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# Correlating Engineering with Development – The Case of Mechanical Engineering in Africa

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**Abstract**

This paper reviews the academic, economic, industrial, and human resource conditions and endowments of the African continent with regard to the potential contributions of Mechanical Engineering higher education and practice to the socio-economic development of the African continent. It develops a compelling rationale for reforming and revitalizing mechanical engineering higher education curricula across Africa with a view to making them more responsive to Africa's developmental needs. Key findings are that with the notable exceptions of South Africa and Egypt, most African countries possess highly agrarian economies, where most labour is employed in the agricultural sector. However, the contribution of that sector to total GDP is hugely disproportionately low. The proportions of the populations in the respective surveyed countries below the poverty level are unacceptably high and very probably linked to the low figures for the mechanical engineer to population ratio in African countries, which is an underpinning factor in industrial and socioeconomic development. This calls for policies that would bring about huge increases in that ratio, as well as mechanization of agriculture and a shift in the structure of the productive sector of African society to a more manufacturing industry-based, value-adding economy. The development of an engineering culture through a conscious effort to increase the engineer to population ratio can play a key role and make a difference in this effort. This activity is part of the "Tuning Africa" project, which is funded through European Union-African Union collaboration.

Keywords: *mechanical engineering, economic development, education, Africa*

## 1. Introduction

The plight of much of Africa in light of changes on the international scene including globalization teaches us that mere possession of natural resources is not a guarantee for development and prosperity; instead knowledge economy has become the main driving force for inducing tremendous breakthroughs in the exploitation of the resources of nations. This knowledge economy requires high quality education based on well-defined reference standards. Good practice in education should encourage students to develop and improve their innovative and creative capabilities, be able to employ appropriate technologies to solve problems and pursue independent and life-long learning. This quality education has become the main gate to human resource development. Human capital is thus counted as one of the most important determinants of national sustainable development.

The GDPs per capita of most African countries are known to lie below the world average, and so African countries need to generate far more wealth than they are currently doing. But this can only be achieved through a gradual shift from the current primary resource-based economy through beneficiation to a knowledge based economy. Mechanical engineering, as an essential profession to all other types of economic activity, does play an important role in this wealth generation process. In contrast to ME profession being an underpinning factor of industrial and socioeconomic development in developing world, ME in Africa is only now emerging as a field and is yet to demonstrate any real impact on the economy. These arguments underscore the rationale for ME's identification and selection as one of the subject areas whose curriculum reform and enhancement in African universities is essential for the technological and socioeconomic development of African countries.

Already, at the international level rapid developments in the area of curriculum development are impacting African higher education in several ways. Many engineering higher education curriculum development studies reported in the literature (e.g. Jackson, H., Tarhini, K., Zapalska, A., & Zelmanowitz, S., 2010; Sunthonkanokpong, 2011, Patil & Codner, 2007) have focussed on the globalisation dimension of engineering education. Others have discussed the achievability of standards set by accreditation bodies, observing that unrealistic requirements could raise legitimate questions as to whether these skills can be effectively imparted and evaluated (e.g. Häfner P., Victor H., & Jivka O., 2013). A few more studies (e.g. Abu-Goukh, M.E., Ibraheem, G.M., & Goukh, H.M.E.A., 2013), have analysed the impact of engineering curriculum reform on economic growth and sustainability while others (e.g. Markes, 2006; Thom, 1998) have focused mainly on industry's perspective and its demands on engineering graduates. In all these works, it is

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commonly recognized that the effective training of an engineer requires not only the acquisition and strengthening of technical knowledge, but also the development of other generic competences that are required by both employers and other stakeholders in the wider society.

## 2. Research Aim, Scope and Questions

The aim of the research was to investigate the relevance of mechanical engineering higher education to socio-economic developmental issues in Africa. The initial research questions that guided the study are given below:

1. What has been the impact of mechanical engineering higher education in Africa on the continent's overall socio-economic development?
2. To what extent is mechanical engineering higher education in Africa adopting systems that will position it to make an impact similar to what it has achieved for the industrialised parts of the world?
3. Are the current curricula of mechanical engineering programmes in African universities supportive, responsive and relevant enough to Africa's desire to industrialise?
4. How is mechanical engineering higher education in Africa reforming to accommodate the realities of globalisation?
5. Are there any links between ME socio economic indices such as, the GDP structure of an economy, general poverty levels on the continent?

The purpose of the above questions was to guide the literature search, the design of the stakeholder surveys, and the overall study.

## 3. Instruments and methods

This research is a descriptive, inductive survey-based study that generalises findings based on the study of particular cases. Relevant stakeholder groups were surveyed to investigate their impressions on curriculum issues and as well as qualities to be looked for in ME graduates. These groups include employers, students, graduates, peers and other stakeholders involved in higher education in eight African countries. The main instrument used for each case study was a data gathering via questionnaire. These were complemented by general literature and online sources. The literature search strategy involved first identifying the relevant data sources and key words. These sources included journals, conference proceedings, books, technical reports, articles from trade journals and certain websites. The search was conducted by using a range of keywords and key phrases that could be relevant to engineering higher education more generally, and mechanical engineering higher education in Africa in particular. Examples include, but were not limited to: engineering higher education, mechanical engineering higher education, Africa, engineering and socioeconomic development, engineering and globalisation. The words *mechanical engineering* were sometimes combined with higher education and Africa in the search.

## 4. Results

### *4.1 Demographic, economic, and ME academic data*

Table 1 displays demographic, economic, and ME academic data along with estimates of the numbers of Engineering and ME Graduates in thousand capita per each ME Bachelor degree granted annually in a number of African countries. These, together with results of the literature review and case studies, were analysed to identify trends and patterns, followed by interpretation of these to elicit inferences and draw conclusions. Apart from South Africa and Egypt, the above index is found to be far below the world average. This finding may seem to justify why African Governments have been criticized for failing to develop technical skills to support industrialization.

**Table 1: Thousand Capita per ME degree granted Annually in several African countries**

| African Country | Population (Million Capita) | Engineering Degrees Granted Annually | ME Degrees Granted Annually | $10^3$ Capita per 1 ME degree granted annually | $10^4$ Capita per 1 ME degree granted annually | % of Population per 1 ME degree granted annually |
|---|---|---|---|---|---|---|
| Egypt | 83 | 30000 | 5500 | 15 | 1.5 | 0.02 % |
| Ghana | 25 | 1000 | 180 | 139 | 13.9 | 0.56 % |
| Zambia | 13 | 500 | 100 | 130 | 13 | 1.00 % |
| Malawi | 14 | 100 | 20 | 700 | 70 | 5.00 % |
| South Africa | 51 | 7888 | 1570 | 32 | 3.2 | 0.06 % |
| Cameroon | 20 | 700 | 150 | 133 | 13.3 | 0.67 % |
| Ethiopia | 91 | 20000 | 800 | 114 | 11.4 | 0.13 % |
| DR Congo | 71 | 200 | ND | ND | ND | ND |

Source: In-country survey data

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### *4.2 Number of Capita per ME degree granted Annually in several African countries*

Table 2 estimates the numbers of Engineering and ME Graduates in thousand capita per each ME Bachelor degree granted annually in a number of African countries. Apart from South Africa and Egypt, the index is found to be far below the world average. This finding may seem to justify why African Governments have been criticized for failing to develop technical skills to support industrialization.

**Table 2: Relationships among ME graduate numbers, the structure of African economies, and overall unemployment and poverty levels on the continent**

| Country | Measures of ME degrees Granted Annually | | | Economic Indicator (%) | | | |
|---|---|---|---|---|---|---|---|
| | $10^3$ Capita per 1 ME degree granted annually | $10^4$ Capita per 1 ME degree granted annually | % of Population per 1 ME degree granted annually | Industry's portion of GDP | Agriculture's portion of GDP | Labour force in Agriculture | Population below poverty |
| Egypt | 15 | 1.5 | 0.02 % | 37.4 | 14.7 | 32 | 20 |
| Ghana | 139 | 13.9 | 0.56 % | 27.4 | 24.6 | 56 | 28.5 |
| Zambia | 130 | 13 | 1.00 % | 33.5 | 20 | 85 | 64 |
| Malawi | 700 | 70 | 5.00 % | 16.9 | 29.6 | 90 | 60 |
| South Africa | 32 | 3.2 | 0.06 % | 32.1 | 2.4 | 9 | 50 |
| Cameroon | 133 | 13.3 | 0.67 % | 30.9 | 19.8 | 70 | 48 |
| Ethiopia | 114 | 11.4 | 0.13 % | 14.6 | 46.6 | 85 | 29.2 |
| DR Congo | ND | ND | ND | 25.9 | 38.3 | N/A | 71 |

*Source of economic indicators: GDP, ppp, employment & poverty data from obtained from https://www.cia.gov/library/publications/the-world-factbook/geos/et.html oer – based on exchange rate*
*ME – Mechanical Engineering*
*QA – Quality Assurance*
GDP/capita ($)

### *4.3. Linking Annual per Capita ME graduate degree output with socioeconomic indices in 8 African countries*

Table 2 further links Annual per Capita ME graduate degree with demographic, macro-economic, social, and ME graduate output indicators for 8 African countries. Countries that grow at a rapid economic rates are known generally to have higher engineer to population ratios. This ratio also determines the success (in extent and quality) of a country's infrastructure development programme. Comparatively speaking, African countries in general have engineer to population ratios that lag far behind developed and other developing countries. Africa owes this disproportion to its reliance on a predominantly agrarian economy as well as on foreign technical expertise. Even though the number of engineering graduates is increasing, this growth is far from adequate and is not enough to meet Africa's need for mechanical engineering skills.

When the figures in each of columns 4, 5, 6, and 7 are plotted against the figures in column 3 (the $10^4$Capita per 1 ME degree awarded annually), the self-revealing graphs shown in Figures 1 – 4 are obtained.

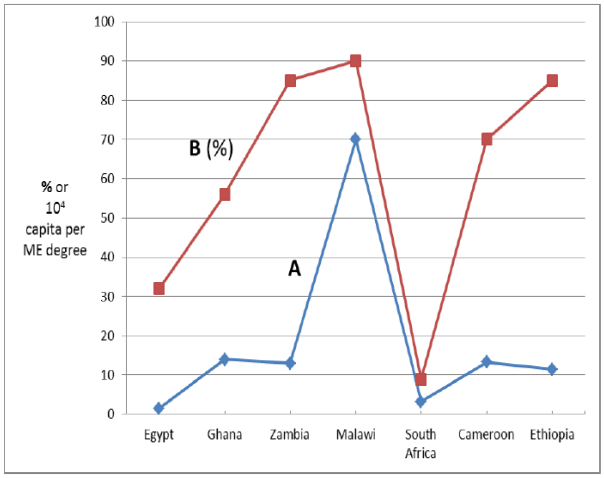


**Figure 1. Correlation between $10^3$ capita per ME degree awarded annually (A) and % of population below poverty levels in 7 African countries (B).**

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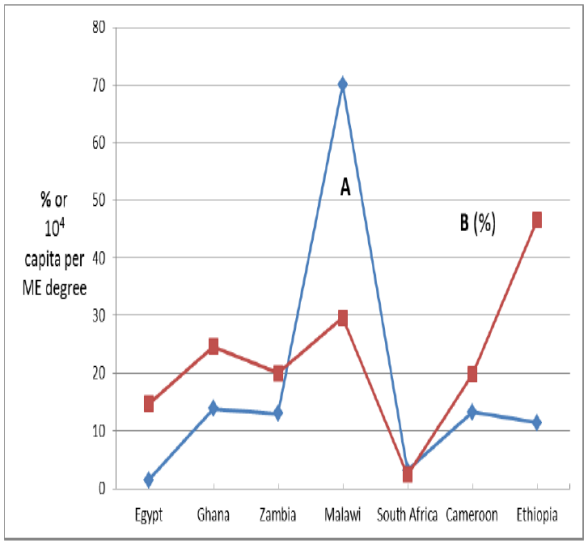


**Figure 2. Correlation between thousand capita per ME degree awarded annually (A) and percent of Agriculture's portion of GDP in 7 African countries (B)**

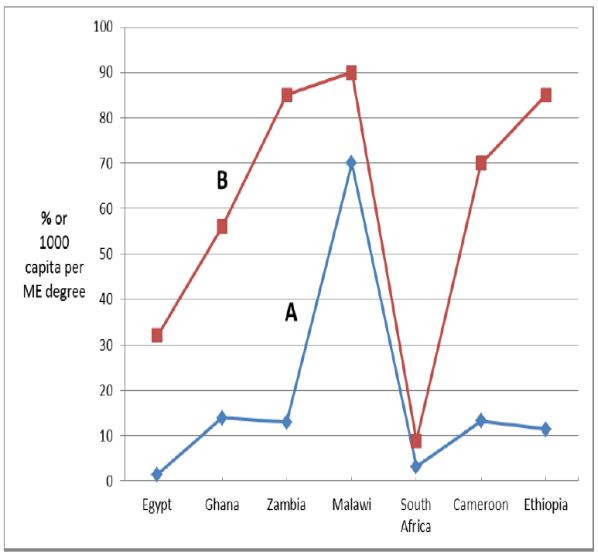


**Figure 3. Correlation between thousand capita per ME degree awarded annually (A) and percent of labour force in Agriculture in 7 African countries (B)**

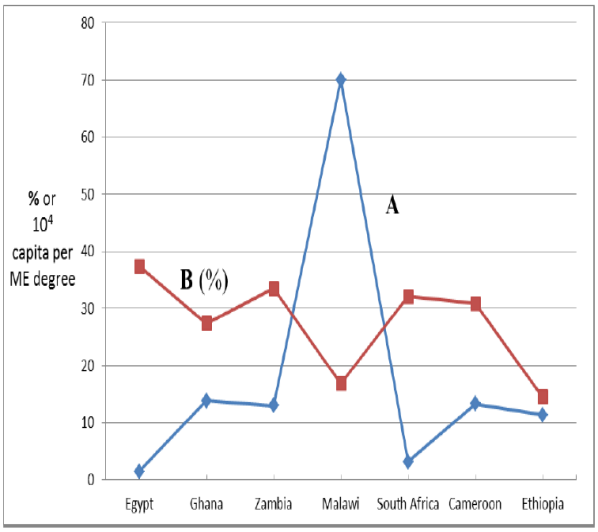


**Figure 4. Correlation between thousand capita per ME degree awarded annually (A) and percent of Industry's portion of GDP in 7 African countries (B)**

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## 5. Discussion of key findings

The literature review process, coupled with the results of the fieldwork and of the previous section, generated the following findings:

### *5. 1 Finding 1*

*There is a strong negative correlation between ME degrees Awarded (Annually) and the general poverty level in an African country. The greater the number of degrees awarded per capita, the lower the poverty level of the country, generally.*

This is evident from Figure 1, which reveals the relationship between the poverty level in an African country and the thousand capita per ME degree that country awards annually. Those countries that train more mechanical engineers tend to have lower poverty figures. Malawi clearly is an outlier, producing too few mechanical engineers in relation to the size of its population; otherwise the strength of the correlation comes out even more clearly. It is further observed that Zambia has the highest poverty rate even though it has a similar average number of people sharing the same mechanical engineer as Ghana, Cameroon, and Ethiopia, and a far fewer of them per mechanical engineer than Malawi. This may suggest an under-utilisation of Zambia's mechanical engineers.

### *5.2 Finding 2*

*There is a strong correlation between* per capita *ME degrees awarded (annually) and agriculture's share of GDP of an African country. The greater the number of degrees awarded per capita, the less agriculture's share of GDP of the GDP.*

Figure 2 shows the relationship between the agrarian nature of an African country and the thousand capita per ME degree that country awards annually. It can be seen that with the notable exceptions of South Africa and Egypt, which have lower the thousand capita per ME degree awarded annually, most African countries possess highly agrarian economies, however the contribution of the agriculture sector to total GDP is hugely disproportionately low. Ethiopia is the only outlier because even though it has a *thousand capita per ME degree awarded annually* similar to those of Ghana, Zambia, and Cameroon (in fact Ethiopia's is even slightly lower), the share of its agriculture's sector of total GDP is much higher. This may hint at either a comparatively high labour employment its agricultural sector or a relatively higher mechanisation of that sector than in the other countries.

### *5.3 Finding 3*

*There is a strong negative correlation between thousand capita per ME degree awarded (annually) and an agrarian workforce of an African country. The greater the number of ME degrees awarded in relation to the size of the total population, the less agrarian the workforce of the country.*

Figure 3 shows the relationship between extent of agrarian nature of the *workforce* of an African country and the thousand capita per ME degree that country awards annually. It is clear that higher the thousand capita per ME degree that a country awards annually the greater the size of the labour force employed in the agricultural sector.

### *5.4 Finding 4*

*There is a strong correlation between ME degrees awarded (annually) and the structure of GDP of African country. The greater the thousand capita per ME degree awarded annually, the greater the share of Industry as a fraction of the overall GDP of the country.*

Figure 4 depicts the interaction between Industry's share of GDP in an African country cast against thousand capita per ME degree the country awards annually. It can be seen that those countries that train more mechanical engineers per 1000 people have higher industrial outputs as a percent of GDP. This connection is seen the clearest in regard to Malawi. However, it is rather, surprisingly, Ethiopia that raises the most concern since it is the country where industry's share as a fraction of overall GDP is lowest among the countries surveyed even though it has a far higher annual thousand capita per ME degree awarded.

### *5.5 Finding 5*

*For several decades there have been relatively few and small ME Programmes in African universities; however in recent years the numbers are increasing, albeit, slowly. There appears to be an interesting confluence of efforts in African universities to boost the number of ME graduates trained each year by increasing either the number of universities offering such programmes or by increasing the intake into existing ME Programmes.*

All the earlier findings point clearly to a very strong and direct connection between the number of MEs an African country trains annually as a fraction of its total population and socioeconomic development indices. In summary, the higher thousand capita per ME degree a country awards annually, the more favourable the indices become. Unfortunately for most African countries the indices

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are not very positive because a key driving factor, thousand capita per ME degree awarded annually is weak. But despite all these findings there may still be some hope, however little.

We now consider some positive actions and interventions either currently underway or that must be undertaken to change the situation for the better. These include the role of policy in relation to ME numbers trained per year, ME Programme Review, Quality Assurance, and Accreditation, role of Licensing/Certification for practice, role of Professional bodies, role of adoption of modern mechanical engineering systems and adaptation to global trends, and lastly but not least, ccurriculum reform and modernization in mechanical engineering in Africa geared toward increased industrialisation and socioeconomic development.

*5.5.1 Role of policy related to mechanical engineering higher education at national and institutional levels*

Reports form the case studies reveal that in Malawi a wide range of Governmental level reforms have been undertaken including curricula review and programme restructuring adopting the multi-entry and multi-exit model, the credit based structure, the modular system, student-centred outcome based approach, and incorporating internship, and entrepreneurship modules. Mechanical Engineering has been upgraded from the ordinary five year BSc programmes to the Bachelor Engineering honours level. In Cameroun the Ministry of Higher Education recently enlisted UNESCO experts to help produce a global strategic plan for the ministry embracing reform. In Egypt the government is highly committed to reform and enhancement of higher education and started a reform plan which produced a Declaration in February 2000. The Declaration identified 25 specific reform initiatives addressing all the reform domains, to be implemented over three phases until 2017. In Ethiopia the Ministry of Education controls the Universities and other Higher Education Institutions. Several programmes have been launched like Education Sector Development Programme (ESDP), Engineering Capacity Building Programme (ECBP) and UCBP (University Capacity Building Programme) to strengthen the Higher Education sector followed recently by Growth and Transformation Plan, 2010-2015 (GTP).The Ghana government for its part, is highly committed to reform and enhancement of higher education. The National Council for Tertiary Education (NCTE) plays an oversight role in HE reform and quality assurance. The NCTE works hand-in-hand with the National Accreditation Board (NAB) to ensure quality objectives for HE are achieved.

*5.5.2 Number of universities offering ME programmes at the Bachelor level and intake/enrolment rates*

In light of the above finding one key area where reforms at the national level need to make a big impact concerns the number of universities offering ME programmes at the Bachelor level. There is a criticism that is levelled against African governments for Africa's lack of technical skills. Africans have the fewest number of engineers relative to their population sizes.

The study reveals that in the past, the number and size of ME Programmes offered in African universities have been small. For example, in Ghana only one university offered ME at the degree level for over 40 years but now, like Zambia and Egypt, there are three, and the number of ME graduates has increased correspondingly. A similar picture can be painted of Ethiopia where great strides are being made in changing the Science and Technology/Social Science enrolment ratio from 30:70 to 70:30, translating directly into increases in the yearly enrolment into ME Programmes (from 800 average to 2700 average) in the coming few years. In Cameroon general enrolment figures have exceeded existing capacities, now reaching 150 engineers/year. Even though Malawi has only one university offering HE in engineering, there, too, the numbers have shot up. However, in a few countries such as Egypt and South Africa, there are relatively high numbers of engineering bachelors per capita which places them not far behind countries like the USA and Germany. Even so, in South Africa there are still plans to boost the numbers of engineering graduates from 7888 to 15000 per year by 2014. In 2009 alone 1459 ME degrees were granted at the BSc level plus 111 at the postgraduate level. This signals progress and highlights the need to restructure ME Programmes and their curricula to meet future challenges.

*5.5.3 Role of adoption of modern mechanical engineering systems and adaptation to global trends*

In addition to the traditional core mechanical engineering curriculum, globally many mechanical engineering programmes are now offering specialized subjects such as mechatronics/robotics, advanced manufacturing, safety, reliability and risk, micro- and nano-systems engineering and packaging, transportation systems and logistics, cryogenics, fuel technology, automotive engineering, biomechanics, optics, and others, if a separate department does not exist for these subjects. The study contains evidence that indicates that some of these trends are now being adopted in African universities. For examples, several African countries (e.g. South Africa, Ethiopia, Cameroun and Ghana) have introduced

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mechatronics programmes or elements in their ME curricula. The study further reveals that in almost all countries new trends and innovation in teaching/learning methods are being embraced such as the Black Board platform, Moodle, Interactive boards in classes, PowerPoint presentations, internet connectivity, uploading of lecture notes, lecture delivery via U tube, group projects, and industrial attachments.

### 5.6Finding 6

*In recent years, a significant number of African universities are embracing technology, i.e., ICT as a medium for Teaching/learning delivery.*

## 6. Concluding remarks and Recommendations

In summary the centrality of mechanical engineering to all industrial and socioeconomic progress has been established with compelling evidence. The Tuning Project gives Africa an opportunity to improve and enhance the curricula of HE institutions in order to impact African society more positively. The results of the study have brought to the fore the need for harmonisation of engineering programmes across Africa, and the development of curricula that address the specific technological needs of the continent (Galal Abdel-Hamid Abdellah et. al, 2006).

By way of recommendations the main strategic focus of the curriculum reform and modernization effort should be to build the capacity of the African universities to provide quality higher education and increased access to growing numbers of young people on the continent in order to contribute significantly to increasing the mechanical engineer to national population ratio. Strong relationships need to be developed among both regional and sub-regional bodies, and university communities within and outside Africa. A new emphasis on university-industry linkages has the potential to meet the educational and development needs across the continent. Training of new engineers should take account of increasing globalisation and its demands and challenges by developing the following competences:

a. Managerial and entrepreneurial skills to enable ME graduates to face unemployment
b. Innovation and new-product thinking mind-set
c. Flexibility and adaptability to other African countries and the wider world

In addition to the above, the following recommendations and observations by Mohamedbhai, G. (Mohamedbhai, 2014) are set forth.

i) Africa's HE sector needs to expand and enrolment in HE must continue to increase, especially in S&T
ii) Only quality skilled human resources can help in achieving Africa's development

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