all spears of life, the role of scientists is to clear the pathways for the masses.

Role of Science Communication

Effective science communication informs people about the benefits, risks, and other costs of their decisions, thereby allowing them to make sound choices. Although, the most effective communication cannot guarantee that people will agree what those choices should be, it is helpful for most of the population to evaluate merits and demerits among alternative choices in front of them. It would help to arrive at relatively rational decisions than being in dark. Furthermore, inculcating the elements of an analytical mind helps for collective rational choices for the betterment of society. The role of science communicators is to instill science within narratives which are relatable to non-scientists. This enhances public awareness of science, increases enjoyment and interest in science, technology and engineering. The goal of science communication is primarily, to inform and inspire, but it may also entertain (Burns *et al*., 2003). Scientists themselves need to be well equipped to take the role of a communicator with the support of media and media personnel. They have the best awareness and competencies to distinct science from the rest, and to inoculate trustworthiness of scientific discourse in the mind of the public.

Role of SLAAS

SLAAS since 1944 championed the vision, *"Scientifically Advanced Nation"*, and mission, "*To promote, support and foster scientific endeavor and technological innovation in an ethical, humane and sustainable manner for the benefit of the people in Sri Lanka*". One of the goals is directly related to dissemination of scientific knowledge and promotion of discussion. The role of the Committee for Popularization of Science (CPS) is to engage the community and that of the Science and Technology Advisory Committee (STAC) is the advocacy of decision makers to consider evidence and scientific method. Both deal with effective communication to influence better choices.

Present Status of Science and Science Communication

Sri Lanka has a long history of science communication and communicators in local language. It goes back to late 19th century print media and more specific scientific publications in the form of magazines and regular science pages in mainstream newspapers. Science programmes have been a regular feature in radio since the mid 1960s and to some extent in the television media, mainly focusing on environment. Teaching of science as a subject in the school curriculum and in the higher education dates back 75 years. All of the above factors have contributed to science communication, directed towards different audiences.

Those who are literate in English have better opportunities to access scientific material than those who depend on local languages. However, it is observed that, since the turnover of the new millennium, the space for science in media and even policy cycles are diminishing. As forecast by Cal Sagan, pseudo-science and superstition have returned and have a major impact on daily life. Superstition is gradually being institutionalized to a large extent and has acquired power positions to dictate terms in key policy decisions. This is followed by campaigns to enlist a sizable portion of the public to believe these as facts and truth. The share of science is pushed to a minimum and the space for evidence informed choices is shrinking further. Unfortunately, true scientists are taking a back seat while those who propagate bad science and pseudo-science are heard. Hence, the scientific community under the banner of SLAAS needs to take the lead in transforming the nation back to an informed society for better choices.

Way Forward

To propel the country forward, many initiatives based upon a strong foundation is mandatory. The dissemination of timely, evidence-based knowledge generated through scientific method is the role of professionals. SLAAS can support two initiatives in this direction.

1. Enhancing General Science Communication
2. Supporting Science Education at Schools

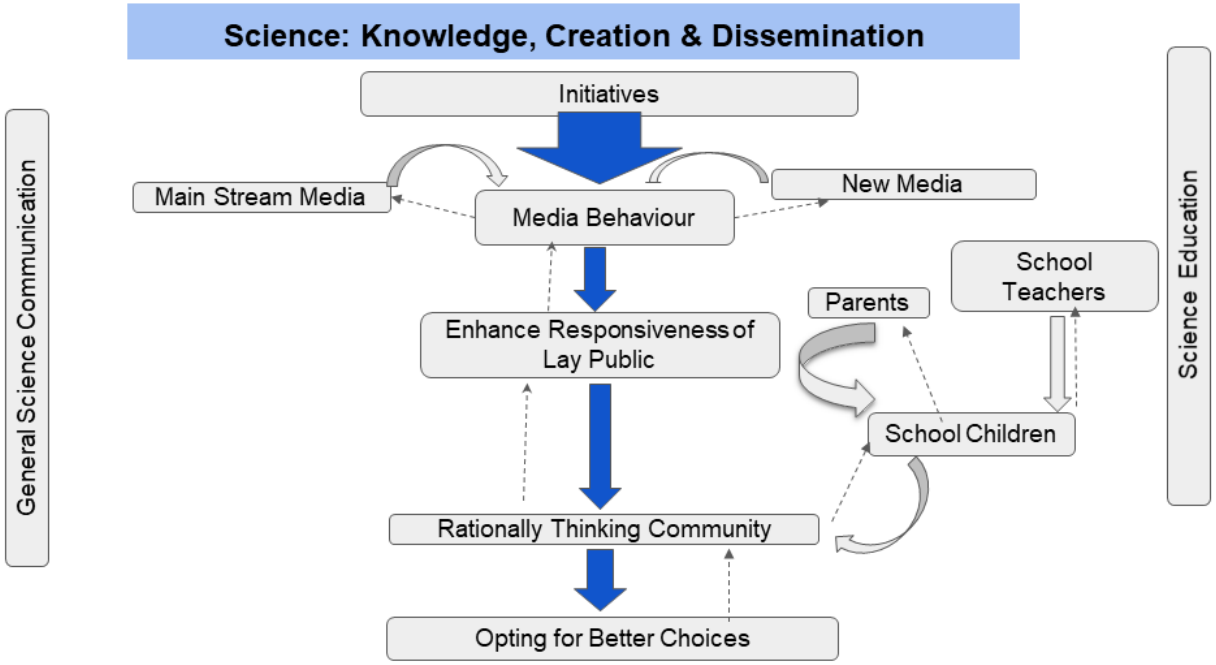

Figure 1. Framework for knowledge creation and dissemination in science

The two initiatives are of a complementary nature. General science communication will target the lay audience to support their daily activities through promoting scientific thinking to opt for better choices. Realizing the short- and medium-term benefits they enjoy, at least a proportion of the public would be transformed as influences/multipliers of such thinking.

The second is our contribution on science education. One of the key barriers in science education is to convey complex scientific concepts to the students in a coherent and readily understandable manner. Even though tools and educational videos are available in the web-based platforms, most are in foreign languages and are based on different contextual settings making them inaccessible / unacceptable and/or non-coherent for a majority of the student population as well as teacher community in our country.

While tackling the lay public through mainstream and new media an effort to support teacher community through innovative approaches on science education will have a synergetic effect on scientific thinking for a better future in our country. Some of the potential initiatives for consideration are listed below.

- Planning seeds in mainstream media for scientific approach in communication for better choices
- Planning seeds in new media for scientific approach in communication for better choices
- Developing a web-based platform for the engagement of scientist and to serve as an interface for the public to foster effective science communication under the banner of SLAAS
- Development of a repository of science teaching / learning tools for teachers and students
- Establishing a panel of subject experts to respond to the contemporary scientific issues in media and regular media / public sessions to disseminate information
- Developing science communication module for undergraduate in science and mass media students in universities.

SLAAS in year 2022 under the theme of "*Effective Science Communication for an Informed Society*" deliberated much of the time and resources to initiate a dialogue and to foster an interphase between science and media, that could help to provide an effective platform for scientists to champion their obligation on science communication and the media to internalize as a duty.

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Section A

Research Advances and Opportunities in the Field of Gynaecology

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Gynaecology is a medical discipline dedicated to female healthcare. During their life span, women experience multiple reproductive development related events including menarche, menstruation, pregnancy, maternity and menopause. These developmental events in female reproduction have induced more drastic alterations compared to development events in male reproduction. Furthermore, pathologies that may appear during these episodes are specific. Gynaecology has been practiced since ancient times and is dedicated to the above female health care concerns. Details on gynaecological care was mentioned in a document compiled in 1800 BC during the 12th Egyptian dynasty. Even in other medical systems gynaecology related topics have been included in their earliest documents.

The current medical era is being revolutionized tremendously by scientific and technological achievements. Improvements in imaging technology, endoscopic equipment and scientific innovation have all contributed to recent advances in gynaecology. Moreover, gynaecology has developed as an independent section of endoscopic surgeries. The use of artificial intelligence (AI) and robotic manipulators in the areas of screening, prediction, drug development, treatment, monitoring, is being gradually introduced to the field of gynaecology and obstetrics (Ghi et al., 2022). This creates an opportunity to introduce a third participant that is able to contribute towards a patient-care relationship in health care.

Investigations in Gynaecology

In gynaecology, the minimally invasive approach such as laparoscopy gained increasing popularity over time, for both investigative and management purposes. In this scenario,

technological enhancement with the development of a 3 mm laparoscopic instrument (mini-laparoscopy) allowed further improvement in outcome, such as aesthetics, compared with conventional laparoscopy (Casarin et al., 2021). Similarly, due to the development of hysteroscopy it is possible to achieve a target endometrial biopsy under direct visualization at a point where there is no screening protocol for the early detection of endometrial carcinoma (Torok et al., 2020). Laboratory tests play an important role in obstetrics and gynaecology as in any other discipline of medicine. It has been identified that the prevalence thresholds of various screening tests used in this field are well above the estimated disease prevalence indicating that high chances of false positive results are obtained at screening (Elfassy et al., 2021). Hence, it is important to individualize the result interpret.

Biopolymers have been identified to be a safer alternative to conventional polymers in many biomedical applications. They are used in screening, examination and operation materials in obstetrics and gynaecology. Even with promising trends of biopolymers for applicability, they still need to be improved to give the desirable properties required for the particular application. Rapid degeneration rate and low mechanical properties may not be desired in some gynaecological applications such as early pregnancy stents (Jummaat et al.,2021)

Medical Management / Hormone Based Treatments

Hormones are central to women's health. Women get support by hormone based medical management through their lifespan, especially during the time of hormonal change. Hormones are used to help avoid unwanted fertility and to treat infertility, common gynaecological conditions such as uterine fibroids, endometriosis and conditions such as menstrual migraines and premenstrual dysphoric disorder. For women with pain and endometriosis, suppression of menstrual cycles with gonadotrophin-releasing hormone (GnRH) analogues, the levonorgestrel releasing intrauterine system (LNG-IUD) and danazol are beneficial interventions (Capozzoli et al., 2022).

The prolonged life expectancy of menopausal women and their high expectations for good health have encouraged new developments in hormone replacement therapy. The increased use of such therapy has also increased surveillance and thus, recognition of other common problems affecting women of older ages.

Hormone treatment for gynaecological cancers involves the use of medications that reduce the level of hormones or inhibit their biological activities which stop or slow down the growth.

Aromatase inhibitors, estrogen receptor antagonists, GnRH antagonists and progesterone are used successfully for vulvar cancer, cervical cancer, vaginal cancer, uterine cancer and ovarian cancer. The past decades have seen an explosion of knowledge on mechanisms of action of steroid hormones, their nuclear receptor superfamily and their modulation at the level of gene expression. Advances in biochemistry have led to the design of sex steroid hormone-mixed agonist and antagonists, selective estrogen receptor modulators and selective progesterone receptor modulators as well as tissue-specific estrogen complexes which can tailor hormone action at the receptor level (Santoro et al., 2021)

Invasive Management

At present, minimally invasive surgeries are the standard treatment procedure in most gynaecological diseases and laparoscopic surgeries have gained prominence by overriding traditional laparotomy. Laparoscopy and operative hysteroscopy are the most popular surgical procedures used for gynaecological disorders. Decreased blood loss, post operative pain, short hospitalization period, faster recovery are the advantages when compared with laparotomy. Operative hysteroscopy, another common invasive procedure facilitates intrauterine and intracervical lesion excision using mechanical or electrosurgical restriction methods as well as laser techniques. Due to technological advances and miniaturization of the hysteroscopic tools, the number of hysteroscopies is steadily increasing.

Fertility sparing surgeries (FSS) are progressively being offered to women with gynaecology malignancies who wish to preserve fertility. It has become a mandate that counseling by experts and management involving a multidisciplinary team of experts are essential to develop a tailor-made treatment protocol in oncology care. In instances when FSS were offered, it was noted that ovaries, uterus and cervix are preserved. However, surprisingly about 50% of the ladies do not pursue pregnancy despite FSS and the reason for these decisions have not yet been well studied.

Fertility Management

Delaying childbearing has resulted in a greater demand for effective fertility treatments and for surgical procedures that preserve fertility. Treatment of infertility has evolved as the understanding of reproduction improved. Although correct gonadal dysfunction by hormonal treatments and fertility promoting surgeries with recent advances have broken new ground, still

multiple gestations continue to be a significant complication. Assisted reproductive technologies (ART) have improved and advanced by incremental optimization of existing techniques and development of new disruptive technologies (Schuurman,et.al 2021). Artificial intelligence and stem cell technologies on ART will have a huge impact in the near future. Extensive research is being conducted on induced pluripotent stem cells (iPSCs) and mesenchymal stem cells (MSC) for their potential application in reproductive medicine.

Fertility preservation and restoration strategies undergo chemotherapy and radiotherapy. Among the most effective fertility preservation options available today, oocyte and embryo cryopreservation and ovarian tissue cryopreservation take an important place. Techniques have been developed that show promise for extending the use of this technique while also enhancing the lifespan and quality of grafted ovarian tissue and preventing the spread of cancerous cells. (Dolmans and Manavella, 2019).

The report developed by the Ethics Committee of the American Society for Reproductive Medicine recommended development of patient centered policies for each fertility center to enable clinicians to make evidence-based assessments (Daar et al., 2019). By that clinicians may ethically decide to consider the treatments believed to be futile or to carry a very poor prognosis and support the society with quality reproductive supporting service.

Diet and Lifestyle on Gynaecological Disorders

Applying preventive approaches in primary and secondary health care levels are even more important than curative measures. Healthy lifestyle, correct dietetic habits and hygiene must be included to the treatment plans which is lacking at the moment. Now it has been found that lifestyle and dietary habits can drive epigenetic changes on the genes or in other words, drive changes without alteration of the DNA sequence responsible for gene activity and its expression. Studies have proven that the Mediterranean diet, which is rich in vegetables, fruits, whole grains, legumes, nuts and healthy oils and low in red meat lowers the risk of ovulatory infertility and instead, increases the chances of *in vitro* fertilization (Grant, 2010). Furthermore, incorrect lifestyle and obesity affects women and many patients presenting at gynaecology clinics are mostly at risk of associated comorbid condition. Sri Lankan traditional medical systems have introduced recommended and non-recommended food and diet for many conditions that women suffer from, which is needed to be scientifically studied to finds its importance.

Traditional Medicine

Most of the countries practice indigenous medicine in this specialized area (Park et al., 2012). Financial crisis, inadequate approaches to quality medicine in the present scenario focus the attention to other medicinal systems, including alternative methods. Hence, this is a great time to strengthen the alternative systems which could support women's health. Effective and safe treatment lines have been reported for most of the common gynaecological conditions; POCS (Cao et al., 2019, Zhang, 2017 and Manneras et al., 2009), endometriosis (Fu and Xia, 2005, Han, Yan and Xiang-Gui, 2010, Wu et al., 2007 and Yu, 2005), uterine fibroids (Lee et al., 2004)., ovarian cysts, etc. (Zhao et al., 2021, Mobli et al., 2015, Hirata, Chan et al., 2006 and Swiersz and Zell, 1997). Furthermore, subfertility management and supportive treatment for assisted reproductive techniques are also covered by research in traditional medicine (Ried, 2015).

Olden day evidence on indigenous medicine-based outcomes were limited. However, prevalence of publishing traditional medicine based clinical studies on gynaecology has been increased during the past few years. However, the evidence is still not significantly convincing; further research should be performed to establish the efficacy of each therapy. Active reporting and systematic management of the safety of herbal medicine and adverse drug reaction would be needed by establishing a herbal drug monitoring system. As a case report from Sri Lanka ?? some of the pragmatic research findings can be considered as evidence-based approaches in major diseases considered in gynaecology. An integrative system of medicine is immerging in the country with herbal drug development on gynaecology with standard scientific data.

Conclusion

Advances in gynaecology and women's health are making giant strides but there are many more challenges remaining. Current medical treatment approaches are still far from optimal. Further studies should be continued to adapt to every patient's individual desires and their personal wishes as to the optimal outcome.

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Section B

Sustainable Postharvest Management: The Key to Attaining Food Security

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Introduction

Postharvest management is the handling of produce from farm to fork/table such as harvesting, transporting, handling, storing, processing and value addition. Post-harvest loss is a threat to food security and results in the loss of farmer income and inefficiency in the global food system. A recent Food and Agriculture Organization (FAO) report indicates that at a global level, the volume of lost and wasted food in high income regions are higher in downstream phases of the food chain, but that just the opposite is observed in low-income regions where more food is lost and wasted in upstream phases. Food security affects almost everyone on the globe; Global Hunger Index (GHI) and Global Food Security Index are two major indicators of food security in any country and Sri Lanka is ranked very low. According to the FAO, food waste can be avoided in various ways or be re-purposed before expiry for the benefit of the food insecure population. In fact, about 22% of the total population in Sri Lanka does not have sufficient food to sustain a healthy life and 33% of the people cannot afford a nutritious diet (WFP, 2020). Other research has indicated that 7.6% of Sri Lanka's population is undernourished and that 15.1% and 17.3% of children under five years suffer from wasting and stunting, respectively (GHI,2020).

Important elements of the challenge of overcoming post-harvest loss include: multiple points of intervention, multiple value chains, multiple technologies, and value chains embedded in weak and poorly developed agricultural systems. Postharvest loss can be defined as the degradation in both quantity and quality of a food production from harvest to consumption. These losses are generally more common in developed countries. Quantity losses refer to those that result in the loss of the amount of a product. Loss of quantity is more common in developing countries.

Developing countries face major food losses specially due to technical and structural limitations in harvesting technique, storage and transport infrastructure combined with challenging climatic conditions. Sri Lanka estimates food waste to range up to 30% annually. Causes for food waste are a combination of factors such as consumer behavior and lack of efficiency in the supply and value chains. Increased food prices and unemployment are also a major factor behind food insecurity and hunger in Sri Lanka. Different policies are intended to help fulfill Sri Lanka's food requirement such as the National Climate Change Policy and the National Adaptation Plan for Climate Change Impact. The Food and Agriculture Organization reported that 54% of food wastage occurs during production, post-harvest handling and storage and that 46% occurs after processing, distribution and consumption. To reduce waste, it is very essential to diversify the food system, promote home gardening and to ensure that excess food from supermarkets, hotels, restaurants is given to needy people and finally, to segregate food at household and organizational level by recycling and utilizing as a fertilizer or energy resource.

Food Systems and Nutrition in Sri Lanka

Food systems are typically thought of as a collection of activities that range from production to consumption (Ericksen, 2008). It consists of farming systems, their input supply systems, waste management systems, as well as trade and health systems. A sustainable food system produces and distributes food in a manner that is both ecologically friendly and meets the nutritional needs of current and future generations. Sri Lanka's food system consists of locally produced and imported food, accounting for 78% and 22% of domestic food consumption, respectively. The majority of domestic demand is for rice, meat, eggs, fish, vegetables, and fruits. Wheat, tinned fish, lentils, milk powder, sugar, and vegetable oil are all imported in significant quantities from India, China, the United States, Thailand, and Ukraine (Fernando, 2021).

The three types of food systems present in Sri Lanka include traditional food systems, mixed food systems, and modern food systems. Traditional food systems such as chena cultivation and home-garden systems are characterized by consistent production and/or exchanges of primary products in informal market places with short and local supply chains. Mixed food systems are characterized by semi-subsistence or commercial food production and processing, with processed foods packed, labeled, and sold in both formal and informal marketplaces with regular branding and advertising. Food safety is monitored and enforced, and storage and

transportation infrastructures such as cold chains are generally prevalent and reliable. Modern food systems include more diverse food production options throughout the year, with significant processing and packaging to extend the shelf life of food and food safety being monitored and enforced. Food production by large farmers, protected agriculture cultivation, food processing in manufacturing industries, retailing in supermarket chains as well as connections with global value chains can all be considered as modern Sri Lankan food systems (Marambe *et al*., 2015).

Traditional Sri Lankan diets are diverse and provide a variety of health and nutritional benefits, such as protection against non-communicable diseases (NCDs) and micronutrient deficiencies. Typically, these foods are derived from natural sources, with proteins derived from various plant species. Traditional food, preparation, and consumption patterns were more diverse than they are now. The traditional Sri Lankan diet is high in nutrients is primarily comprised of green leafy vegetables. Green leaves are an important source of vitamins and other medicinal properties. However, the traditional food system in Sri Lanka is shifting (Weerasekara *et al.*, 2018).

Today, many health and nutritional issues in Sri Lanka are due to unhealthy eating patterns and intake of low-quality food. Nutrition deficiencies, malnutrition and non-communicable diseases are the most significant problems facing Sri Lanka. The birth rate is low at 17%, and one-sixth of women have a BMI of less than 30. Lactating women have a 19.6% anemia rate, while reproductive women have a 16.2% anemia rate. Other micronutrient deficiencies, such as iodine deficiency, iron deficiency, zinc deficiency, and vitamin A, D, and B deficiency, have been found in Sri Lankans of all ages (Weerasekara *et al.,* 2020).

Food Security in Sri Lanka

Sri Lanka has a comparatively high level of social welfare among South Asian countries, despite the fact that food security for its 20.1 million people has not been achieved. This is due to the phenomenon of smallholder farming systems generating 90% of the food necessary in low-fertility soils under marginal conditions (Sangakkara & Nissanka, 2017).

True food security requires increasing economic, social, and physical access to a balanced diet, clean drinking water, environmental hygiene, and primary health care, in addition to increasing the market availability of food. These phenomena are not readily seen in developing countries (Swaminathan, 2007). Sri Lanka is a predominantly agricultural country, with 60% of the

population employed in food production or processing. It has a long history of placing high importance on basic human needs, channeling assistance and subsidies to rural areas where small farms provide 90% of the country's food. Successive governments have taken these steps to ensure the nation's food security and employment while also working to ensure that people have access to primary health care, appropriate food, and basic education (Amarasinghe *et al.,* 2005).

Food security is defined as physical, social, and economic access to sufficient, safe, and nutritious food to meet human dietary needs and food preferences for an active and healthy life. Four basic pillars of food security have been identified: food availability, food access, food use, and food stability (Henegedara, 2018). Food availability refers to the production, distribution, and exchange of food (Gregory *et al.,* 2005). Thus, land distribution and usage, soil management, crop selection, breeding, and livestock management all influence food production. Physical and climatic conditions often change food production. Growing food or using agricultural land have a significant opportunity cost when compared to alternatives such as urbanization or non-agricultural usage. Desertification, salinization, soil erosion, and sedimentation are all environmental impacts of agricultural land use that have harmed sustainable food production. However, the domestic availability of other food items such as roots and tubers, vegetables, fruits, meat, fish, eggs, and milk is adequate. According to estimates of the Hector Kobbekaduwa Agrarian Research & Training Institute, the country is able to produce 79% of roots and tuber, 30% of pulses and nuts, 82% of vegetables, 83% of fruits, 98% of meat, 100% eggs, 90% of fish, 81% milk, 98% of oil and fats and 7% of sugar required by the country (Henegedara, 2018).

All of these factors have a significant impact on Sri Lanka's domestic food production. Food distribution, which includes food storage, processing, transportation, packaging, and marketing, is also a significant activity. Market infrastructure, as well as storage methods and facilities, may have an impact on the amount of food wasted during the distribution process.

According to Zoysa and Silva, food availability has increased mostly as a result of increasing factor production linked to technological progress programs (Zoysa and Silva, 2008). Food access, which indicates food use and affordability, is viewed as an important aspect of food security analysis. The availability of adequate food at a national level does not necessarily ensure food security at a household level. Therefore, it is important to ensure that national food availability adequately ensures access to food at the household level.

The Link between Post-harvest Management and Food Security

Postharvest technologies can contribute to food security in multiple ways. They can reduce Post Harvest Losses (PHL), thereby increasing the amount of food available for consumption by farmers and poor rural and urban consumers. The benefits to consumers from reducing losses include lower prices and improved food security. Techniques to reduce food losses require cultural and economic adaption. This is so because all food losses occur at a particular socio-cultural environment. The issue of food losses is of high importance in the efforts to combat hunger, raise income and improve food security in the world's poorest countries. The current world population is expected to reach 10.5 billion by 2050, further adding to global food security concerns. This increase translates into 33% more human mouths to feed, with the greatest demand growth in the poor communities of the world; accordingly, food supplies would need to increase by 60% in order to meet the food demand in 2050. Food availability and accessibility can be increased by increasing production, improving distribution, and reducing the losses. Thus, reduction of post-harvest food losses is a critical component of ensuring future global food security. Food and Agriculture Organization of U.N. predicts that about 1.3 billion tons of food are globally wasted or lost per year. Food production is currently being challenged by limited land, water and increased weather variability due to climate change. To sustainably achieve the goals of food security, food availability needs to be also increased through reductions in the post-harvest process at farm, retail and consumer levels. Technology interventions play a critical role in addressing the issue of PHL, and several efforts have been made to develop and disseminate these technologies for smallholders in developing countries.

Food Losses

Postharvest food losses, occurring at production, harvest, postharvest and processing phases, are the most prominent in developing countries, due to poor infrastructure, poor temperature management, low levels of technology and low investment in food production systems, especially the cold chain.

Key factors affecting food losses and the gaps in knowledge/skills that we have identified include the following:

- Poor understanding of harvest indices of plant-based food and how maturity is related to quality and shelf life.

- Poor sorting and grading practices during preparation for market, allowing damaged /decaying food to enter the supply chain and to spread decay to other food.
- Poor temperature management and lack of control of relative humidity, leading to shriveling, wilting and deterioration of perishable food.
- Poor quality packages which provide little or no protection during handling, transport and storage.
- Delays in transport to market without proper storage (cool storage for perishables, drying of staple grains/beans/legumes before storage).
- General lack of education on appropriate postharvest handling practices and technologies, leading to rough handling, mechanical damage, improperly handled mixed loads, and food safety concerns.
- Lack of the utilization of sustainable, cost-effective postharvest practices, leading to high levels of food loss on the farm, as well as in wholesale and retail markets.

Food Waste

Food waste is more of a problem in industrialized countries, most often caused by both retailers and consumers throwing perfectly edible foodstuffs into the trash.

Key factors affecting food waste and the gaps in knowledge/skills that we have identified include:

- Over-sorting and over-grading on the farm and in the packinghouse, based on strict guidelines that have more to do with appearance (color, size, shape) than nutritional value or eating quality, leading to increased discards of edible food.
- Poor choice of packages and packaging materials, with focus on cosmetic features rather than on strength, cleanliness, ventilation, moisture control, etc., which would help extend shelf life.
- Over-reliance on long term cold storage, refrigeration and freezing, leading to development of off-flavors, chilling injury and freezer burn, resulting in discard of improperly stored foods along the supply chain.
- Confusing or unnecessary “sell-by” or “use-by” dates, based upon cosmetic changes or inventory management schemes rather than on food safety concerns, leading to the wastage of edible food at the retail level.

- Lack of education regarding proper packaging, cooling/cold storage, storage of cooked foods and reusing left-over food, leading to increased discards of food in the home front.

Factors Contributing to Total Food Loss

Factors that contribute to food loss range from mechanization of practices such as harvesting to handling, processing and others, to weather conditions, production practices, management decisions transportation facilities, grading issues, infrastructure, consumer preferences/attitudes, and availability of financial markets. A typical post-harvest chain comprises of a number of stages for the movement of harvested output from the field to the final retail market. The losses incurred at each step vary depending upon the organization and technologies used in the food supply chain. In Sri Lanka, supply chains are less mechanized, larger losses are incurred during storage, processing and in transportation.

Biological and environmental causes on postharvest losses

Biological (internal) causes of deterioration include respiration rate, ethylene production and action, rates of compositional changes (associated with color, texture, flavor, and nutritive value), mechanical injuries, water stress, sprouting and rooting, physiological disorders, and pathological breakdown. The rate of biological deterioration depends on several environmental (external) factors including temperature, relative humidity, air velocity, and atmospheric composition (concentrations of oxygen, carbon dioxide, and ethylene), and sanitation procedures.

Socioeconomic factors

Although the biological and environmental factors that contribute to postharvest losses are well understood and many technologies have been developed to reduce these losses, they have not been implemented due to one or more of the following socioeconomic factors.

Inadequate marketing systems: Growers can produce large quantities of good-quality fruits, and vegetables, but, if they do not have a dependable, fast, and equitable means of getting such commodities to the consumer, losses will be extensive. This problem exists in many developing

countries including Sri Lanka. It is accentuated by the lack of communication between producers and receivers, and lack of market information. Marketing cooperatives should be encouraged among producers of major commodities in important production areas. Such organizations are especially needed in developing countries because of the relatively small farm size. Advantages of marketing cooperatives include: providing central accumulation points for the harvested commodity, purchasing harvesting and packing supplies as well as materials , providing proper preparation for market and storage when needed, facilitating transportation to markets, and acting as a common selling unit for members, coordinating the marketing program, and distributing profits equally. Production should be maintained as close to the major population centers as possible to minimize transportation costs. In several countries, there are plans to build better wholesale marketing facilities, but their implementation has been delayed more because of social and political than financial considerations.

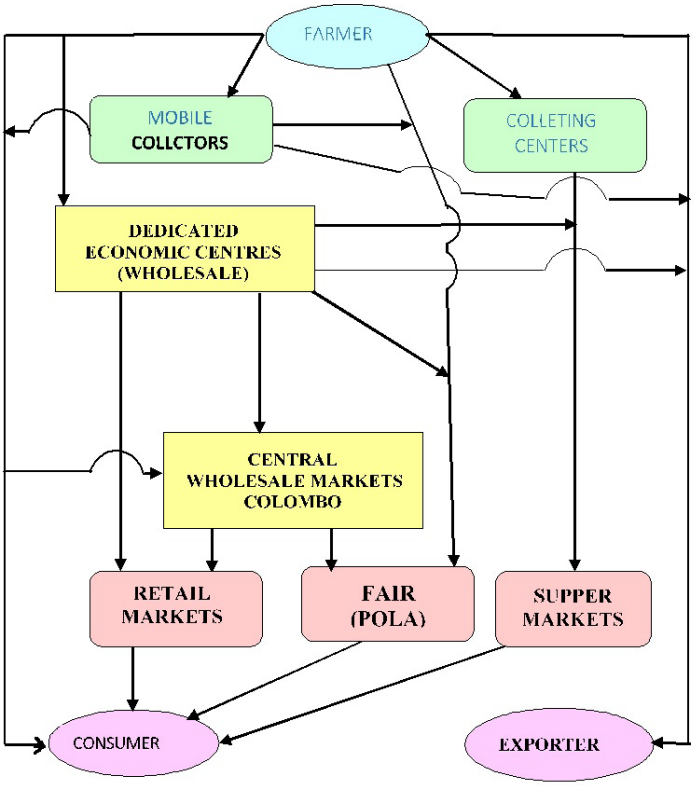

Figure 1. Vegetable and fruit fresh (marketing) channels.

Inadequate transportation facilities: In Sri Lanka, most rural roads are not adequate for proper transport of horticultural crops. Furthermore, transport vehicles and other modes, especially those suited for fresh horticultural perishables, are in short supply. This is true whether for local marketing or export to other countries. Most producers have small holdings and cannot afford to own their own transport vehicles.

Government regulations and legislations:

The degree of governmental controls, especially on wholesale and retail prices of fresh fruits and vegetables, are not adequate. Although intended for consumer protection, such regulations encourage and provide no incentive for producing high-quality produce or for postharvest quality maintenance.

Inadequate transportation facilities:

In most developing countries including Sri Lanka, roads are not adequate for proper transport of horticultural crops. Also, transport vehicles and other modes, especially those suited for fresh horticultural perishables, are in short supply. This is true whether for local marketing or export to other countries.

Unavailability of needed tools and equipment:

Even if growers and handlers of fresh horticultural crops were convinced of the merits of using some special tools and/or equipment in harvesting and postharvest handling, they will most likely not be able to find them in the domestic market. This is true of harvesting aids; containers; equipment for cleaning, waxing, and packing; and cooling facilities. Most of the tools are neither manufactured locally nor imported in sufficient quantity to meet demand. Various governmental regulations do not permit direct importation by producers of their needs. It is imperative that the tools, that will enable handlers to use recommended technology for a given situation, be available for them to use. In many cases, such tools can be manufactured locally at much lower cost than those that are imported.

Lack of information:

The human element in postharvest handling of horticultural commodities is extremely important. Most handlers are involved directly in harvesting, packaging and transporting.

Key Factors to be Considered on Post-harvest Management of Perishables

Harvesting: Harvesting should be carried out as carefully as possible to minimize mechanical injury such as scratches, punctures and bruises to the crop. The time of the day when harvesting is done also affects quality of produce and shelf-life. In general, harvesting during the coolest time of the day (early morning) is desirable; the produce is not exposed to the heat of the sun and the work efficiency of the harvesters is higher. If harvesting during the hotter part of the day

cannot be avoided, the produce should be kept shaded in the field to minimize product weight loss and wilting.

Handling: Mechanical injury provides sites for pest attack and increases physiological losses. Therefore, avoiding mechanical injury to the crop while handling is important. Due to soft texture, all horticultural products (fruits and vegetables) should be handled gently to minimize bruising and breaking of the skin. The skin of horticultural products is an effective barrier to most of the opportunistic bacteria and fungi that cause rotting of the tissues. Breaking of the skin also stimulates physiological deterioration and dehydration. Reducing the number of times the commodity is handled reduces the extent of mechanical damage.

Sorting and cleaning: Systematic sorting or grading coupled with appropriate packaging and storage, will extend shelf life, maintain wholesomeness, freshness, and quality, and substantially reduce losses and marketing costs. Sorting is done to separate poor produce from good produce, and to further classify the good produce based on other quality parameters such as size.

Packaging: Proper packing is essential to maintain the freshness of leafy vegetables. Packaging should be designed to prevent premature deterioration in product quality, in addition to serving as a handling unit. Using clean, smooth and ventilated containers for packaging is a very important factor in cutting down losses in these crops during harvesting, transportation, marketing and storage. Containers that are appropriate for each crop should be used.

Transportation: Minimizing losses during transport necessitates special attention to vehicles, equipment, infrastructure, and handling. Loading and unloading crops from transport vehicles carefully, using clean, well-ventilated vehicles covered at the top for transportation as well as transporting crops during the cool part of the day by driving carefully over smooth roads all minimize damage to crops. Fresh produce must not be watered prior to loading, as this will lead to decay, rotting, and extensive losses. Major causes of losses are improper handling during loading and unloading.

Storage: Only crops with high initial quality can be stored successfully; it is therefore essential to ensure that only crops of the highest quality (mature, undamaged) are stored. Shelf life can be extended by maintaining a commodity at its optimal temperature, relative humidity and environmental conditions.

Processing: Processing is an important value-added activity that stabilizes and diversifies food supplies and creates employment and income opportunities. It can minimize the high perishability problem of fruits and vegetables. Processed products are also more stable, have improved digestibility, and permit a better diet diversity, giving consumers access to a wider choice of products and a wider range of vitamins and minerals.

Research contribution in a Sri Lankan Context

Postharvest research contributes to food security and health in several ways. Improved storage technologies, such as biological pest control or controlled atmosphere storage reduce postharvest food losses. Although minimizing postharvest losses of already produced food is more sustainable than increasing production, thus far, relatively little has been invested in postharvest research. There is potential for tremendous growth if constraints and bottlenecks are removed. It would thus be desirable to reexamine the current funding priorities and to allocate a larger proportion of resources to postharvest research.

Conclusion

Postharvest Management is handling of produce from the farm to fork/table, i.e. harvesting, transporting, and handling, storing, processing and value addition. Minimizing postharvest losses of crops are a very effective way of reducing the area needed for production and/or increasing food availability. Postharvest technologies can contribute to food security in multiple ways. They can reduce PHL, thereby increasing the amount of food available for consumption by farmers and poor rural and urban consumers. Food availability and accessibility can be increased by increasing production, improving distribution, and reducing losses. Thus, reduction of post-harvest food losses is a critical component of ensuring food security in Sri Lanka in the future. Generally, reductions in food loss play a significant role towards contributing to food security.

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Section C

Cycling and Micromobility: A Sustainable Sri Lankan Trip?

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Introduction

Short distance trips such as running errands or shorter commuting to work or school, are a major component demand for mobility. Micromobility is a wheeled type of transportation that is low-speed, operated by a single person, and meant for travel over a short distance. Motorbikes, scooters, three-wheelers and bicycles are frequently used micromobility. Recent surveys suggest that people are open to micro-mobility options but the uptake may vary with country. On a global average, 40% of people prefer the bicycle as a micromobilty for their daily commuting. Irrespective of its historical usage in several districts in Sri Lanka, the popularity of cycling as a mode of sustainable transportation has declined over the years due to multiple challenges faced by cyclists. Hence, cycling has become popular as a recreational activity. Furthermore, due to the recent economic crisis, the number of people using cycles for commuter and errand trips have increased even after the availability of fuel. This address investigates the issues and opportunities to promote cycling as a mode for short-distance trips in Sri Lanka and the way forward for promoting cycling contribution of multiple stakeholders for cycling including cyclists, urban planners, transport planners, highway designers and policymakers and law enforcement agencies.

The Transportation Sector and Sustainability

Transport has the highest reliance on fossil fuels than any sector and accounts for 37% of the CO_2 emissions from end-use sectors in 2021. While total carbon dioxide emissions have fallen by 23% since 1990, transport emissions grew at an annual average rate of nearly 1.7% from

1990 to 2021, faster than any other end-use sector. In order to combat the adverse effects of climate change and to maintain the global temperature rise above 1.5 ^{0}C than it was in the late 1800s, nations around the world are targeting a net zero status. In other words, human-caused emissions of carbon dioxide (CO_2) need to reach net zero around 2050 (United Nations Environment Programme, 2022). In order to get on track with the Net Zero Emissions by 2050 Scenario, CO_2 emissions from the sector must annually fall by about 3% until 2030 (IEA, 2022); (IEA, 2022); (Destatis, 2022).

Approaches of the Transportation Sector for Net Zero Status

The key strategies of the transport sector to achieve net zero status are,

- shift to low-emitting modes including public transport (walking and cycling) is required alongside the electrification of transport modes
- an acceleration of the move to zero-carbon cars and trucks and
- preparation for the move to zero-carbon aviation and shipping

At a specific target level the number of trips by private light-duty vehicles is expected to decrease to levels 4-14% below the business-as-usual levels by 2030. A further doubling in the number of kilometers of public transit per 1,000 inhabitants by 2030, and a fivefold increase in the number of kilometers of high-quality bicycle lanes per 1,000 inhabitants are targeted (United Nations Environment Programme, 2022).

Among many emissions sources of the transport sector, personal vehicles using road transport are the major emission source in many countries including Sri Lanka. As per the aforementioned strategies, citizens are expected to reduce the number of private light-duty vehicles and also adopt active mobility practices such as opting for walking and cycling whenever permitted by ability and distance. Cycling is one of the modes of micromobility which can contribute to emission reduction for short-distance trips.

In comparison to some other modes of micromobility such as motorbikes and scooters, three-wheelers and cycles are associated with zero emissions. A new McKinsey survey found that on a global average 40% of the respondents identified the bicycle as their preferred form of micromobility for daily commuting. The findings indicated that a growing number of workers prefer smaller and more environmentally friendly modes for traveling to work (Heineke et al, 2021).

Studies in other countries have shown evidence for the successful promotion of cycling as a sustainable transport mode. A case study in Mexico indicated approximately a 3% reduction in greenhouse emissions of around when the bicycle is used for utilitarian purposes (Bussière, et al., 2010).

Modal Choice for Short-distance Trips in Sri Lanka

In reporting the modal share of Colombo Metropolitan area in 2013, Madhuwanthi, et al indicated that modal share cyclists have been fairly low at 1.5% when the other personal modes were 11.4% motorcycles, 6.9% three-wheelers, and 8.5% cars (Madhuwanthi et al., 2013).

According to the Comtrans survey in 2013 (JICA, 2014) average trip lengths in Colombo Metropolitan area stands at 10 km for home-based work trips 5.7 km for home-based education trips, 5.8 km home-based other trips and 5.9 km for non-home-based trips. Among those trips, 18 to 26% of home-based trips (whether work, school or other trips) uses non-motorized modes. Some of these trips may reflect those trips of the last mile which could be done by walking or cycling. The acceptable distance for a bicycle is found as 5.08 km in one previous study (Karanikola, et al., 2018). Some of the above trips (home-based work trips; home-based education trips and non-home-based trips) have the potential of being shifted to cycling.

This lower modal share of cycles in comparison to other personal transport modes indicates the presence of possible challenges for cycling. However, if these issues are addressed, modal shifts from personal modes such as three-wheelers and cars can be envisaged. In other words the promotion of cycling as a micromobility should be an important agenda in Sri Lanka's journey towards net zero status.

However, this calls for careful identification of the potential cyclist categories, motivating factors towards to cycle, the nature of trips to be targeted for shifts, barriers for encouraging the decision to shift to cycle, and facilitating an environment where the barriers for cycling are addressed.

Global and Local Motivators for Cycling for Transport Purposes

Cycling has been favored for multiple reasons including travel time saving in heavy congestion (compared to crowded city car travel), modest parking requirements, door-to-door travel without transfers, lack of parking time, and cost-effectiveness (Dahanayaka & Kankanamge, 2018). Cycling is a form of exercise for a hectic life that requires no additional time. Daily cycling can bring about extraordinary health benefits (Murnane, 2017). Cyclists may have better physical

health and fitness condition than normal people. Research carried out by a team of investigators at the University of Glasgow to find the health benefits associated with different transport modes, tracked 263,450 people for five years who traveled to work and lived in England, Scotland or Wales (Murnane, 2017), according to which the risk of cyclists dying from all causes was 41% lower than people who drove or used public transport. Their risk levels for developing cardiovascular disease was 46% lower and risk of dying from cardiovascular disease was 52% lower.

Most personal transport modes such as cars, motorbikes or scooters, require initial capital investment as well as recurrent expenditure for fuel and maintenance which is proportionate to the distance traveled. Cycling requires less capital cost, average maintenance cost, and zero recurrent cost for fuel.

The recent economic crisis and resultant fuel crisis have led to a drastic increase in inflation in Sri Lanka. As indicated in Figure 1, during the period between March 2022 and September 2022, the inflation values indicated by the Colombo Consumer Price Index (CCPI increased by 48% while the transport cost component of CCPI increased by 94% (Statistics, 2022). Figure 2 indicates how the recurrent transport cost for a sample trip between Dehiwala and Bambalapitiya has varied in the context of increasing fuel prices (Ceypetco, 2022) and bus fare (NTC, 2022). Accordingly, the recurrent cost of all modes except cycles has doubled. A cost increase of this magnitude may induce travelers to reconsider their transport options resulting in a modal choice towards more cost-effective modes, at least for short-distance trips. With its zero recurrent expenditure levels, a micro-mobility choice towards cycling can be encouraged if the other barriers towards cycling can be overcome.

Furthermore, supply of mobility from almost all of the motorized transport modes (cars, buses, three-wheelers and motorbikes) became closer to zero level in most parts of Sri Lanka due to the national level fuel scarcity. Under such very low levels of mobility supply conditions, most users started to switch to bicycles. Some of these users have switched back after the partial restoration of fuel supply and thus, mobility supply. This crisis had many other negative consequences such as twenty or more deaths in fuel ques (Lankaxpress, 2022) , loss of employment, disturbances to the education sector, shortages of service and material provision, and disturbances to all manufacturing sectors and construction sector and many economic activities (English news.cn, 2022). While the nature of the problem calls for a comprehensive understanding about the complexity of the problem, the potential adoption of cycling for short-distance trips should be considered through appropriate short-, medium- and long-term measures.

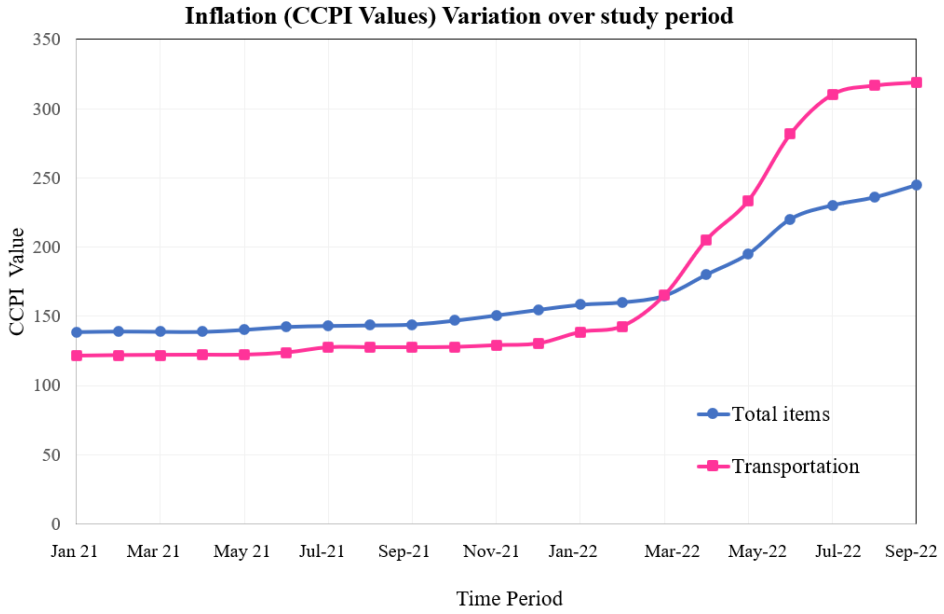

Figure 1. Variation of inflation in Sri Lanka in the period of January 2021 - September 2022

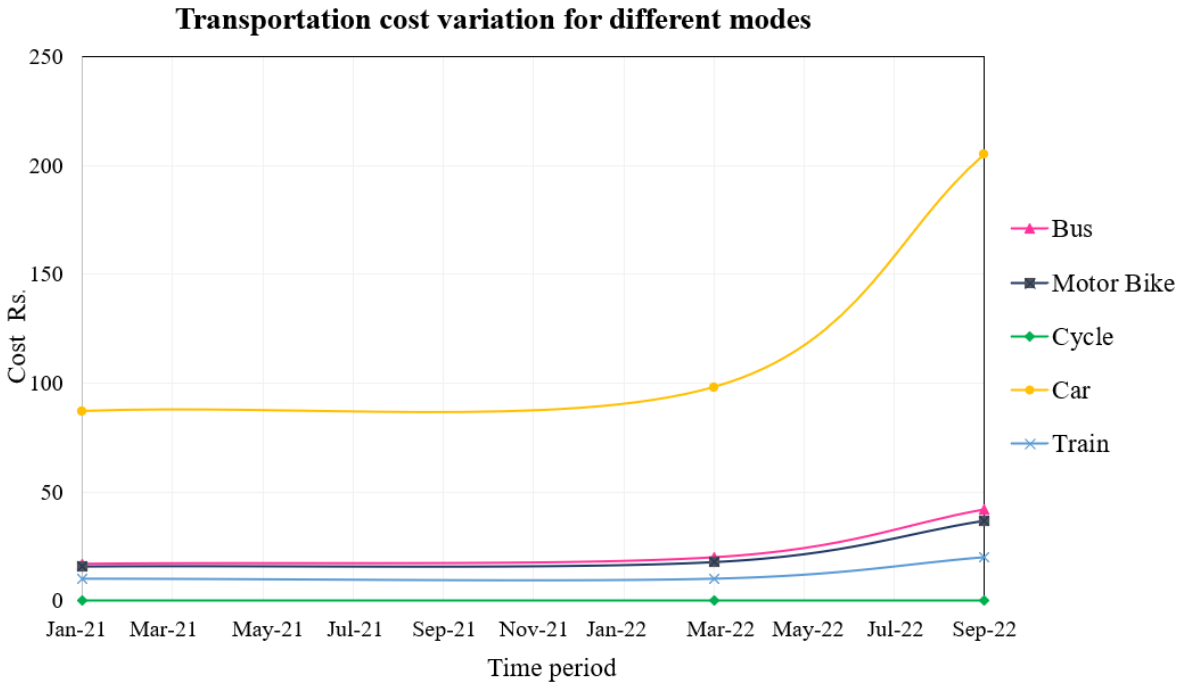

Figure 2. Variation of recurrent transport cost for different modes for a selected trip in Colombo

Global and local Barriers for Cycling

Irrespective of the health and environmental benefits, zero operational cost and many other motivators, the full potential of cycling is yet to be realized in Sri Lanka. Careful identification of the barriers and finding proper solutions is vital for cycling to be sustained as a sustainable mode.

Strömberg & Karlsson (2016), identified several barriers for cycling in Sweden which included lacking sufficient fitness, long distances, being tired, too much effort, difficulties with trip chaining, shopping and picking up children with the help of their bicycles, bad weather, being too busy, lack of time, lack of daylight, inconvenience, too dangerous and too much traffic. Aldred, et al.(2019) have reported that low investment in cycling infrastructures was a barrier for cycling in England and the reason for the lack of growth in cyclists between 2001 and 2011. The lack of bicycle-only routes and roadway accommodations were barriers for cycling in Rochester (Pucher & Buehler, 2007). These highlighted the need for a separate space for cycling.

As a part of previous efforts to promote cycling in Sri Lanka, several roads have been provided with cycle lanes. Bandara, et al.,(2016), who studied two such cycle lanes in Colombo have identified these lanes were utilized mainly be university and school children. The authors also identified several barriers associated with such cycling in Sri Lanka. These barriers included sweating, long travel distances, poor road conditions, lack of facilities and parking for cyclists, and social stigma.

Dahanayaka and Kankanamge, (2018), in a post occupancy study of one of the aforementioned cycle lanes, between Katubbeda and Piliyandala, studied the reasons for lower levels of cycling in the said lane. Authors found the existence of bends and the absence of significant buffer width to safeguard cyclists from trespassing vehicles, illegal parking, and overtaking using cycle lanes as factors discouraging cycling.

In summarizing some of the challenges for cycling in Sri Lanka, Ambuldeniya & Samarasekara (2021) classified those as physical barriers and personal barriers. Accordingly physical barriers included poor road conditions, lack of facilities for cyclists, the existence of bends, absence of significant buffer width to safeguard cyclists from trespassing vehicles, absence of safe parking, absence of connectivity in cycle lanes, and parking in the cycle lane. At a personal level lack of sufficient fitness, tiredness, the effort needed, difficulty in shopping and picking up children with bicycles, social stigma, poor driver discipline of different transport modes, and heavy congestion, bad weather and unpredictable precipitation events, and lack of daylight were identified as environmental barriers.

According to Sri Lanka police, cycling usage for public transportation has increased due to the fuel shortage in the recent past. However, they observed an increase in the number of bicycle accidents. Between January and June 2022, approximately 1,202 fatal accidents were reported and 96 of those were cyclists. This indicates a marginal increase in cyclist fatalities in comparison to the annual average of about 5% cycling fatalities. The causes for these accidents as identified by the Police included the lack of headlights and rear-end lights on bicycles, cyclists wearing dark-colored clothing at night, non-compliance with road signs and not paying attention to oncoming vehicles while crossing the road (Adaderana, 2022). These causes call for more safety features especially for nighttime cycling and the need to adhere to road rules. Furthermore, conflicts may occur at intersections due to ambiguities of priority between cyclists and other road users. Any efforts to promote cycling in Sri Lanka should be launched after addressing these safety concerns.

Profile of Cyclists in Colombo: Recent Observations

Bandara, et al. (2016), identified school children and university students as having a higher potential for cycle usage. This indicated a set of groups cycling for educational trips. Since late 2021, the country has been experiencing severe disruptions to the supply of mobility, as a result of fuel supply shortages. Furthermore, the fuel cost has also increased as shown in Figure 1. This has led to some new profiles of cyclists on the road who have moved away from the use of personal vehicles. With the introduction of the QR code system, a percentage of these users have switched back to their original mode of transportation such as cars.

Encouraging cyclists in Sri Lanka requires an understanding of their profiles. Based on a series of qualitative observations and face-to-face interviews of cyclists in several urban roads in Colombo, seven categories of cyclists were identified, as shown in Table 1. The table also includes some of the important characteristics of cyclists including age, quality of the bike, trip purpose, adherence to safety and cycle accessories used.

Cycling is used for a range of trip purposes including work trips, errands, school and other educational trips, as well as recreational trips. General and long-term commuters may use those for economical purposes whereas professional commuters have opted for high-end bikes with many safety accessories. Some of them have shifted to bicycles due to dependability issues of personal/ public transport, especially during the recent fuel crisis. They are concerned about the safety of their journey. Those who use bicycles for courier services representing a recent modal shift are also concerned about safety.

Table 1: Profile of recent cyclists in Colombo

Category	Purpose	Age	Cycle	Adherence to rule	Schedule	Safety features	Cycle accessories	Attire
Commuters - Professional	W, E	18 -50	S/ H/ E	H	F	H, RL, FL, SJ	FB	C
Commuters - General	W, E	18 -50	S	M	F/NF	FL	RB	C
Young Rider	E, S, R	6 -20	S/ H	M	F/ NF	H, FL, B		C/ S
Leisure/ sports riders	R	any	R	L/ H	NF	H, FL, RL		CK
Long term riders commuters	W	40 - 60	B / S	L	NF	FL, B		C
Long-term riders – sellers; good carriers	D/S	18 or more	B	L	F	FL, FB		C
Riders of courier/ delivery services	D	18 - 40	S	L/M	F	H, FL, RL, SJ, B	FB, RB	C
Weekend / Errands riders	E	40 - 60	S	H/M	F	FL, B	RB	

Purpose – D - Delivery, E – Errands, R – Recreation, S- Sales, S – School, W – Work

Cycle type – B – Basic; E- Electric, H - High end, R – Racing, S – Standard,

Adherence to road rules – H – High, L – Low, M – Mid

Schedule – F- Flexible, NF – Not Flexible

Safety Features – B – Bell, FL- Front Light, H – Helmet, RL – Rare Light, SJ – Safety Jacket

Cycling accessories – FB – Front Bucket; RB – Rare Bucket/ Rack

Attire – C – Casual, CK- Cycling Kit, S – Sportswear

Some of these riders, especially those professional commuters, have switched back to their previous modes of transport. The possibility to remain as cyclists under varying levels of fuel supply and fuel prices is shown in Table 2. If the challenges faced by them are understood and addressed properly, it would be helpful to sustain them as long-term cyclists.

Table 2: Potential riders in the context of different levels of fuel supply and fuel prices

		Level of fuel supply			
Level of fuel price		Rider category	Not restricted	Restricted using a quota system (Ex QR code)	Heavy restrictions where fuel cannot be easily obtained
	Low	Commuters - Professional	**N**	**M**	**Y**
		Commuters - General	**N**	**M**	**Y**
		Young Rider	**M**	**Y**	**Y**
		Leisure/ sports riders	**Y**	**Y**	**Y**
		Long-term riders commuters	**Y**	**Y**	**Y**
		Long-term riders – sellers; good carriers	**Y**	**Y**	**Y**
		Riders of delivery services	**N**	**M**	**Y**
		Weekend / Errands riders	**N**	**M**	**Y**
	High	Commuters - Professional	**M**	**M**	**Y**
		Commuters - General	**Y**	**Y**	**Y**
		Young Rider	**M**	**Y**	**Y**
		Leisure/ sports riders	**Y**	**Y**	**Y**
		Long-term riders commuters	**Y**	**Y**	**Y**
		Long-term riders – sellers; good carriers	**Y**	**Y**	**Y**
		Riders of delivery services	**M**	**Y**	**Y**
		Weekend / Errands riders	**M**	**Y**	**Y**
Y - Have the high potential to ride bicycles, N -No potential to ride a bicycle; M - May or May not ride the bicycle					

Cycling as a Sustainable Transport System

The four basic elements of a transportation system are the Right of way, Terminal, Motive power, and Carriage unit. Accordingly, a cycling system consists of the right of way (road), terminal (parking), motive power (cyclist), and carriage unit (cycle). Right of way (ROW) indicates the space to cycle and consists of two components; namely, the through lane and intersections. In providing solutions, addressing barriers through the four elements of the transportation system could be effective. The key approaches in this regard are summarized in Figure 3 and Tables 2-5.

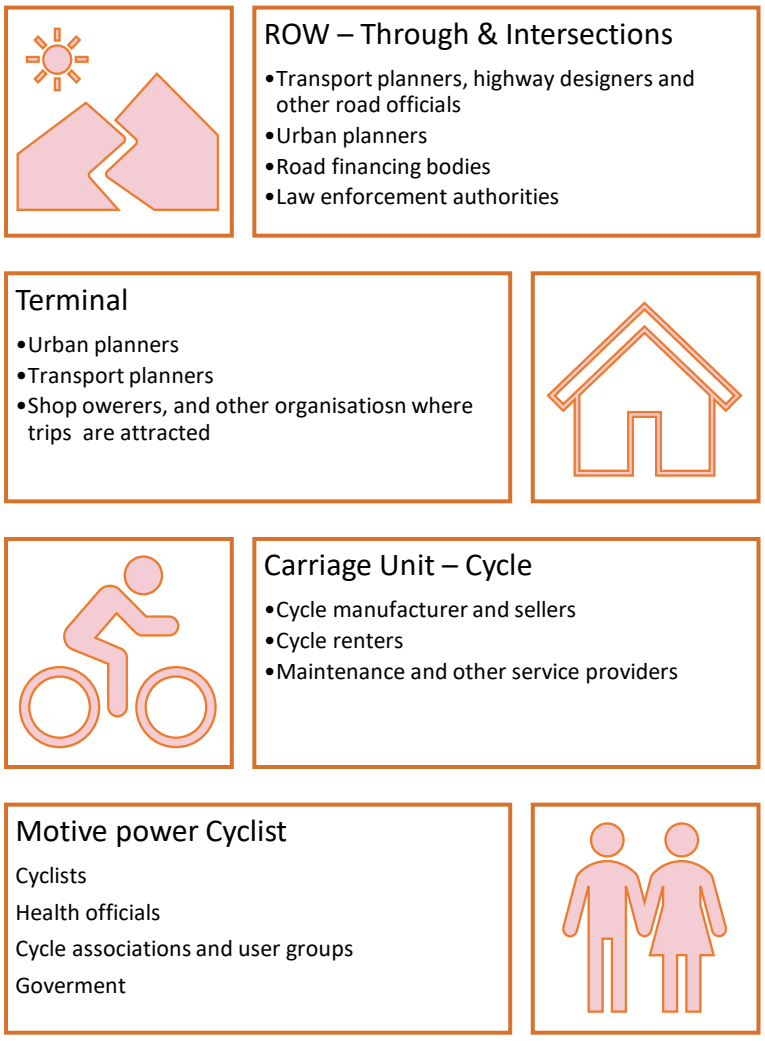

Figure 3: Key elements of a cycling system and stakeholders for each element

The improvement listed in Table 3 to rights of way (routes and intersections) fall under the purview of transport planners and highway designers. Facilitating the cyclists would require actions in long-, medium- and short-term.

Table 3: Improvement measures to Right of Way

	Aspect	**Target improvements**
Improvement in through lane	Level of Separation of cyclists	Adopt context-sensitive separation options - Share the right of way (carriageway) with vehicles - Share the right of way with pedestrians - Provide an exclusive cycle lane that could be extended to a connected cycle route Modes of separation can be (FHWA, 2015) - Road marking - Delineator posts - Bollards - Concrete barrier - Raised median - Raised lanes - Planters
	Size	At least 1.5 m for a cycle lane (Bandara, et al., 2016)
	Comfort (Surface; shade; amenities/ attractions)	**Riding surface** - Surface smoothness, absence of undulations **Weather** - Presence of shade **Amenities/ Attractions** - Resting and parking spaces - Pleasing appearance of route
	Signage	Lane marking should be clearly visible
	Network	Individual road segments should be connected so that a connected network/ route of cycling space is available
	Regulation on usage	Police should enforce the law as regulating authority
	Car door opening	Introduce the rules for cycle lanes
Improvements to Intersections	Rules of operation for priority and communication among cyclists and other road users	Clear rules should be spelled out All road users should be educated about the rules and trained to do so
	Signage and marking	**Markings** (FHWA, 2015) - Cycle lane marking in approaching the intersection should be terminated at intersections and final 15-20 m may be marked as dotted lines. The lane marking should begin immediately after the intersection. - Stop lines should be marked prior to intersection for all relevant lanes - Crosswalks should be clearly marked **Signage** (FHWA, 2015) - Install sign boards for a cycle lane, intersections

- **Long-term:** Sri Lankan road network mainly consists of two-lane or four-lane roads even for major arterial roads (A or B class). Allocation of sufficient safe space for cyclists such as cycling lanes should be done from project feasibility/ planning stage of all new road projects in the future. Long-term transport plans should give priority to accommodate cyclists as indicated in net zero strategies for transportation sector.
- **Medium-term:** Provision of additional space in existing roads can be effectively done in road widening projects for which social and financial challenges for land acquisition should be effectively managed.
- **Short-term:** Demarcation of sufficient carriageway width for cycling lanes at least in a few road segments (so that a connected cycle route can be created) could be adopted as it was done for bus priority lanes. Even the option of transforming the bus priority lane as a shared lane could be considered.

In road segments where sufficient space is not available sharing the carriageway with vehicles might have to be promoted with strict adoption of clear rules for priority between cyclists and drivers of motorized transport modes (including bicycle riders) should be created along with suitable educational and training sessions for all road users. Ambiguities in priority on roads could be eliminated through proper education. As reported by Dahanayaka and Kankanamge in 2018, operations of cycle lanes would be hindered by vehicle parking in such. Interventions of police as the law enforcement authority is vital to ensure an undisturbed and safer journey for cyclists.

Table 4 shows the intended changes at parking facilities and changes that should be made available in the trip destinations of cyclists. These may be their workplaces, shops or some intermodal facilities like a park and ride facility. Planning regulations in the future should be modified to incorporate cycle parking spaces and changing facilities in different types of commercial, educational, and administrative organizations. However, such regulation changes would take some time be legally enforceable. Furthermore, the existing establishments which may not be subjected to a planning approval process, should be educated about the importance of accommodating cyclists considering the long-term impacts of encouraging cycle parking facilities. Some of the commercial establishments have already allocated some dedicated and safe cycle parking spaces.

Table 4: Improvement measures to Terminal

Aspect	Target improvements
Parking	- Public destinations such as shopping malls/ parks/ public offices should have dedicated cycling parking spaces and preferably locking facilities ability to lock the bicycle to a fixed feature so that bikes cannot be lifted - Parking in destinations such as own office should have parking space and shelter for parking as well as locking of the bicycle or surveillance system for parking space to avoid cycles or components (E.g.; battery) being stolen - Multimodal facilities should have park and ride option with a safe parking facility
Changing facilities	Availability of - Changning rooms - Showers - Lockers

The type of cycle and accessories required by different cyclists varies due to personal preferences. Table 5 details the measures focused on the supply and maintenance of cycles and accessories. Government policies related to the commercial sector and manufacturing industry should ensure that people get access to a range of options (in terms of cost and technology) in buying cycles and accessories.

Table 5: Measures to improve the access to buy or rent cycles or parts therein

Aspect	Target improvements
Purchase facilities	Options to buy - different cycle types – (basic, medium, high end); E-bikes, special (cargo, sports); folding - Different Accessories (helmets, lights, locks, racks, child seats, raincoats) Minimize import restrictions Develop the local industry to manufacture bicycles at low cost
Repairing and servicing facilities	- Availability of repairing and service facilities - Availability of spare parts
Bicycle renting & Sharing	- Schemes for short-term bicycle rental available at urban hubs - Operated and monitored through mobile apps (registering, renting, returning, damage refunding, location tracking, cost calculating etc.) - System should offer services at an affordable price for traversable designations - Government support to ensure the Initial investment; security, accessibility

At present several bicycle renting options are available for recreational cycling both in cycling/ jogging tracks in Colombo and in historical districts such as Anuradhapura. However, Sri Lanka

should explore possible investments for advanced user-friendly cycle renting systems such as Velib in France.

Personal factors including safety concerns have been major determinants of modal choice in Sri Lanka favoring automated personal vehicles. The recent fuel crisis and higher price levels have however made a significant impact to this decision. In a context where people are reconsidering their decision, correct forms of interventions as detailed in Table 6 targeting personal barriers may promote more cyclists. At the global level many interventions targeting cyclists have been successfully organized by multiple stakeholders to address these personal-level challenges.

Table 6: Measures focusing on cyclists

Aspect	Target improvements
Safety	Awareness of rules for rights of way Creating a culture where adherence to safety practices is a must
Interventions	Interventions through addressing multiple stakeholders - Cycling group activities - Information and Apps on cycle routes - Early age promotions - Awareness programs (Cycling to school, Cycling to work) - Learn to ride, maintain - Training and education of cyclist - Cycle tourism - Flexible workplace rules - Car Free days; Cycle days, Cycling Fridays, Cycling Sundays

Conclusions

When the transport sector is working towards net zero emission targets through the promotion of low carbon modes, this paper discussed a way forward for short-distance trips through cycling as a micromobility solution. Potential opportunities and characteristics of potential riders with a potential of a modal shift were identified along with the challenges such riders may face. The intended changes to promote cycling were discussed by focusing on the four main elements of the transport system; namely, Right of way, Destinations, Cycle, and Cyclists. The improvements should be instrumented through responsible stakeholders including transport

officials, urban planners, law enforcement authorities, suppliers of cycles and associated services, and a range of cycling enthusiasts. A series of coherent and continuous programs with the participation of these stakeholders could improve the modal share of cycles in Sri Lanka to achieve net zero emission targets as well as a healthy population. Among the many proposed improvements following measures can be vital for the journey towards net zero status:

- Identification of cycling as a key aspect of a long-term transportation policy to ensure the right of way and associated investment
- Short-term and medium-term measures to ensure right of way by way of exclusive rights of way (cycle lane) at least selected routes (network of cycle routes) and shared right of way for some other frequently used road segments.
- Ensure the safety of cyclists by enforcing the rules and encouraging safety practices, creation of new rules and best practices for ambiguities in right of way along with associated awareness programs
- Cycling industry should be facilitated through government policies so that the industry can cater the qualitative and quantitative demands of the cyclists
- Interventions focused on cyclists in multiple ways, multiple attempts and multiple forums

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Section D

Life Science: Role and Tools for Problems at Hand

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Understanding the world and all living things in it is the goal of life science. The impact of COVID-19 on the life sciences was greater than we could have imagined before the pandemic. We had to scale our day today activities at a rate that was previously unheard of and quickly adjust to working remotely. More importantly, the pandemic has served as a reminder of how important life science is. We look to science for guidance and answers, and science delivers. The first vaccines for Covid 19 were approved less than ten months after the pandemic started. Therefore, life science is essentially about us humans, animals and the earth.

This year, all day-to-day activities have come to a complete halt once more due to the economic crisis, which started just as the Covid 19 pandemic started to recede. However, life scientists around the world, including those in Sri Lanka, persevered despite all obstacles. As you are aware, scientists from many universities in Sri Lanka, made significant contributions to the pandemic management efforts. Not only that, but a lot of other people helped, by coming up with and implementing preventative measures to stop the spread. In order to lessen the spread, devices like soap dispensers, pandemic ventilators, and UV ambient air purifiers have been invented and innovated. Thanks to the men and women who committed their time to the laboratory, and to a career of hard work, very often with little recognition, it was possible to successfully lessen the impact of the pandemic in Sri Lanka.

The economic crisis has intensified global issues that were already problematic. We now have new problems to deal with in our country. Over a long period of time, the excessive reliance on imports not only reduced the nation's foreign exchange reserves but also stifled human ingenuity, especially among scientists; none of our discoveries was valued by the successive governments, the private sector, or the general public.

Everyone was content to import purportedly superior goods or technologies. All medications, including simple wound care medicines such as Betadine, were imported. Although the knowledge and technology were there to produce it locally, no one was interested in investigating the possibility. We failed to realize that we were attempting to walk in shoes designed for someone else. We have lost sight of the fact that increasing our mental capacity, rather than physical labour, makes us more productive as a country.

It is a very positive outcome that much of what life scientists do contributes to the nation's economy, whether it is biotechnology, agriculture, environment protection and biodiversity, disease prevention, or any other field. All of this is feasible if discoveries, inventions, innovations, and improvements of scientists are acknowledged and supported. When scientists, the private sector, or start-up businesses collaborate, innovation results. Otherwise, discoveries are just pretty journal paper stories. Modern infrastructure and tools are necessary for life science; the government should give this serious consideration if Sri Lanka is to develop its own solutions for many of its problems at hand. Hence, investment in science must be given top priority.

In order to illustrate why and how life scientists must contribute to the nation's reconstruction, one recent example could be highlighted. The recent chemical fertilizer crisis and the effects of limiting or prohibiting the use and import of fertilizers and agrochemicals, such as insecticides and herbicides could have largely been avoided if the scientific community intervened.

According to the United Nations, by 2030, the world's food production will need to be increased by more than 40%. There is no question that in the long run, sustainable practices must be adhered to, and new technologies must be utilised to boost production yield and food quality. However, to bring about sustainable changes to long followed practices, it is necessary to work alongside science. Have all pertinent discoveries made by our scientists—life scientists, agriculture scientists, and others—over the years been applied practically to enhance agriculture and boost national food production is a question that is in the minds of many local scientists. Contrarily, is it true that our scientific community does not connect theory and practice, or was the issue with previous governments? Concerns about local scientists' capacity to successfully translate scientific research into real-world solutions have existed for a very long time. We need to seriously consider thinking along those lines if we want to make sure that we contribute more to the efforts of our nation rebuilding.

The description below provides how biotechnology, more specifically life sciences, could have helped. Over the past century, the use of agrochemicals—pesticides, fertilizers, and plant growth promoters—has been essential for humanity. They have prevented millions from starving

by enabling agricultural productivity to keep up with population growth. However, their impact on the environment has grown to be too great to ignore, and people increasingly perceived them as doing more harm than good. Recently, a number of nations set targets to drastically cut the amount of chemicals use by 2030. These include cutting back on fertilizer use and reducing the use of dangerous and chemical pesticides by 50% which may have been the aim of Sri Lankan policy makers too. We made an attempt to immediately reduce fertilizer use by 100%. It would have been a significant achievement to accomplish it without experiencing a significant decline in yields. Yet the consequences were not what was expected. The issue could have been resolved and the transition away from fertilizers/agrochemicals made much less painful if cutting-edge agricultural biotechnology was used.

Recently how crops are grown has been improved by a variety of inventive biological strategies discovered by life scientists. Crops can be genetically modified to increase their resistance to pesticides, diseases, and drought. Since so much of what we eat has been genetically altered, most of us may have consumed at least some genetically modified food. It is possible to isolate specific genes and add them to food crops to produce desired traits, such as increased yields and infection resistance. For instance, genetically modified rice has been developed to increase its pest resistance and Vitamin A content. Biotechnology can lessen food shortages by increasing crop yields and nutritional value. In turn, this expands the food supply.

A sizable portion of agricultural emissions and 2% of all global emissions are caused by synthetic fertilizers. One way to reduce the emissions linked to our food production systems is to increase efficiency or use less synthetic fertilizer. Living microorganisms are present in bio-fertilizers and pesticides, which improve plant nutrition by mobilizing or boosting nutrient availability in soils. It would have been possible to prevent the drastic drop in crop yield in many of the crops we grow if biofertilizers had been used. Pesticides are a bigger concern because of their persistence, toxicity, and negative effects on human health. Despite the world's increased awareness of food security, pesticides still exist, though biopesticides are a better option. Bio pesticides are known to be safe and environmentally friendly. These are produced without the use of many chemicals. Why couldn't Sri Lanka think of this alternative instead of trying to cultivate without any pesticides is a question that everyone must be asking themselves. The adoption of genetically modified crops is another tested method of lowering pesticide usage. According to estimates, the use of pesticides decreased by 9% between 1996 and 2019 as a result of the adoption of GM crops. In addition, it has resulted in a significant decrease in fuel consumption as the amount of tillage necessary has decreased. There is no question that food production needs to be increased in order to reduce imports. However, it is required to achieve sustainable intensification of

agriculture, increasing productivity while safeguarding biodiversity and avoiding practices that degrade soil quality.

In order to make sure that mistakes are not repeated, all concerned must participate in collective policy-level decision-making. SLAAS needs to take that into serious consideration going forward and actively participate in policymaking.

A cultural transformation in addition to the scientific and technological transformation is also required. In order to achieve this, all attempts must be made to take science into every household and every neighborhood. At all levels, it is required to invest in scientific education. It is also the responsibility of SLAAS to educate young generations about persisting problems. They must be educated about the functioning of our planet and how the environment's limited resources could be used sustainably. The only defence against a mindset that favors imported goods and services over locally developed solutions is a pervasive scientific culture.

As life scientists, we are not serving the community if we are not generating new knowledge and sharing it with the masses. As the pandemic winds down and the economic crisis eases, we see a return to regular life, all must focus on working more effectively together. Let us identify what is best for Sri Lanka - and support it.

Section E1

Trends in Superconductivity; Marvel Materials in the Odyssey to Room Temperature Superconductors

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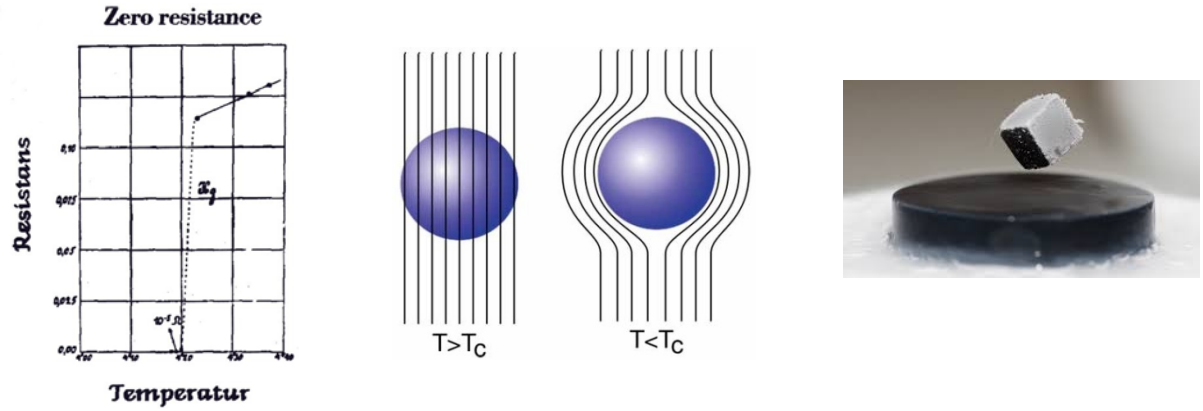
Introduction

Superconductivity (SC) discovered in the 20th century is a fascinating state of matter, which shows a remarkable quantum phenomenon operating on a macroscopic scale. The two main properties of superconductivity are the zero resistance (Figure1) and the perfect diamagnetism (Meissner effect), which were first observed in mercury below a critical temperature (T_c) of 4.2 K by Kamerlingh Onnes in 1911(de Bruyn Ouboter, 1997), who was awarded the Nobel Prize in Physics in 1913. The Meissner effect of superconductors can be explained as shown in Figure 1(b) i.e., when the material becomes superconducting below the critical temperature, the zero-resistance surface current produces the magnetization within the material. The magnetic field due to magnetization opposite to the applied magnetic field, and internal magnetic field within the superconductor is zero as shown in Figure 1(b). This will demonstrate the diamagnetic property in superconductor materials that will repel it from the applied magnetic field. When a magnet is placed above a superconductor, this repelling force can be stronger than gravity, allowing the magnet to levitate above the superconductor as illustrated in Figure 1(c). Magnetic levitation technology can be used as an efficient technology in various industries due to lack of contact; thus, no wear and friction which in turn increases efficiency, reduce maintenance costs, and increases the useful life of the system. The most important usage is in the operation of magnetically levitated trains.

The above finding triggered an immense research effort, involving many experimental and theoretical work towards finding the most advantageous superconducting elements discovered under different conditions as shown in the periodic table. These are known as conventional

superconductors. Additionally, synthesized compound materials have also displayed superconducting properties at very low temperatures. The timeline of progress in achieving the high critical temperature or in other words high temperature superconductors is shown in Figure 3.



(a) (b) (c)

Figure 1. (a) Zero resistance below critical temperature for Hg (b) External magnetic field behavior in normal conductor and superconductor (c) Meissner effect.

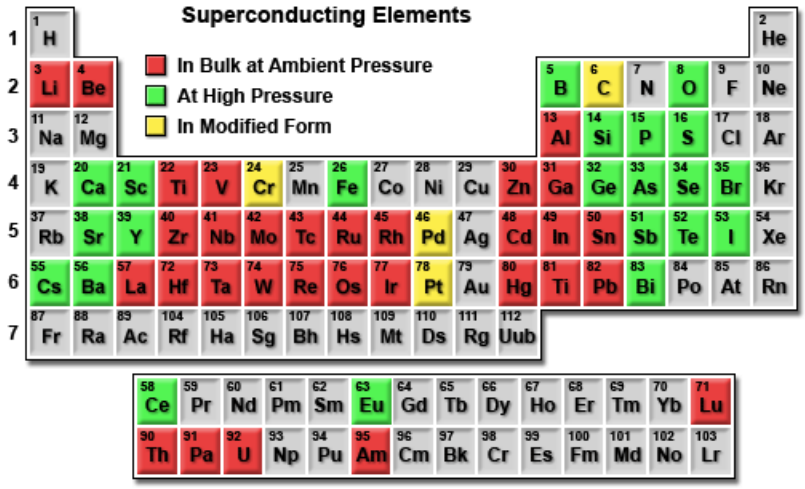


Figure 2. Superconducting elements in the periodic table under different conditions.

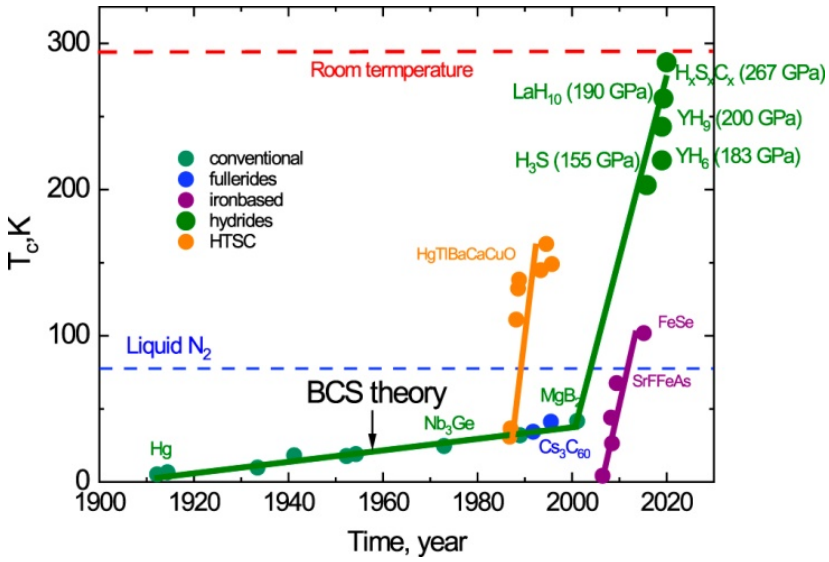


Figure 3. Timeline for superconductor material with respect to their critical temperatures.

Theoretical Approach

In 1957, Bardeen, Cooper and Schrieffer proposed the BCS theory; this was the first satisfactory theoretical explanation of superconductivity, and the contributors were awarded the Nobel Prize in Physics in 1972. BCS theory opened a new era to modern physics theories. BCS theory describes a two-body interaction between either electrons or holes that leads to a Bose condensation of electron pairs (Cooper pairs as shown in Figure 4-(a)) into a superconducting state. Coulomb repulsion between carriers of the same sign is overcome by an attraction mediated by vibrations of the lattice, phonons. The formation of Cooper pairs follows the Pauli exclusion principle, so, two Cooper pairs can occupy the same wavevector space in momentum space. An energy gap (Δ) at the Fermi level, defined as the energy difference between the lowest state of the quasiparticle excitation and the superconducting ground state, is a signature of the superconducting state as shown in Figure 4-(b). For “conventional” superconductors, usually defined as those which can be well described by BCS theory(Bardeen et al., 1957), the energy gap is isotropic in momentum space as shown in Figure 5-(a). Specific heat measurements gave the first experimental evidence for the existence of such a gap. The BCS theory predicts the ratio between the zero-temperature gap ($\Delta(T) = 0$)) and the transition temperature to be 1.76 K, which is a universal constant independent of the particular material, and which is in excellent agreement with experimental measurements.

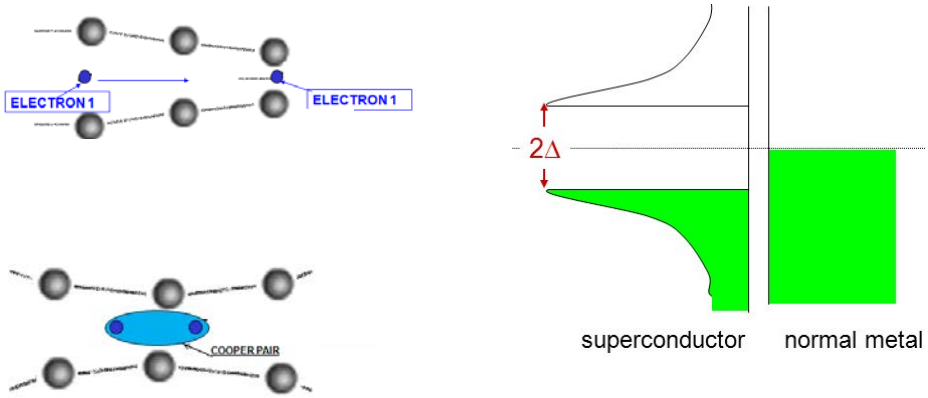


Figure 4: (a) Formation of cooper pairs (b) Superconducting gap

After the end of the 1970s, novel classes of strongly correlated superconductors such as heavy fermion superconductors, organic superconductors, and cuprate superconductors were discovered and they possessed complex phase diagrams with several adjacent superconducting phases with high transition temperatures, establishing their unconventional nature. “The challenge is the theoretical understanding of how highly directional oriented electron pairing with an anisotropic nature (Figure 5-(b)) can form compared to the isotropic nature in *s*-wave pairing (Figure 5-(a)).

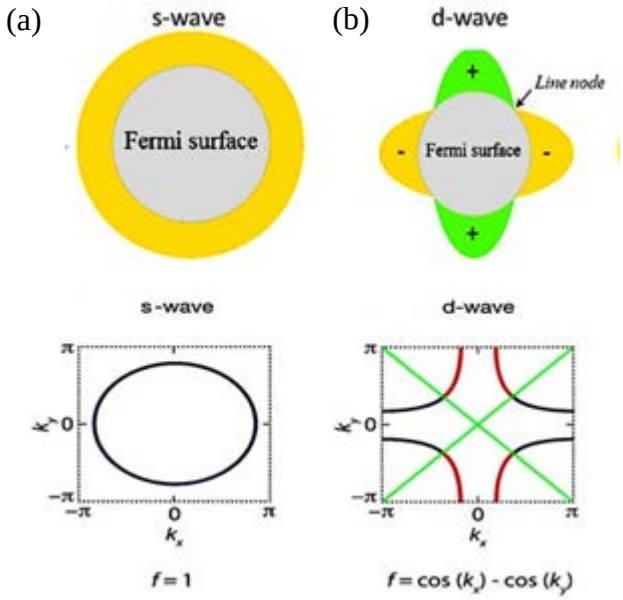


Figure 5. (a) Isotropic energy gap in momentum space (*s*-wave pairing) (b) Anisotropic energy gap in momentum space (d-wave pairing)

Unconventional superconductivity has been known experimentally since the discovery of heavy fermions in $CeCu_2Si_2$, strongly correlated with its *4f* electrons, leading to superconductivity below 0.6 K in 1979. The theoretical explanation for unconventional superconductors is attributed to antiferromagnetic spin fluctuation in a doped system adjacent to the superconducting state. Other than spin fluctuation, weak coupling theory explains the pairing wave mechanism with the existence of d-wave pairing as shown in figure 5-(b). Another explanation of the interlayer coupling model shows that *s*-wave pairing symmetry enhances its superconductivity introducing an additional tunneling interaction between each layer. Unfortunately, there is no common agreement to properly figure out the mechanism for unconventional superconductors. Therefore, it is worth looking into superconducting families and whether they follow common features within the family. Here, such major families which were highlighted in the timeline of superconductors will be explained.

Organic superconductors

The investigation of organic superconductors with the intention of achieving a high T_c has been an active research area of modern condensed matter physics over the past thirty years. Many strange phases and phenomena occur in organic superconductors due to electron correlations, dimensionality, and geometrical frustration, which can be tuned by magnetic field, temperature, and pressure. Among these ideas, the concept of moving electrons in highly polarized organic polymers, proposed by W.A. Little in 1964 (Little, 1964), was theorized to create room temperature superconductors. This idea had a strong impact on the synthesis of organic superconductors. Scientists have synthesized high conductivity organic materials that are quasi one dimensional (1D) and two dimensional (2D), in a novel research interface between Chemistry and Physics.

The charge transfer solid (CTS) TTF-TCNQ (tetrathiafulvalenetetracyanoquinodimethane) was the first stable, conducting organic compound which showed metallic properties below room temperature. The TTF-TCNQ crystal structure has parallel conducting stacks of TTF and TCNQ molecules. A loss of conductivity can occur due to the metal-insulator (MI) transition via the Peierls distortion, which occurs at T = 31 K for the TTF-TCNQ. The Peierls ground state can be suppressed at the high pressure of 8 GPa (Yasuzuka et al., 2007). The first organic superconductor $(TMTSF)_2PF_6$ (bis-tetramethyltetraselenafulvalenehexafluorophosphate $C_{10}Se_4H_{12}$ (abbreviated as TMTSF)) was discovered to have a T_c of 1.1 K under an external pressure of 6.5 kbar by K.Bechgaard, D. Jerome and others in 1979. Another two dimensional organic superconductor family was found in the BEDT-TTF (bisethylenedithio-tetrathia-

fulvalene-$[(CH_2)_2]_2C_6S_8$ (abbreviated as ET)). The first superconductor discovered, $(ET)_4(ReO_4)_2$ belongs to the ET family, with the critical temperature 2.0 K under an external pressure of 4.0 kbar in 1983. Another such well known superconducting family is the CTS family. The TMTSF and ET molecules have charge-carrying holes and the halogen anions in a closed shell structure, which is believed to be the trigger of their superconductivity. These organic superconductors can be further discussed as Quasi 1D organics and Quasi 2D organics based on their dimensions.

Quasi 1D organic superconductors

The quasi 1D superconductor materials known as Bechgaard salts share the common formula $(TMTSF)_2X$. Here, the TMTSF molecules are stacked in columns; along which the highest conductivity (Figure 6-(a)). The $(TMTSF)_2X$ has 2:1 stoichiometry, and one electron is transferred from two TMTSF molecules to one X; therefore, the π band of TMTSF is 3/4 -filled. After the discovery of $(TMTSF)_2PF_6$, by replacing PF_6^- by a variety of anions such as AsF_6^-, SbF_6^-, ClO_4^-, PF_4^-, ReO_4^-, and TaF_6^- a new series of superconducting materials was found. Among them, only $(TMTSF)_2ClO_4$ is superconducting at 1.2 K at ambient pressure (Vescoli et al., 1998), others display superconductivity under external pressure. Another 1-D superconductor family is the family of TMTTF (etramethyltetrathiafulvalene). It was discovered by replacing the Se in TMTSF by S (Figure 6-(b)). These two families are isostructural. TMTSF has a more widespread wave function due to larger *Se* orbitals compared to *S*. As a result, transfer integrals of TMTSF are larger compared to TMTTF and $U/t_{TMTTF} > U/t_{TMTSF}$ (U is the onsite Coulomb interaction, and t is the transfer integral). All the physical properties of TMTTF and TMTSF materials have been summarized in a temperature pressure phase diagram as shown in Figure 1.5.

$(TMTSF)_2PF_6$ has a MI transition at around 10-20 K due to a spin density wave (SDW) state as shown in Figure 6-(c). These 1D organic materials serve as model systems for the study of spin-Peierls (SP) and SDW transitions. Since these transitions occur in the vicinity of superconductivity in the phase diagram, it is speculated that magnetic ordering is related to the mechanism for superconductivity. Comparing the two materials, the $(TMTTF)_2X$ materials lie on the low-pressure side and the $(TMTSF)_2X$ materials lie on the high-pressure region in the phase diagram. Changing the external pressure or chemical pressure (due to different size anions) results in these materials having different ground state phases, such as antiferromagnetic (AFM), spin-Peierls, spin density wave, charge-order (CO), and superconductivity.

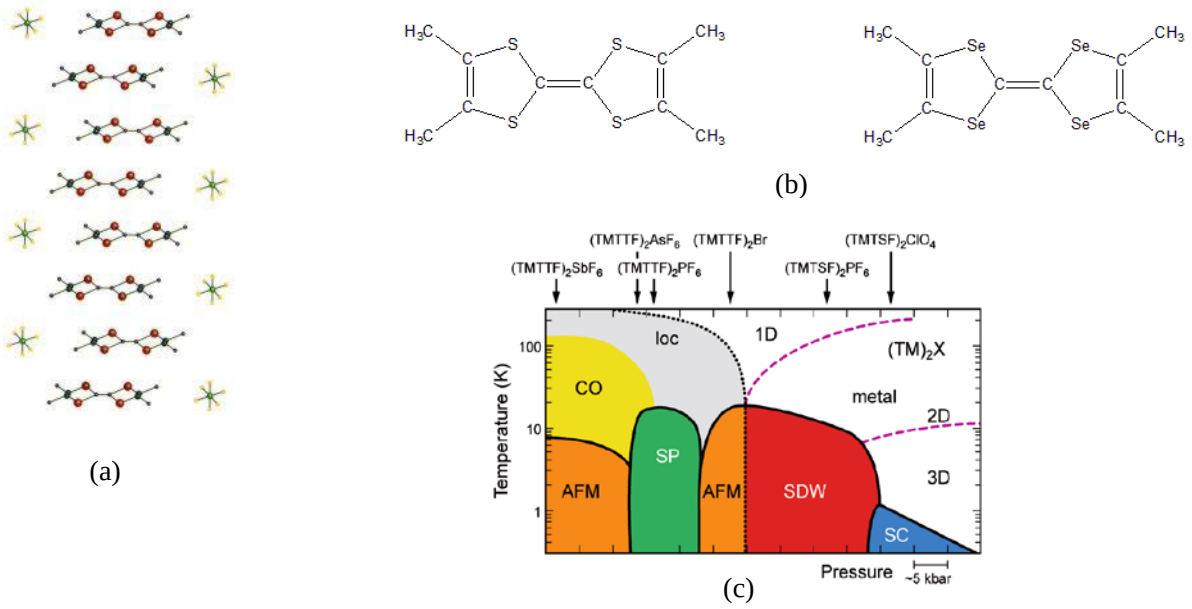


Figure 6. (a) $(TMTSF)_2PF_6$ crystal structure. The TMTSF organic molecules are stacked along the x-axis. (b) Molecular structure of the (a) TMTTF (b) TMTSF (c) Phase diagram for TM salts. (M.Dressel *et al.*, 2007).

Quasi 2D organic superconductors

In the beginning of the 1980s, the next generation of organic superconductors was discovered, based on the bisethylenedithio-tetrathiafulvalene (BEDT-TTF-abbreviated as ET) molecule as shown in Figure 7-(b). As with the $(TMTSF)_2X$, the composition ratio of ET superconductors is 2:1 ($(ET)_2X$) with alternating layers of anionic X^- and cationic $ET^{+1/2}$ (Figure 7-(a)) whose π band is 3/4 -filled. Increasing pressure tends to decrease the distance of adjacent molecules, so that the side-by-side overlap integrals between molecules are increased. The first ET superconductor, β-$(BEDT\text{-}TTF)_2ReO_4$ is superconducting under a pressure of 0.4 GPa(Pal et al., 2004) with a T_c of 2 K. Many anions (such as I_3^-, $Cu(NCS)_2^-$, $Cu[N(CN)_2]^-$, and $SF_6CH_2CF_2SO_3^-$) give different crystal structures with different electronic properties. In the case of dimerization, many theoretical explanations replace each dimer pair of ET molecules with a single site, giving an effectively 1/2 -filled band. Unlike the Bechgaard salts, because of their two-dimensionality, no universal phase diagram fits for all superconducting materials in the ET family. Like the TMTTF/TMTSF materials, ET materials show several unusual ground states other than the superconducting state, such as AFM, CO, quantum spin liquid (QSL), etc. The spin localization characteristics of antiferromagnetic and quantum spin liquid states have been

intensively studied in CTS. Figure 7-(c) shows a generic pressure versus temperature phase diagram which was proposed by Kanoda et al.(Yasuzuka et al., 2007). The different κ-$(ET)_2Cu[N(CN)_2]Cl$ (T_c = 12:8 K)(Tomeno et al., 2020), κ-$(ET)_2Cu[N(CN)_2]Br$ (T_c = 11:6 K), and κ-$(ET)_2Cu(NCS)_2$ (T_c = 10:4 K) are indicated along the effective pressure axis in the phase diagram due to the effect of counter-anions and external pressure.

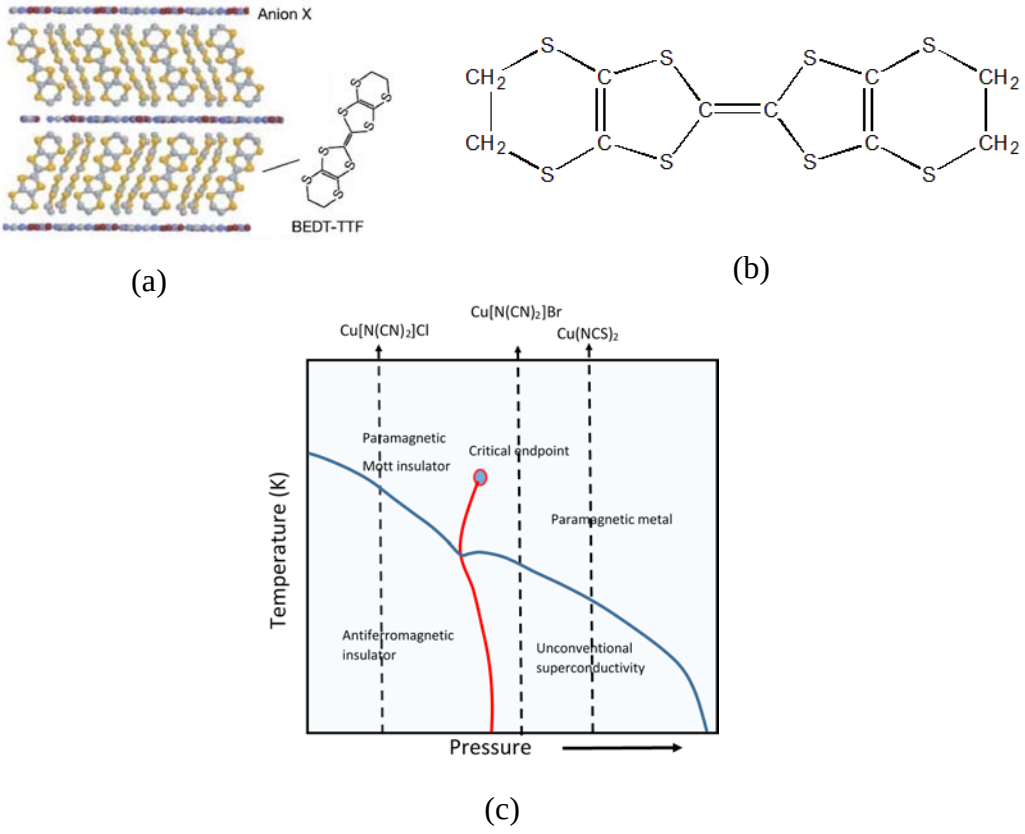
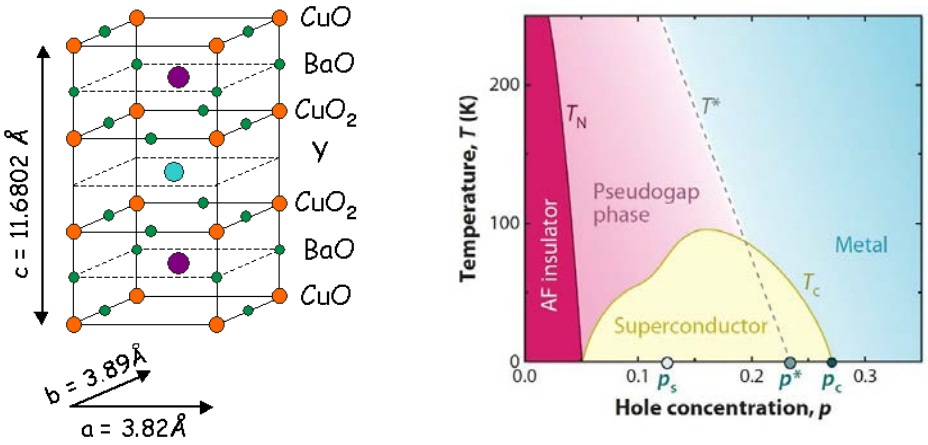


Figure 7. (a) Layered crystal structure of the $(BEDT\text{-}TTF)_2X$. (F. Kagawa, K. Miyagawa and K.Kanoda Nature (2005) (b) Molecular structure of the BEDT-TTF charge transfer salt (c) A generic phase diagram of κ -type salts.

Cuprates

In 1986, George Bednorz and K. Alex Muller discovered superconductivity in a perovskite structured lanthanum based cuprate at a T_c of 35 K, and won the Nobel Prize in Physics in 1987. This was a remarkable starting point for high temperature superconductors (HTS). Subsequently, chemical substitutions in the cuprates lead to high transition temperatures

beyond the boiling point (77 K) of liquid nitrogen. A replacement of Lanthanum (L) by Yttrium (Y) gave YBa_2Cu_3O-x, which has an optimal T_c of 93 K . The T_c of Thallium and mercury-based cuprates is nearly 133 K(Craig, 1998). These materials made of layers of copper oxide alternating with the layers of other metal oxides (lanthanum, barium, strontium) act as a charge reservoir providing electrons or holes into the CuO_2 layers as shown in Figure 8-(a). The higher electrical conductivity is associated with the parallel direction to the CuO_2 plane. The critical temperature of these materials depends on the chemical compositions, cation substitutions and oxygen content. A schematic phase diagram (Figure 8-(b)) for cuprate superconductors shows how their phases and temperature change against hole concentration. At zero-hole doping, it is an antiferromagnetic insulator and the highest doping shows a metallic state. The pseudo-gap phase has appeared above the critical temperature of the superconducting state; the relationship to the superconducting state is yet to be discovered. Unlike conventional superconductors, the BCS theory cannot explain the mechanism of high-T_c and other exotic superconducting materials; however, some BCS concepts such as Cooper pairs are commonly used to interpret experimental results. Understanding the pseudo-gap is the key point of explaining high T_c cuprate superconductors.



(a) (b)

Figure 8. (a) CuO_2 layered structure (b) A schematic phase diagram of temperature vs hole concentration for cuprate superconductors.

Theoretical debates on the high-temperature superconductors have been going on for a long time. There are two theories proposed to understand the mechanism of cuprates. The weak

coupling theory suggests that superconductivity emerges due to spin fluctuations in the antiferromagnetic state showing $d_{x^2-y^2}$ wave pairing as an order parameter as shown in Figure 5-(b). In the second approach, theorists support the interlayer coupling model which shows *s*-wave symmetry as BCS-type superconductors. High critical temperature is achieved by introducing additional tunneling interactions via impurities between each CuO_2 layer. As an example La_2CuO_4 is arranged in alternating layers of Cu_2O and LaO and if some percentage of La is replaced by Sr, it leads to enhancing the interlayer coupling which can be explained using the cooper pair mechanism as conventional superconductors.

Graphene -based superconductors

Graphene is a single atomic thick layer made of carbon atoms in a hexagonal ring that can be easily isolated from graphite flakes using exfoliation. The wonder material, graphene, is conductive, transparent, strong, and flexible, with unique electronic properties (Dirac material). When the two sheets are close enough to interact, the position and orientation of the sheets highly affect the electronic properties of graphene. Pablo Jarillo, in a work done at MIT focused on the new platform for strongly correlated superconductivity based on magic-angle twisted bilayer graphene super-lattices as shown in figure 9-(a)(Cao et al., 2018). The *k* points of the two layers are misaligned due to the twist angle, which leads to a shift in the Dirac cones of the two layers with respect to one another as shown in figure 9–(b). In addition, intersects of points above and below the Dirac point due to interlayer intersections give rise to a new flat band formation within the twisted graphene system.

Superconductivity in twisted bilayer graphene at the magic-angle 1.1° is demonstrated by the emerging field of twistronics. There are currently no other twisted materials that exhibit superconductivity. The same research group investigated superconductivity in tri-layer graphene (Figure 9-(g)), in which the middle layer is twisted compared to the outer layers (Tomeno et al., 2020). This is explained by the theory of superconductivity in a graphene bilayer due to the arrangement of electron pair symmetry at a specific angle of 1.1°. The twisted angle was predicted by the theorists for a tri-layer arrangement with an angle of 1.56° in the middle layer. This was successfully investigated by experimentalists with the strongest coupled superconductors which can achieve high-temperature superconductivity. This is a motivation to investigate twisted graphene layers with more than three layers, which will be promising for room temperature superconductivity due to their high electron density and electron pair symmetry at small angles. In addition, changing the number of electrons flowing through the materials using an external gate voltage can produce tunable bilayer superconductors. A few challenges faced

in producing twisted bilayer graphene are the difficulty of fabrication at small angles and characterization. Theoretical interpretation is uncertain and a few ideas play a role other than BCS and pairing mechanism. The new proposed idea is that superconductivity in graphene arises due to interaction between electrons and bogolons rather than phonons in BCS explanation. Bogolons are excitations within the Bose-Einstein Condensation which have some characteristics of a particle and is the valid mechanism for superconductivity up to 70 K within the graphene hybrid structures.

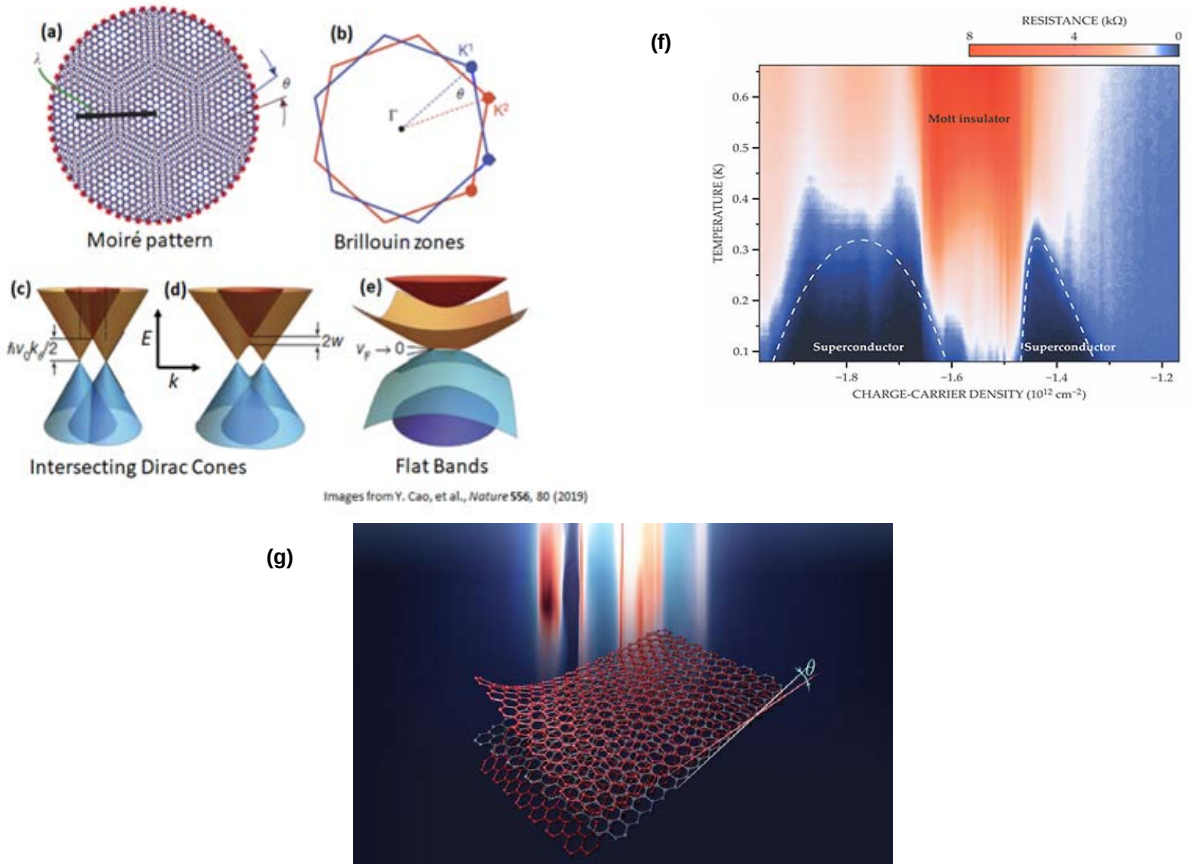


Figure 9. (a) Twisted bilayer Graphene *moiré* patterns (b) Dirac points of two layers ue to the twist of two layers (c) Intersects of points above and below the Dirac point (e) Flat band for twisted Graphene (f) Phase diagram for twisted bilayer Graphene at 1.1^{o} magic angle (g) twisted tri-layer Graphene.

Carbonaceous sulfur hydride; room-temperature superconductor

In the journey towards achieving room-temperature superconductors, some hydrogen-rich materials have been investigated as superconducting at high temperature and high pressure.

Dias et al. have reported superconductivity in a photochemically transformed pressure-driven carbonaceous sulfur hydride system, disproportionation of hydrogen sulfide (H_2S) to H_3S, with a maximum superconducting transition temperature of 287.7 ± 1.2 K (about 15 degrees Celsius) achieved at 267 ± 10 gigapascals (2,635,023 atmospheres) (Snider et al., 2020). This is the world's first room-temperature superconductor reported at high pressure. Figure 10 shows critical temperature vs pressure for different superconducting materials over the past 100 years until find the high pressure room temperature superconductors.

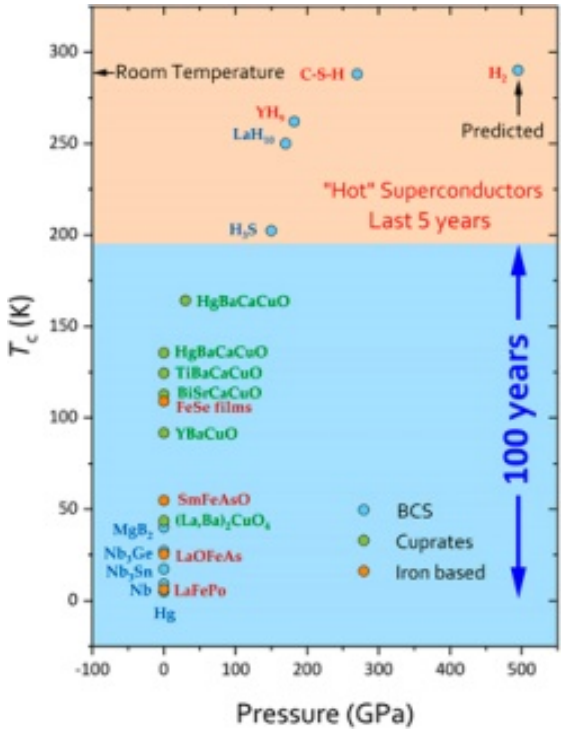


Figure 10. Critical temperature vs Pressure for different superconducting materials over 100 years.

The preparation of the mixture by adding hydrogen gas to precursor materials of carbon and sulfur. An ultra-high pressure device called a diamond anvil cell was used to keep the system compressed to 4 GPa, induced by laser at 532 nm for several hours.

The important parameter of pressure cannot be incorporated through other synthesis methodologies than the ultra-high-pressure called a diamond anvil cell, which includes two diamond anvils used in the experiment to achieve room temperature superconductivity at high pressure. It is important to develop methodologies to quench the materials to have similar high-pressure properties while maintaining low ambient pressure.

By introducing chemical pressure and raising the kinetic barriers to decomposition, this can be accomplished. When an atom or ion is situated at a crystalline site with a radius that is smaller than the atomic or ionic radius, the latter can be produced. In order to increase superconductivity, chemical modifications offer potential substrates for the epitaxial growth of superhydrides, which will lessen the pressure that is applied externally. Another challenge is the determination of location in hydrogen by x-ray diffraction (XRD) in superhydrides hindrance due to difficulties in probing lighter elements that arise in XRD because the scattering power of the sample is weak. The heavier nuclei would dominate the signal. To overcome such limitation, it is vital to develop an alternative characterization suite of X-ray spectroscopy tools that could alert us on the local electronic structure and coordination environment of a target element.

Superconductor Applications

Due to low temperature or high-pressure requirements, the practical applicability of superconductors is constrained. Nevertheless, superconductor materials are currently used in a few small- and large-scale applications.

Magnetic levitation is employed in trains. As a result of the lack of friction between the train and the rail, great speeds are possible. Changsha, China, and Shanghai's maglev trains both started running in 2004 (Figure 11-(a)).

Another crucial use of superconductivity is the energy-loss-free transmission of electricity. Also, power systems like transformers, generators, and motors have benefited from superconductor materials in aspects like efficiency, the capacity to operate overrated power without harming transformer life, and being smaller, lighter, and quieter. A 630 kV, three-phase transformer was put through testing by the ABB Company for the Swiss utility to utilize for a full year under normal operating conditions. The Siemens Company devised a different project, and successfully tested a 1 MVA demonstrator transformer for use in railway applications.

Electricity from the grid can be stored using a variety of technologies. One of the technologies uses magnetic energy storage as its foundation. However, it was suggested that superconductivity be used to boost these systems' capacity. These "superconducting magnetic energy storage" (SMES) systems actually work by creating a magnetic field in a coil made of superconducting wire with almost little energy loss. These devices typically consist of a superconducting coil that has been cryogenically chilled, coupled to the power supply by a power conditioning system.

A potent spectroscopic technique called nuclear magnetic resonance (NMR) uses the creation of a strong magnetic field to change the orientation of the atoms and nuclei that make up the human body (Figure 11-(b)). It currently uses superconducting coils made of NbTi operating at 4.2 K to produce powerful magnetic fields around 3T to obtain high-resolution images.

For the past several decades, one of the main forces behind advancement in high-energy physics (HEP) has been the use of superconducting magnets in particle accelerators. The beams are bent and quadrupled using superconducting dipole magnets to focus the beam. The business was greatly impacted by CERN's Large Hadron Collider (LHC), which is by far the largest superconducting device ever constructed (Figure 11-(c)).

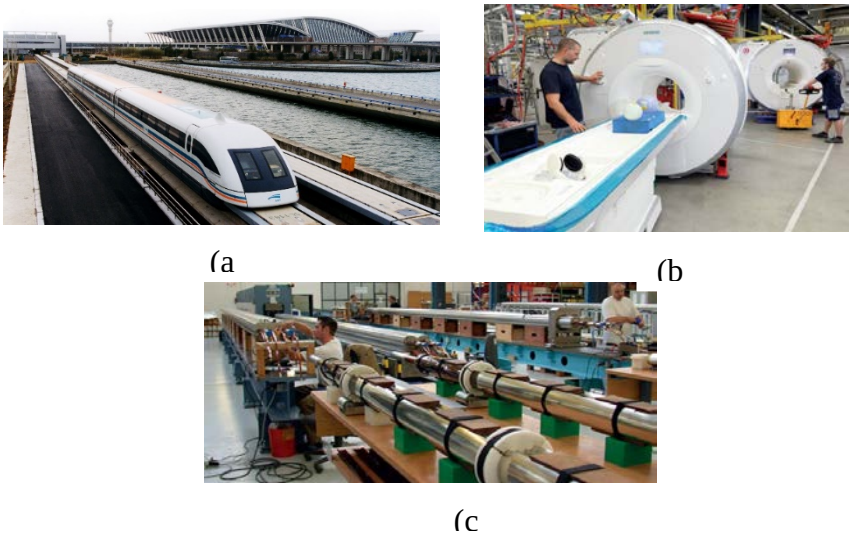


Figure 11. (a) Shanghai's maglev trains (a) A nuclear magnetic resonance imaging (NMRI) Scanner. (b) CERN's Large Hadron Collider (LHC)

The two main areas where the superconducting field will face difficulties in achieving ambient conditions are as follows: (i) Coming up with fresh experimental techniques for carefully regulated synthesis and characterization. (ii) Knowledge of the process underlying superconductivity on a theoretical level.

The greatest issue with superconducting applications is related to cooling costs, which frequently lead people to opt for conventional systems. The immense potential of high temperature superconductors to lessen risks to the environment, public safety, and health is through its potential to advance technologies for electrical or shaft power storage, which would eliminate the need for fossil and nuclear fuels. Superconductors in ambient settings would benefit the entire globe as a green energy source in the future.

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Section E2

The Pursuit of Controlling Matter at the 'Nanoscale': Perspective of Materials Chemistry

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Nanotechnology has already changed the world we live in today in ways beyond our imagination. For many, it might be intuitive to believe that this technology had only delivered sophisticated scientific output that is far from our reach. Nevertheless, from the food that we consume, to the clothes that we wear, nanotechnology has already proven the momentous potential of its presence in our everyday life to a remarkable extent. Although many technological advancements of this unique discipline have already been exploited via prominent scientific research, not to forget within its relatively short lifespan, an abundance of work is still ongoing, which will hopefully open many doors that would otherwise likely remain locked.

Hence, in appreciating how this novel technology has transformed our lives to date, it is certainly worth understanding what goes on behind those locked doors where scientists continue to uncover the hidden beauty of these tiny miracles before which a nanotechnological marvel could be unleashed. Thus, it is important to discuss about the perspective of a materials chemist, perhaps the logical thought process that one may go through in his or her everyday life, in terms of delivering the unimaginable with nanotechnology. As far as science is concerned, nanotechnology is all about understanding the unique properties of material at the nanoscale, i.e., 1 to 100 nm, to exploit them in novel technological applications. However, along the process, there are many considerations to be adopted in ensuring the eventual applicability of nanomaterials.

Firstly, it is very important that the synthetic parameters of a given nanomaterial are taken into careful consideration, both in terms of tunability in ensuing properties as well as sustainability. Nevertheless, allowing efficiency in chemical reactivity, controlling particle growth during synthesis, and ensuring the stability of produced nanoparticles are notable challenges to

overcome during nanoparticle preparation. This, however, typically requires the use of strong chemical agents and stringent reaction conditions which collectively facilitate the controlled nucleation and growth of nanoparticles, leading to the formation of morphologically and dimensionally homogeneous, stable nanoparticles. However, the same above factors may deter the eventual applicability of the nanoparticles as the reagents and conditions used during synthesis may result in adverse environmental and/or biological implications, while the presence of any unreacted reagent in the final product, even at minute levels, may result in complication when the many prominent *in vivo* applications of nanoparticles are concerned. Hence, novel, facile, and robust green synthetic approaches, competent of producing homogeneous and stable nanoparticles, are warranted to allow their anticipated applications to be conducted in an effective yet eco-friendly, biocompatible, and safe demeanor.

Secondly, it is well established that the properties at the nanoscale are intricately related to the size as well as morphology of the nanomaterials concerned. Several factors including the variation in surface energy and quantum confinement effects are, in combination, believed to be responsible for such correlation. Of note, as per the definition of nanoparticles, they may be of any shape, as long as there is at least one dimension limited to the nanoscale, enabling a host of morphological variants to be considered as nanoparticles. Hence, the size as well as morphology of a nanomaterial provides a handle in tailoring the properties of nanoparticles according to those anticipated for the eventual application. At the same time, many technological applications require modifications to be conducted at the nanoparticle surface, which are essential for the intended action. For example, in the case of targeted drug delivery via nanoparticles, the drug as well as any suitable targeting moiety would need to be anchored at the nanoparticle surface for the desired action of the composite system. Nevertheless, the optimal capacity at which a material could be functionalized depends on the surface area available and any specific chemistry at the surface. Therefore, it is indeed important to explore the widespread array of morphological variants in understanding how they correlate with the ensuing properties, thereby being able to rationally design and develop nanomaterials for optimal activity.

Thirdly, attaining an understanding on how to optimize nanotechnological applications requires rigorous analysis of the metastability of nanoparticles under ambient application conditions. Although many studies may aim to conduct this via experimentation under such conditions, nanoparticles are highly susceptible to the environmental conditions which may alter their intrinsic stability. Nevertheless, when the stability is lost, nanoscale particles tend to form clusters of material, namely aggregates or agglomerates, thereby causing the original properties

to be lost, hence losing their efficiency, effectivity or perhaps even the applicability altogether. Such subtle variations in the system conditions may result via a multitude of reasons during the application and hence, experimentally optimizing the application conditions for a given nanoparticulate system is far from being achievable. Alternatively, theoretical modelling provides close approximations to the experimental observations, specifically in terms of the transient stability of the nanoparticles under ambient as well at varying system conditions.

Predicting the surface chemistry driven interactions among, and the ensuing stability of, nanoparticles suspended in a medium is, therefore, of primary importance for all nanoparticle applications. Commonly, this is achieved via the classical DLVO (Derjaguin, Landau, Verwey, and Overbeek) theory, or the extended DLVO (xDLVO) theory when non-classical interactions are present, where the stability is predicted by modelling the interactions that exist between pairs of nanoparticles in a given system. The challenge in theoretical prediction of functionalized nanoparticle stability depends on the determination of the individual interactions between nanoparticles with sufficient accuracy. Approximations or assumptions in determining individual interaction potentials, however, are common in nanoparticle stability modelling, often leading to inaccurate predictions. Hence, more attention needs to be placed at carefully looking at the parameters that go into the theoretical calculations and to hence understand any subtle modifications that are deemed important in delivering theoretical predictions at better accuracy.

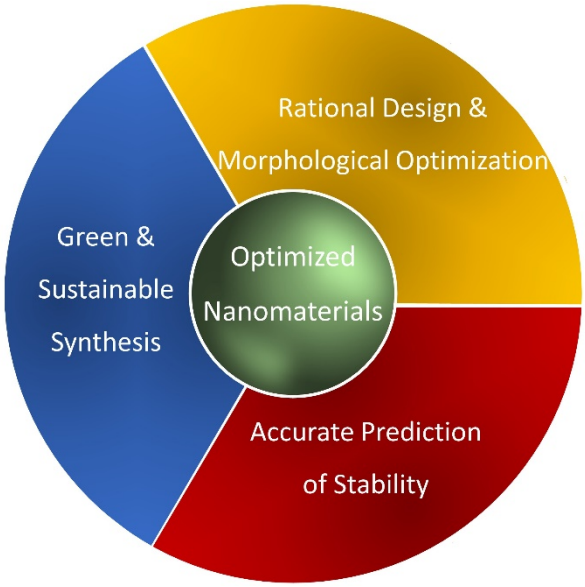

Figure 1. Considerations to be adopted in ensuring the eventual applicability of nanomaterials

Although the objectives described above may not be aligned in the same direction, with perhaps little or no overlap, in-depth and concurrent investigation into each is strongly important in arriving at a realistic understanding that will greatly enhance the efficacy and applicability of a material developed via apt scientific research. Hence, it is important to independently look at each objective, in separate scientific contexts, to explore how green and sustainable synthesis, rational design and morphological optimization, and accurate prediction of stability, in unison may effectively deliver optimized nanomaterials of greater scientific significance as indicated in Figure 1, while the following sections will describe some of our recent work that has focused on such objectives.

Plant Extract Mediated Preparation of Composite Nanoscale Architectures

It would not be an exaggeration to state that one of the most elaborated trends in current research and technology is to 'go green'. Hence, akin to all other disciplines, many of the recent work on nanotechnology had focused on developing green synthetic routes for nanomaterials (Huston, et al., 2021; Singh, et al., 2018). However, much of this work has focused on the development of single-component, simple nanoarchitectures such as nanospheres, while extending green principles into more complex morphological forms, as shown in Figure 2, is relatively less explored. This is mainly because controlling the synthetic conditions, via comparatively mild green reagents and approaches alone, is challenging in producing complex nanoscale architectures. However, composite nanomaterials with complex architecture indicate notably distinct and desirable properties as opposed to simple single-component systems. Hence, it is indeed significant to explore the possibility of adopting greener approaches in effectively producing such systems.

Among the many metals that are widespread in technological significance, gold (Au) and silver (Ag) nanoparticles have been the subject of intense research due to their unique properties and ensuing applicability (Ristig, et al., 2014). The prominent application prospects result from their broad antibacterial spectrum, unique antibacterial mechanisms, theranostic efficacy, and excellent biocompatibility (Dykman & Khlebtsov, 2017; Krutyakov, et al., 2008). Although many advanced applications have been independently realized with Au and Ag nanoparticles, it is certainly intuitive to imagine that combining Au and Ag would likely lead to the formation of composite architectures that exhibit many synergistically improved properties compared to their one-component counterparts (Fasciani, et al., 2014; Lu, et al., 2013; Ding, et al., 2017). As such, core-shell nanostructures of Au and Ag creates an inimitable platform for synergistically harnessing the unique nano-dimensional properties of Au and Ag in many novel applications.

To date, chemically synthesized core-shell nanostructures of Au and Ag have been extensively studied owing to their distinctive applicability in biomedical applications such as *in vivo* imaging, drug delivery, and photo-thermal cancer therapy, etc (Jiang, et al., 2020; Wang, et al., 2019). However, there is an innate need to develop greener synthesis routes for core-shell Au-Ag nanostructures owing to the potential risks to human health posed by the traditional chemical routes to these unique nanostructures.

Nevertheless, the synthesis of bimetallic core-shell architectures is non-trivial. Thus, only a limited number of reports exist on the green synthesis of core-shell nanoparticles containing Au and Ag. Hence, systematic investigations on the possibility of producing Au core-Ag shell (i.e., Au@Ag) nanoparticles in an entirely green procedure are warranted to allow the applicability of these unique nanostructures especially where biological applications are concerned. In our recent work, we developed a novel, inherently safe, green approach for synthesizing Au@Ag nanoparticles using only green tea extract and the metal precursors. The composite here indicated marked distinction in optical properties as opposed to the core Au nanopartlcles, as shown in Figure 3, panels (A) to (C). The tea extract played dual roles of a reducing (for both Au and Ag) as well as a stabilizing agent, thus obviating the need for any auxiliary chemicals during the preparation, stabilization, and storage of the nanoparticles. Microscopic images of the composite material prepared herein indicated the presence of a thick and uniform coating of Ag on the core Au nanoparticle as shown in Figure 2, panels (F) to (I). Furthermore, significant monodispersity and exceptional stability were observed with both the green synthesized Au as well as Au@Ag nanoparticles, even in the absence of any chemical stabilizing agent, indicating the efficacy of the synthetic approach.

According to previous reports (Samal, et al., 2013), the tunability of the dimensions of the core-shell Au-Ag nanomaterials allow the control of their properties for many applications ranging from controlled drug delivery, photoluminescence based bioimaging, biological labelling, and tunable cytotoxicity for specific theranostic applications. Notably, the thickness of the Ag coating in the composite nanomaterial presented here was found to be efficiently controllable by the simple variation of synthetic conditions, giving precise controllability to the developed procedure. Hence, this novel approach was found to be capable of producing a sustainable and biocompatible route for the preparation of Au@Ag nanoparticles applicable in a variety of *in vivo* nanotechnological applications, while the knowledge acquired here could likely be extended to devising novel and sustainable synthetic approaches for the preparation of many other technologically significant composite nanomaterials of core-shell architecture.

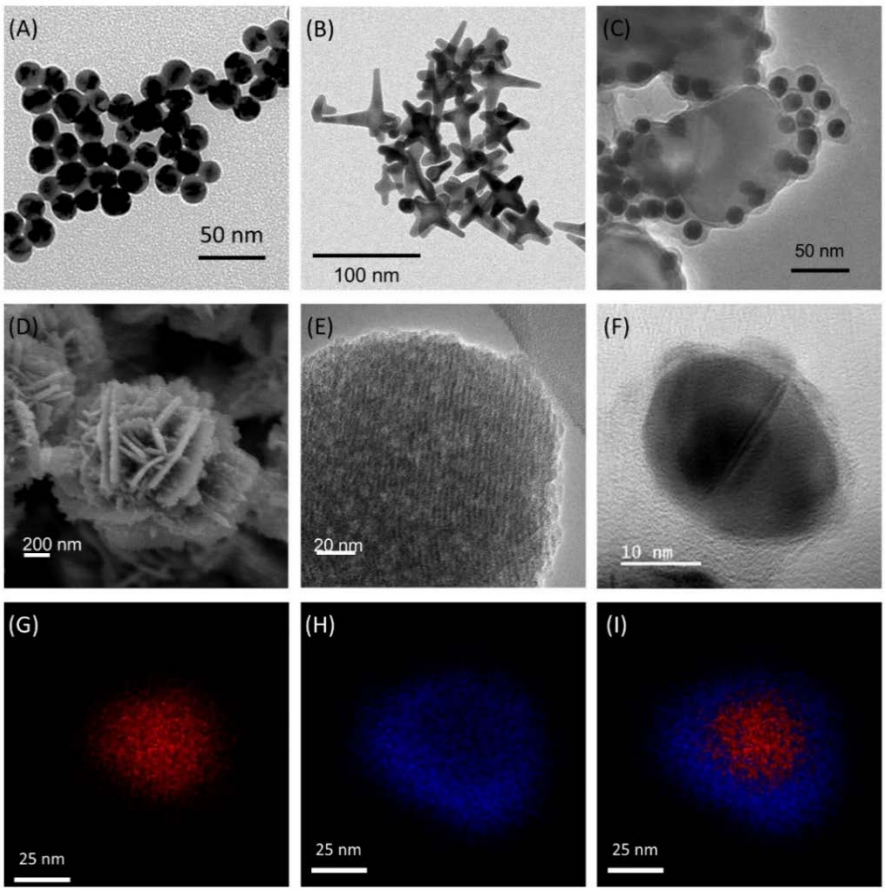

Figure 2. Electron microscopic images of (A) spherical, (B) nanostar, (C) surface-decorated, (D) nanoflower, (E) mesoporous, and (F) core-shell nanoarchitectures produced in the various studies discussed here, and elemental distributions maps for (G) Au (in red) and (H) Ag (in blue) for a core-shell Au@Ag nanoparticle, while panel (I) indicates the overlap in the elemental distributions for Au and Ag for the same area shown in panels (G) and (H)

Agricultural Waste to Fertilizing Nanoparticles: A Paradigm of Sustainable Agronomy

Oryza sativa (rice) is the main agricultural crop in Sri Lanka. The rice plant accumulates and greatly benefits from silicon (Si), where it is deposited beneath the cuticles as a double layer in the form of silicic acid. Si may, in addition, interact favorably with other applied nutrients; hence, improving the agronomic performance, crop yield, as well as the tolerance of rice plants to abiotic and biotic stresses, making it essential in sustainable rice production (Somapala, et al., 2016; Pati, et al., 2016). However, many studies have proven that the association, activity, as well as the transport, of salient nutrients through a plant may change markedly at the nanoscale, while such size-mediated effects of this imperative nutrient in rice cultivation has not been systematically explored thus far.

The hull, or the hard protective layer of the rice grain, is mostly regarded as a bulk-scale waste produced during the post-harvest processing of rice. Nevertheless, it is notable that Si is a prominent constituent in rice hull. Hence, there have been recent attempts to utilize rice hull as a precursor to produce Si nanoparticles. However, such approaches, still being in their infancy, requires further systematic investigations to optimize the nanoparticle preparation, in terms of the ensuing properties such as size, morphology, and porosity etc. as well as the process economies themselves. Notably, if novel, facile, efficient, and scalable strategies could be developed for the preparation of Si nanoparticles from waste rice hull, and the ensuing shape, size, and concentration effects of the same in fertilizing rice cultivations is systematically evaluated, the knowledge acquired would be greatly significant in intensifying agricultural practices, specifically in many developing parts of the world, where rice remains to be a prominent crop.

Hence, recently we focused on the development of a novel method to effectively prepare Si nanoparticles using rice hull as the Si precursor, and to assess the effect of the same in rice cultivation. The work was mainly based on the hypothesis that Si present in rice-hull can be effectively used as a precursor for the facile and scalable preparation of non-porous and mesoporous nano-silica, which can be used as a rich source of Si for the cultivation of *Oryza sativa*, with or without the presence of loaded nutrients, in order to produce notable improvements in plant growth and crop yield. Hence, the overarching objective of the study was to develop a novel and efficient Si based nano-fertilizer for *Oryza sativa* utilizing rice hull as the Si precursor, and to investigate the effect of the same on the growth and crop yield of *Oryza sativa*.

Overall, the study produced a novel, facile and salable approach to prepare homogeneous and significantly stable mesoporous and non-porous silica nanoparticles as shown in Figure 2 (E), using only waste rice hull as the Si precursor. The understanding ensued via the study allowed to elucidate novel, efficient, economical, and scalable methods to produce Si based nano-fertilizer using industrial waste rice hull as a raw material, while simultaneously providing an insight into the mechanistic role of nano-silica in regulating plant growth and crop yield. Thus, the findings of the study delivered a novel application in sustainable agriculture using rice hull, which is otherwise regarded as agricultural waste. Notably, further studies on optimization of the morphology, concentration, nutrient loading, and nutrient release characteristics of the developed material on plant growth and crop yield will allow optimization of the developed technology for widespread agricultural application through ongoing and future work that will follow based on the findings of this study.

Rational Design and Morphological Control of Nanomaterials

Nanomaterial properties are intricately related to the size and morphology of the particles (*vide supra*), as visualized by the optical properties of various morphological forms of nanomaterials shown in Figure 3. Nevertheless, tunability in nanomaterial properties is one of the dominant factors in determining their eventual applicability. For example, nanomaterials are an essential component in many spectroscopic techniques such as surface enhanced Raman scattering (SERS), where the optical properties of the nanoscale substrate are imperative in determining the possibility as well as extent of signal enhancement. At the same time, morphology allows the optical properties of a given nanomaterial to be effectively tuned, and hence, one may aim at controlling the nanoparticle morphology to tune, or perhaps optimize, its optical properties according to the desired application.

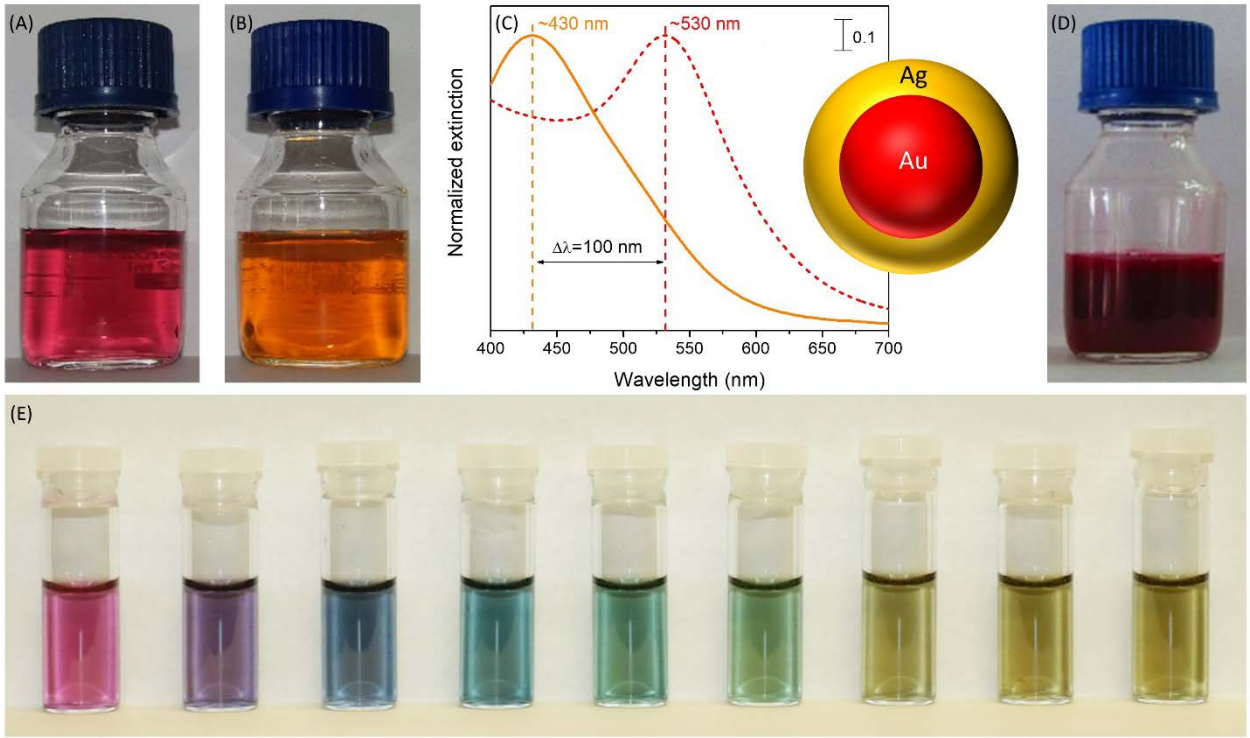

Figure 3. Variation of optical properties of nanomaterials with morphology. Panels (A) and (B) indicate spherical Au and Au@Ag nanoparticle suspensions respectively, while (C) indicates the variation of the localized surface plasmon resonance (LSPR) properties of the Au (red dashed) and Au@Ag (orange) nanoparticles. Panel (D) indicates the appearance of Au@TiO_2 nanoparticles while panel (E) indicates the controlled variation of the optical properties of Au nanostars prepared by varying buffer concentration

Some of our recent work (Harder, et al., 2021) was focused on developing a novel spectroscopic technique of two-dimensional surface enhanced infrared absorption (SEIRA) spectroscopy. As with SERS, the signal enhancements in SEIRA are expected to depend on the optical properties of the primary metal nanostructures. Based on our previous work, we expected that either spikey nanoparticles or nanoparticles with aspect ratios greater than one will exhibit larger enhancements than isotropic structures such as Au nanospheres. Accordingly, we have demonstrated the synthesis of gold nanostars via a simple, seedless, one-pot synthetic procedure, where 2-[4-(2-hydroxyethyl)-1-piperazenyl]propanesulfonic acid (EPPS) is used as the reducing agent as well as the template that drives anisotropic growth as seen in Figure 2 (B). The synthesized gold nanostars indicated plasmonic behavior extending into the infrared wavelengths. Furthermore, the plasmonic properties of these structures could be easily tuned by simply changing the buffer concentration used during synthesis as seen in Figure 3 (E), while the plasmon tuning was manifested via manipulating the nanoarchitectures with varying buffer concentrations, as was revealed by the detailed morphological analysis. Accordingly, the gold nanostars synthesized here indicated promising plasmonic behavior to be utilized in SEIRA as well as other surface-enhanced spectroscopic techniques where the optical properties could be efficiently tuned via rational design and morphological control.

Gardening at the Nanoscale: Harnessing the Beauty of Nanoflowers for Optimal Activity

Semiconducting nanomaterials bear equal importance in technology as their metallic counterparts. For example, zinc oxide (ZnO) nanoparticles have received much attention due to their unique physical and chemical properties such as high chemical and mechanical stability, photocatalytic activity, broad range absorption of radiation, high photostability, high electro-coupling coefficient, and pronounced non-toxicity (Srivastava, et al., 2013; Shi, et al., 2014).

However, the application of ZnO becomes limited, specifically in those that require the activation of the nanoparticles via electromagnetic radiation, while the response of ZnO is greatly limited to ultraviolet wavelengths. A strategy that has been commonly adopted to overcome this limitation is to functionalize the nanoparticle surface with photo-responsive agents that would allow the amplification of the photoactivity of ZnO nanoparticles (Bourlinos, et al., 2006). This strategy, as reported in recent literature has allowed modest improvements in the intrinsic properties of ZnO. However, it is intuitive to believe that the enhancement in the properties here would be proportional to the degree of surface functionalization. Hence, the challenge in hand is to devise novel nanoarchitectures of ZnO with increased surface area such as to allow increased levels of functionalization with a given photo-responsive agent.

Among the many morphological variants of nanomaterials, the spherical morphologies are those that have been widely studied, while their physio-chemical properties and environmental and biological compatibility are well established. Nevertheless, the compatibility of spherical particles is known to be more than their non-spherical counterparts, owing to the higher degree of morphological stability compared to the latter. Thus, it is important to develop novel nanoscale architectures with increased surface area available for functionalization, while being akin to spherical nature. Accordingly, we have developed flower-like ZnO nanoparticles, which are composed of multiple layers of ZnO amassed together, resembling sheets of paper crumpled into a ball. Interestingly, the crevices formed by this architecture provides more surface area for functionalization, while the structures collectively appear spherical as anticipated (Figure 2 (D)). Although similar architectures have been previously reported, the preparation of such requires extreme and controlled conditions (Wang, et al., 2008), thus hindering their applicability. The optimized synthetic strategy developed here, on the other hand, is facile, scalable, and does not require any extreme controlled conditions, offering credit to the work conducted. Initial investigations have indicated that these nanostructures have marked increases in the surface loading capacity as hypothesized, while the studies on the ensuing applicability are currently ongoing.

Combining Nanoscale Architectures for Synergistic Activity

A common and viable approach of engineering nanomaterials for enhanced activity is conjugation of functional molecules at the nanoparticle surface as discussed earlier. Such modifications have well-proven to produce modest improvements in intrinsic nanoparticle properties (Colino, et al., 2021; Trequesser, et al., 2013). Nevertheless, nanoparticulate matter have many distinctive and desirable properties compared to molecular substrates. Hence, we postulated that combining multiple nanomaterials into composite architectures will likely produce a novel platform for synergistic improvement in material properties, as opposed to molecularly functionalized nanoparticles. In this regard, we have looked at conjugating two active nanomaterials into a composite architecture, with the hypothesis that such would lead to synergistic enhancements in the composite's properties compared to that of individual nanomaterials (Perera, et al., 2020).

Hence, titanium dioxide (TiO_2) and Au nanoparticles were prepared separately and eventually combined where the surface of the larger TiO_2 particles could be effectively decorated with the relatively minute Au nanoparticles as seen in Figure 2 (C), giving rise to a red colored milky nanoparticle suspension as shown in Figure 3 (D). This was believed to be more effective,

compared to combining the precursor materials at the synthetic stage, as it allows the controllability during the individual nanoparticle synthesis to prevail, while limiting the conjugation of the smaller particles on the surface of the larger, which is essentially sufficient to enhance the many phenomena which are mechanistically limited to the material surface. Furthermore, adding an extra dimension of novelty to the study, the synthesis of Au nanoparticles here was conducted via a green tea extract mediated sustainable approach.

Overall, the synthesis involved only the metal precursor and green tea, obviating the need for any solvents and/or harsh chemical reducing or stabilizing agents, while the entire procedure was conducted under comparatively mild conditions, allowing notable sustainability to prevail within the synthetic approach. Further experimentation with the Au nanoparticle decorated titania (Au/TiO_2) indicated superior adsorption capacity towards dyes in solution, while the photocatalytic rate constants for the degradation of the same on Au/TiO_2 indicated synergistic improvement compared to bare TiO_2 or Au. Notably, the adsorption capacity as well as the increase in reaction rate observed here were significantly higher compared to those previously reported, while there being no previous accounts of akin sustainable synthetic procedures for the preparation of composite nanomaterials of this nature. Hence, this novel green synthesized Au/TiO_2 nanocomposite shows promising potential for sustainable environmental remediation via efficient contaminant capture and subsequent photocatalytic degradation.

Improved Theoretical Prediction of Nanoparticle Stability

After focusing on an abundance of experimentation, it is probably time to shift gears to look at things in a slightly different perspective. Nevertheless, assessing and controlling the stability of solution-phase nanoparticles is important for exploiting their chemical and physical properties, as well as determining their fate in complex environments. Typically, achieving this control requires considerable experimentation while optimal conditions are attained only after a detailed series of studies varying the nanoparticle composition, size, surface chemistry, surface potential, as well as the solvent composition etc. However, such experimental approaches are extensive and includes the measurement of optical or electrical properties, sedimentation, and structural characteristics since many nanoparticle and medium attributes contribute to the overall stability of the nanoparticles. Alternatively, theoretical calculations are employed using the DLVO, and xDLVO theories where the metastability of the nanoparticles are theoretically predicted, obviating the need for any extensive experimentation.

Predictions using the classical DLVO theory, which describes the stability of two objects in a medium assuming only van der Waals and electrostatic interactions to be present, are often inaccurate. Hence, the xDLVO theory is widely used instead to describe nanoparticle stability and fate as a function of interparticle separation distances under various medium conditions. Previously, contributing xDLVO factors from acid−base interactions, bridging attractions, as well as elastic, hydration, hydrophobic, magnetic, and osmotic parameters had been used to predict and describe nanomaterial stability. Despite these modifications, xDLVO theory often only qualitatively describes the nanoparticle stability observed in experiments. Errors arise from a combination of xDLVO theory interaction potential contributions and limitations to the input parameters for the various xDLVO parameters, as well as from assumptions regarding the chemical environment and nanoparticle morphology.

Approaches to improve the prediction of, and reduce the error in, solution-phase nanoparticle stability calculations date back to the 1950s and continues to date. As a result of both experimental and theoretical approaches, nanomaterials are now synthesized and stored as stable suspensions for months. Despite this success, the predictions of nanoparticle stability often deviate significantly from the experimental results. For example, predictions of the Au nanosphere stability are often qualitatively consistent with experimental results, but the underlying reasons for this stability are not well-described. As the Au nanosphere diameter increases, the stability of these materials has been described as increasing because of a variety of effects including kinetic retardation, surface chemistry, and solvation differences. Although any or all of these may be involved, the relative importance of these contributions remains unresolved by the current models, at least in part, because of uncertainties related to the parameters used as inputs.

In our recent work (Wijenayaka, et al., 2015), methods to refine the values of electrostatic, van der Waals, and steric interaction contributions in xDLVO theory have been considered for improving the predictability of functionalized Au nanosphere stability. Specifically, here the xDLVO theory was used to accurately predict the stability of alkanethiol-functionalized Au nanospheres by uniquely employing the simultaneous inclusion of surface potential estimations in determining electrostatic interactions and a size-dependent Hamaker constant for Au nanoparticles which governs the extent of van der Waals interactions, coupled with a novel approach for estimating and including the alkanethiol monolayer tilt angle for predicting steric interactions between nanostructures as summarized in Figure 4.

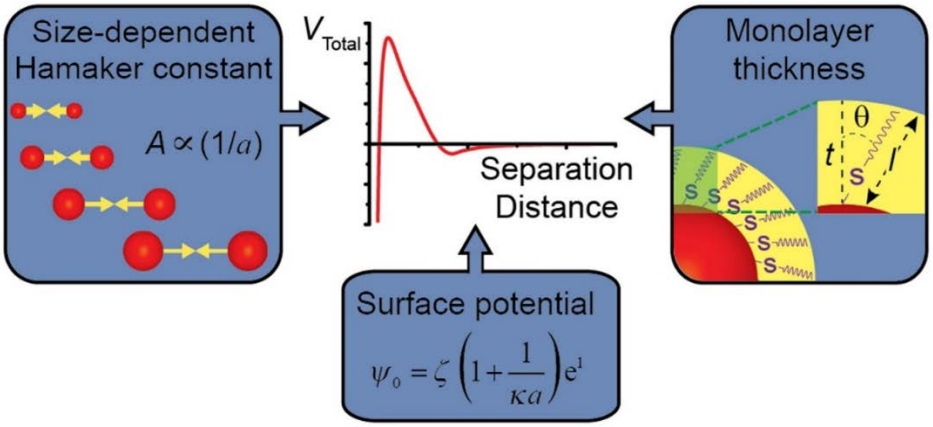

Figure 4. Summary of modifications conducted in refining the electrostatic, van der Waals, and steric interaction contributions to the xDLVO theory, thereby improving the accuracy of theoretical prediction of nanoparticle stability

Eventually, the stability of surface-functionalized Au nanospheres was predicted using the modified xDLVO theory and validated experimentally using conductivity experiments. In more detail, firstly, the electrostatic interactions between two spherical Au nanoparticles were modeled using surface potentials rather than directly using experimentally measured zeta potentials so that this contribution was not underestimated. Secondly, the size-dependence of the Hamaker constant for Au was incorporated into the van der Waals potential so that the attractive interactions between nanospheres were not underestimated. Thirdly, the monolayer thickness was determined empirically, which accounts for both the ligand length and the self-assembled monolayer tilt angle and was used in calculating both the osmotic and the steric interaction potentials.

Based on the reparametrization performed, the experimental results of the conductivity measurements on Au nanoparticles functionalized by various functional moieties provided strong agreement with the predictions of xDLVO theory using the new approaches for determining the parametric inputs to the model. In addition to the strong correlation between experimental observations and the theoretical predictions, the study also resulted in a comprehensive MATLAB based program, inclusive of a simplified graphical user interface as shown in Figure 5, where one could input the parameters concerning a given nanoparticulate system and hence, effectively model and accurately predict the temporal stability of the same. Importantly, this exciting new approach can be readily extended and adapted for nanomaterials of various functionality, morphology, and dimension, thereby allowing the facile tuning of application conditions to optimize the stability and hence the ensuing efficacy of the nanoparticles, which is indeed a challenge to be surmounted in this salient technology.

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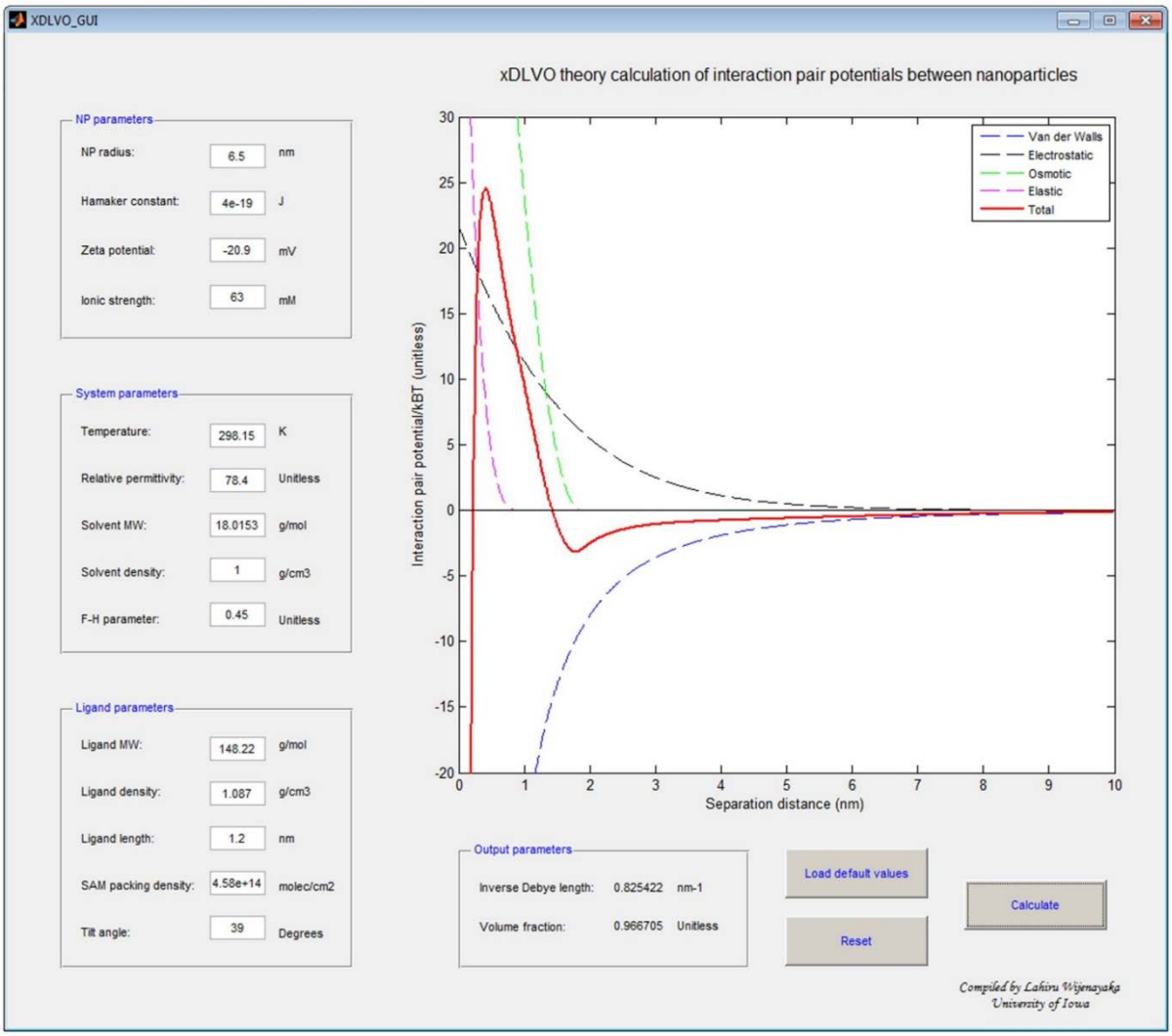

Figure 5. Simplified graphical user interface of the MATLAB based program developed for the improved theoretical prediction of nanoparticle stability via the reparametrized xDLVO theory

So, Where is All This Heading?

Regardless of the abundance of research conducted focusing on nanotechnology, and the extent to which this emerging technology had already proven its potential in changing the landscape of contemporary science and technology, it is certainly the case that there would be many more miles to walk before we may discover the various unorthodox deportments in which it will continue to penetrate, influence, and dominate the sphere of advanced science and technology. Nevertheless, a materials chemist would have a notable role to play in the task of

successfully translating ongoing and future research in nanotechnology into viable social outputs. The above sections have laid out some of the recent work we had conducted in this pursuit of controlling matter at the 'nanoscale', in the perspective of materials chemistry. Overall, the work has emphasized on green and sustainable synthesis, rational design and morphological optimization, and accurate prediction of stability, which in combination are imperative in ensuring the pertinence of any nanomaterial that is produced through systematic scientific research. Hence, the interplay between the findings of the work presented herein, alongside the careful look at how these tiny marvels could be put into novel, eccentric, and advanced applications, would hopefully lead science to discover the unparalleled potential of nanotechnology in transforming the future of the entire mankind, as well as the world we live in.

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Section E3

Ethics in the Metaverse

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The two terms *ethics* and *metaverse* are derived from Greek roots; "*ethos*", meaning way of living (Singer, 2018), and "*meta*", meaning beyond or after, respectively. Metaverse is considered as the universe of universes like metadata refers to data about data (Yuan et al., 2022).

Ethics is about what is right and wrong and what is good and bad. In ordinary language, ethics and morals are often used interchangeably without taking their subtle differences into account. However, there is a difference. Moral refers to expected human behavior whereas ethics is the rational examination of morals (Churchill, 1982). In certain contexts, the term ethics is used to refer to the expected behavior of members in a profession which is known as the code of ethics (Quinn, 2020). Providing a precise and comprehensive definition for ethics is challenging. Hence, it is often explained through examples, analogies, and comparisons with other related disciplines such as religion, law, etc.

It could be said that ethics is what we expect from a person beyond his/her general duty. For example, when a person greets another, it is expected that the second person also greets the former. In a business transaction between a buyer and seller, there are many interactions between the seller and buyer, in addition to exchanging money for goods or services. An ethical seller would inform the product's limitations, precautions to be taken when using the product, the quality of the product, and so on. Likewise, the buyer provides feedback on the product. The expected ethical relationship is clearly visible when it comes to professional relationships. For example, in the case of a medical doctor and a patient, it is expected that a good medical practitioner will consider the long-term health issues of a patient before prescribing medications and advising the patient. Additionally, it is expected that medical information and other information divulged to the medical practitioner would be kept confidential. Placing trust in the other party also comes under ethics. There are various ethical theories to explain ethical or

moral issues. Some are relative to a person, culture, religion, etc., while others are more objective theories such as consequentialism, deontological, social contact, etc. Ethical theories could broadly be categorized into three categories; the utilitarianism-based theories are about the utility of actions while deontological theories discuss the will or intention of the doer. The third category is Nicomachean Ethics that states the correctness or rightness of an action depends on the virtuousness of an individual (Quinn, 2020).

Comparing ethics with the related disciplines is the other method of defining ethics. If you take a very sudden decision without considering and evaluating the facts, such a decision does not fall into the realm of ethics. Laws and ethics overlap in some situations but not always. There are many cases that are unethical but not illegal and vice versa. Both ethics and religion may have either concordant or discordant views on the same matter. Ethics cannot be proved in a scientific manner. However, further advancement might solve many ethical issues and provide convincing arguments on some ethical issues. Ethics might be changed over a period of time. Some cultural practices are considered ethical in some cultures but not in other cultures. Some practices are considered ethical in a certain period of time but considered unethical after some years and *vice versa*.

When talking about the history of ethics, on one hand, it goes back to the era of Socrates in 600 BCE in the West; on the other hand, according to the Agganna Sutra (Anon, 2019), ethics goes back to the era of the beginning of the cultivation of paddy. According to this sutra, there was no “hunting era” between human inception and the agricultural era. When it comes to the code of ethics of professionals, the discussion goes back to 5 BCE when “The Oath of Hippocrates” was presented. In contrast, the Vinaya Pitaka was verbally prescribed between 563 BCE to 483 BCE and was written around 1 BCE. In this context, the history of the code of conduct for particular groups of people might date back even before the time of Lord Buddha. When examining the Vinaya Pitakaya, the basic characteristics of the modern code of conduct could be identified. It prescribed the duties and responsibilities of Sanga, what the lay people could expect from Sanga, and disciplinary procedures for the violators. The disciplinary actions are taken by the Sanga themselves as other professional associations (Journal of Buddhist Ethics, n.d.).

In the past, the professionals who were in positions to do more harm were expected to be more ethical. The legal and medical professions which were considered matured professions are two examples. The Association of Computing Machinery (ACM) and the Institute of Electrical and Electronics Engineers (IEEE) recognized that computing professionals are also in a position that could harm individuals and a code of ethics for computing professionals was introduced jointly

by the ACM and IEEE in 1999 (ACM Ethics, 2018). This code was subsequently amended by the ACM in 2018.

The latest Code of Conduct has given certain guidelines on building IT artifacts (Association for Computing Machinery, 2018). It includes a lengthy discussion on identifying and preventing harm. Section 2.9 gives more power to computing professionals so as not to even implement an information system. It states, "*In cases where misuse or harm are predictable or unavoidable, the best option may be to not implement the system."*

Metaverse has not been precisely defined to date. This could be a parallel space (virtual space) where one can place his/her avatar and sense the feelings of the avatar. In other words, when the avatar is feeling happy, it also makes the owner, who is a natural person, feel happy. It is also possible for the avatar to take autonomous actions which would affect the feelings of its natural counterpart. This could be considered a new universe or an extension of our current universe. Another characteristic of Metaverse is persistence. The artifacts created will remain in this universe and it is also possible to go back to the past. Then obviously change the conditions in the past such that present conditions get changed according to the changes made to the past conditions. This in turn, means that one can change the conditions in the past that would thereby change the present conditions. This could be considered as the mechanism of a time machine.

Metaverse could be considered science fiction. However, recent advancements would clear doubts. The Metaverse will contain many technologies such as virtual reality, augmented reality, artificial intelligence, cryptocurrencies, and social media. One of the major barriers is the brain-machine interface. As of 2018, a system was designed at the MIT lab to order a pizza by just sending a message to a computer. In other words, there was no physical body movement. It is expected that much information could be sent to machines in the coming years without any physical movement of a human. According to IEEE Standards Association (2022), it would be possible to read every action by an implanted chip in a human brain by 2025 and write to the human brain by 2035. In other words, simulating the human brain by externally generated signals. In line with this prediction, it was reported that progress has been made in simulating the human brain by external signals (www.youtube.com, 2022.). Another challenge to advance Metaverse is developing digital objects with properties similar to that of physical objects. It is expected that this challenge will be met by 2027 (IEEE Standards Association, 2022).

In the expected Metaverse, the enjoyment received by the owners of avatars when their avatars meet and have a cup of tea on a nice evening would be similar to the enjoyment gained by owners when they physically meet and have a cup of tea on a similar evening. This platform

could be used for the advancement of many fields such as training surgeons to conduct operations, conducting real operations remotely, designing and experimenting with new products, conducting dangerous experiments in a safe environment, simulating various conductions in the environment to identify the outcomes, visiting remote places and gaining the experience and sense as visiting real places such as visiting underwater caves.

It could be said that “Second Life” is an early version of Metaverse which was launched in 2003 by the Linden Lab. Individuals could build and control avatars in “Second Life”. Thereafter, various organizations presented similar artifacts. For example, Mozilla Hubs, Avakin Life, VRChat, OpenSimulator, and Furcadia.

Many ethical issues are associated with modern technologies. Some of these issues are completely new and others take different forms of existing issues. There are many cases where technology is banned due to geopolitical issues as well as misuse of technology in different cultural settings. One example is the banning of ultrasonic scanning in India (Tabaie, 2017). On other hand, researchers are working on identifying the values of different cultures. A group of researchers from MIT has developed a virtual model called - a “moral machine” in order to investigate how people with diverse backgrounds prioritize protecting people and animals. This experiment is based on one of the classical ethical dilemmas known as the “trolly problem” (Moral Machine, n.d.). The result would help design driverless cars.

When it comes to ethics in Metaverse, there are three sets of issues, the first being accessibility. Would we be able to access this technology? Will everyone in countries like Sri Lanka be able to use it? The second set of questions is about ethical issues in general; irrespective of the country, society, or religion, these are challenging issues. The last set of issues is the placing of ethics and values on other countries, communities, and societies through the Metaverse. The accessibility issue is not going to be discussed here. However, Metaverse is a good opportunity for countries with highly talented youth. If a country could target the right market with the right product, it could bring in billions of dollars. Since the focus of this address is on the last two issues; ethics in general and placing values and ethics in other cultures, they will be discussed in detail.

Since Metaverse is a completely new parallel world, there might be serious privacy and security issues. As mentioned before, some of these issues are universal and hence apply to the entire Metaverse. The Metaverse would gather a huge amount of personal data that includes psychiatric and physiological data such as mood, hormone levels, blood pressure, etc. Therefore, this is a serious privacy issue. Surveillance and surveillance are other issues related

to privacy. Intellectual property and identity are some other issues. Would it be possible for a male physical person to have a female identity in the Metaverse? Likewise, change skin color and other identity attributes. Even though these issues are not new issues in cyberspace, the possible negative impact might be severe due to the nature of the Metaverse. Additionally, avatars are in one global space, but the owners of avatars are geographically and politically divided. Which laws to be applied to the avatar and the owner of the avatar is not certain. Another issue is protecting our children from harmful content and activities. How can we protect an avatar from hijacking? How do we know that we are meeting the avatar of a real person? What about a dead person? Does the avatar commit suicide when the physical owner dies? Can a person have two or more avatars? What are the crimes in Metaverse? Who is going to define illegal activities in this universe? This universe would change the entire landscape; most of the jobs would disappear. For example, if people can get the same level of happiness in a virtual world, there is no reason to travel. A robot nanny could look after a baby. How would it affect the solution to the unemployed issues? One of the solutions under discussion is the minimum wage given by the government. The next question is how people would spend their days without a job.

The ability to control the human brain is the most serious issue along the path to Metaverse. What would happen if additional dopamine was injected into an individual through the hijacked avatar of that individual? Another issue is what would happen if a person always wanted to be happy via the avatar without fulfilling basic human needs such as food and clothes. This is commonly known as “hikikomori”.

There are a few initiatives taken by several platforms that run systems that could be considered to be the early stage of Metaverse. One such implementation was preceding an avatar to come closer to another avatar without the consent of the second avatar (The Guardian, 2022).

When the Internet was introduced to Sri Lanka, it was portrayed as a golden egg. It was told that the people would collect information in a short time period. Therefore, people would make more informed decisions. Furthermore, there is no room to share misleading or false information since the majority would react and update with the correct information. However, today we have witnessed that there is no space for true information on the Internet. Therefore, before popularizing the Metaverse, it is necessary to see the possible local consequences and take actions to minimize or mitigate possible harm.

There might be issues that are specific to particular local settings. It is also a known fact that culture is not a statistic, and that it evolves over time. It is the duty of the community to change

it instead of other communities or tech companies. It is also important to address how these technologies would be used to promote bad practices.

What would happen if a communication platform designed for one community was introduced to another community that has different cultural practices? Some communities have very hierarchical structures and members of these communities address each other using terms that depict the relationships between them. On the other hand, in most of the Western world where society is flat, each one is addressed using the first name except their parents. What would have happened when communication platforms such as Facebook are introduced to communities with hierarchical structures? This would lead to either changing the cultural practices of the community or rejecting the technology by the second community. There are cases of changing the cultural norms instead of rejecting the new technology.

The second issue is that technology is heavily misused in the imported culture. In other words, technology is used to promote negative practices. For example, highly separated communities might use technologies to make the distance wider instead of using technology to come to a common platform. Furthermore, this would be a common platform for those who have extremely negative mindsets. More cyberbullying could be seen in communities where bullying is not severely dealt with.

As we discussed above there are many ethical issues around the Metaverse. Some initiatives have taken place to mitigate or reduce possible harm. One is developing a set of boundaries. The developers must develop Metaverse artifacts within the given boundaries. One example is developing a set of standards for ethically aligned autonomous and intelligent systems (Ethics In Action | Ethically Aligned Design, n.d.). Another one is educating and making sure to follow the professional Code of Conduct designed for Computing Professionals. Another possible approach is developing the ethical sensitivity of developers. Those who have moral (ethical) sensitivity would be able to identify possible ethical issues at an early stage. This would help to mitigate or take less harmful actions.

The IEEE has published a book titled “Ethically Aligned Design - A Vision for Prioritizing Human Well-being with Autonomous and Intelligent Systems” (2018), which discusses how to address ethical issues according to Buddhist, Confucian, and Ubuntu ethics. However, this took Buddhism in a very limited sense and also states that Buddhist ethics do not question what a good life is as questioned in Western philosophy. Furthermore, it states that Buddhism is all about the path to attain liberation. It is argued that IEEE Ethically Aligned Design (2018) has taken a very narrow view of Buddhism and a lot from Buddhism could be learned to regulatory

boundaries in designing, building, and operating the Metaverse and providing a code of conduct for the users. As mentioned before, Buddhism has a code of conduct for Buddhist monks and also disciplinary procedures governed by Sanga themselves. Another salient feature of Buddhism is that once a person becomes a Buddhist monk, that person belongs to a community irrespective of his past identity. In other words, this person gets a new identity. The example given was flowing water from various rivers reaching the ocean. Since once the water reaches the sea, it becomes a part of the sea. Many teachings of the Buddha could be found related to a good life. One is supposed to consider whether a particular action would cause suffering to oneself or another, if it is so, the action is not recommended. In another instance, the Buddha preached that an action should not be taken if that action leads to suffering oneself at this moment or future. These could be considered ethical theories and also used to develop the ethical sensitivity of individuals. These two propositions are very similar to the principles of Utilitarianism. Compared with deontological theories, the Buddha has stressed the importance of the intention of an individual in deciding whether an action is right or wrong. The entire life of the Buddha is virtuous and very much aligned with the Nichomachean ethics of Aristotle. Both Aristotle and the Buddha discussed the importance of having the middle path during the same period. Buddhism recognizes the importance of protecting information privacy. Once the Buddha met a Sigalaka, the qualities of a good friend were mentioned. One of the qualities is protecting the secrets of a friend. In other words, not divulging the secrets of your friend (www.accesstoinsight.org, n.d.). This recognizes that individuals might have secrets that need to be protected. Furthermore, the ability of a person to decide whom to share the secret with. This is the core foundation of data protection. Buddha also emphasized the importance of the right to be left alone when going to a forest due to the noisiness of some monks.

The above-mentioned points are a few points taken from the Buddhist texts. From these examples, it should be evident that there is a lot to learn from Buddhism in developing ethical and regulatory frameworks and guidelines for the Metaverse. In order to make a contribution, it needs intellectuals who are aware of further technological advancements, underlying technical and philosophical underpinnings, and the fundamental teaching of the Buddha. In the end, it is stressed that technology should not be covered with Buddhist icing as done almost everywhere in Sri Lanka.

The Sri Lanka Association for the Advancement of Science (SLASS) and its sectional committees could take the initial step by organizing study groups on various ethical aspects in the Metaverse.

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Section F

Sri Lanka's Future: Towards a Blue Economy

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Background

As a small island developing country, the ocean has had a strong influence on the culture, beliefs, and values of the people of Sri Lanka. The strategic location of the country, on the margins of the east-west naval route, has also made it the home of immigrants of different cultures and religions and attracted the attention of world superpowers as an avenue for expanding their jurisdiction over the marine space. Amidst all these influences lie colossal amounts of oceanic resources offering bounteous opportunities for strengthening the country's economy and improving the wellbeing of the people. As "small island developing nations" (SIDs) are now confronted with a grave resource crisis due to their small resource base, they are increasingly shifting their focus from green to blue economic growth.

The ongoing economic crisis in Sri Lanka is one of the worst crises that the world has witnessed in recent times. Sri Lanka's real Gross Domestic Production (GDP) is expected to fall by 9.2 percent in 2022 and a further 4.2 percent in 2023. In July 2022, inflation in the country hit a record high of 54.6 per cent while food inflation rose to 80.1 per cent. Sri Lanka's GDP is expected to contract by -8.8% in 2022 and the unemployment ratio by more than 5.5%.

Our Resources and Potential

Sri Lanka has 1,620 kilometers of coastline and has territorial waters of 21,500 km^2. It has an exclusive economic zone of 517,000 km^2, which is almost eight times the country's land area (Figure 1). This coastal and marine environment harbours a variety of natural resources and

ecosystems, such as coral reefs, seagrass beds, mangrove forests, lagoons, beaches, salt marshes, and estuaries. The literacy rate of Sri Lanka for 2020 was reported at 92.38%.

The future prosperity of Sri Lanka depends on how well we control our geographical location as a sea hub and utilize the marine resources effectively in the surrounding sea. Our location in the Indian Ocean has shaped our history over a long period of time and will continue to do so in the future. New consumer markets are emerging all across Asia and the major economies of China, Japan and India contribute to the growth of maritime activities in the busy **east-west shipping route,** which is only a few nautical miles south of the island. On this route, more than 150,000 ships annually carry two-thirds of the world's oil supply and a half of the total ocean freight. Furthermore, Sri Lanka has the jurisdiction for its seabed resources up to 200 nautical miles and we have claimed beyond 200 nautical miles under the United Nations Convention of the Law of Sea since geographic conditions support our river sediments reaching far beyond.

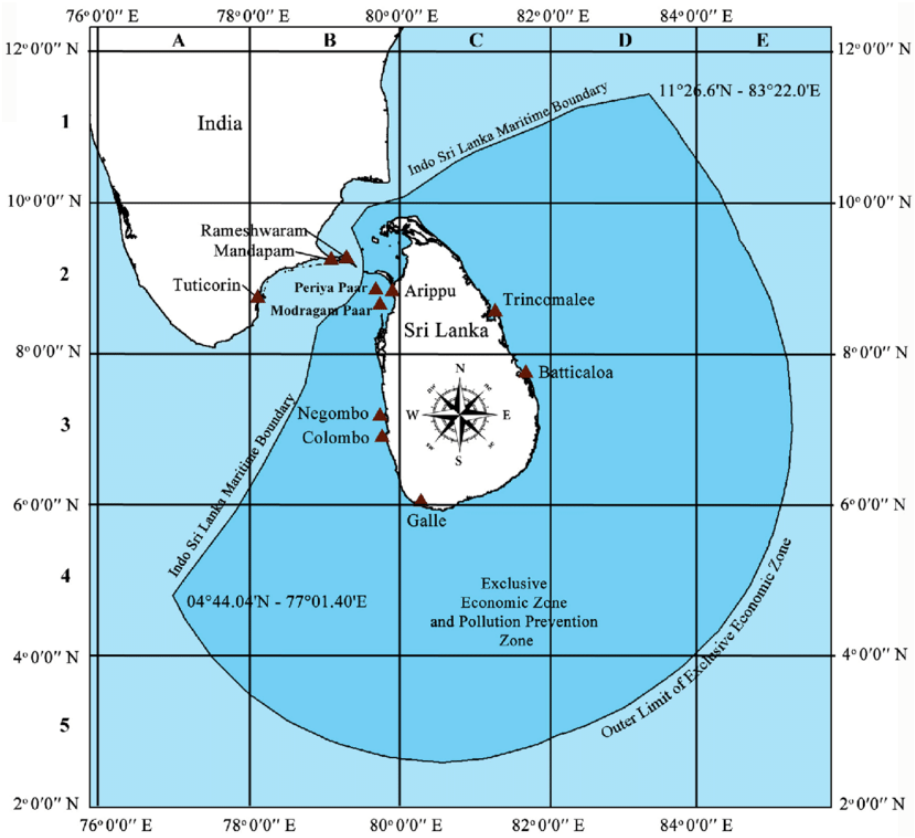

Figure 1. Map of the Sri Lankan Exclusive Economic Zone (Source: Maritime Boundaries Geodata Base, Flanders Marine Institute)

Blue Economy Concept

Blue Economy is a fairly new concept, having been first spoken of in 2012 and developed thereafter (from 2014 onwards) with its inclusion in the Sustainable Development Goals. Goal 14 of the Sustainable Development Goals expresses the 'Blue Economy' concept while Agenda 2030 identifies the importance of 'life under water'. Rio+20 marks the first instance where the phenomenon of 'Blue Economy' was raised in an international platform. The ideology behind the concept is that oceans, being the common heritage of the human kind, represent the man's quest for sustainable development.

"Blue Economy" serves as an umbrella term for a number of economic activities that promote inclusive growth and environmental sustainability, such as ocean-based renewable energy, fisheries, aquaculture, mariculture, maritime transport, tourism, and waste management. UNESCO defines Blue Economy as "the decoupling of socioeconomic development through oceans-related sectors and activities from environmental and ecosystems degradation". Apart from traditional oceanic activities such as shipping and tourism, blue growth also entails off-the-coast energy generation, marine aquaculture, sub-marine mining, biotechnology, bioprospecting, marine tourism, etc. Also included are services such as carbon sequestration, coastal protection, and biodiversity, which are not yet captured by the market.

World's Outlook

As the UN Secretary-General said in his letter to Heads of States and Government when inviting them to participate in the 2022 UN Ocean Conference, the ocean is home to up to 80 per cent of all life in the world. It contributes to the social and economic well-being of people by playing a significant role in poverty eradication, shipping and trade, climate resilience, food security, job creation, and the sustainable Blue Economy. For instance, the ocean food sector provides up to 237 million jobs globally and provides key nutrients and protein to over 3 billion people. In fact, food from the sea is the primary source of protein to over 50 per cent of the population in the least developed countries. Coastal and marine ecosystems contribute up to 11.5 billion USD to global tourism, while also protecting our coasts from storms and floods, providing habitat for biodiversity, carbon storage, and detoxification. In terms of the global economy, around 90 per cent of all internationally traded goods are shipped by sea, and the market value of marine and coastal resources and industries is estimated at USD 3 trillion per year or about 5 per cent of the global gross domestic product. Sustainable use of

ocean, seas and marine resources, as set out in SDG 14, lies at the center of a sustainable Blue Economy, though common principles are yet to be determined.

The seabed provides for 32% of the global supply of hydrocarbons and contributes to the global tourism industry. Developing sustainable coastal tourism is beneficial to the Blue Economy. In 2015, coastal tourism is 8.5% of the world tourism industry. However, only 5-7% of the ocean has been explored to date; thus, the potential for expansion and development is vast. Advancing technologies are opening up opportunities for activities ranging from bio-prospecting of the oceans to mining of seabed mineral resources and for extracting oil and other bio gases as well as renewable 'blue energy' sources like wind, tidal, thermal and biomass.

The Blue Economy, also known as the sustainable ocean-based economy, comprises a range of economic sectors and related policies that aim at fostering economic and social progress while maintaining the health of our oceans and coasts.

Where We Stand

People in Sri Lanka get about 50 percent of their animal protein from fish, which is about three times the global average. Although, according to the Food and Agriculture Organization (FAO), nearly 50% of the seafood consumed worldwide comes from aquaculture, over 90% of Sri Lanka's seafood is still caught wild. The fishery sector's contribution to the GDP is 1.3% (Marine sector = 1.1%). Coastal and marine fisheries provide full- or part-time, direct or indirect, employment to some almost 1 million people in Sri Lanka and support the livelihoods of another 3.6 million Sri Lankans. Table 1 shows the fish, dried fish, and canned fish production and the country's requirements. As shown in it, though Sri Lanka is an island, we still import part of our fish requirement from other countries spending scarce foreign exchange.

As mentioned earlier, the 'Blue Economy' concept covers a wide range of activities which can be identified by their geographical locations and sectors and specializations. The potential of the Blue Economy ranges from fisheries and aquaculture to renewable ocean energy to marine biotechnology to tourism and coastal management. The taxonomy of the Blue Economy and observations on each sector are given in Table 2.

Table 1: Fish production in Sri Lanka

	Requirement	Production	Remarks
Fish production		331,675 metric tons (Marine) and 104,235 Metric tons (inland)	Price variations – Sri Lanka imported USD 218 million worth of fish.
Canned fish	275,00 tins per day	220,000 per day	Importing from other countries
Dried fish	90,000 Mt annually	55.000 Metric tons	Importing from other countries

As Table 2 shows, there is great potential in the area but lack of knowledge, skills, and fund limitations are key factors affecting engagement in the Blue Economy sectors in Sri Lanka. Meanwhile, religious beliefs, cultural practices, and attitudes of the people involved in fisheries and marine-related sectors also affect development in these sectors.

Table 2: Taxonomy of Blue Economy Sectors and Activities

Sr. No.	Sector	Activities	Remarks
1	Fishing	Capture fishery, aquaculture, sea food processing	- Fish price is high - Quantity is not sufficient and import dry fishes and processed sea food from other countries - Mostly traditional knowledge is applied - Modern Technology is not used at a satisfactory level - Cultural and religious barriers There is a huge potential for 'Mariculture', 'Sea weed Culture' and 'Sea cucumber culture' -Lack of skills -Lack of knowledge -Lack of funds for research -Lack of funds for purchasing machinery and equipment

2	Marine Biotechnology	Pharmaceuticals, chemicals, sea weed harvesting, seafood products, marine derived products	Much less developed sector in Sri Lanka -Lack of skills -Lack of knowledge -lack of funds for research -Lack of funds for purchasing machinery and equipment
3	Minerals	Oil and gas, deep sea mining, exploration of the rare earth metals and hydrocarbons	-Resources are available - Untouched sector in Sri Lanka due to -Lack of skills -Lack of knowledge -lack of funds for research -Lack of funds for purchasing machinery and equipment
4	Marine Renewable Energy	Off-shore wind energy production, wave energy production, tidal energy production	Off-shore wind energy production is found to be not at a satisfactory level. Other activities are not done due to -Lack of skills -Lack of knowledge -Lack of funds for research -Lack of funds for purchasing machinery and equipment
5	Marine Manufacturing	Boat manufacturing, sail making, net manufacturing, boat and ship repair, marine instrumentation, aquaculture technology, water construction, marine industrial engineering	Activities are going on but at unsatisfactory level due to -Lack of skills -Lack of knowledge -Lack of funds for research -Lack of funds for purchasing machinery and equipment -Government policy decisions, experts are hired
6	Shipping, Port and Maritime Logistics	Ship building and repairing, ship owners and operations, shipping agents and brokers, ship management, liner and port agents, port companies, ship suppliers, container shipping services, stevedores, call-on, roll off operations, custom clearance, freight forwarders safety and training	Except ship building other activities are going on at a moderately satisfactory level. The government's rules and regulations are not user friendly and practical. Developed ports are not utilized properly.
7	Marine Tourism and Leisure	Sea angling from boats, sea angling from the shore, sailing at sea, boating at sea, water skiing, jet skiing, surfing, sail boarding, sea kayaking, scuba diving, swimming in the sea, bird watching in coastal areas, whale/dolphin watching, visiting	Overall, a lot of activities are going on. This sector can be easily developed. -Lack of skills -Lack of Knowledge -Lack of funds for purchasing machinery and equipment

		coastal natural reserves, trips to the beach, seaside and islands	
8	Marine Construction	Marine construction and engineering	Much less developed sector - Lack of skilled human resources - Government policies and procedures
9	Marine Commerce	Marine financial services, marine legal services, marine insurances, ship finances and related services, charterers, media and publishing	In adequate knowledgeable human resources. This sector can be easily developed
10	Marine ICT	Marine engineering consultancy, meteorological consultancy, environmental consultancy, hydro-survey consultancy, project management consultancy, ICT solutions, geo-informatics services, yacht design, submarine telecom	-Inadequate human resources -Lack of skills -Lack of Knowledge
11	Education and Research	Education and training, R & D	-Inadequate trainers and experts -Lack of skilled staff -Lack of funds for research

Way Forward: Facing the Challenges

a) Need of a policy direction

In order to meet the objectives of Goal 14 of the sustainable development goals (the SDGs) for the 2030 agenda, Sri Lanka must adopt measures that are efficient, sustainable, and suitable. For an effective plan for the purpose of acting, there must first be a national maritime policy. Lack of a national policy and therefore a national strategy to deal with the ocean can lead to inefficiency and unaccountability on the part of the authorities paving the way for misapprehensions of the process. When adopting a national Blue Economy policy, Sri Lanka can learn from Mauritius and Seychelles who have successfully adopted the Blue Economy as “small island developing states” (SIDS) in the region. Though Sri Lanka does not come within the ambit of SIDS, lessons can be learnt from their practices on the fishing industry and tourism.

While focusing on a policy and national strategy on blue economy, it is also necessary that the existing oceanic activities are revised and accustomed to incorporate sustainable, efficient measures. As one of the busiest ports in the region, Colombo can recommend Triple E class

(economy of scale, energy efficient and environmentally friendly) vessels to come into operation. More than 2/3rd of the global seaborne trade is routed through the Indian Ocean and Sri Lanka's geostrategic location gives immense potential for port and shipping services. By imposing more systematic, target-oriented and futuristic policies and regulations, the services can be enriched.

It is also believed that under an appropriate policy direction, people's engagement in the fisheries and marine sector can be enhanced and the 'Blue Economy' sector can be further developed.

b) Human resources development

Table 2 shows that we have not efficiently and effectively utilized our geographical location as well as the natural resources in our ocean for the future development of the country. We, as a nation, need to reposition our country to maximize these advantages. To fully tap this potential, Sri Lanka needs to develop its human resources and, hence, the relevant higher educational or vocational institutions in the country must equip themselves to cater to this important task. Among the key factors impeding the 'Blue Economy' development in Sri Lanka are lack of skills, knowledge, inadequate fund allocations, and inadequate policy directions.

With the type of training offered, I am sure the Ocean University will produce graduates and mid-level managers who are accomplished and competent to take up employment in the newly emerging sectors and to address the diverse oceanic issues such as resource degradation, unsustainable fishing practices, pollution, and adverse impacts on other sectors, such as the displacement of small-scale fisheries while working towards securing a sustainable ocean ecosystem.

c) Use of modern and advanced technology

This necessitates training the youth of this country to take up new challenges that emerge from this growth process, a function that the Ocean University of Sri Lanka has covenanted to perform. Focusing on key areas such as fisheries and marine sciences, and marine engineering and management, the Ocean University has undertaken to train the future decision makers and managers, offering ample learning and training opportunities through the undergraduate and post-graduate degree programmes, and vocational training offered by its training centers spread out right across the country.

d) Tourism development

The flora and fauna of the Indian Ocean provide the biggest opportunities for tourist investment in the region but it is necessary that all activities are monitored to ensure optimization. Coastal tourism accounts for 70% of the total tourism infrastructure in the country. While coastal tourism can be expanded to new heights, there must be regulations in place to manage the activities and control the quality of the services. It must always be borne in mind that the activities should not disturb the development of the natural marine-cycle or break apart the habitat. Coastal management should be a major component of the Sri Lankan blue economic policy.

Developing sustainable coastal tourism is beneficial in the Blue Economy. In 2015, 8.5% of the world tourism industry amounting to US$ 670 billion was from the India Ocean Rim Association (IORA) region. Water-based tourism and leisure-based activities which foster smart, sustainable and inclusive growth should therefore be implemented. Sri Lanka currently has a wide array of leisure and pleasure activities based on coastal areas but the endurance of the same is questionable. For example, whale watching in the Northwestern and Southern provinces of the country has gained much popularity over the recent years.

e) Renewable energy

According to the International Energy Agency, the global primary energy demand would increase by 40% by 2030 and Asia and Middle East are predicted to be major contributors (IEA, 2015). In Sri Lanka, wave, solar, wind, and hydroelectric energy can all be generated with the available resources in the country. What we need is proper research, development, and implementation. Experiencing two monsoons throughout the year, Sri Lanka has great potential for tidal and wave energy along the southwest and northwest coasts.

f) Research and development

While improving the existing measures and adopting new sustainable measures, the country must also invest in research and development. Since Blue Economy is a new concept, research in the area is very much needed. In order to introduce marine biotechnology or marine technology, the technological know-how must first be brought into the country.

g) Regional corporation

It is necessary that in order to move ahead with sustainable oceanic activity, there must be effective regional cooperation since the goal is to prevent a tragedy of the commons. It is therefore vital that challenges and issues are identified and addressed. Sri Lanka's ongoing conflict with India over the International Maritime Boundary Line in the Palk Bay and Gulf of Mannar prevents the two countries from identifying the common goals of the Blue Economy. The unhealthy practice of bottom trawling by the Indian fishermen causes severe harm to the marine eco-system.

i) Climate change

The excessive release of greenhouse gases and the increase in surface temperature are leading to the melting of the glaciers, thereby raising the sea level. Along with the rising sea levels, changes in surface sea temperature would directly affect salinity, ocean acidification, thermal stress, and the aquatic cycles. These changes will affect the fisheries distribution and migration leading to a break in the marine eco-cycle. These natural phenomena along with overexploitation and pollution are a cause for concern for the fisheries industry. Rising sea levels would eventually lead to a depletion of the coastal area of the land, thereby affecting more than 25% of Sri Lanka's population. With an annual population growth rate of 0.9%, the pressure on the land-based resources is increasing exponentially and the strain will only intensify with the reduction in land area due to rising sea levels. This can only pose issues for the coastal community as they will be bereft of social, economic, and food security. If solutions are not found for these issues and they are allowed to continue for a prolonged period of time, there is bound to be an alarmingly real risk of the coastal community being hurled into illegal oceanic activities like piracy and trafficking.

Although a member of the IORA, Sri Lanka has not taken any initiative at the national level to address the global challenge of climate change. As 25% of the country's population depends on the coastal economy, Sri Lanka must ideally take effective policy measures and initiatives to uphold the Blue Economy. The advantageous location and circumstances of the country must be used tactfully to economically enhance the country. However, lack of interest, knowledge, awareness, and differing priorities have so far prevented successive governments or as well as the various authorities in charge from taking any initiative in this direction. With Sri Lanka's marine territory and the willing and able coastal population, the nation must take steps to combat global warming and climate change at the initial stages, which is right now, rather than looking for fixer-uppers after tragedy strikes.

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