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ENGINEERING EDUCATION AS A TOOL FOR HUMAN WELFARE IMPROVEMENT IN AFRICA: A MULTIDIMENSIONAL MODEL ANALYSIS

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ABSTRACT: *One of the arguments to answer the Malthusian thesis stood on the hope the world had in Engineers. It is however getting more difficult to ascertain the possibility of satisfying the needs of a growing world population while preserving the carrying capacity of ecosystems and biodiversity particularly in Africa. The role of the engineer and engineering education in addressing the issues of water, sanitation, energy, shelter, site planning, infrastructure, food production and distribution, communication, poverty and human welfare has been rather limited in Africa. It is therefore doubtful whether human welfare could be optimized through engineering education and practice in Africa for current and future generations. This paper sought to analyze the extent to which engineering education and practice can enhance human welfare in Africa through a multidimensional model approach to human welfare. Data was obtained through face-to-face interviews with engineering educators, engineering students, engineers and beneficiaries of engineered facilities in Ghana. The College of Engineering of the Kwame Nkrumah University of Science and Technology which has provided engineering education for students across Africa since 1952 was used as a proxy for an engineering educator in Africa. Even though Africa has produced engineers who have practiced in the field since the 1950s, the bridge between the engineer and the society he works for has been weak and wobbly. This has not worked well for human welfare improvement. The welfare implications of rethinking the engineer were also discussed.*

KEYWORDS: Africa, Engineering education, Ghana, Human welfare, Multidimensional model

INTRODUCTION

The optimistic world of the nineteenth century saw promise in the role of engineering as a means for human welfare enhancement. This hope to a large extent informed their response to the Malthusian theory. While the major problem of the Malthusian theory was its failure to recognize the advance of agricultural engineering (Kula, 1994), the benefit of hindsight suggests that human welfare enhancement goes beyond the current state of engineering, particularly in Africa. Thomas Malthus, postulated that population growth posed a trap for nations seeking to develop. He contended that the adjustment mechanisms would involve rising death rates caused by environmental constraints, rather than recognition of impending scarcity followed by either innovation or self-restraint (Tietenberg and Lewis, 2009). Roberts (1997) argued that engineering successes could provide an answer to the Malthusian thesis while at the same time take blame for compounding the population explosion with its attendant human hardships particularly in the developing world. In 2005 the world population stood at 6.45 billion people, which was projected to grow to 8.13 billion by 2030. Some 98 percent of this growth between 1999 and 2025 was expected to occur in developing countries, particularly in Africa (Tietenberg and Lewis, 2009).

This increase has brought with it an unprecedented demand for energy, food, land, water, transportation, materials waste disposal, earth moving, health care, environmental sanitation, telecommunication and accompanying infrastructure in Africa. The challenge then is for engineers and engineering education to rise to the occasion at various levels.

Lending credence to the Malthusian theory for Africa's admonition is the Webster *et al*. (2000) study (cited in Tietenberg and Lewis, 2009) of the Mayan Civilization, a once vibrant and highly cultured society in South America. The collapse of Copan one of the major settlements followed the bumping of population growth into environmental constraints in the fifth century, especially the agricultural carrying capacity of land. With a growing population that depended heavily on maize for food, by the early sixth century, the carrying capacity of most productive land had been exceeded. Farmers then used more fragile parts of the ecosystem with food production failing to keep pace with increasing population due to diminishing returns to agricultural labour. Widespread deforestation and erosion followed, intensifying the declining productivity. Infant and adolescent mortality and widespread malnutrition was the result. Finally the royal dynasty of Copan collapsed abruptly around AD 820 – 822 (Tietenberg and Lewis, 2009). This sounds like a story of Africa without innovative engineers.

The problem and objectives

Generally, upon recognizing a problem, one expects a reaction prompted by change in behaviour. However, such problem-solving response (the hallmark of engineering today) may not provide the answer; it probably could even aggravate the situation. Human welfare improvement in the 21st century will be impossible without the active contribution of the Engineer. However, most engineering achievements of the past were developed without consideration for their social, economic and environmental impacts on natural systems (Amadei, 2004). This is because engineering educators trained men and women to drive technological change while sometimes forgetting that these must work in a developing social, economic and political context (Vest, 2005). Amadei (2004) suggests a revisit of the mindset of the engineering profession and the adoption of a new mission statement for engineers to contribute meaningfully to the solution of the complex problems of today's world. Such rethinking will be particularly more demanding in developing countries, especially Africa where food scarcity, deprivation, water and sanitation, lack of access to modern infrastructure and energy seem to be intractable problems, even in countries like Ghana.

The problem solving nature of engineering education is thus no assurance that the issues about increasing deprivation in Africa will be adequately addressed through it. The downward trend of welfare improvement in Africa seems to cast doubts on whether engineering education has the capacity to solve the complex problems showing up. Thus a more holistic approach to engineering appears a basic necessity for the relevance of engineering education to be felt in the 21st century Africa. This paper thus sought to ascertain the capacity of engineering education to improve human welfare in Africa through a multidimensional approach. It specifically tried to assess the extent to which engineering education and practice could enhance human welfare in Africa. Data was obtained through face-to-face interviews with engineering educators, engineering students, engineers and beneficiaries of engineered facilities in Ghana. The College of Engineering of the Kwame Nkrumah University of Science and Technology (KNUST) which has provided engineering education for students across Africa since 1952 was used as a proxy for an engineering educator in Africa.

THE THEORETICAL MODEL

Engineers are primarily involved in problems related to technology development and deployment. These include designing, developing, and building the cars, computers, television sets, and other consumer products that people enjoy. Engineers also design and build all the manufacturing processes, industrial technology, and transportation infrastructure needed to extract, transport, and refine raw materials; fabricate products; and distribute the goods and services of modern societies worldwide. Figure 1 shows how engineers are involved in the human welfare improvement agenda. The challenge gets more complex through growth in human populations and economic activity, initially, social sciences centered activities. The impacts of these activities draw in the engineer to solve problems of all kinds which at some points require the inclusion of other scientists.

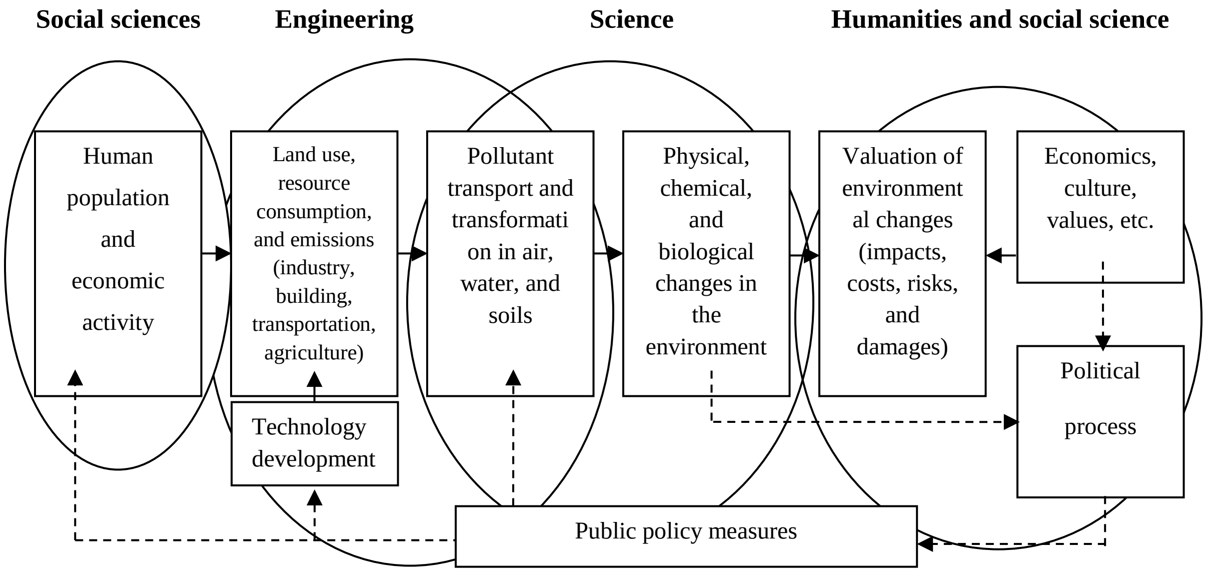

Figure 1: The place of engineering in human welfare improvement (Source: Rubin, 2001)

These solutions eventually fall back into the domain of the humanities and social sciences where their ultimate success or failure is assessed based on the extent to which human welfare is enhanced. Today however, it appears as if the African engineer has not delivered the welfare hoped for and the expense of educating the engineer in the way Africa has become accustomed to is itself welfare reducing. Engineering education will be delivering sustainable development if it is able to improve social, economic and biophysical welfare in Africa.

Engineering education in Africa

Charles Deakin created the first proper department of engineering in Ghana. He did it in Achimota School. This department was later transferred to the KNUST in Kumasi in 1952. Charles Deakin, an Englishman, spent twenty years in Achimota, after he had graduated in engineering and mathematics in Cambridge. He gave almost all the lectures himself. He equipped the laboratory in which he taught engineering to the standard of London degree for a total cost of £2,500. His students did a great deal of practical work. They had to build a lot of their apparatus for one thing. Mr. Deakin went with them to survey the site of the Volta Bridge which stands today where he and his students suggested it should be. He drained the swamps and killed the mosquitoes for miles around Achimota and Legon. But his greatest achievement was to educate Robert Baffour who was his very first pupil and who later became Vice-chancellor of the Kwame Nkrumah University of Science and Technology (KNUST). Robert Baffour was the first Ghanaian student to graduate as an engineer in London University (Bowden, 1977) and subsequently the first African engineering lecturer to teach Africans in Africa. The KNUST has been an important centre for the training of engineers not only for Ghana but Africa and beyond (KNUST, 2005).

The wealth of any country depends on its industries. In England people rely on heavy engineering, on electrical engineering, mechanical engineering, chemical engineering, the refining of oil products, the manufacture of new fibres, new plastics, new drugs, and so many other things like that. These are the industries upon which in the end most of the wealth of England depends. In Ghana the great industry upon which most wealth depends are agriculture and other primary products, particularly cocoa (Bowden, 1977). It is worthy of note that the College of Engineering of the KNUST has played a significant role in Africa's development. However, the Electrical/Electronic Engineering programme of the KNUST is "designed to give the skills essential for graduate engineers to become immediately employed in the global competitive environment" (KNUST, 2005) and so are the other engineering programmes. Thus while the African continent is the darkest from outer space and the United Nations Organization is striving to attain energy for all Africa by 2030 to boost output and improve welfare, the African engineer is being trained to get a job in the international market.

METHODOLOGY

Having gained much insight into the nature of the engineer's task, Amadei (2004) suggested a worldwide transition to a more holistic approach to engineering, requiring a major paradigm shift from controlling nature to participating with it. He also envisaged the inclusion of an awareness of ecosystems and their services as well as the presentation and restoration of natural capital and a final embracing of sustainable development as a guiding principle for engineering. While these suggestions are laudable, he did not show how to achieve them. The multidimensional model proposed by this paper probably provides the steps to the vision of Amadei and like-minded engineers particularly regarding solving Africa's complex problems.

Human problems are multidimensional in nature – social, economic and biophysical. The biophysical dimension is normally addressed through the physical and engineering sciences with technology and appropriate equipment being indicators for successful delivery by the engineer. The economic dimension addresses the issues of markets, exchange, production, distribution and consumption expenditure which have the extents of economic efficiency and equity attained through delivery as indicators. The social dimension deals with the cultural, political and religious systems of human societies, where community participation and local acceptability of engineered products as key indicators of successful engineering. To obtain welfare improving solutions, isolating only one of these dimensions for action will end up in frustration and lack of fulfillment because it would not provide the desired solution. This is simply because a multidimensional problem requires a multidimensional solution. Figure 2 illustrates how these dimensions interact to enhance human welfare.

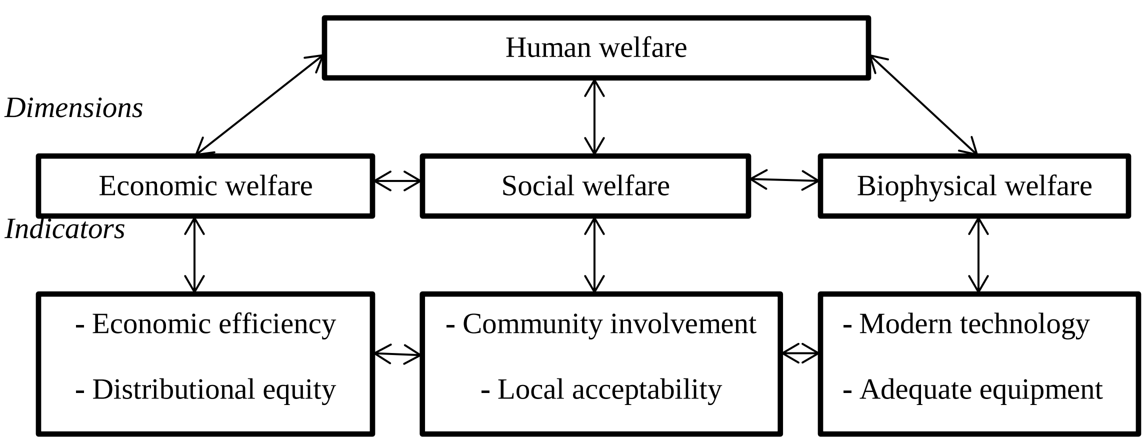

Figure 2: The concept of multidimensionality of human welfare

Figure 2 shows that to meet human welfare needs within the complex issues in Africa, engineering education must complement its technical and analytical abilities with social and economic dimensions. Such achievement would to a large extent result in sustainable development. Amadei (2004) testifies to the fact that the social, environmental, economic, cultural and ethnical aspects of a project are often more important than the technical engineering aspects. Thus the least one can probably do is to place all the dimensions as equally important in the execution of every project. The evidence in the following section reveals the extent to which this is understood and practiced by stakeholders of engineering projects in Africa.

Engineers, engineering educators, engineering students and the general public in Ghana were engaged in various discourses to ascertain their understanding of engineering education and practice and how these could positively affect the various dimensions of human welfare for improvement. The analysis presented radar charts of the six indicators for the three dimensions. A sample of 88 respondents provided responses to questionnaires and interviews for the study. This comprised 65 non-engineers (24.6% engineering students of the KNUST, 49.2% science and social sciences students of the KNUST and 26.2% non-student adults familiar with engineered facilities in Ghana) and 23 engineers. Among the engineers 34.8% belonged to the national professional association of engineers with only one not being an engineering educator. The questions generally required respondents to assess the strategies, outcomes, strengths, weaknesses and prospects of engineering and engineering education with respect to human welfare improvement in Africa.

RESULTS AND DISCUSSION

Based on the 6 indicators the prospect for engineers and engineering educators to help attain optimum human welfare is shown within the green border in Figure 3. To do the assessment engineers ranked the degree of importance they attached to each indicator in the execution of an engineering project. The ranking was in numerical order from 1 to 6, where 1 was the least and 6 the highest. This provided the means to assess the extent to which the concept of multidimensionality had been applied in the jobs of these engineers whether on the field or in the lecture room.

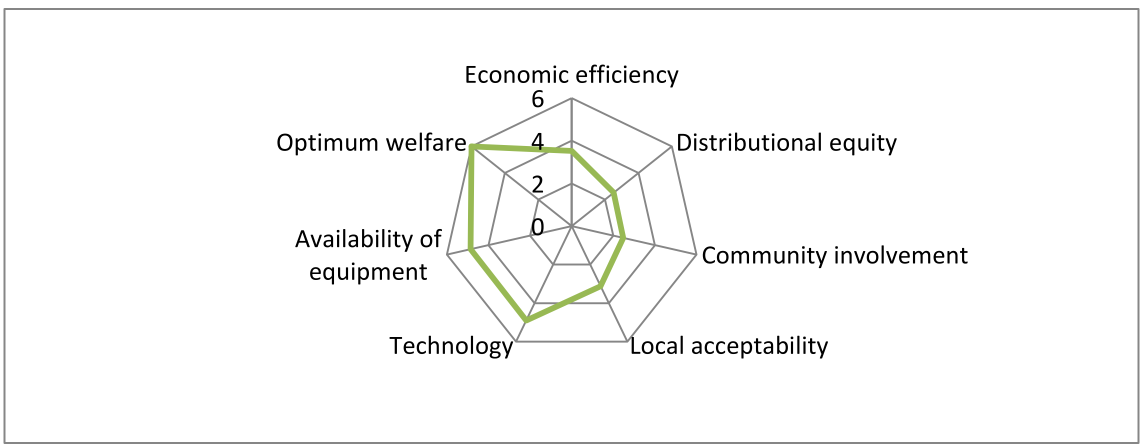

Figure 3: Extent of human welfare attainable with the status quo (engineers)

Optimal welfare required the green border to fall on the outer boundary of the radar chart. This was however not the case for all the indicators, showing only 59.5% coverage of the multidimensional radar chart. The best achievements were in the biophysical dimension. The second was the economic dimension while the social dimension was the most neglected dimension in the execution of engineering projects. This shows that maintaining the status quo for engineering practice and education in Africa will not lead to optimum human welfare. The most poorly addressed indicator (community involvement) depicts alienation of people from projects supposed to improve their welfare.

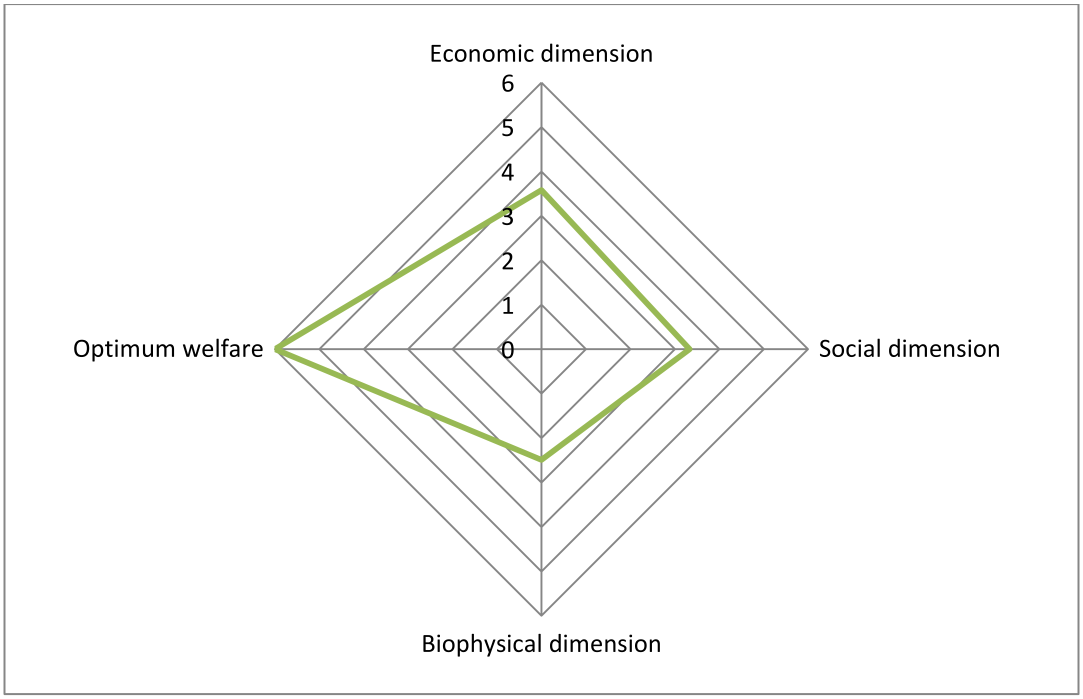

Figure 4: Extent of human welfare attainable from non-engineer experiences

The assessment of non-engineers shown in Figure 4 also indicates a vast deviation from optimum welfare if the status quo is maintained. Here, the analysis was with respect to the dimensions rather than the indicators since respondents did not appear very conversant with how each indicator was connected to its corresponding dimension. The most acknowledged dimension was the economic followed by the social and then the biophysical. This showed 51.7% coverage of the radar chart depicting low prospect for achieving optimum human welfare. The result also indicates that non engineers saw less application of the concept of multidimensionality than engineers in the execution of projects and in training engineers.

Figure 5 illustrates what respondents considered to be the missing elements in engineering education in Africa. Three major reasons were assigned for the inability of engineering education to play its rightful role in human welfare enhancement. Lack of adequate practical training was cited by 44% of respondents, 31% cited the lack of adequate facilities while 25% blamed the situation on the non-appliance of the holistic approach to engineering education.

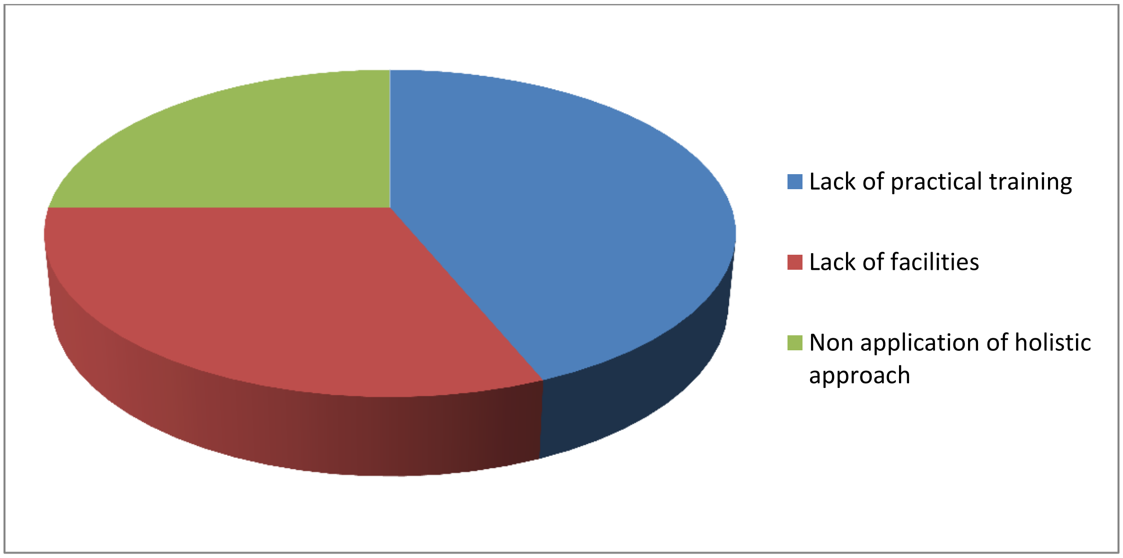

Figure 5: The missing elements in engineering education in Africa.

On the way forward for rethinking engineering education for optimum welfare, the following remedies were put across by the accompanying percentages of respondents: (i) give more attention to practical training (50%) (ii) need for holistic approach (15%) (iii) link to the African environment (15%) (iv) link to industry and professional association (15%) and (v) strengthen technical education at lower levels of education (5%).

CONCLUSION AND POLICY IMPLICATIONS

Figures 3 and 4 indicated that while engineers and their educators saw the biophysical dimension as the most important for engineering projects, non-engineers on the contrary considered the biophysical dimension as the least important. This means a vast difference in what should be priority exists between engineers and communities which they hope to solve problems for. Thus even though Africa has produced engineers who have practiced in the field since the 1950s, the bridge between the engineer and the society he works for has been weak and wobbly. This has not worked well for human welfare improvement.

To implement remedial and long term policies to make engineering education more human welfare enhancing will first of all mean a reorientation of Africa's engineering education policy, which, should be a matter of urgency. The other most important requirement would be funding, which, Sraku-Lartey (2000) indicated was in deficit of about 45% in Ghana. Meeting this deficit would require cutting down on the provision of some essential services within the education sector if the already high budgetary allocation of the sector is not to be increased to the detriment of other equally demanding sectors. Certainly, these would mean a mobilization of already scarce resources from African governments, which, in the short term may appear welfare reducing but is set to pay off immensely in the future. Within the present circumstances it is recommended that apart from carrying out the measures above to restore hope in the role of the African engineer in human welfare improvement, project execution teams which comprise of experienced engineers, economists and sociologists be set up to provide the needed guidance for the execution of projects on holistic basis. To make up for what has already gone wrong, governments and development partners should assess the extent to which the social and economic dimensions have suffered neglect and try to make amends where possible. A 21st century Africa definitely needs a multidimensional engineer to make the difference Africa is looking for.

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