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IMPROVING COMPETENCES OF ENGINEERING GRADUATES THROUGH STUDENT INDUSTRIAL SECONDMENTS

A STUDY IN EAST AFRICA

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Foreword

Engineering practitioners are important for technological change and innovation in our societies. They design, operate and oversee manufacturing processes, construction projects, public works and transport systems. They also provide technical assistance and advice in activities of innovative and productive nature in agriculture, business, industries and logistics. They monitor, assess, and continuously improve complex systems that we find in modern societies, systems that combine scientific applications, human factors, and economic and physical considerations. They also participate in educating, inspiring and supporting innovative solutions that serve people in various ways.

Technological change and innovation activities, in which engineering practitioners participate, are important for economic growth and sustainable development. Historical evidence establishes strong links between improved technological capabilities of countries and high human development indicators. Historical evidence also shows that seminal advances in human development in the 20th century were largely attributable to technological improvements and breakthroughs in different sectors (e.g. health and hygiene, agriculture, transport, etc.). Global debates in international development have now moved from the notion of 'science, technology and innovation as by-products of development' to 'science, technology and innovation as vehicles of development'.

Therefore, countries and regions that are currently striving to increase their development are keenly interested in advancing technological change and innovation. East African countries are among those countries. One clear way of achieving their goal is producing more engineers. And yet, there is clear evidence that a significant number of engineering graduates fail to be productively employed.

The project reported here sought to identify challenges to the employability of engineering graduates in East African countries – particularly Tanzania, Uganda, Rwanda and Kenya – and then explore possible remedies and mitigations for these challenges. Given that the increase of competent engineering practitioners in the national labour force is important for development, this topic is of relevance not only to academia and industries, but to governments and policymakers as well.

Report authors
1 January 2022

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The authors maintain that the views and conclusions in this report do not necessarily reflect those of IDRC or any of the persons and organizations mentioned above.

Executive summary

Relative shortage of engineering practitioners in sub-Saharan Africa has been reported as a major concern in many studies on industrial and technological development of the region. However, the region simultaneously records a significant number of existing engineering graduates who find it difficult to find employment in engineering fields. While that situation reflects the inability to absorb human capital in industrial processes, it can also be partly explained by a relative deficit (real or perceived) in the competency of local engineering graduates in the ever-advancing areas of science, technology, engineering and mathematics (STEM), and/or a scarcity in opportunities to hone and demonstrate competency of local engineering graduates in the labour market. Consequently, local engineering graduates have inadequate hands-on experience needed in industries as well as for establishing start-up engineering firms/businesses. To address this situation, it was postulated that promoting engineering student industrial secondment (SIS) programmes can be a suitable approach to strengthening the linkages between engineering education, practice and employability. Since completing an academic engineering course is apparently not enough by itself to bridge the skill gap and prepare engineers to enter their countries' engineering practice fields, and the currently existing student industrial placements seem to have some serious flaws, the present study was launched with the aim of exploring best practices and for evidence-based policy learning in establishing and running robust engineering SIS programmes coordinated between universities and industries. Using innovation systems and systems thinking as conceptual and theoretical frameworks, the study included undertaking surveys in Tanzania, Kenya, Uganda and Rwanda, in addition to action research by piloting four SIS placements in Tanzania and Rwanda, the main objective being to observe closely, try potential models, and learn from and synthesize effective SIS experiences.

The findings of the study are broad, being more detailed in some countries than others. In Tanzania, the research team was able to get more information and talk to many informants, given that STIPRO is based in Tanzania as a registered research organization, and has broader established connections with academia, industry and public institutions in the country. It was therefore easier to get more information and insights, (in the form of documents as well as interviews from government, academia and industry – the 'triple helix'). For the other countries, the research team mostly relied on documents and public information that were openly shared by informed personnel in universities and science councils.

Similarities were observed across countries regarding experiences with student industrial training programmes and initiatives – the models, the challenges, and the feedback and perspectives of stakeholders. It was hence noted that SIS models are the same and have been like that since engineering departments were established in most of the East African region. These models worked well in the past, with limited numbers of engineering students and effective involvement of the public sector in securing useful SIS experiences. Currently, the circumstances have generally changed, but the models have remained the same, which causes stress to the old system and creates poor outcomes.

All four SIS pilot placements were completed, and student reports duly reviewed and approved by the respective industry and academic supervisors, were submitted. Across the board, students and industrial and academic supervisors reported a positive return from the SIS placements. The students' reports show similarities in two aspects: an increase in employable skills and an increase in confidence in being employable. General characteristics and patterns were revealed through this study. The four East African countries share many similarities, in history and in current challenges in university-industry interlinkages, making them a good example of a regional 'engineering ecosystem' that exists along national ecosystems as well. The study's findings support that SIS placements of a longer duration than currently practised help increase the employability of engineering students but, in view of the small number of placements, further evidence is needed.

1.0 Introduction

While there is a relative shortage of engineers in East Africa, there are equally many graduate engineers who do not find employment in their fields. It is also common that foreign agencies involved in engineering-related activities in the region (as private companies, NGOs or international agencies) resolve to hire expatriate engineers before employing local engineers, citing lack of competency and knowledge of industry standards among local engineers, particularly among the young and early-career ones. For instance, a study on local technological capabilities and foreign direct investment in Tanzania, carried out by STIPRO in 2011, indicated that one of the reasons for the weak linkages between local firms and multinational enterprises (MNEs) operating in Tanzania (as foreign direct investment firms) was a common concern among MNEs about the limited capacities of local firms (and their labour force) to engage with MNEs in activities that transfer technological capabilities (Diyamett, Ngowi, and Mutambala 2012). A logical question arises from these two realities: if significant numbers of the existing engineering graduates find it difficult to find employment in engineering fields, how can it be concluded that African economies require more engineering graduates for their development? There must be a gap that is responsible for this dissonance.

Improving the status of engineering endeavours in sub-Saharan Africa in research, training, employment, standards, etc. is positively related to sustained economic development as defined by the Sustainable Development Goals (SDGs) 8 (Decent Work & Economic Growth) and 9 (Industry, Innovation & Infrastructure), particularly for its contribution to strengthening the capacity of the industrial sector which is critically needed to sustain economic growth. The same endeavour would also contribute to achieving SDG 4 (Quality Education) which is aimed at ensuring that all learners acquire the knowledge and skills needed to promote sustainable development in their private and public lives. Given their broad reach and involvement in modern societies, engineering fields can be linked to almost all the SDGs, either directly or indirectly. Yet, even when we look at the importance of engineering from the angle of economic growth, we find that there are visible correlations between GDP per capita and the number of engineering practitioners (EPs) per 100,000 persons in countries – countries that have a larger number of EPs also happen to be those with higher GDP/capita (see Table 1). A global study in 2016 found evidence to support a strong, positive link between engineering strength[1] in a country and both GDP/capita and investment/capita (Cebr and Royal Academy of Engineering 2016). The same study quotes Prof. Calestous Juma, of the Harvard Kennedy School, mentioning that "you cannot have an economy without engineering…" (p. 10).

Knowledge deficits in science, technology, engineering and mathematics (STEM) in East Africa have been partially documented, and they are both quantitative and qualitative (Mohamedbhai 2016). Besides the challenge of skilled labour size, the problem with enhancing engineering ecosystems in Africa is twofold: the relative knowledge deficit

[1] Engineering strength in countries was measured according to an index named 'engineering index' (Ei), which is defined as 'a measure of country's ability to conduct key engineering activities in a safe and innovative way'. Components of Ei concern the size and quality of: digital infrastructure, engineering industry, infrastructure, knowledge, labour force, and safety standards (Royal Academy of Engineering 2020).

(real or perceived) in competency of engineering graduates in ever-advancing areas of STEM, and the scarcity of chances to hone and demonstrate that competency in the labour market.

One practice that has a positive contribution in preparing engineering students for employment after graduation is student industrial secondment (SIS) programmes. SISs are temporary placements of college and university students in relevant industries where they receive direct on-the-job training, with actual work responsibilities. Besides getting to put what they learned in classes and labs into practice, thus honing their theoretical attainment with practical experience, SIS placements allow students to gain tacit knowledge and an appreciation for additional important employability skills that are not often taught in academia (e.g. teamwork and professional communication, performing under real-world pressures, dealing with operational and logistical constraints, and meeting industrial standards). In both developed and developing countries, correlations have been found between engineering SIS programmes and increased employability of STEM graduates (Friel 1995; Hackett, Martin, and Rosselli 1998).

Table 1: Correlation between countries' GDP/capita and EPs per 100,000 persons

Country	Approx. GDP/capita US$	Approx. EPs/100,000 pop
Seychelles	14,000	500
Mauritius	11,000	400
Botswana	7,500	275
South Africa	6,000	200
Eswatini	3,500	140
Zambia	1,700	75
Tanzania	1,000	70
Mozambique	500	35

Source: SADC 2019; Mohamedbhai 2021

It was in light of the above that STIPRO, with the support from IDRC, initiated a project to explore best practices in running robust engineering SIS programmes coordinated between universities and industries. The project was carried out in three main phases: (I) surveying of SIS best practices in East Africa and other developing countries, (II) action research by piloting long-term SIS placements, (III) synthesizing the findings and widely disseminating the results to stakeholders.

In this report, after the executive summary and introduction, a literature review of engineering education in East Africa, and experiences of SIS in Africa and other parts of the world is presented. The report then outlines the design of the project and its implementation. This is followed by the findings from phase I of the project (country-specific surveys) and from phase II (pilot SIS placements). Dissemination of the findings then follow (phase III). Finally, after the section on discussion, the report ends with conclusions, recommendations, and suggestions for future research.

2.0 Engineering education in East Africa

2.1. Historical development

Engineering education in East Africa began later than many other disciplines at the post-secondary level. Post-secondary education institutes started with social sciences, and as the need for more local engineering practitioners appeared – especially after political independence from colonization – engineering education was introduced. The formation of the East African Community (EAC) in 1967, shortly after independence, helped to unify the education system across the countries of the EAC, especially as higher education institutes were not that many (Despres-Bedward, Ibrahim and Newfield 2015; Kumar, Ochieng and Onyango 2004). At the time, engineering students from Tanzania and Uganda used to study at the University of Nairobi, Kenya, which served as the engineering school in the EAC.

> "Kenya went ahead in 1985 to introduce a Canadian system of education: 8 years of primary education, 4 years of secondary, and 4 years in the university (8-4-4). The 8-4-4 system of education then discouraged students from Tanzania and Uganda who by that time formed the highest population of international engineering students in the University of Nairobi. This resulted in a further decrease in the number of the international students whose population was already dwindling after the collapse of the EAC. Following the collapse of the EAC, there was a need for the other EAC countries to strengthen or start engineering programs in their own universities. Tanzania, therefore, through a collaboration with Germany and Norway, put in the University of Dar es Salaam (UDSM) not only the most well-equipped engineering laboratories in East Africa but also the first university in East and Central Africa to offer a course in chemical and process engineering (CPE)" (Kumar, Ochieng, and Onyango 2004, p. 379).

Since then, matters evolved. Engineering schools and engineering graduates increased. However, not in concert with the increasing needs for qualified engineering practitioners in East Africa (Nganga 2014). In the 1980s Structural Adjustment Programmes, promoted by the World Bank and the International Monetary Fund (IMF) affected the education sector in African countries in visible ways. "The pull back on full state funding saw cost-sharing introduced across most levels of the system. The gains in expansion, particularly of schooling, stagnated and even reversed in the economic decline of the 1990s" (Case et al. 2015, p. 282). In Tanzania, for example, the quality of university-level education received a significant blow, which it sought to mitigate by increasing classroom size, introducing measures of cost-sharing with student families, and even cutting budgets on items and services such as the maintenance of laboratories and updating of curricula. The situation in Kenya was not very different (Case et al. 2015). The picture in East Africa was similar to the average situation in the entire African continent. A global report by UNESCO (2010) emphasized that Africa was struggling with a serious shortage of engineers and technicians needed for its development, and estimated that 2.5 million additional engineering practitioners were needed to meet the Millennium Development Goals (MDGs) for water and sanitation alone. Subsequently, surveys from academia and industry in Africa indicated that both numbers and competencies of local engineering practitioners in the continent required significant improvement (Beaudry, Mouton, and Prozesky 2018; Royal Academy of Engineering 2012).

2.2. Dissonance between demand and graduate employment

The required number of engineering practitioners in any developing society is an educated guesswork that takes into consideration the average number of engineers for any population size of a modern, developed society, and the conventional ratio of engineers-to-technologists/technicians,[2] as well as differences between engineers and incorporated engineers (or engineering technologists) on average. It is generally accepted that it is very difficult to obtain precise figures, or even reliable estimates, partly because of lack of statistical records. However, a comparative look at numbers from other countries could provide guidance. In 2013, the UNESCO Director-General mentioned that "in Namibia, Zimbabwe and Tanzania, there is one qualified engineer for a population of 6,000 people – compared to one engineer per 200 people in China [and 1/311 in UK; 1/227 in Brazil]". Table 2 shows the number of registered professional engineers in East Africa.

However, there is a particular dissonance in reporting the status of engineering in East Africa and Africa at large. If there is a significant shortage of engineers from what is required, then it follows that the recent engineering graduates should quickly find appropriate employment; but that is not the case. While some countries are reporting that most local engineering graduates find employment within one year of graduation, and that even engineering practitioners from neighbouring countries are in demand locally – such as the case in Uganda (Barugahara and Sebbale 2016) – other countries report a significant number of local engineering graduates finding it difficult to find jobs within their fields (Royal Academy of Engineering 2012; Mohamedbhai 2014; Confederation of Tanzania Industries 2018). The competency of engineering graduates has been called into question by some studies and reports. A survey in 2014 by the Inter-University Council for East Africa (IUCEA), which regulates higher education in the East African Community's countries, reported that, in Uganda at least 63% of graduates were found to lack job market skills; while in Tanzania, 61% of graduates were found to be ill prepared. In Burundi and Rwanda, 55% and 52% of graduates, respectively, were perceived to be incompetent, and in Kenya 51% graduates were believed to be unfit for jobs (Nganga 2014). In Tanzania, the Science, Technology and Innovation Policy Research Organization (STIPRO) conducted a study in 2011 on local technological capabilities and foreign direct investment. The findings of the study relayed that in manufacturing, agriculture and mining, firms that were based on foreign investment capital had weak linkages with local skills and capabilities (including labour and other firms) and that was partly due to expressed concerns about the limited technological capabilities of local labour and firms (STIPRO 2018). In the same line, a study that was carried out by the Royal Academy of Engineering (2012) concluded that engineering academic staff in sub-Saharan Africa, although qualified "had very little exposure to engineering practice [in industries and public works]". It also pointed out the teaching style adopted in most academic institutions in the region could be described as "chalk and talk" as opposed to problem-based-learning (PBL) and more practical/engaging styles of teaching and learning. A number of these same studies report that, in most African countries, there is heavy reliance on engineering practitioners brought from outside Africa to work on

[2] The current average engineer/technician ratio is reported to be 1:1.5 in Africa, while it is generally preferred to be around 1:5, as a globally perceived ideal ratio.

engineering projects and in industries, making opportunities of employment limited for local practitioners.

Table 2: Number of registered engineers in East Africa

	No. of registered engineers	Population	Population per registered engineer
Uganda	1,406	43,000,000	30,714
Kenya	2,586	55,405,672	21,425
Tanzania	7,610	62,080,012	8,158
Rwanda	850	13,394,215	15,758
Burundi	15	12,378,962	825,264
South Sudan	??	11,375,047	??

Source: Alinaitwe 2021

As a result of poor institutional infrastructure, limited use of new teaching and training techniques and equipment at engineering schools, weak industry-academia linkages, and challenges with accreditation and registration of engineers and technologists, there is no question that engineering education in East Africa, and the continent overall, needs review and readjustment or restructuring (SADC 2019; Sheikheldin and Nyichomba 2019; Kraemer-Mbula, Sheikheldin and Karimanzira 2021). In general, the picture that emerges is that there is a shortage of competent engineering practitioners to meet the needs of local engineering activities (including local industries, public sector, training, consulting, etc.). The challenges are both quantitative and qualitative.

2.3. Engineering education for development

Engineering education is intimately related to development, which makes it a collective 'technosocial' problem. It has always been acknowledged that engineering is important for development in all countries, but that importance deserves reiteration and emphasis from time to time. Beginning from the new millennium, interest in paying more attention to engineering, particularly in developing countries, was renewed (Ibrahim, Luo, and Metcalfe 2017; UNESCO 2010; Royal Academy of Engineering 2020).

Technological capabilities, industrial activities, and economic growth are all important to development, and all rely on engineering. It is no surprise that in the last few years several international reports were published that try to diagnose engineering challenges in Africa (UNESCO 2010; SADC 2019; Royal Academy of Engineering 2012; UNESCO 2021). Some scholars argue that, in most of history, thus far, technological breakthroughs often ushered in scientific breakthroughs more than the other way around as typically perceived nowadays. The industrial revolution, for example, was ushered by the steam engine, a product of engineering, that opened demands and curiosities for understanding heat transfer and thermal energy, ushering investigations that led to the discovery of the laws of thermodynamics (Sheikheldin 2018). In developing societies, we can view engineering as a catalyst of technological change, while technological change is essential for economic growth and human development. Engineering in this sense is the process of digesting and combining knowledge, resources and arts to create and operationalize technology (Sheikheldin 2018); it is not necessarily the designated profession itself, but the designated profession is surely part of it—an important part. In the same vein, sustainable growth requires increasing high-skill labour, which leads to engineering education. Therefore, engineering education should be understood as quite influential on innovation and hence economic growth in Africa. In its pre-colonial history, Africa had its share of advancing the field of engineering (Diop 1988), yet the current post-colonial conditions and challenges of development make us deal with engineering as understood and practised in the modern, globalized world.

The UNESCO 2010 landmark report entitled '*Engineering: Issues, Challenges & Opportunities for Development*' is the collective result of contributions from 120 experts from around the world. The report itself was a response to a call from the global engineering community for a specific study on engineering (as opposed to UNESCO's periodical global science reports), particularly engineering in global development. The report does not only emphasize the importance of engineering in development, but also puts forth a general call for the need to (p. 6): develop public and policy awareness and understanding of engineering, affirming the role of engineering as the driver of innovation, social and economic development; develop information on engineering, highlighting the urgent need for better statistics and indicators on engineering [such as needs and numbers in each country, tracer studies of engineering graduates, etc.]; transform engineering education, curricula and teaching methods to emphasize relevance and a problem-solving approach to engineering; and more effectively innovate and apply engineering and technology to global issues and challenges such as poverty reduction, sustainable development, and climate change.

Improving the status of engineering endeavours in sub-Saharan Africa (research, training, employment, standards, etc.) is positively related to sustained economic development, particularly for its contribution to strengthening the capacity of the industrial sector which is much needed to sustain economic growth. For example, while its GDP has been increasing about 5–7% annually over the past decade, and being called one of the "African growth miracle" countries, Tanzania still faces three major problems (Page 2016): First, the increase in GDP does not take into account rapid population growth which adjusts per capita GDP growth to 2.5–3.5% over the same period—not a significant growth rate when compared to the rest of sub-Saharan Africa. Second, fewer 'good' jobs have been added to the national economy in that period, i.e. jobs paying decent wages and offering reasonable employment security. Third, the seemingly rapid economic growth did not reflect proportionate reductions in poverty. At a closer look, we find that both productive sectors of agriculture and manufacturing declined in terms of their contribution to GDP in Tanzania, while the contribution of the service sector (including tourism) increased (United Republic of Tanzania 2015). This recipe of economic growth is not sustainable. To achieve genuine economic growth, and tangible development, there is a need to increase the contribution of the agricultural and manufacturing sectors, such as agro-processing. Such an approach will increase the number of 'good' jobs nationwide that require skilled labour. That should consequently increase the national technological capabilities as well as the purchasing power of Tanzanians on average, which can transform the local market. Additionally, increasing industrial activities will likely lead to adding value to the exports of Tanzania, which can result in increasing Tanzania's access to foreign exchange and investment, altogether leading to stable and inclusive growth. Overall, such changes would render more genuine economic growth, and they will not be possible without good engineering systems. The case of Tanzania is not isolated in East Africa.

Additionally, a current high priority for Africa is digital transformation and the digitalization of key sectors of Africa's economies. It is widely perceived that digitalization can increase employment and reduce poverty, and is arguably "one of the most powerful tools for implementing the 2030 Agenda for Sustainable Development and Africa's Agenda 2063" (Songwe 2020). Under that light several African countries are taking steps in that direction. However, these endeavours themselves will require the training of a large number of capable African ICT engineering practitioners.

2.4. Gaps in policies and capacities

The existing problem of dissonance between shortage of engineers and unemployment of engineering graduates, as explained above, can be traced down, through careful reading of related literature, to gaps in policies and capacities. Such gaps may not be specific to engineering and engineering education but can be discussed from such a perspective. Some of these main gaps are as follows (as cited by Sheikheldin and Nyichomba 2019):

- As mentioned earlier, the dramatic decrease of national funding to African higher learning institutions (HLIs), since the late 1980s and early 1990s, resulted in crowded classes, poorly-equipped laboratories and decreased abilities to provide effective education/training (Case et al. 2015; Beaudry, Mouton, and Prozesky 2018). The policy environment changes that took place under the Structural Adjustment Programmes had a significant effect on engineering education (and science education overall).
- Due to the limited national budgets of most African countries, and the decrease of public spending on education, reliance on foreign funding in Africa's higher learning increased. Yet, this did not solve the problem. According to Mouton (2008), this shift is rather a sign/symptom of the 'de-institutionalisation of science' in Africa, and indicates how local capacity building in science, technology, engineering and mathematics (STEM), and in other important fields of training, is not receiving national support.
- There appears to be a lack of sufficient understanding among policymakers of engineering problems. For example, a report on engineering capacities in sub-Saharan Africa, by the Royal Academy of Engineering (2012) reported that, "42% of the professional engineers believed policymakers had a poor understanding of engineering issues, with only 14% believing they had a good understanding". With such profound need for bridging policy and engineering practice, current weak linkages between industries, training and research and development (R&D) are not surprising.
- The continuous, massive out-migration of highly skilled Africans, resulting in 'brain drain', weakens human resources overall in the continent and affects all sectors that rely on skilled labour in the country (Hanlin, Tigabu, and Sheikheldin 2021). Some reports indicate that, at times, over half of all university graduates of some African and Central American countries migrate outside these regions (Nunn 2005). Future forecasts also indicate that the phenomenon is likely to continue in the foreseen future. A report by the IMF (2016) stated that "migrants [from sub-Saharan Africa] in OECD countries could increase from about 7 million in 2013 to about 34 million by 2050," while acknowledging that "the migration of young and educated workers takes a large toll on a region whose human capital is already scarce." (p. 197–198). Additionally,

> challenges to achieving the SDGs in Africa are more prevalent in the rural areas and this is where engineering practitioners are most needed. Yet, most of them, especially fresh university graduates, are reluctant to take up posts in the rural areas.

All the above reviews and syntheses show that engineering education is nowadays a topic of critical importance in East Africa, Africa generally, and all developing societies. The gaps in policies and capacities may be a good entry point to addressing a multi-faceted, complicated problem. A recent way of looking at the problem is to approach it within 'engineering ecosystems' in countries and regions (Klassen and Wallace 2019; Sheikheldin and Nyichomba 2019). The notion of 'ecosystem' implies many things, such as multiple actors with interdependency between them, and the important role of aspects of systems, such as communication channels, feedback loops, timeframes (short-term, medium-term and long-term), unintended consequences, and so on (Meadows 2012; Lundvall 1992). It is a promising approach because it admits complexity. According to Meadows (2012), systems are "sets of things [people, machines, procedures, etc.] interconnected in such a way that they produce their own pattern of behaviour over time" (p. 2). In the case of engineering ecosystems, we can consider them 'technosocial systems', i.e. systems where people and technologies combine efforts that fulfil various and interconnected functions in society (Woodhouse and Patton 2004).

3.0 Practical training and co-curricular activities

Being an important bridge between theory and practice, engineering education has been observed to yield more favourable results when practical training is integrated in various ways. One noticeable approach is co-curricular activities that include applying what is learned in class and learning by working to solve real-world problems. These co-curricular activities include industrial training/attachments of students while at school, internships with industries right after graduation (or during times off school), voluntary activities related to the field of study (such as community service or development projects), and joining clubs or organizations that include activities that engage students with the larger environment and society (Burt et al. 2011). Studies from North America and Europe on the outcomes of co-curricular activities in engineering education – especially co-ops (or industrial secondments) and industrial attachments programmes – converge on important conclusions:

- "When engineering students are involved in co-curricular experiences, they exhibit greater leadership skills, are more thoughtful about their ethical decisions, and can articulate how involvement influences their ethical development" (Burt et al. 2011, 1).
- With good preparation, students perform well in co-ops/attachments to levels that satisfy both the student and the employer (Hackett, Martin, and Rosselli 1998; Friel 1995).
- Co-ops and internships may make students graduate later than their cohorts who do not undertake the same co-curricular activities, however, their employability upon graduation tends to be higher and also their starting salaries (Kotys-Schwartz, Besterfield-Sacre, and Shuman 2011; Friel 1995). Some studies also show a correlation between improved academic performance and co-ops.
- Companies that engage in well-structured co-op programmes tend to praise the experience, and refer to both qualitative and quantitative benefits of these programmes, such as that co-ops reduce training costs of newly-hired graduates because they already knew a good deal about the company and operations from the co-op, and that co-ops help in diversifying future employees as well as easing them into the work environment. Friel (1995) concludes his study on the topic by saying, "it appears that cooperative education develops a graduate that is better prepared for permanent work and helps a company identify potential new hires prior to the graduation date that may require less training" (p. 6).

Other studies – in Europe and Africa – focus on curricula design that deliver much of the same benefits of co-curricular activities, or complement them, in ways that aim to produce competent, work-ready engineering graduates. Context-based curriculum design (Case et al. 2015) and problem-based learning (PBL) (Aalborg University 2015) are perhaps among the most important ideas and practices in that line. A form of PBL is to engage students in projects taken from real-world cases (past or on-going) to work on. The projects are 'exemplary', meaning that "learning outcomes achieved during concrete project work are transferable to similar situations encountered by students in their professional careers" (Aalborg University 2015, p. 5). In early March 2020, the Royal Academy of Engineering, UK, held a global conference under the title "Problem-based learning: Teaching engineers to tackle the SDGs", emphasizing not only the relevance of PBL to engineering education worldwide, but also the utility of PBL in engineering at addressing development challenges at both local and global scales. Context-based curriculum design is a loose term – not as established as PBL – that simply refers to the approach of taking into consideration, while designing curricula, the level of technological capabilities, as well as needs and priorities in the country/region so that they reflect on such context and help graduate students to become familiar with them and can therefore positively influence them. While such studies on co-curricular activities and innovative/practical curricular design were mostly drawn from samples and cases outside of Africa, with quite different conditions than those in Africa, they can legitimately inspire similar experiments and studies in Africa.

East African countries, and African countries at large, have had their share of implementing programmes of co-curricular activities and practical training. In Tanzania, for example, it is standard practice for decades that all university-level engineering students (except last year) are required to spend eight weeks in 'practical training' attachments with industries, R&D parastatals, or state agencies in work relevant to their fields (University of Dar es Salaam 2018). Makerere University, in Uganda, has a similar programme (Makerere University, n.d.). Rwanda is now placing emphasis on 'workplace learning' as an important component of linking academia to industry, not only for university-level education but also at polytechnic institutes where diplomas are the highest awards (Republic of Rwanda 2015b); and for Rwanda, this approach is considered to be part of national strategies that aim to enhance the country's profile in science, technology and innovation (STI) to make that profile contribute to national development (UNCTAD 2017; UNESCO 2015). The SADC region, of which Tanzania is also member, is seeking to rethink engineering numbers and needs in the region, for the benefit of industrial and economic development and infrastructure improvement (SADC 2019). In Zimbabwe, for example, industrial attachments programmes (IAPs) for students in HLIs have been practised since the 1980s (Dondofema, Mwenje, and Musemwa 2020) with reported classical benefits to students, HLIs and industries, as well as reported challenges such as the overload of students compared to available industries for IAPs, mismatch of skills between students and industries, weak linkages between HLIs and industries, and difficulties for HLIs in coordinating IAPs for a large number of students (Munyoro, Nyandoro, and Musekiwa 2016). Similar benefits and challenges to those IAPs in Zimbabwe seem to appear in other countries such as Ghana (Adjei, Nyarko, and Nunfam 2014; Nduro et al. 2015). Nigeria has the largest higher education system in Africa and has the Students Industrial Work Experience Scheme (SIWES) in which almost all universities participate, as a part of fulfilling course requirements for graduation, and is aimed for all students that study in the STEM and other related programmes. What is significant about SIWES is that it requires longer than 24 weeks (six months) as the minimum duration of an IAP, for engineering students, to be recognized. According to (Oyeniyi 2012), SIWES has been quite successful in increasing students' skills and utilizing them in industrial development.

In the background of these historical developments and challenges, other issues need to be considered or reconsidered. For example, there is the diminishing number and appreciation of technologists and technicians, and the reduction in the number of polytechnic institutes, as opposed to universities. Many of these polytechnics are being converted to universities. These challenges can be more appreciated when we understand that engineering enterprises do not require only professional engineers, but engineering practitioners (EPs), including technologists and technicians (Mohamedbhai 2017;

UNESCO 2021). Effective engineering operations are often determined to require a 1:5 or 1:6 ratio of professional engineers to technologists/technicians (UNESCO 2010). Achievement of such a ratio requires a higher valorisation of technologists and technicians in any country and ensuring that they play a meaningful role among the EPs.

Another issue to be considered is the growing support for the argument that one way of reducing engineering graduate unemployment in Africa is to train the engineering students to become entrepreneurs, so they emerge as job-providers rather than job-seekers. This growing argument sounds more relevant given the reality of the low absorption capacity of Africa's industrial environment for engineers due to Africa's industries being mostly small-scale enterprises that can employ very few engineers and cannot provide student internships or post-graduate training in engineering. However, this approach poses many challenges of its own, such as the need to establish/increase capacities to provide entrepreneurship training for students, which requires not only a revision of curricula but also the training of faculty – bringing us back to the challenge of capacities and the need to modify or transform engineering education programmes. Additionally, while there is clear merit to the argument that many engineering graduates could become industry builders and job-providers, not all engineers can or should be. The need for enhancing the employability of engineering graduates remains.

4.0 Project design and implementation

This project proposed a study of best practices to produce evidence-based and evidence-informed policy recommendations in establishing and running robust engineering SIS programmes coordinated between universities and industries – and perhaps with support from the public sector – to serve both the industries and students. While there are currently sporadic cases of SIS placements in various university programmes, clear, broad and standardized programmes with visible outcomes are yet to be found.

4.1. Objectives

The main objectives of this project, along with its action research pilot component, were to:

(a) gain, through policy learning, reliable knowledge and understanding of the potential of tertiary SIS programmes in strengthening engineering ecosystems in East Africa;

(b) examine selected best practices in SIS pedagogical approaches, through initiating, monitoring and evaluating SIS placements;

(c) map existing and past experiences of SIS programmes within tertiary education institutions in East Africa, and produce a knowledge inventory of such experiences; and

(d) share the findings of this project with concerned circles of training and policy responsible for STI enhancement in East Africa and sub-Saharan African overall, through proper dissemination channels.

4.2. Methodology

The project used surveying and action research in learning and synthesizing effective experiences of SIS programmes from various developing countries (especially ones that achieved recent industrial successes), as well as piloting four SIS placements from two universities, and in two engineering majors, to serve as both demonstrations and close learning opportunities. The project also included exploration of conducive pedagogical methodologies, such as Problem Based Learning (PBL), as they relate to preparing SIS students for their placements. Engagement with a group of universities and science granting councils (SGCs) in East Africa was embedded in the project activities. SGCs can be instrumental in establishing policies and supporting SIS initiatives in the future (based on the expected recommendations of this project), and so their early engagement in this project will facilitate that. The pilot programme will also feed into curriculum design at higher learning engineering institutions.

The approach that was used by this project was based on the hypothesis – or lens of inquiry – that strengthening the linkage between engineering study, practice and employability is a 'leverage point' in the engineering ecosystem of a country or region. Leverage points are places of intervention in a complex system where change has a significant ripple effect throughout the entire system, influencing many components that were not touched directly (Meadows 2010). The research team postulated that promoting engineering SIS programmes can be a suitable approach to strengthening the linkage between engineering study, practice and employability. They have the potential of changing engineering curricula towards PBL, student-based teaching, and orientating academic fields towards connection with demand in industry. If such outcome is achieved – through curricula change and policy support – that in turn can increase student enrolment in engineering programmes in a country/region, and graduation, as a response to increased employability of engineers after graduation. If this hypothesis proves to be sound, the results can have significant influence on policy and practice of engineering ecosystems in East Africa.

This research lens relied mainly on the conceptual framework of national innovation systems (NIS) and the theoretical framework of systems thinking. NIS framework aims to organize the productive forces and structures, and the flow of information and skills in a country, in order to increase the output of innovative solutions to development constraints (Lundvall 1992). In this framework, STI play a central role, and thus require strategic investment. At the policy level, the NIS will include careful investments in education systems, enterprise support and labour markets (Maharajh, Scerri, and Sibanda 2013). Systems thinking, on the other hand, overlaps with such understanding of NIS, and views various phenomena as 'systems', i.e. sets "of things—people, cells, molecules, [machines, procedures, etc.]—interconnected in such a way that they produce their own pattern of behaviour over time"(Meadows 2012). If we look at the engineering ecosystem in a country from the NIS perspective, it will be critical to understand that engineering academic programmes and engineering jobs in local industries are tied together by the flow of information and technology, through human resources as well as knowledge, including economy/market feedback. Using systems thinking, we understand these relations as feedback loops that influence each other's own dynamics through the information flow, rules and connections of the whole system. The type of system we are dealing with here is a "technosocial system", where people and technologies work in combined efforts that form functional wholes (Woodhouse and Patton 2004). This project will pursue its objectives through a theory of change illustrated in Figure 1.

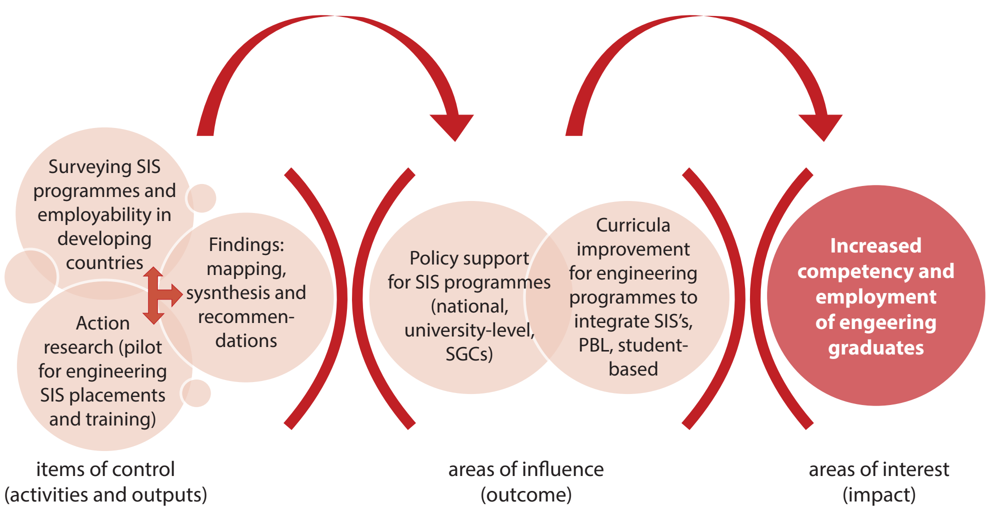

Figure 1: SIS Project theory of change

Four students from two different universities in East Africa were selected for SIS placements for one year in a number of engineering entry-level or apprenticeship positions in suitable industries. The students had just completed their junior year (i.e. one year left to graduation). The selection of the students was carried out by their respective faculty advisors – in consultation with STIPRO – who would be partners of STIPRO in this project. All placements began in the second year of this 3-year project, after surveying, partnerships, agreements with respective industries (for placements) and selection of students were completed. The students were given stipends as reasonable salaries while on SIS placements (based on stipends considered reasonable at their levels in their respective countries). Their universities handled the stipend disbursement accordingly (as well as some administrative funds specific to the project) and agreed to report them to STIPRO. Of the four students, two were from Tanzania, both females, and two from Rwanda, one male and one female.

The four students were entirely funded by the project's budget itself. At this phase, where the employability of undergraduate students is a challenge, the research team did not want to risk the possibility of not having any firm/industry accepting to pay stipends for SIS students, or participating universities not having a budget allocated for that. If the pilot succeeds, it will hopefully encourage industries, universities and science granting councils to pay SIS student stipends due to the foreseen benefits of the placements. However, the project team tried to convince industries to pay at least part of the student stipends or pay for additional students to join the pilot (so more students can join the pilot phase), but there was no success.

The surveying and mapping part of the research included two overlapping field studies: the first was collecting data/information about all significant engineering SIS projects or programmes that took place within universities and colleges of repute in the East African countries of Tanzania, Kenya, Uganda and Rwanda; the second was exploring best practices in engineering SIS programmes in both East Africa and in developing countries which were similar to East African countries. The method for executing the second field study was developed within the first four months of the beginning of the project. Principles of responsible conduct of research (PRC) were embedded in the entire project, in data collection and sharing, with protection of all human participants and participating institutions (including SIS students and the hosting firms). It was agreed to rigorously address other unexpected ethical issues as they arose, in accordance with STIPRO's principles and the participating universities' codes.

4.3 Project phases

The project was carried out in three main phases, as outlined below and in the workplan in Appendix 3.

Phase I – Survey of SIS practices in East Africa

In this phase, the research team conducted three complimentary activities. The first activity was a mapping of the four East African countries of Tanzania, Kenya, Uganda and Rwanda in terms of all previous and current experiences of engineering, undergraduate SIS programmes and their indicators of effectiveness (qualitative and quantitative). The mapping involved collecting and organizing data on the history of the practices in East Africa. The second activity – conducted simultaneously with the first one – was surveying best practices among such mapped programmes (if existent within East Africa) as well as best practices known in other countries from the economic South and with comparable industrial and economic conditions to East African countries, so as to establish engineering education programme gaps. This surveying was expected to produce critical findings on recommended ways to design and implement engineering SIS programmes in the region. The third activity was to focus on identifying the second partner university for the pilot phase, selecting students for the SIS programmes, identifying partner industries/firms that will host the SIS students, finalizing agreements between all actors for the pilot project, and preparing students for SIS placements.

Within Tanzania, the research team was able to get more information and talk to many informants, given that STIPRO is based and registered in Tanzania as a research organization, and has broader established connections with academia, industry and public institutions in the country; it was therefore easier to meet more people from government, academia and industry (the 'triple helix') and obtain more information and insights in the form of documents as well as interviews. We used a semi-structured interview guide. For the other countries, namely Rwanda, Uganda and Kenya, the research team mostly relied on documents and public information that can be shared with visitors, and there were general discussions with key organizations in each of the four countries, such as Uganda National Council of Science and Technology (UNCST); Rwanda National Council of Science and Technology; EASTECO (East African Science and Technology Commission); Linking Industry with Academia (LIWA); African Centre for Technology Studies (ACTS); University of Nairobi; and Kenyatta University (See Appendix 1). For Rwanda, the research team reached the conclusion that it was not necessary to carry out additional surveying since there were existing publications that covered the situation in Rwanda sufficiently for the purposes of our study, and the research team did not need further information to partner with the University of Rwanda for phase II of the project (the pilot phase, for which the university took control and STIPRO only provided the funds). For Kenya, the research team was able to conduct a small survey through partnering with the African Centre for Technology Studies (ACTS), a long-term partner of STIPRO and a registered research organization in Kenya.

An identical set of questions was put together for each country to respond to, and the research team collected as many responses as possible from each country. The questions were:

What are the current arrangements between academia and industry that involve engineering students or fresh graduates?

What are the numbers and trends that tell the story of engineering education and employability in your country?

What are the main policies and institutions that influence the current situation?

What are the observations and potentials relevant to your country's engineering ecosystem?

Phase II – Piloting student placements

This phase involved the actual placement of the SIS students, observing their work and drawing notes and lessons from the pilot project. Phase II was planned to begin after phase I as it required significant feedback from phase I. It also included gathering experiences on university engineering teaching, especially the use of problem-based-learning or PBL.

One of the weakest aspects of the pilot is that it included only four students, and they were paid. We needed to do that to persuade industries and universities since the idea of training students for an extended period, as employees, was rarely tried before. We chose to make our pilot for an entire year for a number of reasons – one is that it was actually easier to get an excuse from university administrations and student loan boards, for a full academic year off than to get an excuse for a semester, because a semester will make students out of sync with year-based academic curricula. Additionally, for the duration of the project funding, a year made more logistical/administrative sense.

Phase III – Synthesis and results dissemination

This phase included synthesizing the lessons learned from both previous phases, highlighting them and writing-up reports and scholarly publications, and disseminating the findings and policy recommendations to all stakeholders.

Phase I took one academic year (the first year of beginning the project), as students were prepared to begin the pilot phase the next academic year (to be synchronized with their university academic programme). Phase II was the second year, and phase III the third year of the project. Given the layout above, finalizing university partners took place in phase I. In phase I of the project, the selected hosting organizations and the university partners agreed upon criteria to make sure that the students were hosted by industries/firms that had the capacity to host them and assign them productive tasks, as well as mentor their work through senior managers. At phase II, the university partners, as well as STIPRO, agreed to be both involved in making sure that students were occupied at work with relevant tasks and careful evaluation of their progress and performance.

In the early period of phase II, the global COVID-19 pandemic struck the planet, and many measures followed, such as closure of businesses and public facilities and restrictions on travel (especially international). These significant changes affected the flow of the project in considerable ways, but adjustments were made, and the project continued according to its main workplan (see Appendix 3).

5.0 Main findings from phase I and II

The findings of this study were broad across countries. However, we found overwhelming consensus that the current industrial attachment programmes (IAPs) in East African countries are not only similar but also not working well and for the same reasons—mainly insufficient industrial attachment periods, the overwhelming number of students compared to the number and size of industries to receive them, and the mismatch of skills and work in IAPs (partly due to the two reasons mentioned first).

Activities of phase I took place successfully, overall, but with some challenges. Mapping of previous and existing SIS programmes took place, with many similarities found across the four countries and yet there was a general absence of reliable documentation of such experiences. Some information of best practices from past experiences was obtained, but with the realization that circumstances in the past were quite different from the present, rendering it difficult to emulate past practices. Selection of the second partner university, along with the selection of students and industries and preparation for phase II took place in partnership with the University of Dar es Salaam (College of Engineering and Technology) and the University of Rwanda (College of Science and Technology), the latter being the selected second partner. Below, the findings are presented as country-specific findings and general findings of phase I, and pilot SIS placement findings of phase II.

5.1. Findings from phase I country-specific surveys

The following brief profiles of each country are based on phase I survey information and literature:

5.1.1. Tanzania

Academia-industry student placement programmes

Annual practical training periods of eight weeks every year, except for the final year, are standard in all Tanzanian higher education engineering schools. Industries are required by the state to accept students for these periods. For engineering, after the first year of studies, students undergo their first practical training period as artisans; after the second year as technicians; and after the third as engineers. The placement pyramid was designed in this way to enable the engineering students to experience, hands-on, the various and important levels of engineering practice.

However, criticism is emerging from faculty, students and industries, with high consensus[3] that few students and industries benefit from such training due to crowdedness (as even other schools/disciplines have practical training programmes around the same period) and the short period of training. Students, faculty and industry supervisors are all less invested in elaborate learning and follow-up. On average, 2,500 students from Dar es Salaam Institute of Technology (DIT), and 1,800 students from University of Dar es Salaam (UDSM); go for practical training every year, all spread across about 200 industries, public and private, but normally not all students get placements every year,

[3] At DIT, the consensus exists but less than at UDSM; perhaps because DIT students are trained with a different curriculum that emphasizes hands-on engineering skills, due to the history of DIT (which was originally built as a polytechnic college).

so on average around 120 industries participate each year. The number is overwhelming, and the capacities of industries are both limited and spread thin. Another constraint is that all other non-engineering final-year students, or students from other fields from other universities, also attend the practical training every year and at the same time of the year, resulting in even more crowding.

In the past, UDSM had the only engineering programmes in the country. Engineering students were few and the main industries known. Besides, most graduates were recruited for jobs, or further studies, before graduation. Smaller classroom size and relatively fewer industries allowed for focus and enabled decision makers to place almost all the graduates, who were also fully funded. Also, at UDSM, from the 1980s to early 1990s, students were allocated employers (state-owned-enterprises or parastatal organizations) by their third year, where they would go for their eight-week practical training and where they would work after they graduate. This process was done nationally but UDSM was the only university with engineering programmes. There was limited room for students to change their allocation. The placement was for five years, after which the graduate engineer was free to move around or remain in their job.

Engineering education and employability

Tanzanian registered engineers form the majority of registered engineers operating in East Africa, and they work all over the East African Community (EAC). This indeed is a testimony to Tanzania's engineering education and certification quality compared to the rest of the region. "Proportionately, 63% of the registered engineers in the EAC are from Tanzania" (Barugahara and Sebbale 2016, p. 41). However, globally speaking, Tanzania's engineering training has much room for improvement.

According to a recent SADC report on 'Engineering numbers and needs' of SADC member countries (SADC 2019), Tanzania has about 60 engineering practitioners per 100,000 persons, a low number among SADC countries. Yet, engineering is quite important to Tanzania, as activities involving engineering contributed, overall, 63.8% to the total GDP in 2015, as an example.[4] A total of about 30,000 engineering practitioners work in Tanzania, of whom 26.8% work in the public sector (government and state institutions, companies, etc.), which makes the public sector the largest employer of engineers in the country. The 'manufacturing and suppliers' sector employs around 6,000 engineers, and the same for 'contracting', while only 700 engineers work in the agriculture sector, although that sector is a main contributor to GDP and employment in the country (SADC 2019, p. 48). Around 1,800 engineers work in academia and research (including public universities and colleges).

For university level engineering degrees, there are two tracks in Tanzania: The TCU track (regulated by the Tanzania Commission for Universities which succeeded the former Higher Education Accreditation Council) and the NACTE track (regulated by the National Council for Technical Education). The two tracks differ in the percentages of theory versus hands-on content in the curricula—one with more focus on graduating

[4] Activities involving engineering, include agriculture, construction, manufacturing, electricity, gas & water, mining operations, and transport and communication (SADC 2019, p. 8).

students with state-of-the-art knowledge of the engineering discipline, and one with more focus on graduating students with advanced hands-on skills of engineering work. In other countries around the world, the two tracks are usually distinct, one that produces engineering graduates and the other that produces 'engineering technology/incorporated engineering' graduates (UNESCO 2010). If graduates from either track wish to continue on post-graduate paths (for Master's and PhD levels), the tracks converge. Requirements for becoming registered, certified engineers in the country appear to be the same for both tracks. Overall, it could be said that the engineering ecosystem in Tanzania is both vibrant and challenged.

For this research, the team was able to survey two types of organizations in Tanzania: universities (particularly engineering and technology colleges/departments) and partnering organizations with universities, particularly those of industrial or technological orientation and which typically receive engineering students from universities (such as UDSM, DIT, Arusha Technical College, and Mbeya University of Science and Technology). In the survey, the research team visited many organizations (see Appendix 1) but four cases summarize our findings: TANELEC (electrical equipment manufacturer), Confederation of Tanzania Industries (CTI), Tanzania Engineering Design and Manufacturing Organization (TEMDO), and the Centre for Agricultural Mechanization and Rural Technology (CAMARTEC). These organizations are located in Dar es Salaam and Arusha. In this survey, particular information was drawn about the status of students that are received for practical training (PT) and other challenges and peculiarities related to it—all summarized in Table 3. In general, the existing PT programmes are not a complete failure, as they seem to match some students with future employers, and they also have interesting stories of success where students are almost transformed in terms of their engineering skills. However, the challenges and problems remain, and remain more or less the same across all student-receiving organizations, among which are the burden of hosting more students than organizations are able to closely supervise, and the relatively short period of time that does not allow for building reliable competence in the students.

Policies and institutions that influence the current situation

The Engineering Registration Board (ERB) is an institution that is established to regulate the engineering profession in the country through making sure that licensed engineers are competent enough to lead projects and missions of an engineering nature and are capable and aware of safety and quality standards. Tanzania's ERB is similar in that regard to many ERBs in other countries across the globe. The East African Community has a shared engineering registration framework.

> "Under Article 104 of the EAC treaty, partner states agree to a protocol to facilitate the free movement of persons, free movement of labour, free movement of services and the right of establishment and residence. Specifically, the Mutual Recognition Agreement (MRA) for engineering professionals in the EAC enables a professional in one state in the region to be recognised as a professional in all the member states. The MRA for EAC engineers was signed on 7th December 2012 between Uganda, Kenya and Tanzania"(Barugahara and Sebbale 2016, p. 41).

The Structured Engineers Apprenticeship Programme (SEAP) is a publicly-funded programme that was launched in 2003 and is supervised by the ERB.[5] According to the recent SADC report on engineering needs and numbers for the region, SEAP "aims to enable Tanzanian graduate engineers to qualify for registration as professional engineers in the shortest possible time. The ERB monitors progress, engages with mentors and reviews quarterly reports" (SADC 2019, p. 70) This adds additional importance to the ERB as an influencing institution in the engineering ecosystem of Tanzania.

The Higher Education Students Loans Board (HESLB), which offers loans to students to meet costs while studying in HLIs in the country, is also an important actor/influencer in the ecosystem as it plays a critical role in financing/funding mechanisms, without which the system is crippled. Big industries and industrial chambers (such as the confederation of Tanzania industries) are an obvious actor/influencer in the system. Their own policies and their level of participation in co-curricular activities for students, as well as providing work opportunities, and determine characteristics of the entire ecosystem.

Academic institutions are mostly at the centre of the ecosystem. Any meaningful change or enhancement in the system will likely begin with them or at least include them as main partners – especially large academic institutions such as UDSM, DIT, and Sokoine University of Agriculture.

Observations and potentials relevant to the engineering ecosystem

From this survey, and from established expertise with the Tanzanian scene through previous research and consulting work, it can be argued that Tanzania has functioning frameworks that build upon traditions established in the period right after independence and under the first government. However, these frameworks seem to work at the minimum capacity level now and few changes take place or divert from what was established, even when the surrounding circumstances have changed dramatically. The political stability of the country is unique in the region, yet one of its correlations is that resistance to change in existing frameworks is high, making it very hard to move gears to adjust or transform the enabling environment. Political will could maximize change, but it tends to focus on grand issues at macro-national and regional levels, while policy change remains very difficult at the meso and micro levels.

5.1.2. Uganda

Academia-industry student placement programmes

A similar industrial secondment programme (called 'field attachment') is in place, that also lasts about eight weeks, particularly at Makerere University and its engineering school (CEDAT – College of Engineering, Design, Art and Technology). Also, most university schools at Makerere University do the same field attachment, which means more competition for existing industries. Makerere produces the majority of engineering graduates in the country.

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[5] It was launched by the then Minister of Works, John P. Magufuli, who in 2015 became the President of the Republic of Tanzania.

Table 3: Summary of feedback from industry partners about current state of SIS programmes (Tanzania)*

Organization	TANELEC (electric equipment)	CTI (Confederation of Tanzanian Industries)	TEMDO	CAMRTEC
SIS/internship existence	yes	yes	Engineering students are supervised by engineers at TEMDO. They are introduced to TEMDO (orientation), and then they are assigned their jobs and supervisors. The same training as UDSM (first year artisan, second year technician, and third year engineer). For third year students, they are assigned to the design office, because they are treated like engineers.	When students come here, they feel estranged and challenged. Making the students deal directly with the technological creation work takes them away from the classroom environment to face real-world challenges. More of that is required.
Students received for training (annually)	about 12-15 every year	n/a (but with members of CTI)	Sometimes we get more than 10 students every year (roughly) from all the PT levels. They come from UDSM, SUA, ATC, DIT, etc.	Every year, over 50, but they usually come in groups of 20s or so per season.
Are some students employed after PT training with the same organization?	Yes, currently have three students from UDSM (graduates) as our employees.	Yes, experiences of member industries that take students as interns after they graduate, for about a year – some are employed.	----- (employment through public sector)	----- (employment through public sector)

Organization	TANELEC (electric equipment)	CTI (Confederation of Tanzanian Industries)	TEMDO	CAMRTEC
General assessment about current state of SIS (problems/ challenges and university-industry linkages)	- Some students are useful to have, but some students are a burden. - Our resources and capacity limit the number of students we can receive. - Many of the students find our work here quite new and interesting. When you start training them you find that there is a big difference between what they are being taught in school and what they find here.	Currently, there is a 'skills development levy' of 4.5% of basic pay of all employers (higher than most countries around), so the industries feel that they are already contributing to skills development in the country and without benefit.	Staying longer (in the SIS) will make the student learn more. At 2nd and 3rd year they need to be guided to understand how to deal with design challenges and be more accurate.	Not enough time for them to actually master any part of the process. They end up covering a little of everything, making them versed in nothing. Also, teaching them is a challenge, because there is a lot that they do not know.

*Info drawn from survey that included public documents and semi-structured interviews with leaders/representatives from each organization.

Contrary to other countries, a tracer study of engineering graduates in Uganda showed that most of them end up working in their field (or related to their field). For Uganda, it seems that studying engineering remains a good choice for graduates in terms of employability (Barugahara and Sebbale 2016).

Yet, problems in the industrial training programme persist. Similar complaints to those in Tanzania, of fatigue in the programme, where students, faculty and industry are not sure of the benefits of the programme, show that industrial training works on paper, as a requirement that has to be fulfilled, while a fair assessment may reveal an unfavourable situation.

In the past, Makerere University had the only engineering programmes in the country. Just like UDSM in Tanzania, engineering students were few and main industries known and, most graduates were recruited for jobs, or further studies, before graduation.

Engineering education and employability

According to a tracer study of Ugandan engineering graduates between 2008 and 2012, the dominant fields of engineering studies in the country over that period were civil (25.7%), mechanical (17.2%), telecommunication (17.6%), electrical (14.1%) and agricultural (5.4%) engineering.

The study also provided a number of intriguing findings, such as:

> "Most engineering graduates (74.6%) found their first job less than a year after graduation. This could be because 61.9% searched for engineering related jobs, three years prior to graduating. In this survey, 78.8% of engineering graduates were employed while 3% and 0.6% were either unemployed or inactive respectively. Most of the engineers (64.6%) were working in the Business sector. Proportionately, there were more civil engineers working in the Government sector than all the other fields of engineering combined. Over half (57.6%) of engineers were working in firms that were undertaking 'core engineering'. Most (63%) of the engineering graduates in non-core engineering firms were either sales agents, brokers, accountants, bank tellers or other related clerks. Whereas 72% of engineering graduates described their current occupation as being 'closely related' to their undergraduate training, a third (34%) of female engineers were in professions that are not related to engineering. In addition, whereas the number of male engineers in 'unrelated' professions reduced by 11%, the number of female engineers in such professions increased four-fold (400%) between 2008 and 2012. The number of engineers in 'closely-related' professions increased by 46% and 123% for female and male engineers, respectively" (Barugahara and Sebbale 2016, p. iii).

For the majority of graduates to find a job in less than a year after graduation, and for the majority of those to describe their job as 'closely related' to their field (albeit a subjective description) sheds a positive light.

Yet, some aspects require revisiting, such as that 91.7% of the engineers were not formally registered, according to the tracer study; the main reason cited for that was that they lacked minimum requirements for registration. Particularly, far fewer women were registered engineers. The value of registering, and how it pushes engineering practitioners further in their engineering careers, may need to be promoted. And like Tanzania, although there are higher numbers of engineers in the population, "Uganda still has one of the smallest per capita ratios of engineers per population (one engineer per 53,000 people vs a desired global average of 1:770)" (Barugahara and Sebbale 2016, p. iv). Moreover, less engineers were involved in traditional mechanical/manufacturing and agricultural fields, which are critical fields for national developments at this stage of development in East Africa if countries are to advance into semi-industrialized economies.

Policies and institutions that influence the current situation

The Engineering Registration Board (ERB) of Uganda plays a similar role to its counterpart in Tanzania. Makerere University is also the oldest/largest academic institution, so it has broad influence. As mentioned earlier, only few Ugandan engineering graduates seek to become registered/professional/certified engineers to practise as such in the country. They cite reasons for that, but the reality remains that when looking at the number of registered engineers, the shortage becomes visible. "The number of registered engineers in Uganda is still low compared to the other countries in the East African Community (EAC). Kenya has a register of 1,400 engineers which is twice that of Uganda. (By 2015, Uganda had a register of 772 engineers of whom 494 were in practice.)" (Barugahara and Sebbale 2016, p. 41).

Observations and potentials relevant to the engineering ecosystem

Uganda's tracer study indicates that, despite engineering graduates being mostly employable, the engineering sector is still dominated at high/advanced levels by expatriates who come with companies contracting projects in the country. Additionally, professional/certified engineers from other countries in East Africa seem to fill a large gap among local (Ugandan) professional engineers. This may make Uganda more interested in seeing the regional engineering ecosystem improved.

5.1.3. Rwanda

Academia-industry student placement programmes

Rwanda has recently embarked on enhancing the STEM capacity of the country at large, with most public funding being directed towards STEM institutions and also inviting many international institutions to establish educational and research posts in the country (UNCTAD 2017). That focus also includes providing practical training opportunities for engineering students as well as implementing policies to normalize workplace training for TVET level graduates.

At the University of Rwanda, students are provided practical training in their workshops as part of the curriculum (e.g. machine tools, laboratories, individual projects) in addition to an industrial attachment programme that is a compulsory credit-rated module for every specified diploma/degree programme at the College of Science and Technology. This industrial attachment is typically assigned after the student completes the third year and it lasts for 10 weeks. During the attachment, the students are expected to experience the application of learned skills in an organization related to their specialty. This is quite similar to 'practical training' and 'field attachment' placements in Tanzania and Uganda, with some variations.

Challenges of the industrial attachment programme also seem to be similar to those in Tanzania and Uganda, and they include difficulty in finding proper industry placements for students, problems with funding and students' welfare during attachment periods, constraints in finding time and resources to monitor and supervise students sufficiently during their attachments, and students' lack of motivation in maximizing learning benefits from the attachments.

Engineering education and employability

A 2014 tracer study of graduates from HLIs found that "graduates from Economics and Business, Education and Arts and Social Sciences are over-produced vis-à-vis other fields like Medicine, Engineering, and ICT" (Republic of Rwanda 2015a, p. ix). Between 1996 and 2013, 6,180 students graduated from HLIs in Rwanda with an engineering degree (compared to 2,286 from medicine and 3,739 from ICT). In 2014, the World Economic Forum Executive opinion survey ranked Rwanda as number 74 (out of 148) in the world in terms of the availability of scientists and engineers, and the country ranked 125 in objective measurements of enrolment in tertiary education[6] (UNESCO 2015). The tracer study did not provide aggregations for engineering in particular, but the study concluded that there is a critical skill gap in fields of medicine, ICT and engineering. Overall, there was a 15% unemployment rate, and "there appears to be lack of sufficient formalised synergies and partnership between public and private employment agencies with HLIs. As a result, relevancy of internships and acquired skills to the labour market were rated weak" (UNESCO 2015, p. 114). Weaknesses were also noted by employers among graduates in the areas of hard-skills in areas of research and problem-solving skills.

In 2017, a review by United Nations Conference on Trade and Development (UNCTAD) on STI policy in Rwanda spoke about engineering graduates from the University of Rwanda, indicating that, on average, "each year, 1,400 engineering students successfully graduate. In the last promotion [2016], 300 had found a job in government structures and 200 in the private sector, while the others are searching for a job, and this in spite of an unresolved skills gap" (UNCTAD 2017, p. 21). The same review also indicated serious moves by the Rwandan authorities to address challenges:

> "There is growing awareness of the need to create an innovation culture among science, technology, engineering and mathematics (STEM) students and technical trainees, as well as among those training in and studying soft disciplines relevant to commerce. Technical and vocational education programs are well founded and valued among the business community. Central national policy is developing a factual and timely assessment of skill gaps and their effective narrowing through a combination of incentives and support measures" (UNCTAD 2017, p. 2).

A good example of serious trends towards change is Rwanda's national policy of workplace learning (Republic of Rwanda 2015b). Although the policy is designed for technical and vocational training, rather than for tertiary education, it reflects a general approach/ thinking by authorities towards bridging skill gaps in STEM by using workplace training, a synonym of internships and industrial secondments.

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[6] Data taken from 2012.

Policies and institutions that influence the current situation

UNCTAD's 2017 review of STI policy in Rwanda indicates that Rwandan authorities are keen, in thinking and action, to enhance the STEM education-employability environment in the country and are being hands-on about it. In such case, state policymakers and ministries are directly leading the process.

Observations and potentials relevant to the engineering ecosystem

Being a small country, central authorities in Rwanda make and implement national policies with strong coordination, and plans seem to be more likely to be enforced once approved. This could be either good news or bad news for the engineering ecosystem, depending on the policies and institutions responsible for implementing them. If policies are sound, they have a higher chance of being materialized, but if they are not well-studied, they also have a similar chance, with unintended consequences.

Currently, a shortage of engineering practitioners in Rwanda is visible, as many related positions are filled by expatriates from various parts of the world (including from neighbouring African countries, which is not as problematic as having all major engineering leading positions filled by experts from outside the region), because expatriates from neighbouring countries are part of the regional engineering ecosystem, which is important as this study illustrates.

5.1.4. Kenya

Academia-industry student placement programmes

Similar to Tanzania and Uganda, engineering colleges and universities in Kenya also conduct students' practical training through placements and attachments. The time allocated for the field attachment is between eight and 12 weeks depending on the course programme. Students have a logbook to record their daily assignments and universities ensure that students report to their respective attachment places through an assessment form.

University curricula require the second-year students to go for internal (in-school) hands-on training for two weeks and third year and fourth year students to go for external placements. The Linking Industries with Academia (LIWA), an organization that provides match-making internship services between industry and graduate students for industrial placement, internships and work-based training, estimates a proportion of 50% of students get internships under their initiative; and employers such as the Kenya National Highways Authority (KeNHA), which deals with the construction of major roads and comprising two more authorities such as the Kenya Urban Roads Authority (KURA) and Kenya Rural Roads Authority (KeRA) receives an average number of 70 graduates for placement; and thus the authority assigns PT tasks in consideration of the degree course; the students generally work around operating activities, workshops, and laboratories.

Engineering education and employability

Several challenges in industrial training programmes have been identified. Although students are evaluated by industries as having strong hard engineering skills, they complain that students lack soft skills. Secondly, supervision is limited in following up students' performance. In the past, engineering colleges and universities used to conduct two rounds of supervision per academic year, but this supervision arrangement has changed to one round. The decrease in the number of supervisions was explained by the number of students that keeps increasing in all the engineering institutions. The University of Nairobi, for example, registers around 290 students who go for placements per year against 20 supervisions at different students' placements. Similarly, the number of industries does not comfortably accommodate the increasing number of students in Kenya. This not only challenges students to get appropriate placement but also brings in the system different experiences about placements and attachments.

Moreover, according to the University of Nairobi, universities rely on tracer study reports to get insight in terms of employability and the way graduates perform in the labour market. The last report has informed that students perform well.

Policies and institutions that influence the current situation

Employers, such as KeNHA, recognise the existence of government policy that make early graduates' internships mandatory.

Observations and potentials relevant to the engineering ecosystem

The survey conducted in Kenya revealed different experiences in terms of students' placements and attachment, which also impact students' performance differently. Depending on the types of activities and seasons/times, industries engage different volumes of operating activities that may differ from the time universities engage students' placements.

Financing during the students' placement has also some levels of influence in the way students find relevant placements. Students opt for places where the living costs are affordable without much consideration to the volume of operating activities in industries and the course they undertake.

The experience with linkages between academia and industry is manifest through the students' assessment forms designed by the universities and filled in by industries. Universities rely on those forms to understand students' performance since they record students' performance.

5.2. General findings from phase I

Similarities were observed across countries regarding experiences with student industrial training programmes and initiatives (the models, the challenges, and feedback and perspectives of stakeholders). The SIS models are the same and have been so since engineering departments were established in most of the East Africa region. They worked well in the past, with a limited number of engineering students and effective involvement of public sector in securing useful SIS experiences. Currently, the circumstances have generally changed but the models have remained the same. One cited reason is that the number of students increased dramatically, and many university colleges (non-engineering or 'professional degrees') began to seek industrial training for their students as well, which overburdened industries as they did not increase in number and capacity in the same proportion to the increase of number of students.

Weak documentation of the past and present SIS programmes (or industrial training/attachment programmes) was one major challenge faced by the study team. Most stakeholders that the study team met could not offer more than verbal information, although the team requested that any relevant documentation be shared. The unavailability of, or weak access to, such records made it a challenge to have a rigorous investigation – for this study team or for universities and industries in general – to make informed decisions that could improve the status quo.

5.3. Findings from phase II (SIS placements)

5.3.1. Student selection and placement

For the pilot phase II of the project, third year undergraduate students from two East African universities, University of Dar es Salaam (College of Engineering and Technology) and University of Rwanda (College of Science and Technology), both being the major and historically principal universities in their respective countries, were selected for industrial placement. Each university had two students participating in the pilot, and they were selected and funded to undertake one full year of SIS with chosen partner industries/firms. The selection of students was finalized by the universities themselves based on agreements with STIPRO – drafted and signed between October and November 2019 – through which each partner university received USD 25,000 (United States Dollars Twenty-Five Thousand), to cover student stipends and administrative costs. Each university supervised their students completely, from selection and industry placements to making arrangements with industries to receiving progress reports from students and industry supervisors, as well as having faculty supervisors visiting students at workplaces to assess their performance and learning from the opportunities. Based on the agreement, the universities shared information on the pilot with STIPRO through updates by email and through sharing progress reports from the students (after review and approval by faculty supervisors). Table 4 shows the status of SIS programmes and other relevant information in each of the two universities.

5.3.2. Reports from student placements

All SIS pilot placements were completed, and student reports submitted (after review and approval by their industry and academic supervisors). Across the board, students, industrial supervisors and academic supervisors reported a positive return from the SIS placements. The highlights from the student reports show similarities in two aspects:

(a) Increase in employable skills: All students' reports highlight an increase in hands-on skills and understanding of practical/work environments.

(b) Increase in confidence: Comparing the level of confidence in their own skills, from the point when they began the SIS placement to the point they finalized their placement, the reports show that the students had gained significant confidence in their ability to secure employment after graduation. This is independent of whether or not they would actually secure employment (that remained to be seen), but it showed that they had either received promises or were more confident in their ability to find the right channels and approaches to secure employment after graduation.

Tables 5 and 6 highlight the main takes from the SIS pilot placements, as well as generalized lessons and recommendations for future reference. Overall, while the experiences were positive, the fact that they were pilot placements may have not allowed for experiencing a more structured, systematic and well-planned SIS experience. In these pilots the students and their industry supervisors had to fill the SIS experience with work, and they did that well, but it made them think about how it would have been more rewarding and educational if they had been more prepared in terms of specifying the students' tasks and outputs, and in terms of setting a standard SIS programme to follow. Additional lessons and recommendations addressed challenges and opportunities that might arise if the SIS programme were to be scaled up, involving hundreds or thousands of engineering students each year. Some recommendations ventured into how a long SIS period could be adopted without adding an entire year to the students' curricula. A suggestion by a senior professor from USDM was that, instead of two months every year (the current PT programme), the students could combine them together (along with the training workshop) to have one long attachment of 6-8 months as their SIS. This is a commendable suggestion for policy consideration, especially as some other universities around the world follow a similar model (such the University of Waterloo, Canada).

Table 4: Status of SIS programmes in Tanzania and Rwanda's principal universities*

Institute	CoET (College of Engineering and Technology)- University of Dar es Salaam	CST (College of Science and Technology) - University of Rwanda
SIS/internship existence	Practical Training (PT) every year for 8 weeks (1st, 2nd and 3rd year degrees – artisan, technician, engineer).	Currently, both students and faculty have industrial attachment placements, coordinated and executed with industries.
Overall number of graduates	Graduates of CoET are on average 600 a year. On average CoET has 2,400 students enrolled (all years) every year.	600-1,000 graduates every year (engineering)
Students that go for training (annually)	Average 1,800 per year	Average 1,800 students per year
Industries involved with institute	Over 200 industries, but normally not all would get placements every year, so on average around 120 industries per year	Ministry of Infrastructure: there is a clause for all foreign companies to include students and faculties for industrial training.
Problems/challenges with existing industrial SIS programmes	(1) Industries have little time to help PT students with questions for learning.	

Institute	CoET (College of Engineering and Technology)- University of Dar es Salaam	CST (College of Science and Technology) - University of Rwanda
	(2) PT students are not given proper protective equipment, or are given used ones (which is unhealthy). (3) On PT 3rd year, the student has to write a project on a practical problem, but one cannot have a well-executed project in only 8 weeks of placement. (4) Small allowances.	(1) Not enough industries, especially willing industries. (2) Student welfare during Industrial Attachment (IA) is minimal. (3) Budgetary constraints for staff to supervise IA student participation. (4) Guaranteeing student professional behaviour during IA requires close supervision.

**Info drawn from public records, shared by respective university faculties.*

5.4. Gendered dimension

It was originally planned that about half of the students joining the pilot phase of the project should be female, for gender considerations relevant to the study. Gender-based parameters of their experiences were to be documented and studied for policy lessons (in addition to investigating other SIS experiences of female engineering students). Eventually, the pilot ended up with three female engineering students and one male student. The UDSM's CoET selection committee for students selected two female students from those who applied and were informed of the SIS pilot. The CoET selection committee explained their rationale to STIPRO: from their experience in such programmes, female students were considered more likely to take the opportunity more seriously and responsibly.[7] Therefore, the reports of the SIS students, shown earlier, can be described as reflecting female engineering students 'experiences; although no significant differences could be found with the experience of the one male student.

The tracer study from Uganda also revealed important trends with regards to gender, something which East African countries could pay more attention to. As the study says, "by enhancing the contribution of women engineers, stemming the brain-drain of young engineering graduates, providing continuous professional learning through streamlined engineer registration, updating and reviewing engineering curricula and supporting engineering research and innovation, Uganda has the potential to leapfrog to middle income status by 2040" (Barugahara and Sebbale 2016, p. iv).

[7] STIPRO team is only reporting what we heard from CoET faculty here.

Table 5: Summary of Pilot SIS placements (Tanzania and Rwanda)*

	University of Dar es Salaam		University of Rwanda	
	Student 1	**Student 2**	**Student 3**	**Student 4**
Specialization and year	Chemical engineering, 3rd year completed	Civil engineering, 3rd year completed	Electronics & Telecommunication Engineering programme, 3rd year completed	Civil Engineering, 3rd year completed
Industries joined (with time)	Kilombero Sugar Company Limited (November 2019 - October 2020)	Cost Plan Group (November 2019 - July 2020) and Karanga Leather Factory (August - November 2020	Liquid Telecom Rwanda (LTR) (January 2020 – December 2020)	Rwanda Housing Authority (RHA) (January 2020 – December 2020)
Level of satisfaction with SIS (students)	"The uniqueness of SIS lays on long duration at companies largely leading to long exposure in improving hands-on skills, facing real life challenges and pressure in industrial environment, social and professional networking as well as financial management. Students are more exposed to deliver based on the integration of knowledge acquired from the university and the reality on site."	"The programme enhanced confidence in performing the work with limited interference of the industrial supervisors; it offered exposure to various disciplines."	"Gained experience in telecommunication network such as wired and wireless technologies, fibre networking such as fibre installation, configuration and trouble shoot; work with the network devices configuration, installation and troubleshoot physically as well as remotely such as router, switch, radio, IP, IP phone, access point, etc."	"SIS is a contribution to engineering education as an opportunity to enhance the level of practical competence to students; it allowed performance of different civil works."

	University of Dar es Salaam		University of Rwanda	
	Student 1	Student 2	Student 3	Student 4
Industrial supervisor assessment of performance	Appreciated the programme, having undertaken the ordinary engineering experience at the university, the supervisor found that SIS provided opportunities to experience challenges that companies look for from fresh engineering graduates.	Appreciated the programme, particularly for allowing the students to stay for a long period in the firm. The student was considered as one of the staff members, left with various tasks to perform. The student met the requirements of a formal employee.	"The student is assiduous, enthusiastic, hardworking, tirelessly ready to learn."	At some point COVID-19 affected the SIS pilot at Rwanda Housing Authority (March - June 2020), this was managed in assigning tasks online.
Academic supervisor commentary on benefits	----	"She benefited from the integration of consultant work and contractor work. She got exposed to various work challenges that created the learning opportunities and improved her capabilities of doing well the work; (1) the SIS programme provides a student with much more exposure to real work environment; (2) the students get more time to gain tacit knowledge, develop professional skills and competencies from performing challenging tasks; and (3) the industries get the chance to identify students who can work with them after completing their university studies."	"SIS gave motivation, confidence and power to discover the engineering career since she opted one among different disciplines within the telecommunication field." "Student is interested to learn and link theory to real environment. SIS has been helpful in guiding professional discussions and provision of feedback."	"Pleased in the way the different software packages were learned: reading and interpreting drawings; however, interruption occurred at some point due to partial lockdown due to COVID-19."

	University of Dar es Salaam		University of Rwanda	
	Student 1	Student 2	Student 3	Student 4
Range/list of skills gained/ enhanced (according to student and industry supervisor)	(1) Leadership skills – how to adapt and best fit for working environment; exercise authority and learn from more experienced workers; responsibility and work ethics (2) Planning skills of repair and maintenance activities (3) Hands-on skills and experience in the sugar processing industry (4) Personal-finance management skills	(1) Learnt how to take electronic measurements (2) How to value the executed works at the construction site (3) How to resolve an argument in case of diverging quantities or cost in construction works between the project stakeholders (4) More knowledge on tendering procedures and contract documentation (5) How to supervise construction works, conduct site measurement, material testing and site recording	(1) Customer service and support (2) How to set up a network through a fibre internet connection and broadband internet connection (3) Time management	(1) Supervision skills (2) Execution of civil works at site (3) Confidence in work performance (4) Professional communication (5) Structural design skills using software such as etabs, robot and protastructure (6) How to operate and use detailing software like AutoCAD, ArchCAD, and Autodesk revit (7) Networking with potential stakeholders; reporting skills

	University of Dar es Salaam		University of Rwanda	
	Student 1	Student 2	Student 3	Student 4
Perception of employability increase from SIS (by student and supervisors)	"Acquired hands-on skills in my engineering field of study and further gained on-site experience in terms of work ethics, safety issues, introduction to different workers' associations and NSSF membership and benefits. This resulted in a boost of confidence. All these will enhance my employability in the engineering field after the completion of my studies."	(1) SIS has improved students' capabilities; making the student a good team-player, problem-solver, honest and integral communicator who is eager and capable of working under pressure and meeting deadlines, more accurate and very attentive to details. (2) Improved technical knowledge enables the student to identify the gaps in technical knowledge and skills and that went a long way to build myself and obtain an experience that would make me more marketable in a competitive industry.[8] (3) The programme offered an opportunity to network with likeminded professionals in the industry…which I believe has increased my chances of employability.	SIS enabled teamwork and networking through working with different people of different levels, gained knowledge and skills that I would not get outside the programme, enhanced a competitive mindset in the labour market.	"Engineering knowledge enhanced by practical experience from office and sites that increased the level of competitiveness for job opportunities. Yet, a contractor expressed the intention of hiring me when I was doing my seventh month internship under SIS…. I could not accept until I complete my degree programme."

**Commentaries drawn from student approved reports. Academic and industrial supervisors either commented generally or simply approved the student's report.*

[8] 'For example, at Cost Plan Group firm, I learnt how to value the works, conduct electronic measurements, tendering procedures and contract documentation while at Karanga leather company project, I learnt site supervision, site measurements, material testing and site recording, these made me fit for a competitive job market.'

Table 6: Summary of lessons and recommendations from Pilot SIS placements*

	University of Dar es Salaam		University of Rwanda	
	Student 1	**Student 2**	**Student 3**	**Student 4**
Lessons and recommendations for university (from student report)	(1) Collaborate with industries (organizations and production companies). (2) More funds should be raised for sustaining the programme and engage more students	Get involved in identifying gaps by analysing what the university teaches and what the industry offers, and then design capacity building which has a meaning in the development of more modern training programmes in relation to the level of technology and market in the industries together with new production methods and ideas for student projects for the purpose of improving hands on skills and innovation.	(1) Improve collaboration to facilitate student's industrial placement. (2) Pay visits to students or arrange for virtual meetings in the way to understand what is going on. (3) Ensure that students receive their stipends timely.	Ensure that the allocated funds for students reach them on time.
Lessons and recommendations for industries (from student report)	Need to collaborate with support institutions (e.g. SIS programme and universities). This assists in students' placement and also serves as a ground for engineering graduates' mentorship and recruitment.	(1) Raise awareness of the programme; and meet students in order to understand their challenges. (2) Financially, invite more donors to sponsor the programme, preferably industry to get involved in providing support. (3) Should join the SIS programme, meet the students and make clear what they expect from them; join in interviewing the students as part of selection for internship/ placement; give challenging tasks to interns, not repeated tasks.	Work in collaboration with the university in running the programme; collaborate with other industries in finding and facilitating industrial placements.	Ensure that regular supervisions are undertaken; strengthen partnership with universities and industries to facilitate the internship programme.

	University of Dar es Salaam		University of Rwanda	
	Student 1	Student 2	Student 3	Student 4
Lessons and recommendations for coordinators	(1) Provide information on SIS programme to more students; (2) In relation to the engineering training programme at universities, SIS should serve as a way to advocate for reshaping the university engineering programme in such a way that skills and experience are obtained through a strong link between theories taught at university and reality in industries.	Financially, invite more donors to sponsor the programme, preferably industry to get involved in providing support.	------	Sponsor more students; work together with industries to ensure availability of placements.

**Commentaries drawn from student approved reports. Academic and industrial supervisors either commented generally or simply approved the student's report.*

5.5. Challenges and limitations

Phase I did more surveying in Tanzania than in the other three East African countries partly due to financial limitations, since surveying each country would have required spending longer periods there (which was beyond our budget) while surveying Tanzania was more accessible because the research team resided in Tanzania. Additionally, the research team was not successful in obtaining research clearance to conduct surveys in Uganda or Rwanda, so we did not collect any information that was not readily available in the form of publications and shareable basic information. Although the research team tried, it proved to be a very long and arduous procedure to get research clearance from Uganda.

In phase II of the project, several main challenges were encountered:

- Initial difficulties in securing a second partner university for the pilot (SIS placements) and preparing agreements with universities to lead and supervise placements. After discussions and deliberations, the University of Rwanda became the second partner (the first being UDSM, Tanzania).
- Delays in locating industries and finalizing SIS placement requirements: partially for Tanzania placements and mostly for Rwanda placements.
- Due to national and international measures in response to the COVID-19 pandemic, which hit the world after phase I of the project wrapped up, the pilot phase did not end within the year planned. However, partner universities were able to coordinate with industries and students to make sure that phase II requirements were duly met. All students had a sufficient SIS experience.
- The project team sought additional funding – from sources other than IDRC – to increase number of students for SIS placements with no success.

6.0 Phase III: Synthesis and dissemination

Phase III of the project comprised synthesizing the findings of phases I and II, reflection and writing, and disseminating the information through various communication channels.

6.1. Workshop: Engineering Ecosystems and Education Capacities in Africa

As part of the project activities, and by way of allowing broader reflections with stakeholders on the research topic, as well as disseminating and discussing main findings from phase I and II of the project, STIPRO organized a project dissemination workshop on "Engineering Education Capacities: How Engineering Ecosystems are preparing students in Africa for Employment?" The workshop was held on the 1st and 2nd of December 2021, in Dar es Salaam, on-line attendance and presentation was also accommodated. The two-day workshop gathered engineering educators, industry representatives, engineering practitioners and engineering graduates, and policymakers from various African countries (e.g. Tanzania, Uganda, Rwanda, Kenya, Zimbabwe, and Mauritius), with some joining online from Australia. Participants discussed the supply and demand of engineers in Africa, impacts of engineering on industrial development in Africa, employability of African engineering students, and the findings of the SIS project phases I and II (see Appendix 2). Overall, about 80 participants attended the workshop, including representatives from the press.

The workshop was organized to include a number of paper presentations, followed by discussions. It also included interactive sessions where participants brainstormed on issues as well as made recommendations for policy and practice. The sessions of the workshop were organized under the following issues:

a) **Supply and demand of engineers in Africa:** to discuss the state of quantitative and qualitative supply and demand of engineering practitioners through a benchmark between sub-Saharan Africa and other regions, and to discuss the factors behind either oversupply or undersupply and understand projections in different engineering disciplines.
b) **Impacts of engineering fields on industrial development in Africa:** to discuss relationships between engineering training and employability, the importance of engineering toward meeting national development plans, and the role and challenges around providing adequate and high-quality engineers for Africa's industrialization.
c) **Employability of African engineering students:** to discuss the role of industry, university, and government (the triple helix) and how linkages among them are shaping engineering ecosystems.
d) **Reporting on the SIS project:** The reporting process covered activities and preliminary findings and invited attendants to critique and improve upon the findings, in order to feed the final project report and consequent publications.

Presenters at the workshop included Dr. Goolam Mohamedbhai, former Vice-Chancellor of the University of Mauritius, former Secretary-General of the Association of African Universities, former President of the International Association of Universities, and prominent engineering educator; Dr. Henry Alinaitwe, Principal of the College of Engineering, Design, Art and Technology (CEDAT) of Makerere University; Dr. Burton Mwamila, former Vice-Chancellor of the Nelson Mandela African Institute of Science and Technology (NM AIST) and Saint Joseph University; Dr. Jonathan Mbwambo, representing the Executive Secretary of the Inter-University Council of East Africa (IUCEA); STIPRO high representatives (chair of board of directors, and executive director); representative from LIWA (Linking Industry with Academia) and the Research in Engineering Education Network (REEN); and many other distinguished guests from African academia and East African related industries and state bodies. Among the speakers and discussants were also faculty staff from the College of Engineering and Technology, University of Dar es Salaam, and the Deans of Engineering from the University of Rwanda and Makerere University who were all involved in phases I and II of the project. Students who were part of the project's pilot phase (phase II) also attended and spoke about their experiences.

Reflections and recommendations from the workshop are integrated in this report, and a separate workshop report provides more details on points and insights raised at the workshop.

7.0 Discussion

Engineering ecosystems are broad and interlinked. Elements (nodes or actors) and connections (relations) are diverse and influence each other in various ways. However, the systems approach that was chosen for the study still came in handy (Mutambala *et al*. 2020). Considerable evidence exists for the existing of systems phenomena, such as:

(c) feedback loops (e.g. less competent engineers graduate, less engineers get employed, less new students join engineering schools, less pressure to improve engineering curricula);

(d) system delays (changes in curricula, or training of instructors in PBL, can only show outcome in years after implementation); and

(e) possible leverage points (e.g. changes in structure and financing mechanisms of SIS programmes). This particular part is the main focus of this study, and it will require clearer documentation and investigation of data (analysis and synthesis) to draw an abstract, broad picture of the engineering ecosystem.

From the literature review and survey, there are examples of systems delays in response to changes in the engineering scene. For example, changes in the number of engineering graduates did not change old SIS policies; additionally, there were delays in policies of absorption of engineering practitioners in the job market and adjusting to new needs and numbers. There are several feedback loops, such as:

- ✓ shortage of local engineers (percentage per population) → current graduates don't find jobs in their field → skills are not enhanced, and industries complain about competence → less students join engineering → shortage of local engineers persists (reinforcing feedback loop)
- ✓ industries complain about competence of local engineering practitioners → graduates are expected to prove competence to find employment → requiring work opportunity in order to build competence, but work opportunities often go to expatriates or older generations → graduates unable to build competence → industries complain about competence of local engineering practitioners (balancing/negative feedback loop)
- ✓ low technology localization/transfer in African countries leads to low capacity of local industries to execute large engineering projects with local custodianship → large engineering projects are assigned to foreign industries (translational corporations or bilateral partnerships) → more foreign expatriates oversee delicate technology operations, while most local engineering practitioners are relegated to mundane tasks → large engineering projects are implemented without necessarily transferring their technology locally → low technology localization/transfer in African countries (negative feedback loop)
- ✓ Just as there are feedback loops, there are also potential leverage points. On the level of SIS programmes, perhaps they can introduce a shift in feedback loops: Graduates are armed with practical experience → employability of graduates increases → industries (local and foreign) find a larger pool of competent local engineering practitioners → study of engineering becomes appealing again → steady enrolment and technology localization.

Other leverage points may exist in policies: standardizing long-term, hands-on SIS placements, across the triple helix, could lead to strengthening the local engineering ecosystem (i.e. advancements in industry, registration of engineering practitioners, and technology localization).

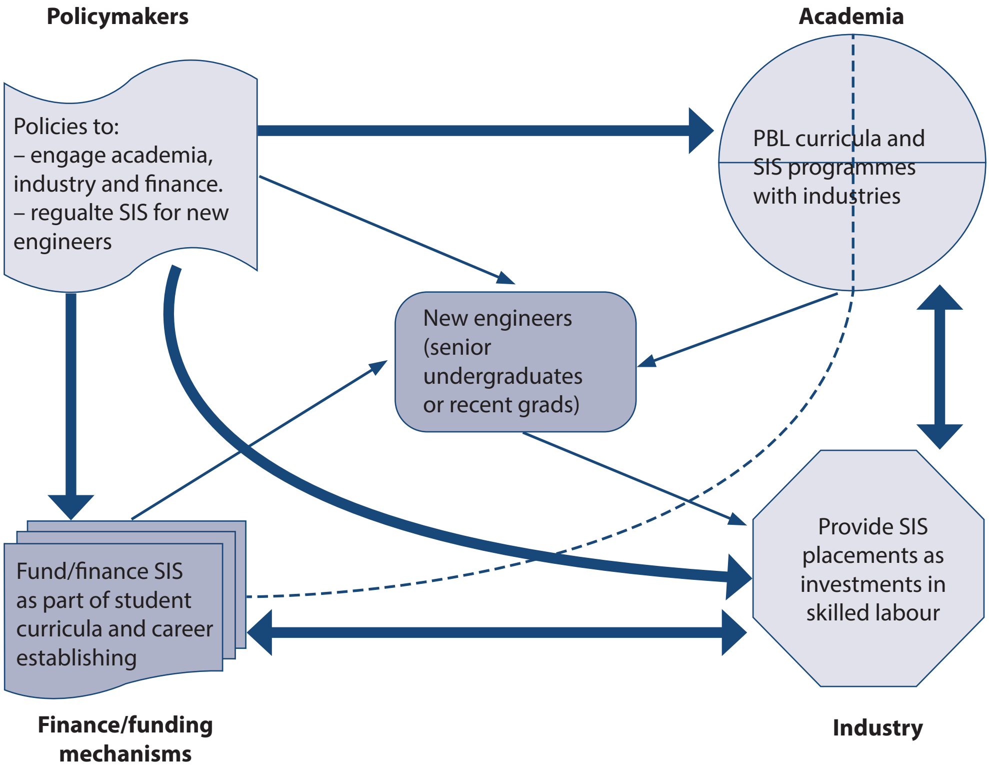
Yet there might be bigger leverage points, at the level of paradigms – perhaps such research points to bigger issues of perceiving engineering practice in developing countries. We can rethink academic engineering training as parallel to the development level of the country, instead of thinking now of engineering training as only relevant when up to standards of technologically advanced countries, or when theoretical skills are well informed and updated with what takes place in such countries. The four influencers/actors of engineering ecosystems (policymakers, academia, industries, and financing/funding mechanisms) could introduce a new, more conducive paradigm.

Figure 2 provides a visualization of the main actors and connections of the engineering ecosystem if new engineers (i.e. senior undergraduates or recent graduates) are taken as the centre of attention. The visualization was developed over the project's period, based on the literature, survey and pilot, but it is still in need of further examination and consultation. In this ecosystem, 'policymakers' play a critical role, and they include regulatory bodies for engineering practice as well as other actors from the state or from regional bodies (such as science councils). Academic institutions also play a major role, particularly when they choose to innovate and tailor their programmes to include more PBL and SIS activities. Industries play a critical role as well, particularly when they realize that providing and organizing well-structured SIS placements is an investment in future skilled labour that they need to grow and innovate. Finance/funding mechanisms play a crucial part in the ecosystem because they can be catalysts that invest in proper engineering training to get returns in the form of more capable engineering practitioners (in quality and quantity) that advance and improve the ecosystem at large, for sustainable development goals.

Employability – for engineers and others – can be generally understood as having the set of knowledge, skills, understanding and attributes to gain and maintain fulfilling work. With such understanding/definition in mind, all existing evidence supports the argument that SIS programmes (and co-curricular activities in general) increase the employability of students. Yet, there are supporting approaches – for example, linkages with industries should be a reality, not an aspiration. Pedagogical approaches such as Problem Based Learning (PBL) are instrumental in realizing these linkages.

In summary, we may think about it in simplified terms this way: if the competency of engineering graduates in Africa is increased, through enhancing and strengthening engineering education, then the employability of those graduates would likely increase, thus making an engineering degree more attractive for incoming college students to enrol in, therefore eventually increasing the number of engineers. Finally, a general understanding is growing that policy is the catalyst of possibilities. To have broad and long-lasting impacts on engineering education in Africa, for the sake of sustainable development and growth, solutions should be articulated as policies – formulated, implemented, embedded and supported.

Figure 2: Engineering ecosystem influencers/actors and employability of new engineers



Legend:

↗ from-to inputs (bolder lines between institutional actors)

- - - inter-influence (various relations)

↔ indirect influence (through policy or relation)

8.0 Conclusions and recommendations

8.1. Conclusions

General characteristics and patterns were revealed through this study about the challenges of university-to-employment transition for engineering students in East Africa. The four East African countries of Tanzania, Rwanda, Uganda and Kenya share many similarities, in history and current challenges and interlinkages, making them a good example of a regional 'engineering ecosystem' that exists along national ecosystems as well. The study's findings show that there is a general consensus that short-term (8-12 weeks) industrial attachments, currently practised, do not allow students to have in-depth industrial experiences that visibly enhance their employability skills. Additionally, industries tend to receive more students in each training period than they can give tailored attention, resulting in completing industrial attachments with little experience and only fulfilling formal requirements to graduate. Weak coordination between universities/colleges and industries also contribute to a general mismatch of placements and miscommunication about how IAPs can be improved to increase the employability of engineering students.

The study's conclusions support that SIS placements over a longer period than at present help increase the employability of engineering students, according to perspectives of industrial supervisors, students and academic supervisors, but further evidence is needed (more scale SIS placements and more tracer studies). A system's approach points towards a need for recognizing feedback loops and delays in the engineering ecosystems as they respond to a twofold problem: the relative shortage of engineering practitioners and the limitations to employability for the existing practitioners. Some ideas came out after recognizing the benefits of long-term SIS programmes, such as a suggestion by a senior UDSM professor of incorporating longer SIS placements by changing the structure of current practical training/industrial training programmes. Pedagogical approaches that aim for strong academia-industry linking, such as SIS and PBL, have the potential of resolving such dissonance (i.e. possible leverage points in the ecosystems), and they can work through policies that act as catalysts for change.

8.2. Project outputs (publications, presentations, and events)

a) Publications:

- Sheikheldin, G. and Nyichomba, B. 2019. 'Engineering education, development and growth in Africa.' *Scientific African*, Vol. 6. e00200.
- Mutambala, M., Sheikheldin, G., Diyamett, B. and Nyichomba, B. 2020. 'Student Industrial Secondments in East Africa: Improving Employability in Engineering' in *Disruptive Engineering Education Amidst Global Challenges: WEEF & GEDC Virtual Conference Proceedings*, 16-19 November, Danvers: IEEE.
- Mutambala, M. and Thomas, H. 2021. Engineering Education Capacities: How Engineering Ecosystems are preparing Students in Africa for Employment? Workshop report. Dar es Salaam: STIPRO.
- Sheikheldin, G., Mutambala, M., Klassen, M. and Matemba, E. 2022. Alternative models for engineering student industry placements in East Africa. Briefing paper.
- Sheikheldin, G., Mutambala, M., Diyamett, B. and Nyichomba, B. 2022. Improving Employability of Engineering Graduates Through Student Industrial

Secondments: A Study in East Africa. Project report. Dar es Salaam: STIPRO (*in-print*).
- o Sheikheldin, G., Mutambala, M., Diyamett, B. and Nyichomba, B. 2022. Challenges around Employability of Engineering Graduates in Africa: Can Industrial Secondments be a Remedy? Policy brief. Dar es Salaam: STIPRO (*in-print*).
- o *Forthcoming*: 1-2 scholarly papers (one possible in a special journal issue, co-edited).

b) Presentations:
- o Participation in AfricaLics special session: On the 4th AfricaLics conference, held in Dar es Salaam, 22-24 October, a special session was organized on 'engineering education, growth and innovation in Africa', in which the project lead presented a paper about this project, sharing the project rationale, methodology and preliminary findings.
- o IDRC presentation (May 28th): Project lead, Gussai Sheikheldin, prepared a presentation on the project, in general, for IDRC, Ottawa, in a visit to Canada. That same presentation was used to present to the potential partners and other stakeholders in East Africa (particularly with the College of Science and Technology, University of Rwanda, and in Kenya).

c) Events:
- o Dissemination and reflection workshop: Engineering Education Capacities: How Engineering Ecosystems are preparing students in Africa for Employment?" 1-2 December 2021, Dar es Salaam. (International attendance).

8.3. Future possibilities

- Further research on scaling is needed to strengthen evidence and better understand the ecosystem, but for undertaking such research, there needs to be buy-in from the triple helix (government-academia-industry) to increase the number of SIS placements, perhaps for a 'second' larger-sample project.
- Partnering with regional and/or continental agencies, such as the Association of African Universities and the African Union's Scientific, Technical and Research Commission (STRC), to vocalize the issues that are relevant to this project and to create more interest and generate additional ideas.
- Funding for increased SIS placements remains a challenge. Possible pathways for scaling up, and possible pathways for sustainable (continuous) funding and management should be explored.
- Looking at regulations and logistics related to engineering students taking longer periods off their university programme to pursue SIS placements. Can such SIS placements of longer periods be included in curricula (as in some universities) or be officially accommodated?

8.4. Recommendations

- Improve communication, collaboration and planning between government, academia and industries to address demand and supply of engineering practitioners (EPs).
- Long-term co-curricular activities have proven worldwide to improve graduates' preparedness for employment after graduation. Higher learning institutions should

seek to enhance and invest in co-curricular activities, including long-term student industrial secondment (SIS) programmes.

- Problem Based Learning (PBL) and Challenge Based Learning (CBL) in engineering curricula can be treated as essential, not only an option. Engineering fields are often highly practical and hands-on, with physical results to produce and maintain. That level of practicality requires learning that integrates real-world problem-solving experience.
- In the same vein as promoting PBL, change from 'knowledge-based curriculum' to 'outcome-based curriculum' is also recommended to reduce the mismatch between training of engineering practitioners and requirements of industries.
- Bring engineering to the forefront of the debates and policymaking for the STI Strategy for Africa (STISA) 2024 and for the SDGs. They need to be at the forefront because they influence almost every aspect of both STISA and the SDGs.
- Collaboration and communication between East African (and African) engineering boards would enhance and promote engineering in the region because it will broaden the work/employability prospects of EPs and encourage improved and dynamic accreditation of EPs.
- African governments should legislate to ensure that transnational corporations and engineering companies from foreign countries provide professional training to local engineering students and employ local engineering graduates wherever possible to enable technology transfer.
- Incentives should be explored to make more engineering practitioners, especially fresh engineering graduates, willing to work in rural areas in Africa, where the biggest challenges to SDGs are.

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Appendices

Appendix 1: Phase I country-specific surveying activities

Country	Activities (and dates)	Responsible team members
Tanzania	Dar es Salaam (Feb–June 2019) Entities/agencies engaged: UDSM (College of Engineering and Technology), COSTECH (Tanzania Commission of Science and Technology), Engineering Registration Board, Industries (MMI Steel), Dar es Salaam Institute of Technology, and St. Joseph University Arusha (25–31 March 2019) Entities/agencies engaged: Nelson Mandela African Institution of Science and Technology, SIDO (Small Industries' Development Organization), CAMARTEC (Centre for Agricultural Mechanization and Rural Technology), TEMDO (Tanzania Engineering and Manufacturing Design Organization), TANELEC Ltd., Arusha Technical College, etc. Mbeya (15– 18 May 2019) Entities/agencies engaged: Mbeya University of Science and Technology, SIDO, and Tanzania Breweries Ltd. Morogoro (18–20 June 2019) Entities/agencies engaged: SIDO, INTERMECH Engineering Ltd, BSK Engineering, Tanzania Tobacco Processing Ltd, Shambani Milk, Sokoine University of Agriculture (SUA) Morogoro (19 May 2020) Entities/agencies engaged: SIDO, Intermech Engineering Ltd, BSK Engineering; Tanzania Tobacco Processing (TCCP), Shambani Milk, Sokoine University of Agriculture (SUA) Morogoro/Kilombero (25 September 2020) Entity: Kilombaro Sugar Company	Gussai Sheikheldin, Musambya Mutambala, Bitrina Diyamett, Bavo Nyichomba

Country	Activities (and dates)	Responsible team members
	Moshi (8 October 2020): Karanga Shoe Company Activities included: interviews with key informants and stakeholders about the status of engineering education, industrial training for undergraduate students, industries' experiences with receiving students for industrial training, records of successful cases or employment retention, challenges and opportunities, etc.	
Rwanda	Kigali (July–August 2019) Entities/agencies engaged: University of Rwanda (and especially the College of Science and Technology), Integrated Polytechnic Regional Centre (IPRC), NCST (National Council of Science and Technology), EASTECO (East African Science and Technology Commission) Activities included: general meetings and discussions about the history of industrial training for students in Rwanda, current initiatives and programmes, and future plans. The research project team also introduced the project to colleagues in Rwanda and shared general findings and perspectives.	Bitrina, Bavo, Gussai
Kenya	Nairobi (Aug 2019) Entities/agencies engaged: Linking Industry with Academia (LIWA), African Centre for Technology Studies (ACTS), University of Nairobi, Kenyatta University, and Kenya National Highways Authority (KeNHA)	Musambya, Bitrina
Uganda	Kampala (Sep–Oct 2019) Entities/agencies engaged: College of Engineering, Design, Arts and Technology (CEDAT), Makerere University, and Uganda National Council of Science and Technology (UNCST) Activities included: general meetings and discussions about the history of industrial training for students in Uganda, current initiatives and programmes, and future plans.	Bavo, Gussai, Musambya

Appendix 2: Dissemination and reflection workshop report

Report of Project Dissemination Workshop
on
"Engineering Education Capacities: How Engineering Ecosystems are preparing Students in Africa for Employment?"[8]

White Sands Resort Hotel, Dar es Salaam – Tanzania
1st – 2nd December 2021

Introduction

The Science, Technology and Innovation Policy Research Organization (STIPRO) organized a workshop with the title "Engineering Education Capacities: How Engineering Ecosystems are preparing students in Africa for Employment?" that was held on the 1st and 2nd of December 2021 at the White Sands Hotel, Dar Es Salaam, Tanzania. The two-day workshop was a hybrid one – used for disseminating the findings of the project 'Student Industrial Secondments in East Africa' (led by STIPRO with partner universities) and on the supply and demand of engineers in Africa, impacts of the engineering fields on industrial development in Africa, and employability of African engineering graduates. This report provides the summary of the workshop and includes a brief context of the workshop. In addition, the report highlights the key outputs from the workshop sessions.

1. Context of the workshop

Engineering practices play a crucial role in addressing development challenges; they bring ideas into reality and particularly contribute to the transformation of the industrial sector that triggers economic growth (Mutambala et al., 2020). Engineering practitioners act as catalysts of technological change, which is linked to the acquisition and enhancement of knowledge and skills that address deficits in science, technology, engineering and mathematics (STEM) and their role in development. There are good reasons to renew interest in, and attention to, engineering education in developing countries (Ibrahim, Luo & Metcalfe, 2017; UNESCO, 2010; Royal Academy of Engineering, 2020).

[8] Prepared by Musambya Mutambala and Heric Thomas, STIPRO

What we refer to by engineering in the context of this discussion is the process of digesting and combining knowledge, resources and arts to create and operationalize technology (Sheikheldin & Nyichomba, 2019; Sheikheldin, 2018).

Given the importance of engineering, the newly independent states in Africa saw the need to establish engineering education programmes to fill quantitative and qualitative knowledge and skill gaps in engineering practices in their countries. In East Africa, for example, the East African Community that was formed in 1967 shortly after independence, played a significant role at that time of facilitating students from Tanzania and Uganda to take engineering courses at the University of Nairobi, Kenya, as the nearest engineering school in the region. Since then, engineering schools have increased in each country. Engineering colleges are now almost everywhere in East Africa (and Africa). They cover different courses such as civil, mechanical, electrical, agricultural, chemical, biomedical, aerospace, environmental, electronics, computer, automotive, structural, industrial, manufacturing, petroleum, mining, transportation, telecommunication, and so forth. These academic programmes lead the process of training future and current engineering practitioners. Within the engineering ecosystem, colleges and other stakeholders put in place models and approaches for preparing engineering students for employment after graduation. This is the case of programmes such as student industrial secondments (SIS) – such as practical training (PT) and structured engineers' apprenticeship programme (SEAP), in East Africa – as well as teaching models such as problem-based learning (PBL).

However, despite increased efforts, the number of engineering graduates in Africa overall is not in concert with the increasing needs of qualified engineering practitioners (Nganga, 2014). Africa faces a challenge of shortage of engineering practitioners (Eps). For example, not long ago, about 2.5 million more engineering practitioners were estimated to be needed in Africa to meet the development goals of access to clean water and sanitation (UNESCO, 2010). Available data from the international benchmark of engineers per population shows that Africa lags behind as far as international norms are concerned (Patel, 2017) both in terms of quantity and quality of engineering practitioners. Whereas the ratio of engineers per population in China, for example, is at one engineer for every 200 persons, and one engineer for every 300 persons in the UK, the ratio in most African countries is close to one engineer for every 6,000 persons. In addition to the challenges of quantity, performance and efficiency of existing engineering practitioners is an additional challenge.

Additionally, we observe dissonance in translating the importance of engineering practices into hiring the engineering graduates. The region that suffers from an acute shortage of engineers still has a significant number of local engineering graduates having difficulty finding jobs within their fields. This dissonance raises concerns that stimulated the need to organize the present workshop, as part of an on-going project led by STIPRO, in partnership with the University of Dar es Salaam and University of Rwanda, and supported mainly by IDRC Canada, to discuss in detail the challenges and opportunities in establishing a balance between engineering skills in development and employability of engineering graduates in East Africa (and Africa at large).

2. Workshop objectives

This workshop aimed at spurring national and regional debate on the relationship between engineering education and employment of graduates. It discussed the role of engineering colleges and universities in preparing engineering students to work in industries and public services, and to chart the way forward. The involvement of three major actors was critical: government (in terms of policies and guidance), research (academic training and research/technology organizations) and industry (private, public, PPP, etc.) — also known as the triple helix.

3. Participants

The workshop brought together about 50 participants from different sectors. The two-day workshop gathered engineering educators, industry representatives, engineering practitioners and engineering graduates, and policymakers from various African countries (e.g., Tanzania, Uganda, Rwanda, Kenya, Zimbabwe, Sudan, and Mauritius), with some joining online from Australia. They were selected based on their experience in the field and thus expected to provide answers to the workshop questions for an appropriate policy action. Representatives from the press were also present.

4. Opening Events

Dr. Bitrina Diyamett, the Executive Director of STIPRO, welcomed the participants and thanked them for accepting the invitation and devoting time to take part in the workshop discussion. Special thanks were given to the Executive Secretary of the Inter-University Council of East Africa (IUCEA) by accepting to officiate at the event, a gesture that showed IUCEA's concern about the issues addressed in the workshop. When presenting the **welcoming remarks and introduction to the workshop**, Dr. Diyamett emphasized that the role of engineering is indispensable for development, especially as it relates to innovation and growth of the secondary sector that results from structural transformation of resources (primary sector) where value addition is important for stable growth and decent employment.

Dr. Diyamett said that the motive of organizing such a workshop on engineering education capacities could be explained by the desire to discuss any existing challenge in terms of the supply, demand of the engineering graduates. She reminded workshop participants that the statistics show that Africa is supplying far less engineers than it should but many of the engineering graduates cannot find employment in the field, something that appears strange.

Dr. Diyamett raised some questions that the workshop needed to respond to in order to address the concern of the engineering education and employability of the engineering graduates in Africa:

Has education attainment gone beyond the needs of African economies as far as engineering practice is concerned?

Is the supply capacity surpassing demand or alternatively do our universities and graduates have skills that are not well matched with those required by the employers; are the engineering graduates aware of the employment opportunities that are available in companies or self-employment; is our social and economic system creating incentives for job creation in the secondary sector?

She thanked IDRC for funding the project and therefore the workshop, highlighting that IDRC is one of the funding organizations that have consistently and persistently supported policy research projects in science, technology and innovation (STI).

The opening event was officiated by Dr. Jonathan Mbwambo on behalf of the Executive Secretary of IUCEA. Dr. Mbwambo reminded the workshop participants that to succeed in engineering we must innovate to bring new products in the market beyond our borders. Recognizing that the unemployment of the engineering graduates is a major concern in the engineering ecosystem, Dr. Mbwambo thanked STIPRO for organizing the workshop that aimed at discussing the fate of the engineering fields in preparing students for employment. He showed confidence that the workshop has brought in renowned scholars in the field of engineering education. As such, many questions on the subject matter will get informed responses; for instance: *how the training of engineers is conducted in African universities and colleges? and how can we make engineering attractive?* Dr. Mbwambo then emphasized investment in engineering through research, innovation and exports, collaboration through a triple helix model for the future of engineering, and participation of local engineers in existing foreign direct investment (FDI) projects so as to shape skills, knowledge and technology.

Dr. Adalgot A. Komba, chairperson of STIPRO's board of directors and professor at the Institute for Development Studies, University of Dar es Salaam, presented a brief vote of thanks for the opening address by the guest of honour. He reminded the workshop participants to reflect on where we are now and the future we want. To him, engineering education in East Africa started 50 years ago to contribute to the sustainable development of societies. However, such contributions are not significantly seen as intended. He urged the participants to think about how we can build engineering capacity for the new generation. He thanked the guest of honour for officiating the workshop, IDRC Canada for continuously supporting innovation studies in Africa, and STIPRO for the organization as well as for the participants for joining the workshop.

5. Workshop moderation and structure

The workshop was moderated by Mr. Theophilus Elifuraha Mlaki. He was however seconded by other moderators who were designated to guide specific sessions. In addition to opening remarks, the workshop contained four sessions, which included keynote speeches and presentations. The sessions of the workshop were specifically organized under the following issues:

a) **Supply and demand of engineers in Africa:** this session discussed the state of quantitative and qualitative supply and demand of engineering practitioners through a benchmark between Africa and other regions, the factors behind either oversupply or undersupply, and the projections in different engineering disciplines.

b) **Impacts of the engineering fields:** this session discussed the results of establishing a relationship between engineering training and employability. Participants reflected on the importance of engineering toward meeting national development plans. The session reflected on the role and challenges around the provision of adequate and high-quality engineers for Africa's industrial development.

c) **Employability of African engineering students:** this session discussed the role of industry, university and government and the status of the linkages amongst the parties in shaping engineering education.

d) **Reporting on the SIS project** led by STIPRO since October 2018. The reporting covered activities and preliminary findings and invited attendants for critique and improvement upon the findings, in order to feed the final project report and consequent publications.

Each issue was covered by one presentation and one discussion followed by a Q&A session as well as sessions on fireside chat, and a final session to deliberate on identified policy issues.

Session one on **"Supply and demand of engineers in sub-Saharan Africa"**, was led by Prof. Goolam Mohamedbhai, former Secretary-General of the Association of African Universities, former President of the International Association of Universities and prominent engineering educator. He made a keynote presentation on *"Engineering Practitioners in sub-Saharan Africa: Demand, Supply, Capacity and Quality"* that emphasized, in terms of demand, that several sectors (agriculture, mining and quarrying, manufacturing, construction, utilities and ICT) demand engineers. This demand relates to the sustainable development goals (SDGs) and Agenda 2063 – The Africa We Want.

Prof. Goolam added, in terms of supply that there is, however, shortage of engineers to support development that leads to reliance on imported expertise. The shortage of African engineers is explained by insufficient supply of engineering graduates. On the capacity and quality, he emphasized the need for a teaching methodology (PBL) and curriculum development that reflect African context and development of infrastructure. He called for up-to-date laboratories and libraries, strong internship programmes, strong university-industry linkages as well as putting in place accreditation mechanisms.

The session had two discussants: Prof. Henry Mwanaki Alinaitwe, Principal of the College of Engineering, Design, Art and Technology (CEDAT), Makerere University and Prof. Burton Mwamila, former Vice Chancellor of Nelson Mandela African Institute of Science and Technology (NM-AIST). Prof. Henry M. Alinaitwe reflected on Chinese training almost everywhere in the world, emphasized training to be the major concern of Africa. He reminded workshop participants that the education curriculum development is within the mandate of the universities; hence Africa should not blame foreigners. Prof. Burton Mwamila emphasized innovation and entrepreneurship in engineering education to help students become problem solvers. He emphasized the need for internships after graduation – that has an aspect of university-industry linkage. Prof. Mwamila called for mindfulness when planning for conversion of technical colleges into universities as technician training and vocational education centres are important;

and he called for the introduction of soft skills in engineering and technology education and the enforcement of laws on local content since these require the participation of local experts in huge projects.

General discussion

- There is need to reflect on whether Africa is a consumer or producer of technological products in understanding the status of supply and demand of engineering practitioners.
- There is a need for a tracer study to understand the industrial requirements of engineers and at the same time ensure establishment of industrial training programmes for lecturers.
- Africa needs to be concerned about the extent to which few African engineers are employed. This calls for self-reflection of African engineers in the way they engage in the problem solving process, and the way they perceive their attitude; here emphasis should be made to teamwork and communication as essential in building engineering capacities.
- There is need to match university skills and market requirements, and the contribution of engineering to economic growth should be reflected in the way the economy invests back into engineering education.
- Emphasis should be put on establishing problem-based learning (PBL), specialization of engineering programmes and enforcement of laws to guide investors on the participation of local expertise in huge projects.
- Stakeholders need to critically think about the kind of engineering courses that are in many universities in Africa.

Session Two on "Impacts of the engineering fields on industrial development in Africa" involved a presentation followed by a fireside chat and general discussion. A presentation from Dr. Esther Matemba from Curtin University (Australia) called for the contextualization of developing practices (culture, workplace environment); engineering education transformation to respond to industry needs (wealth creation), and treating engineering education as an area of research (collect and share data).

The presentation by Dr. Matemba was followed by a fireside chat led by Dr. Savinus Maronga (College of Engineering and Technology, University of Dar es Salaam – CoET), Dr. Juliana Machuve (CoET, UDSM), Dr. Lawrence Kerefu (St. Joseph University) and Eng. Richard Ogomo (Kilombero Sugar Company Ltd.). The team emphasized issues such as conducting industry needs assessment in relation to supply of engineering practitioners; investment in human capital; reflection of African engineering education and industry in relation to the current 4^{th} industrial revolution and making students responsive. Dr. Wilson Nyemba, from the University of Zimbabwe however had a different perspective about the challenges facing engineering graduates by looking at the trainers' side. He emphasized the importance of equipping engineering educators with better understanding so as to build quality engineering graduates and establish engineering networks.

General discussion

- Perhaps engineering education needs to adopt the medical doctors' experience in preparing the graduates.
- Industries to be open to welcome engineering students.
- Emphasis should be on students' exposure, encouragement of establishing and developing start-ups that would employ more engineering graduates, and help students follow the right courses; collaboration between engineers and technicians, and improvement of quality education should start from the lower levels in order to get quality engineering graduates.
- Training should contain issues of self-employment and participation of the local population in mass production (as contributors in the productive sector).
- Issues of incentives need to be looked at.

Session Three on **"Employability of African engineering students"** had a presentation and a discussant, followed by a fireside chat and a general discussion. Prof. Patrick Makungu made a presentation that reflected on the role of triple helix of university, industry and government in shaping engineering education in Africa. The government needs to encourage the links through funding; universities as entrepreneurial entities should be encouraged to identify areas of competitive advantage; and suggested preparing a framework based on research. He raised a concern about whether current education logic systems and employment logic systems are appropriate for shaping engineering education.

In discussing the presentation, Dr. Duncan Mbuge, from University of Nairobi, reflected on factors affecting employability of engineering graduates, namely the stages of growth, structural adjustment programmes (SAPs), national policies/vision/agenda, internships and industrial attachment programmes, and individual traits.

The fireside chat led by Dr. Avitti Mushi (CoET), Ms. Bancy Ngatia (Aga Khan University, Nairobi), Eng. Peter Chisawillo (Intermech Engineering Ltd.) and Dr. Mkabwa Manoko (College of Agricultural Sciences and Fisheries Technology – CoAF) emphasized collaboration, communication and cooperation between the triple helix elements (government, academia, industry), the need to know the purpose of such collaboration, and realize a common agenda, encourage trust among the helix elements; that funding is important to sustain the effectiveness of the linkage.

Session Four was on **reporting on the student industrial secondment (SIS)** project. Dr. Gussai Sheikheldin reported that the SIS project aimed at gaining reliable knowledge and understanding of the potential of tertiary SIS programmes in strengthening engineering ecosystems in East Africa. This regional project was conducted by STIPRO from 2018 and had three phases, namely surveying the EAC region (Kenya, Rwanda, Tanzania and Uganda), pilot, and reporting. The survey findings have shown similarities in terms of characteristics and patterns in history, challenges and inter-linkages. These opportunities and challenges make the EAC region a good example of a regional engineering ecosystem. With regard to the pilot phase, it was found that the long term SIS placements help increase the employability of engineering graduates. This was a result from positive reporting from four students that were supported by the project at CoET, UDSM and the College of Science and Technology, University of Rwanda (UR) for 1-year industrial placements. The pilot findings show high confidence and employability possibilities for the project graduates.

In discussing this reporting, Dr. Dorothy Okello, from Makerere University, appreciated the SIS project's approach, but she showed concerns about the sustainability of similar SIS programmes and suggested that industries should participate in grooming the students. She called upon thinking about the after-graduation period (internships), bureaucracy to get the programme done as it is out of the education curriculum, training of trainers, and shortage of infrastructure.

General discussion

- SIS programmes should be well structured to capture missing knowledge.
- Consideration of the political side in agreeing with the insertion of the programme into the education curriculum (e.g. resistance to change).
- There is need for more evidence on a better way of designing internship programmes in Africa, either within the study or after graduation.
- Establishing SIS programmes raises concern about recognizing the degree as a four (4) or five (5) year programme.

6. Workshop resolutions and conclusion

In the workshop conclusion session, participants highlighted that:

- The demand for engineering practitioners is there to respond to the requirements from the various productive sectors and contribute to SDGs and Agenda 2063.
- However, the supply of African engineering graduates is low compared to other places (China, Europe, etc.). Therefore, it is recommended to conduct research in order to understand the projections of engineering graduates in different engineering disciplines.
- There is a mismatch between training of engineering practitioners and requirements of industries, and therefore it is recommended that the content of engineering education curricula be reviewed, establishment of internship programmes, mainstreaming PBL, collaboration among stakeholders (e.g. Triple Helix), strengthening engineering professional networks, and training of trainers.
- Actors in engineering ecosystems need strong coordination for effective outcomes that increase the employability of African engineering students. The actors involved in the SIS pilot (students, supervisors and industry) spoke positively about the approach. Stakeholders need to work on the challenges raised such as funding, bureaucracy, and delays in locating students for placements.

7. Closing remarks

Dr. Adalgot Komba thanked all the participants for their contributions and presenters for their excellent presentations. He expressed his satisfaction as the two-day workshop raised important issues in engineering education and engineering ecosystems. He reminded participants that Africa, and Tanzania in particular, is not in isolation; it is connected and facing competition. This needs collaboration. To him, "quality of engineering" is a question of supply, demand and policy. He further called upon the new generation of engineers to change their mindset. He finally thanked STIPRO for organizing the workshop.

8. References

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Engineering Education Capacities: How Engineering Ecosystems Are Preparing Students in Africa for Employment

Workshop Programme

DATE: 1st – 2nd December 2021
VENUE: White Sands Resort Hotel, DAR ES SALAAM

WORKSHOP MODERATOR: THEOPHILUS ELIFURAHA MLAKI

TIME	EVENT	RESPONSIBLE
08.30–09.00	REGISTRATION	All
Day 1:		
09.00–09.20	Welcome and Introductory Remarks	**Executive Director – STIPRO** Dr. Bitrina Diyamett
09.20–09.35	Opening Remarks	**Guest of Honour:** Executive Secretary, Inter-University Council for East Africa (IUCEA)
09.35–09.45	Vote of Thanks	**Chairman – STIPRO Board** Dr. Adalgot Komba
09.45–10.00	Group Photo	All
10.00–10:35	**TEA/COFFEE BREAK**	All
Session 1: "Supply and demand of engineers in sub-Saharan Africa"		
10.35–11.05	Keynote Presentation: "Engineering Practitioners in sub-Saharan Africa: Demand, Supply, Capacity and Quality"	**Prof. Goolam Mohamedbhai,** former President of Association of African Universities
11.05–11.30	**Discussant 1**	**Prof. Burton Mwamila,** former VC NM AIST, St. Joseph University
11.30–11.55	**Discussant 2**	**Prof. Henry Mwanaki Alinaitwe,** Principal of CEDAT, Makerere University

11.30–11.55	**Discussant 2**	**Prof. Henry Mwanaki Alinaitwe,** Principal of CEDAT, Makerere University
11.55–12.30	General Discussion	All
12.30–13.50	**LUNCH BREAK**	All
Session 2: "Impacts of the engineering fields on industrial development in Africa"		
13.50–14.15	Presentation II: "Engineering Education Capacities and Employability of Engineering Graduates in southern Africa, through EEEP, HEP SSA and SAE2Net"	**Dr. Wilson Nyemba,** University of Zimbabwe
14.15–14.35	Discussant	**Dr. Esther Matemba,** Curtin University
14.35–15.15	Fireside Chat	**Dr. Savinus Maronga,** CoET (Moderator); **Dr. Juliana Machuve,** CoET; **Dr. Lawrence Kerefu,** St Joseph University; **Eng. Richard Ogomo**, Kilombero Sugar Company Ltd.
15.15–15.50	General Discussion	All
15.50	**REFRESHMENTS AND DEPARTURE**	All
DAY 2		
08.30–09.00	REGISTRATION	All
Session 3: "Employability of African engineering students"		
09.00–09.25	Presentation III: "The Role of Triple Helix of University, Industry and Government in shaping the engineering education in Africa"	**Prof. Patrick J. Makungu,** University of Dar es Salaam
09.25–09.45	Discussant	**Dr. Eng. Duncan Onyango Mbuge**, University of Nairobi
09.45–10.20	Fireside Chat	**Eng. Dr. Aviti T. Mushi**, CoET (Moderator); **Eng. Peter Chisawilo,** Managing Director of Intermech Engineering Ltd; **Ms. Bancy Ngatia**, Aga Khan University (former researcher at LIWA); **Dr. Mkabwa L.K. Manoko,** CoAF

10.20–10.40	General Discussion	All
10.40–11.10	**TEA/COFFEE BREAK**	
11.10–11.35	**Session 4: "Reporting on the SIS project"**	**Dr. Gussai Sheikheldin**, STIPRO
11.35–11.55	Discussant	**Dr. Dorothy Okello**, Dean of School of Engineering, CEDAT-Makerere University
11.55–12.30	General Discussion	All
12.30–13.30	**LUNCH BREAK**	All
13.30–13.50	**Recap**	**Musambya Mutambala & Heric Thomas**, STIPRO
13.50–14.20	**General Discussions for Concrete Policy Deliberations**	ALL
14.20–14.30	Closing Remarks	**STIPRO Board Member** Prof. Benedict Mongula
14.30	**DEPARTURE**	

Appendix 3: Project workplan and calendar

	Year 1			Year 2			Year 3		Outputs	Remarks
	Third 1	Third 2	Third 3	Third 1	Third 2	Third 3	Third 1	Third 2		
Phase I: Surveying	Mapping of existing and previous engineering SIS programmes in East Africa (Tanzania, Kenya, Uganda, Rwanda) and their outcomes								Report on the history of engineering SIS programmes in East Africa (past and present) with indicators of success and lessons from shortcomings.	Through the mapping and surveying activities contact will be established with the wide network of relevant actors, to inform them of the project and recruit partners/ supporters.
	Surveying and identifying of best practices in SIS programmes in East Africa and other relevant cases in developing countries.								An evidence-based list of best practices learned from East African experiences and other relevant experiences.	
		Selecting engineering school from university B, selecting two students from each school, communicating with hosting organizations, finalizing placements and preparations with schools and industries.							University B selected, and four students total are selected and assigned SIS placements for coming year. MOUs with industries signed to take in students.	University B from Uganda or Rwanda (university A is UDSM) as advised by IDRC.

	Year 1			Year 2			Year 3		Outputs	Remarks
	Third 1	Third 2	Third 3	Third 1	Third 2	Third 3	Third 1	Third 2		
Phase II: Pilot SIS				SIS activities take place over the whole year. Each student will have a one-year placement; possibly divided into two firms/industries (depending on availability of qualified and agreeing industry partners).					SIS work begins (four students, two countries, and possibly four different firms/ organizations).	Aim will be for each student to have two SISs, divided into 6-months each, for broader exposure.
					MEL*from SIS experiences. Cases will be closely observed to learn the most from them.				Data, observations and lessons recorded.	*Monitoring, Evaluation and Learning.
					Advocacy for SIS programmes, learning from other relevant research (through scholarly conventions), and beginning of sharing results of phase I.				2-3 relevant workshops or conferences attended, with presentations about the project.	
Phase III: Synthesis and Result Dissemination							Data analysis among project partners, synthesis of findings, and consultations with relevant sources.			Communication with members of the triple helix (university-industry-government) for informing about project findings and recommendations, and invitations to the dissemination workshop.
							Dissemination workshop (planning and event) + Project report (write-up and release).		One knowledge dissemination workshop conducted. Workshop report is produced.	

	Year 1			Year 2			Year 3		Outputs	Remarks
	Third 1	Third 2	Third 3	Third 1	Third 2	Third 3	Third 1	Third 2		
									Final draft of the report of the project finalized (and possibly released or in the process of being released).	Report will be released and distributed shortly after the workshop, in order to capture any new relevant insights, information and reviews that may be revealed during the workshop by participants.

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