

NEW ROLES FOR INDUSTRIAL ENGINEERS IN DEVELOPING COUNTRIES

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ABSTRACT

Current industrial engineering paradigms aim to improve quality and profits, and emphasise labour-reduction, specialisation, analysis and optimisation. This can be at odds with the needs in a developing country. We suggest that the emphasis of industrial engineering be re-orientated to support employment growth, the identification of new products and services, education, and training. Pedagogical methods and computer usage should satisfy the needs of such environments. It is not argued that uneconomic and non-competitive processes should be tolerated, rather that activities, which protect and increase employment levels, should be emphasised. Experiences in Kenya and South Africa are used to support this hypothesis.

OPSOMMING

Huidige Bedryfsingenieursweseparadigmas beoog om kwaliteit en wins te verbeter en plaas die klem op arbeidsvermindering, spesialisasie, analise en optimisasie. Hierdie tendens is waarskynlik strydig met die behoeftes van ontwikkelende lande. Ons voorstel is dat die fokus van Bedryfsingenieurwese verskuif moet word om indiensnemingsgroei te bewerkstellig, te help met die identifisering van nuwe produkte en dienste, onderwys te bevorder en opleiding te verskaf. Pedagogiese metodes en rekenaargebruik behoort die behoeftes van hierdie omgewings te bevredig. Die argument is nie dat onproduktiewe en nie-mededingende prosesse verduur moet word nie, maar dat die aktiwiteite wat indiensnemingsvlakke verhoog en beskerm, beklemtoon moet word. Eksperimente in Kenia en Suid-Afrika sal gebruik word om hierdie hipotese te ondersteun.

1. INTRODUCTION

Soderbom[1] states that ‘the growth of the manufacturing sector in the so-called “developing countries” has long been seen as crucial for economic development’. Tybout[2] called it the ‘darling of policy makers’, indicative of the belief among economists and policy-makers that the sector is, among other things, a potential engine of modernisation, a creator of skilled jobs, and a generator of several positive spill-over effects. Manufacturing remains a key ingredient for a growth-oriented economy. The role of industrial engineers in all elements in an economy is vital, but the main issues to be addressed are not optimisation problems, or simply improving productivity and efficiency. The economies of the developing world are grappling with high levels of unemployment, poverty, and crime, as well as poor infrastructure and a lack of necessary labour skills. The major economic indicators for Kenya and South Africa are given in comparison with those of the USA and the UK in Table 1.

	Kenya	South Africa	USA	UK
Income bracket classification	Low	Middle	High	High
GDP per capita (USD) ²⁰⁰¹	1 000	4 900	36 300	24 700
Population ²⁰⁰²	31,1M	43,6M	281M	59,8M
Population below poverty line	50% ²⁰⁰⁰	50%	13%	17%
Unemployment rate	40% ²⁰⁰¹	37% ²⁰⁰¹	6% ²⁰⁰²	5% ²⁰⁰¹

Table 1. Comparison of Major Economic Indicators –USCIA[3]

The past 15 years have been years of economic decline. In Kenya, per capita income fell by approximately 10 per cent in the 1990s. Soderbom[1] confirms that the formal manufacturing sector barely grew at two per cent. Kenya is a country with a young population; in 1999, the United Nations Development Programme[4] estimated that there were 500 000 entrants to the job market every year. To employ these individuals, the Kenyan government estimated in 1996 that a sustained growth rate of six per cent was needed. This has not been achieved. In South Africa, a similar scenario exists. From 1994 to 2000, six per cent of jobs were lost in the non-agricultural sectors, with 15 per cent of jobs being lost in the private sector, bringing the total unemployment rate to 41,8 per cent. The economic growth rate averaged 2,7 per cent over this period. The economy exhibited small growth, but with decreasing employment. Between February and September 2002, a further 370 000 jobs were lost in the economy according to the South African Department of Trade and Industry[5]. It is estimated that a growth rate of around six per cent is needed just to maintain current percentage employment levels.

Conditions in developing countries vary. While Botswana has had consistent notable

economic growth, the trend in most sub-Saharan countries is toward worsening conditions. Unless this can be reversed, higher unemployment will lead to more crime, poorer quality of life and unstable social and political conditions. It is not all bad news, however. A new government in Kenya and programmes such as the U.S. government's Africa Growth and Opportunity Act (Agoa) offers new opportunities. Kelley[6] has concluded that Kenya and South Africa have already benefited from Agoa, particularly in the textile industries.

2. BACKGROUND

Industrial engineering has been defined by the American Institute of Industrial Engineers as 'the branch of engineering concerned with the design, improvement, and installation of integrated systems of people, material, information, equipment, and energy. It draws upon specialised knowledge and skills in the mathematical, physical, and social sciences, together with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from such systems.' Another definition by Urwick [7] is 'that branch of engineering knowledge and practice which analyses, measures, and improves the methods of performing the tasks assigned to individuals, designs and installs better systems of integrating the tasks assigned to a group, specifies, predicts and evaluates the results obtained.' Rottier[8] defines an industrial engineer as 'the systems engineer' of an organisation. These definitions imply that Industrial Engineers are behind the effective management of organisations. They emphasise the scientific management background of industrial engineering, concerned with information gathering, analysis, efficiency and optimisation. This is understandable if the operational system is in a stable society and economic system. But we argue that the industrial engineer in a developing country, where conditions are not stable, and may be deteriorating, must be more of a leader, and not just a designer or analyst. He or she must be more innovative, entrepreneurial, creative and proactive, to not only optimise and improve, but to originate efficient new enterprises and systems which will provide growth and employment in the future. Instead of improving only an enterprise, the industrial engineer must also tackle the improvement of the society in which the enterprise operates, to ensure the sustainability of both. Kelley[6] states that 'industrial engineers solve problems arising from needs'. These needs should include those of the ambient society.

Is engineering in developing or less industrialised countries similar to that in industrialised countries, but with more constraints? This question oversimplifies and ignores complex social and economic interactions. South Africa is a country with several active and extremely different economies. Industries range from very modern high-technology operations, to roadside artisans. In high technologies, engineering problems and issues are very similar to those in developed countries, but the roadside artisan and low-technology informal businesses deal with different issues. The following sub-sections describe some challenging issues in developing countries.

2.1 Infrastructure

In Kenya and South Africa, most major industry is concentrated in a few urban areas, with large tracts of rural land between them. While the road and highway system in South Africa is considered one of the best in the world, only 14 per cent of highways in Kenya are paved (USCIA[3]). Quality is variable, however. Slightly less than half of firms in Kenya had

tarmac roads in ‘good condition’ in their immediate vicinity. Soderbom[1] also confirms that ‘businesses in Kenya struggle with unexpected power blackouts, malfunctioning telephones, and unreliable postal systems and ports.’ In South Africa, there are still areas without electricity and telephones, while in both countries, clean water provision and waste and sanitation processing facilities do not exist in many areas. In developing countries, isolated “mid-lands” and poor utilities mean that distribution costs to rural markets and customers are high, transport and communications infrastructure is often unreliable, and market information is inaccurate, incomplete and misinterpreted. These constraints exclude rural consumers from the mainstream economies, and force consumer costs higher. This results in further inequalities and exclusion, including lack of access to education.

2.2 Economies and Markets

The most striking characteristic separating developing and more developed economies is the existence of both formal and informal sectors in developing economies. An informal sector can be defined as enterprises outside an economy’s legal framework; these are typically individuals without formal training, premises or legal registration. Informal sector activities in developed countries such as the US and the UK are minimal, and if not registered for tax, illegal. In developing countries, the informal sector is very visible and large. In Kenya, informal sector artisans are the sole source of domestic and commercial goods for a majority of the population. Soderbom[1] states that ‘the informal manufacturing sector employs four times the number formal manufacturers employ.’ In South Africa, 4,9 million are employed in the formal non-agricultural sector, with 6,33 million in the informal sectors according to Chandra[9]. Many dual-sector Asian economies have encouraged economic growth in both sectors through linkages, spin-offs, and supplier relationships according to Borutsky[10], but few links exist between these sectors in Kenya and South Africa.

Quality and variety are often limited. In the formal sector, import substitution policies, coupled with few competitors, result in poor quality products with monopolistic pricing. Firms have little motivation for continuous improvement and market research. Industries attain satisfactory profits from small select groups of customers who can afford higher prices, and therefore they do not actively seek new markets to increase output volumes or strive to attain higher quality. In the informal sector, the market situation is the opposite, with many diverse customers and much competition, but results are similar. The ease of access to the informal sector makes it an attractive option for those unable to secure formal employment. Artisans and others in this sector face steep competition from competitors, but poor skills, and the need to undercut competitors’ costs, result in poor quality products of minimal diversity according to Kabecha[11].

2.3 Crime

Tybout[2] concluded that corruption is an impediment to industrial development. Soderbom[1] found that fourteen per cent of large firms in Kenya rate corruption as their number-one problem. Over half of all firms reported that bribes must be paid regularly to government or public services officials. In 2002, Kenya tied for fourth most corrupt country surveyed by Transparency International [12]. Crime, including petty theft, serious theft, fraud and violence costs the consumer and is a major constraint on growth. A survey conducted by the World Bank reported that 95 per cent of chief executives interviewed rated crime and

violence as their major constraint on growth, according to Chandra[9]. A total of 1,6 per cent of sales revenue in South Africa is spent on security.

2.4 Culture

Geographic isolation and lack of access to communication links in developing countries often result in a high degree of cultural diversity. Recognising cultural differences is vital to satisfying consumer needs, marketing and employee relations. The idea of success and wealth for many Kenyans and South Africans is to own a small tract of land to be used for subsistence farming, enabling, from the perspective of the worker, independence, self-sufficiency, and security in retirement. This is counter to ideas of modernisation and success in industrialised countries, where wealth and security depend on specialisation of labour, efficiencies, and barter. Cultural differences, the legacies of colonialism and apartheid, and lack of education, have resulted in citizens who are unable to relate to, or 'buy into', the economic principles of industrialisation. The South African Reserve Bank[13] reports that only 40 per cent of adults in South Africa have bank accounts, and only six per cent in Kenya. Economically active, but unbanked people, are mostly found in rural areas, informal settlements and townships. Ninety per cent of US citizens have bank accounts.

2.5 Foreign Aid Projects

In Kenya, South Africa and other developing countries, foreign governments and agencies provide assistance funds to non-governmental organisations and local governments to address a variety of issues related to poverty and governance¹. Projects supported by these funds very often bring benefits, but in many cases are implemented to meet the political objectives of the donor or local government. Changing officials, philosophies, and approaches result in a variety of differing, and often inappropriate, assistance projects. Many donor projects, while often generating employment in the short term, are not sustainable due to a lack of indigenous resources or capacities, insufficient training and personnel development, and lack of follow up and sustained management.

3. WHAT CAN BE DONE?

For industrial engineering, we suggest a stronger leadership role, more entrepreneurial activity, and a return to basics, starting with identifying the needs of the society and consumer to shape corporate philosophies, to identify new products and to initiate the redesign of systems. We propose five areas where industrial engineers can effect substantial change in developing countries, namely:

- **Employment generation:** Employment protection and growth are a necessary objective for all projects. Emphasis must be placed on getting more output through innovation, using existing labour, facilities and equipment, thereby creating more employment.
- **Production:** Improve the flexibility for scaling facilities and labour management and output

¹ Kenya received \$457 M in 1997, and South Africa receiving \$539 M in 1999.

- **Product development:** Efforts should be aimed at developing appropriate products for domestic markets, and products for export niche markets. Economic advantages should be exploited.
- **Cultural Diversity:** Recognise uniqueness and exploit its benefits.
- **Education:** Industrial engineers must accept a strong educational and training role.

As a result of the broad nature of their education and training, industrial engineers should be equipped to lead work in these five areas, while communicating appropriately with other disciplines.

4. INDUSTRIAL ENGINEERING IN ORGANISATIONS

Relatively few industrial engineers are employed in South Africa and Kenya, and not many are produced by the educational systems in these countries. Those who are available, work in organisations such as manufacturing industries, government, parastatals and the services sector. The following subsections suggest ways in which industrial engineers could stimulate activities in the suggested five areas in organisations.

4.1 Employment generation:

Currently, when improving efficiencies, usually the first thing to occur is the reduction of human labour. Humans are seen as error-prone, unreliable, expensive and difficult to keep happy. However, automated systems are often introduced which are under-utilised, inflexible and inappropriate. In developing countries, automation should not be the preferred option. Instead, efforts should be put into work organisation and job design, ergonomics, job development, training and motivation. More use of psychology and social science techniques would often be appropriate. Increased use of relatively inexpensive devices, such as jigs and fixtures, to aid manual production, and the design of efficient processes and management systems are essential, so that manual methods stay economically competitive. Surprisingly, Kenyan metalworkers were found to prefer the use of fixtures that were more complex. The reasons were summed up by one artisan as, “more satisfying to use since I can use my head”. Involving the users in the design is important. Where existing equipment or capital facilities are under-utilised, efforts should be made to seek new products, which could utilise this unused capacity, or alternatively, additional markets should be sought for existing products. Process capabilities, spare capacities and bottlenecks should be identified, as normal in industrial engineering work, but in developing countries, emphasis must be placed on identifying new products which will utilise spare capacity to increase throughput. Covers for tea-bags and aircraft headrest covers utilised the spare capacity of a non-woven fabric manufacturing line specifically set up for another product by one South African company.

4.2 Production:

Organisations in developing countries are often unable to make large capital investments. They must however, be flexible enough to scale up to meet extra demand requirements and be able to maintain efficiency and responsiveness. With less likelihood of more capital

equipment and greater reliance on human labour involvement, quality assurance and organisational management abilities are the key, and industrial engineers will have to concentrate on these areas. Larger volumes, produced manually, often mean more variability. ApproTEC, an organisation in Kenya which receives donor funds to design items to be produced in the private sector, contracted a company to manufacture, but quality was controlled by ApproTEC through manual inspection. As volumes grew, inspection was outsourced also, but gave rise to various problems. Training in quality at the source techniques, such as Poka-Yoke, was needed. Increased training to multi-skill manual workers is also necessary for more flexibility.

4.3 Product development:

Entrepreneurs in developing countries tend to be unwilling to risk capital to develop new markets and seek consumer feedback. The culture is not one of market research. There is the underlying assumption that copying products from developed markets is best. Focusing product development on domestic needs must be encouraged. Wind-up clockwork radios and torches are examples of products produced in South Africa for South African needs. For niche export markets, risk can be reduced, by capitalising on existing talents and skills. In the formal sector, examples in South Africa are shipbuilding and mining. New markets (e.g. large catamarans for export) or products (mining consulting) can be identified. In the informal sector, unique craft skills, e.g. wire weaving and beadwork, can be identified, but small-scale entrepreneurs need assistance with marketing, understanding foreign markets, pricing, distribution, and other aspects of business management. The provision of subsidised assistance centres, from which industrial engineers could provide reasonably priced services to entrepreneurs, would be useful. Many developing countries are unable to compete on the basis of labour costs alone. The production of the clockwork radios has been moved to China! It would therefore be advisable to develop products that rely on unique skills or resources that require low investment, and where small to medium enterprises are the optimum models. 'Surgery safaris' and Rooibos tea are two examples of this. Washing and cutting of horticultural items in Kenya for the ready to eat export market translated into additional jobs and much greater profits for growers. Services e.g. private education, tourism, yacht design, can be exported. Nordas[14] found that the earlier in the product life cycle a country's firms are able to adopt a product, and introduce it successfully in domestic and foreign markets, the greater the scope for generating well-paid jobs. As the product cycle unfolds, science and innovation are replaced by specialisation, as the most important factor determining competitiveness. As the product or process becomes standardised, relatively low labour costs become the major factor. Conversely, a country that only has the capacity to take up the production of standardised, mature products is bound to compete mainly in terms of labour costs or efficiencies of scale.

4.4 Cultural Diversity:

Education and skill levels may vary considerably in developing countries. Basic training in simple economic and business systems, as well as in the business practices of other countries, may be vital. In South Africa and Kenya, illiteracy rates in some sectors are high, and must be tackled. In design, Nordas[14] stated that in the textile industry, unique looks had more appeal to customers, and achieved significantly higher returns. Developing countries should thus be able to exploit their abilities to offer new unique designs, because of their cultural diversities

e.g. textile and beadwork patterns and textures, and find profitable niche markets. Displays of cultural history and development are, of course, important products for the tourist market.

4.5 Education in Organisations:

Chandra[9] found that shortage of skills and inefficient work organisation are problems at all levels in South African companies. Fifty-eight per cent of chief executive officers surveyed in South Africa named shortage of labour skills as a major constraint, and this survey was conducted in a year of recession. In developing countries, whose economy is traditionally based on primary sector activities such as mining and agriculture, the change to more services or manufacturing means that many potentially economic active people have skills that are no longer relevant, e.g. retrenched mineworkers. The industrial engineer can facilitate technological advancement, initiatives and innovations by educating and training, by encouraging learning by doing, by helping shop floor teams to brainstorm, and by shop floor organisation. Flaherty and Salinger, [15] in a textile survey in South Africa, found that there was much potential for growth by maximising the talents of the firms' labour in order to bring multiple skills to the fore. It was also found that firms that invest in training are, on average, 32 per cent more productive, and pay six per cent higher wages.

5. EDUCATING INDUSTRIAL ENGINEERS

Education is the key to providing industrial engineers who can lead, improve, adapt, innovate, be entrepreneurial, and provide growth and sustainability. In South Africa, education for industrial engineers is provided by only two universities and four technikons. Kenya has no formal industrial engineering education programmes, but project management and systems design courses are offered as part of most university engineering curricula. Many industrial engineers in developing countries have been educated and trained in developed countries. They will not only have to apply conventional techniques, but will need to educate and train others, and deal with situations such as high levels of illiteracy, poor 'technical' background of employees, tribalism, culture and language differences, health problems, lack of understanding of industrialised economic systems, and lack of confidence. Students in developing countries will often have to be instilled with the ambition to attain 'perfection', as perfection in their environments is often unavailable and/or unaffordable. As the economies of developing countries grow, more skilled engineers will be needed.

Based on our experiences arising from teaching at undergraduate and postgraduate levels, we believe that the following should be considered for teaching industrial engineering in developing countries.

- **Industrial Engineering as a postgraduate course only.** Having students with knowledge and experience in another technical discipline ensures technical background, credibility and experience in which to ground taught theory, and enables real perspectives in classroom discussions.
- **Industry involvement:** 'Action learning' projects, undertaken by groups, or co-operative internships, with visits to enterprises focused on a specific technology or system, exposes students to real world experiences, and gives them an opportunity to test innovative ideas in solving real problems. Project-based learning also provides a

crash course in human relations and in managing cultural differences. Visits to enterprises in developed countries are particularly useful in awakening awareness of competitive practices, but costs are often prohibitive.

- **Mentoring:** Involvement and feedback by experienced industry managers, as well as some degree of supervision of project-based learning assignments, help students navigate new experiences and can provide them with sound role models. Donaldson and Sheppard[16] describe the creation of 'E-pals' in Kenya, where mentors were not locally available. Computers were used for distance mentoring by practising engineers in North America.
- **Appropriate usage of computers:** There are often insufficient computers in institutions in developing countries to meet student needs. Or the institution is so worried about theft that the access to computers is very limited. We believe that even a few computers can play a significant role in instruction, and provide information not available locally, such as pictures of advanced processes or systems. Academics should be encouraged to produce and use affordable 'teaching CDs' with interactive examples, as textbooks are often too expensive in developing countries.

Industrial engineers in developing countries must be educated appropriately and in turn must educate and train others appropriately for the prevailing environment. They should develop suitable methods, tools and models specifically for developing countries. They may have to start at basic levels. The 'township MBA' run by an NGO for aspiring small business owners in townships in South Africa started with 'how to switch on and operate a pocket calculator'! Mrs Frasca-Burman director of the Maradadi training initiative in South Africa for 'grassroots' women, estimates that it can take up to three years for its students to fully accept the industrialised economic system.

6. CONCLUSION

Rottier[8] said that industrial engineers 'solve problems arising from needs'. Industrial engineers are not being redefined. Rather, we are challenging some of the underlying assumptions about progress and improvement. To move to a paradigm emphasising employment growth and greater throughput will require a new emphasis in the education and training of industrial engineers. Industrial engineers by nature of their education and experience are ideally equipped to initiate and achieve sustainable results in promoting growth, development, and employment which are vital for most developing countries, and by implication, for the stability of the world. If industrial engineers adopt the role we are suggesting, and are sensitive to the conditions and needs of developing countries, and their peoples, much could be achieved which could narrow the gap between the haves and the have-nots of the world.

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