OR in Developing Countries: a review

Leroy Whitea,\*, Honora Smithb, Christine Currieb

a *Department of Management, University of Bristol, Bristol, UK*

b*School of Mathematics, University of Southampton, Southampton, UK*

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Abstract**

The relevance of Operational Research (OR) in developing countries has increasingly engaged the attention of operational researchers in both the industrialised and less developed countries over the last 50 years. With this, there has been a considerable amount of interest in the potential for using OR in developing countries. One sign of this is the emergence of a number of initiatives to promote OR in developing countries and the number of new societies for OR that have emerged from the developing world. This paper is an attempt at providing an overall picture of the state of OR in the developing countries. In particular, it will look at the coverage in terms of countries and methods. It will also highlight the contribution OR is making towards the theme of poverty, the reduction of which is regarded as the key focus of development policy interventions as reflected in the Millennium Development Goals (MDGs).

*Keywords:* Operational Research, OR in Developing Countries,Millennium Development Goals

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**1. Introduction**

The relevance of OR in developing countries has increasingly engaged the attention of operational researchers in both the industrialised and less developed countries. It has been an important strand of work for a number of professional societies and has been a constant presence as a theme for major conferences. For example, the International Federation of Operational Research Societies (IFORS) continues to be a strong advocate for OR in development countries (Rand 2004). Since the IFORS Conference held in Japan in 1975, it has been extremely active in promoting OR in developing countries by supporting a range of initiatives, including streams at conferences and the IFORS Prize for OR in Development, awarded at every triennial conference to recognise excellent work in the application of OR to issues of development (Dutta, 2001, 2004).

One significant initiative worth mentioning was the meeting in December 1992 of the first International Conference on OR for Development (ICORD) held in Ahmedabad, India. The participants emerged with their recommendations on how OR could best be advanced in developing countries. This became known as the Ahmedabad Declaration calling for a range of actions from IFORS (and other OR societies) to support and strengthen OR in developing countries. The declaration contained the conviction that OR can make significant contribution to the process of development in general and to developing countries in particular. Thus, asserting that OR has a broader role than just knowledge brokering or technology transfer was firmly on the map (Rosenhead and Tripathy, 1996).

Other OR societies besides IFORS have also developed similar themes (for example the EURO and IFORS Africa initiative (Rand and Tsoukias, 2002). What is common between these themes is the desire to promote OR in developing countries, while being concerned with addressing the process of development more generally. The main aim of the OR and developing countries initiatives appears to be to promote the increase in the use of OR as a practical tool for problems in developing countries. Some of these initiatives include regional workshops as well as academic exchanges. There has also been a flow of students from the developing countries to Europe and the US for training in OR, which has been viewed as crucial to the prospects for developing countries OR.. Thus, the endeavours appear to have both a business and a moral case.. First, there is a desire to expand the discipline in countries where professional groups or societies have not yet, or have recently been formed. This is often combined with a desire to promote better or more relevant practice through training and through developing the subject. Second, there is the desire to evaluate the possibilities and limitations of OR for developing countries, to better understand the role of OR in developing countries, and in some circumstances to think about the role of OR in light of the process for development or globalisation. The latter is borne out of a continuing trend in OR to recognise the profession’s social responsibility (Rosenhead, 1993). Therefore, to undertake a review of OR in developing countries presents a daunting and complex task. As well as providing an overview of what is happening and what has been the effect of the many initiatives, there are bigger questions hanging in the background that somehow cannot be ignored, particularly whether developing countries OR should focus on the relationship between development and the alleviation and/or the creation of poverty. The risk is that if these questions are not at least acknowledged a review may provide little assistance in understanding the nature of OR in developing countries or even development, or worse that no suggestions can be made for the future of OR in developing countries (see Bornstein & Rosenhead, 1990). The intention, then, for this review will be not only to provide an overview of what OR is being utilised in developing countries but also to address the issue of the relevance of OR for development.

It should be noted that there are very few reviews of OR in developing countries undertaken over the years. Indeed, there are only a handful of special issues of academic journals providing an overview of the application of OR in developing countries in the literature (e.g. Kemball-Cook and Wright, 1981; Bornstein, et al, 1990; Datta and Bandyopadhyay, 1994). However, of the reviews undertaken, their objectives were to examine the extent to which OR applications in these areas are relevant to the development problems of the developing countries and whether the existing techniques and methodologies are relevant to tackle such problems. Which begs the question - would a review be useful? It seems to us that a review would be useful in order to help us think about and tackle the question of OR’s relevance in a complex world.

However, how should a review of OR in developing countries be organised? Should it be organised by developing countries, methods used or otherwise? To organise a review is not straightforward. For example, some authors have pointed out that the concept of OR in developing countries is different from that found in the developed world (Aggarwal, 1994). Others have found that the term ‘‘OR’’ used to describe an approach varies quite markedly from one developing country to the next (Smith 2008). Given this, and the extent of the literature, what counts as OR can be interpreted in many different ways, and so it is impossible for a review to be in any sense comprehensive. For a review to draw any inference there would need to be a clear and consistent definition of OR and some means of evaluating good practice across all applications. There would also need to be a clear definition on what is a developing country or what is meant by development. This will be explored below.

Thus, this paper aims to provide an overview of the practice of OR (broadly defined) in the developing countries over the last decade. It cannot be a systematic review, nor is it entirely a critical review along the lines of Bornstein and Rosenhead (1990). Instead it is a snapshot of practice which will hopefully highlight the variety and range of OR practice and help to appraise the relevance of OR for development. A comprehensive search was made of a variety of databases, including the ISI Web of Knowledge, Business Source and the International Abstracts in Operations Research (IAOR) databases. In doing this we are aware that there are a range of places where material on OR in developing countries may appear in print. It has not been possible to access these for this review. The focus of this review is mainly on practical applications of OR rather than theoretical or philosophical debates. However, we have heeded the warning that an appreciation of the contextual aspects of developing countries, their history, politics, and so on cannot be ignored (Datta, 1993; Bornstein and Rosenhead, 1990). Thus, we have structured the paper into three main sections – we begin with the context of OR in developing countries; this is followed by the practice of OR in developing countries; finally, the relationship between development and the alleviation of poverty will be explored through looking at the application of OR to the millennium development goals (MDG). There is inevitably a degree of duplication in doing it this way but we believe that readers may be coming at it either through an interest in a particular country, method or through an application area.

**2. Background to the review of OR in developing countries**

Without doubt we can say that developing countries exists. According to the UN, the developing countries are mainly found in Africa, Asia and the Pacific (excluding Japan, Australia, New Zealand and the member States of Commonwealth of Independent States in Asia), Latin America and the Caribbean. This list excludes Europe, (and the European transition economies) Canada, the United States of America Japan, Australia and New Zealand (UNDP, 2005). but historically there has been a variety of terms used (Rapley, 1996). The term developing country was used immediately after the close of World War II in 1945. ‘Third World’ was the most commonly used term, thereafter, followed by the term ‘underdeveloped world’. Other terms that are sometimes used are ‘less developed countries (LDCs)’, least economically developed countries (LEDCs), ‘non-industrialized nations’. However, there is no singularly recognised definition of a developing country, and what might be recognised as the levels of development may vary widely within so-called less developed or third world countries, with some having high average standards of living. Developing country is a term still used to describe a nation with a low level of material well being. International organizations like the World Bank consider all low- and middle- income countries as ‘developing’, and in 2008, it defined countries with Gross National Income[[1]](#footnote-1) per capita below US$11,905 as developing (World Bank, 2009 (a)). Other institutions use less specific definitions. There are also countries defined as ‘newly industrialized countries**’.** These are countries with more advanced economies than other developing nations, but which have not yet fully demonstrated the signs of a developed country. The use of the term ‘developing country’ has also come under criticism. The term may imply inferiority of a ‘developing country’ compared to a ‘developed country’. It may also assume a desire to ‘develop’ along the traditional 'Western' model of economic development. The term 'developing' also implies mobility and does not acknowledge that development may be in decline or static in some countries (Willis, 2005).

The concept of a developing country is also found, under one term or another, in numerous theoretical systems having diverse orientations —the major theories of development being modernization, dependency, world-systems and globalization. These are the principal theoretical explanations to interpret development efforts carried out in the developing countries and form the basis of more critical reviews of development in developing countries (Rapley, 1996; Willis, 2005). In relation to OR and development, Bornstein and Rosenhead (1990) provide a selective survey, where the central premise is to understand development as underdevelopment which is more or less a set of relationships between developed and less developed countries. The paper discusses the limited extent to which this framework has been incorporated into OR's. Two distinguishable main strands are highlighted.. The first (Modernisation Theory) stresses the need for developing countries to 'modernise', while the second (Dependency Theory) stresses the obstacles in the way of their doing so (Willis, 2005).

Modernization Theory states that the development can be achieved through stages, which is a linear process that every country must go through. This approach is premised on the idea that western societies can provide a developmental model for 'traditional' societies (Rapley, 1996; Willis, 2005). It posits that growth and development arise from the set of values that predominate within any society. Hence, the factors that help or hinder development are seen as largely internal to a society. The main criticism of the theory however, is that the modernization perspective only shows one possible model of development.  Dependency Theory takes a very different perspective (Rapley, 1996; Willis, 2005). It is a view of development and underdevelopment that is relational and claims that for underdeveloped nations to develop, they must break their ties with developed nations and pursue their own path for internal growth (Rapley, 1996; Kingsbury et al., 2004).

One of the main current criticisms of the Dependency Theory (and to some extent the Modernization Theory) is that it continues to base its assumptions and results on the nation-state. It has been also been argued that thinking about development has reached an 'impasse' whereby the conflicting paradigms present irreconcilable accounts of the global order (Schuurman, 1993). Today, there are new activities in the world-economy which can not be explained within the confines of the modernisation nor the dependency perspective.  This created the conditions for the emergence of the world-systems theory (McMichael, 2000; Nederveen, 2001). The idea claims that it is being increasingly recognised that there are worldwide conditions that operate as determinant forces especially for small and underdeveloped nations, and that the nation-state level of analysis is no longer the only useful category for studying development conditions, particularly in the developing countries (McMicheal, 2000).  The factors which have had the greatest impact on the internal development of smaller developing countries are the new systems of global communications, the new world trade mechanisms, the international financial system, and the ease of knowledge transfer and so on.  These factors have created their own dynamic at the international level, and, at the same time, these elements are interacting with the internal aspects of each country (Nederveen, 2001).

In a similar fashion, the "received wisdom" of the last decades has revolved round the idea of free markets, declining government and a transition to a borderless world in which the role of the state becomes ever less important. Globalization is the overarching term given to this process with the evolving global economy based upon the comparative advantage of regions and countries and growing international trade in goods and services (Stiglitz, 2002). Trans-nationalism through the movements of capital, goods, services and labour has revitalised theories of growth. The theory of globalization emerges from a perception of the global mechanisms of greater integration between countries with particular emphasis on economic transactions.  In this sense, this perspective is similar to the world-systems approach (Kingsbury et al., 2004).  However, one of the most important characteristics of the globalization position is its focus and emphasis on cultural aspects and their communication worldwide.  In cultural communication, one of the most important factors is the increasing flexibility of technology to connect people around the world. Through this process nations are interacting much more frequently and easily, not only at the governmental level, but also within the population. Even though the main communications systems are operating among the more developed nations, these mechanisms are also spreading in their use to less developed nations.  This fact, it is claimed, will increase the possibility that marginal groups in poor nations can communicate and interact within a global context using the new technology (Stiglitz, 2002; Wolf, 2004). The interesting thing is that the globalization and world-systems theories take into account the most recent economic changes in world structure and relations that have occurred in the last couple of decades and the current economic downturn has not gone unnoticed (World Bank, 2009 (b)).

The objective of this section was to explore some of the problems in defining what is a developing country and difficulties inherent in the concept of 'development'. It can be seen that the nature of development is illusionary. What is obvious is that to account for OR in developing countries an understanding of the backdrop to development is vital. Some aspects of these theories have a clear relevance to understanding what kind operational research practice is being conducted in the developing countries and, to some extent, they should be able to help in our understanding of what kind of OR is relevant. One of the main arguments over the years is that OR is a technology that should be transferred to the developing countries. The next section will look at this.

*2.1 OR in developing countries as technology transfer*

Technology transfer has been at the core of the strategy for development, which has been impressed upon most developing countries by international agencies. Yet the notion of technology transfer can be seen to be deeply implicated in the processes which maintain a level of dependency between developed and developing countries on the one hand and are intrinsically linked to globalisation on the other. Attempts to improve the economic performance and autonomy of developing countries through industrialisation have largely foundered on this obstacle. For example, many developing countries have attempted to adopt a policy of industrialisation based on import substitution to reduce their dependency on western technology and resources. The aim was both to reduce foreign exchange losses and to foster a ‘local’ productive capacity. However, this has not occurred to a significant extent. Another strategy is to adopt more appropriate technologies, which in principle are drawn out of an awareness of indigenous resources, traditions and skills. Again, this has not led to any significant shift in growth or development. The main issues are that technology transfer depends on a number of things, for example on visiting experts and most significantly on the education of professionals and practitioners. These have been the main mechanisms for bringing OR to the developing countries and as noticed by a number of commentators (see Bornstein and Rosenhead, 1990), these are not without their problems. They mostly concern issues of appropriateness and focus squarely on themes such as ‘the brain drain’ and so on. One such issue is the role of education of O.R. in developing countries. There are many O.R. courses in universities in many of the developing countries. However, those who teach these may not have relevant practical experience in applying O.R. to practical problems of the developing countries, and therefore the material may concentrate on the (more mathematics) techniques rather than the entire O.R. process. It is also worth pointing out that there is little incentive in many academic institutions in developing countries for involvement with the business, commercial and government communities.

Finally, rather than seen as essentially a failure of development, technology and knowledge transfer is now increasingly being considered to be an integral part of the development process itself and one that can lead to poverty alleviation rather than poverty creation. We will pick this up further (and other issues) later in this review.

**3. OR in Developing Countries**

There have been only a few reviews of OR by developing countries. From these there seem to be some asymmetry. The imbalance between regions/countries is not surprising. The large countries in most regions have been relatively well served already by OR activities. But the smaller regions/countries have been overlooked. Table 1 gives the members of IFORS and those that are classified by the World Bank as ‘developing’ are highlighted. There are clearly countries that are not IFORS members that have OR that are not included, for example there is an obvious lack of African countries (Smith, 2008). It should also be noted that there are some recently new countries that are members.

*Table 1 here*

*3.1 What is being done in different regions/countries?*

From the literature, there appears to be only one attempt to create a systematic bibliography for countries in Africa (Smith, 2008). The study provides a useful template for future research on regional usage of OR. For general experiences of use of OR in emerging nations, several studies are available. Stewart (1995) describes challenges to the use of OR in South Africa; Kemp and Yousef (1995) are concerned with OR in a (rich) developing country, the UAE, and Li et al. (2000) give experiences from the use of OR/MS in a fast emerging economy, China.

*3.1.1 Africa*

The development of OR in this region has been highlighted recently in a comprehensive review by Smith (2008), with emphasis on areas of application. It also discusses the challenges to OR in the context of development problems in Africa, and includes exploring the potential for OR (both as a profession and practice) in the region. This review should be seen in light of EURO and IFORS initiatives for development, including supporting OR Practice for Africa initiative (ORPA). The main reviews are: (Smith, 2008; Stewart, 1995; Rand and Tsoukias, 2004)

*3.1.2 Asia*

The most comprehensive review of OR in this region is provided by Chang and Hsieh (2008). The paper reviews articles published by Asian authors in Operations Research and Management Science (OR/MS) journals from 1968 to 2006. The research highlights trends and scope for OR in region through comparing work with the USA (Chang & Hsieh, 2008). The contribution of different countries/regions is as follows: Japan 3.7%, Taiwan 3.2%, India 2.3%, Hong Kong 2.2%, South Korea 2.1%, People's Republic of China (PRC) 1.9%, and Singapore 1.2%. There are other reviews that take a particular focus on China (Bartholdi, 1986; Lasdon, 1980; Li, Wang and Xu, 2000) and Taiwan (Chen and Wei, 2002)).

*3.1.3 India*

Operational research has been firmly established in India since the early 1950s. The Operational Research Society of India (ORSI) was the first operational research society founded in a developing country. It was established in 1957 and predated many similar societies in developed countries. While there has not been a major review of OR in India, details of OR activities in India are provided by a number of articles in the publication: “OR in India: A Retrospective” (Raghuram, 1992), particularly, Datta (1992), Jaiswal (1992) and Gupta (1992). In relation to development, the proceedings from the International Conference on Operational Research (ICORD) held in Ahmedabad in 1992, published in 1996, included a number of contributions on Indian OR (Rosenhead and Tripathy, 1996) and Tripathy‘s paper submitted for the IFORS development Prize in 1993outlined practical application of OR in India (Tripathy, 1993). Operational research in India also flourished in industry and the corporate sector, and there is also a broad based academic community. In the review by Chang & Hsieh (2008) it was highlighted that the Indian Institute of Technology was one the five most productive institutions in relation to OR published articles in Asia.

*3.1.4 South America*

There has not been an extensive review of OR in this region. Particular overviews of national planning and industrial development can be found in Sagasti (1974), Iachan (2009) and Ferrelli et al. (1997).

*3.2 Summary*

In sum, there appears to be a dearth of reviews of OR and development by countries. This may not be a surprise given the breadth of what might count as OR and the worry that a review might provide some worrying over generalisations. However, given that each country is potentially unique in terms of its history, culture, social structure, economic development, there is a case that a review of OR may be invaluable in understanding the potential for using OR in individual developing countries. For example, even the UN definition of a developing country discussed earlier, we see that there is a great range of developing countries and as many commentators have pointed this out, there is a great variety within a region. India is different from its neighbours and the countries of East Africa differ from those in West Africa. We should also point out that we have provided very little reference to O.R. in North Africa, the Middle East and Central Asia. Indeed a review of the current state of management science/OR in the Arab countries may provide a useful point of reference for those interested in OR in developing countries (see for example Yousef, 2009)

**4. “Developed countries” OR applied in developing countries**

OR methods originally designed for developed countries are being increasingly applied in the developing countries. In this section we discuss “developed countries” methodologies that are well suited to developing countries and also application areas.

*4.1 Methodologies used in OR for developing countries*

In this section we are seeking to give a flavour of the methodologies commonly employed in OR for developing countries. We cannot be comprehensive here, but have selected methods (see Table 2) that are well suited to the conditions of developing or emerging nations.

*Table 2 here*

Optimisation methods are well represented in the literature of OR for developing countries. For example, optimisation of mobile health facility routes is carried out by Doerner et al. (2007) as a case study in Senegal. Routeing and scheduling optimisation is used by De Angelis et al. (2007) regarding food aid planes in Angola. Ahmed and Alkhamis (2009) integrate simulation with optimisation for hospital management in Kuwait.

The optimisation techniques of locational analysis are frequently used in the service of developing countries. The optimal locations for new facilities are often under consideration in both urban and rural areas where public and private services are lacking. Rahman and Smith (2000) provide a review of locational analysis for healthcare planning in developing countries. Galvão et al. (2002) apply locational techniques to optimising maternal and perinatal healthcare services in Rio, Brazil. Also focusing on Brazil, Pizzolato et al. (2004) consider the location of public schools in urban areas. Yasenovskiy and Hodgson (2007) apply locational analysis to healthcare provision in the rural area of Suhum, Ghana, as do Smith et al. (2009) for rural regions of India.

DEA, which compares efficiencies of units producing either services or goods, is applicable in situations where new industries or institutions are being developed. Saranga provides examples of applications of DEA in India, both in pharmaceutical production (Saranga, 2007) and in car component manufacturing (Saranga, 2009). Again in India, Sathye (2003) applies DEA to efficiencies of banks. In a broad application, Lu and Lo (2007a) extend DEA techniques in considering regional economic performance, taking environmental factors into consideration.

In situations where a multitude of competing interests prevent an easy optimisation of resource use, the technique of System Dynamics (SD) is able to shed light on areas of complexity. In a Taiwanese case study (Jan and Hsiao, 2004), SD is used to model the efficiency of growth of car production industries in developing countries. Another example of such usage is given by Chen and Jan (2005), who apply SD to the development of the semiconductor industry in Taiwan over a 25-year period. Conclusions are drawn for predicting the possible growth of semiconductor industries in other developing countries of Asia.

It has been argued that “Soft” OR methods, which were developed mainly in the UK, are well suited to the problems of developing countries (Bornstein and Rosenhead, 1990, White, 1994, White and Taket, 1997). Lewis et al. (2003) use soft OR with rapid appraisal techniques in the Hillbrow community of South Africa. Also in South Africa, a soft OR method is employed in education planning by Phahlamohlaka and Friend (2004). It must be said, however, that application of ‘soft OR’ in developing countries has been limited.

In summary, the methodologies developed from the developed world and used in developing countries range from optimisation techniques and Data Envelopment Analysis (DEA) to System Dynamics (SD) and ‘Soft’ OR methods. However, we note a lack of combinations of ‘hard’ and ‘soft’ methods, which may provide powerful applications of efficient planning alongside consideration of local aspirations.

*4.2 Application areas*

In low income economies, large shares of GDP and even larger shares of employment derive from agriculture. Therefore it is no surprise that agriculture is the predominant area of application of OR in most developing countries. There are well-developed models for land-use and crop development, which are priorities for many developing countries. Other matters that are of wide interest to developing countries include manufacturing efficiency, infrastructure and healthcare facility management. It is notable that many such studies are applied in countries known as emerging nations or newly industrialised economies (International Monetary Fund, 2009). We discuss applications from Brazil, Chile, China, Croatia, India, Indonesia, Israel, Jordan, Kuwait, Mexico, Poland, South Africa, Tunisia and Turkey.

*4.2.1 Agriculture and the environment*

A wide variety of OR applications can be found pertaining to agriculture and the environment. In the field of agricultural decision making, Alphonce (1997) proposes application of the Analytical Hierarchy Process (AHP). An integrated method of predicting grain harvests is presented by Chen, Pan et al. (2001) More recently, Ahumada and Villalobos (2009) review the application of planning models in agricultural supply chains.

Optimal use of scarce natural resources is a continual concern for developing countries. Optimisation of crops in dry regions is considered by Haouari and Azaiez (2001) with application in an area of Tunisia. Optimal collection of tendupatta leaf, by destitute families in the forests of India, is modelled by Singh and Shah (2004).

Both ‘soft’ and ‘hard’ OR techniques have been employed in approaching environmental problems. Petraš (1997) uses multicriteria decision analysis to rank sites for nuclear waste disposal in Croatia. A utility-maximising model is used by Kumbaroglu (1997) to develop air quality control strategies for Turkey. Maturana and Contesse (1998) present a mixed integer programming model for the use and disposal of sulphuric acid in Chile in the context of strict environmental laws. Prioritisation of environmental projects in Jordan is carried out by Al-Rashdan et al. (1999), using the structured group decision process Nominal Group Technique along with multiple criteria decision aid software.

Several studies are designed to assess the environmental impact of development. Gielen and Yagita (2002) assess the global impact of greenhouse gas reductions in the uncertain position of developing countries. Tiwari (2004) evaluates housing construction techniques for low environmental impact, cost and employment. The environmental problems caused by development in China are studied by Lu and Lo (2007a, 2007b), applying DEA to different regions.

Green supply chain problems are recently receiving attention in developing countries. Srivastatava (2008) optimises green supply chain logistics in India. Li et al. (2008) optimise rescheduling of waste management vehicles in Brazil. Reverse logistics for recycled vehicles in Mexico are optimised by Cruz-Rivera and Ertel (2009) as an uncapacitated facility location problem.

*4.2.2 Management*

In the context of development, industrial management provides frequent applications of OR, often enabling small industries to gain much-needed efficiency. Instances of efficiency savings are given for vacuum-pan sugar factories in India, (Ferrantino and Ferrier, 1995), for small arc furnaces in the steel industry (Al-Marsumi, 2005) and for the distribution system of a beer producer in Turkey (Pamuk et al., 2004). The effects of congestion on efficiency in Mexican industry are studied by Bannister and Stolp (1995). Pizzolato and Guerrero (1999) advocate appropriate OR methods for a developing country when scheduling production in a Brazilian chemical firm.

ICT and related industries in developing countries also provide opportunities for use of OR modelling. Improvements in customer service for small- to medium-sized Internet Service Providers in Brazil are sought by Fontanella and Morabito (2002), making use of queueing models. The effect of computerisation on manufacturing efficiency in small, large and state-owned firms is investigated by Ng and Chang (2003).

Improvements to supply chains, logistics and transportation networks are well suited to OR application. Examples include supply chain organisation for tractor distributors in India, (Raghuram, 2004) and reverse logistics for recycled vehicles in Mexico (Cruz-Rivera and Ertel, 2009). The throughput of the Suez Canal is improved by Griffiths (1995) using a combination of linear programming, queueing theory and simulation. Chen, Goh et al. (2001) use mixed integer programming in expanding a logistics network in China, encountering a challenging environment with poor roads and excessive bureaucracy.

*4.2.3 Infrastructure*

Infrastructure development is a long-term determiner of the rate of overall development of any country. The provision of energy and water supplies, along with efficient road and other transport networks, is essential for emerging economies and economic growth.

In face of worldwide difficulties of meeting energy needs and rising usage in developing countries, a greater emphasis on optimal use of energy resources might be expected in OR literature. For example, Chattopadhyay (2001) employs an LP-formulation combined with Monte Carlo simulation to optimise electricity production and supply in India. Optimal release of water from reservoirs is achieved by van Vuuren and Gründlingh (2001), using an LP-based decision support system. Peniwati and Brenner (2008) use an AHP process to improve decision making regarding the companies supplying water in Indonesia.

A combined routeing and scheduling heuristic for a transportation network is provided by Groves et al. (2004). It is applied to the South African railway network at a time of rationalisation. Żak (1999) utilises multiple-criteria decision making (MCDM) to optimise an urban mass-transit transportation system in Poznań City, Poland. A vital part of infrastructure development is the provision of petrol stations. With current emphases on conversion to environmentally fuel in mind, Bapna et al. (2002) apply optimisation techniques to the location of unleaded petrol stations in developing countries, with a case study in India.

*4.2.4 Health care and education*

Operational performance of health facilities and in emerging nations has received much recent attention in OR literature. Hospital management is a particular application area, as healthcare resources are often concentrated at secondary levels. Simulation is used for optimisation of resources in a Kuwaiti emergency department by Ahmed and Alkhamis (2009). Günes and Yaman (2009) optimise the allocation of resources in a Turkish hospital network. De Moraes et al. (2010) suggest an MCDA decision tool for improving the efficiency of use of equipment in hospitals of developing countries.

Other aspects of healthcare management are also receiving attention in developing countries. Healthcare waste management systems are optimised by Brent et al. (2007) using an Analytical Hierarchy Process (AHP), with the objective of minimising further infections to patients and healthcare workers. Case studies are demonstrated from sub-Saharan Africa.

Education and meal provision for children is an important contribution to the well-being of an impoverished area, whether provided by state or private support means. Epstein et al. (2004) describe use of integer linear programming models to improve the supply of school meals in Chile. A state agency provides free meals at school to children from low income families through contract assigned by combinatorial auction. Considerable savings and improvements in quality are reported.

The location of schools in urban areas of developing countries is addressed by Pizzolato et al. (2004). A decision support system is described for location of public schools in urban area of Brazil, combining locational analysis with GIS to provide equitable solutions to the problems of under-provision in areas of deprivation.

*4.2.5 Governance, Employment and Migration*

Particular emphasis is given to decision support tools for governance in developing countries. Akinyosoye (1995) finds that establishment of data banks as decision support tools is necessary for successful development planning. Decision tools for improving governance are developed by Zhang and Cui (1999) for evaluating government projects, and by Melgarejo et al. (2009) for improving the resettlement of destitute families in Brazilian Agrarian Reform.

We report a lack of applications in the areas of employment and migration. An exception is Batabyal and Beladi (2002), who carry out dynamic analysis of protection and environmental policy in “a small trading developing country”, modelling the migration of workers from traditional to industrialised employment.

Macro-level national and international studies have attracted the attention of OR researchers in developing countries. Zheng et al. (2000) study income levels as time series, to gain a picture of regional inequalities. Kao et al. (2008) propose a methodology for comparing the competitiveness of nations, highlighting ways in which developing countries can improve their position.

*4.2.7 Investment and finance*

The need for foreign investment to assist development is well recognised. Deng et al. (1997) propose a method for evaluation of the environment for foreign investment, in China and similar developing countries. With existing variable conditions for investment in the different provinces of China, this systematic method takes local resources into account in recommending optimal strategies for different regions desirous of attracting investment.

Data Envelopment Analysis (DEA) is a powerful tool for comparing efficiencies in countries whose economies are badly affected by inefficiency. Sathye (2003) uses DEA in a comparison of the productive efficiency of banks in a developing country, namely India.

**5. OR for development in developing countries: tackling the Millennium Development Goals**

This section looks at applications in the developing countries that meet most people’s perception of the range of attributes which characterise development. These might include: widespread poverty, poor health and health care, high levels of unemployment, urban squalor and shanty-towns, reliance on a single crop or product for export, poor governance (particularly administrative and political institutions), poorly developed financial institutions, and political instability. The relationship between development and the alleviation of poverty will be explored through looking at the application of OR to the Millennium Development Goals (MDGs). Most of the poorest people in the world are still to be found in the developing countries particularly in the rural regions. Most of the contemporary approaches to poverty alleviation is in the context of the MDGs. The Millennium Declaration, which was adopted by the world leaders in 2000 (it was signed by 147 heads of state), summarised the conditions that beset developing countries and was a pledge to "free all men, women, and children from the abject and dehumanizing conditions of extreme poverty." The declaration contained the MDGs, which are a set of targets to reduce global poverty and improve living standards in developing countries by 2015. They are arguably the most ambitious developmental undertaking ever embraced by the international community. It is widely recognised that most of the MDG targets are endogenously related. They are to:

* Eradicate extreme poverty and hunger,
* Achieve universal primary education,
* Promote gender equality and empower women,
* Reduce child mortality,
* Improve maternal health,
* Combat HIV/AIDS, malaria, and other diseases,
* Ensure environmental sustainability
* Develop a global partnership for development

The goals provide a useful summary of the critical issues facing a number of developing countries and Table 3 below is a summary of published OR work relating to the MDGs.

*Table 3 here*

It is clear that in relation to the priorities to reduce poverty, applications of OR on the priority areas in developing countries is scarce. However, this may be as result of the types of methods associated with OR. Below, we summarise studies which may not directly address the MDG but are close enough. In particular we found that the most prominent area of application was in the field of healthcare and in particular in addressing HIV/AIDS.

*5.1 Empowerment of women*

Women’s microfinance savings groups or self-help groups have in many developing countries been found to be effective ways of bringing small businesses to needy areas. Gutiérrez-Nieto et al. (2009) construct measures of efficiency of microfinance institutions in both economic and social terms, including impact on women and a poverty reach index. Smith et al. (2009) optimise numbers of village health workers that can be supported by self-help groups.

*5.2 Healthcare needs: reduction of childhood and maternal mortality and community health*

The reduction of childhood and maternal mortality is a priority in areas of deprivation and poverty. However, research pertaining to the reduction of deaths and diseases of women and children has received scant attention to-date in the Operational Research journals. The reason given often concerns that fact that data concerning mortality is often difficult to obtain in developing areas, as frequently deaths are not officially recorded, and reliance has to be made on hearsay and interview only.

Community healthcare facilities particularly address the needs of those living in poverty in rural developing areas, where access to quality medical care is denied to many people because of travel difficulties and cost. Smith et al. (2009) consider the sustainability of community healthcare facilities in rural regions of India, demonstrating the usefulness of optimisation techniques in planning the location of such facilities. The effect of distance in accessing health facilities in a rural district of Ghana is discussed by Buor (2003), in relation to other factors such as travel time, cost and level of education. Ahsan and Bartlema (2004) analyse performance of primary healthcare facilities in Bangladesh. The effect of healthcare users in developing countries by-passing close lower level facilities to use more distant higher level facilities is modelled by Yasenovskiy and Hodgson (2007). A hierarchical location-allocation model is proposed, based on spatial choice.

Mobile health facilities are well suited to supplying medical care to rural villages at a distance from hospitals or community health centres. Optimisation of mobile health facility routes is considered in case studies in Ghana (Hodgson et al., 1998) and in Senegal (Doerner et al., 2007).

Other healthcare-related studies include: (Bachmann & Barron, 1997; Barr, 2007; Benavides & Jacoby, 1994; Datta, 1993; Dick et al., 2006; Ferrelli et al., 1997; Fiedler & Day, 1997; Goldie et al., 2006; Sudhir et al., 1996; Thunhurst, 2007; Tomson et al., 2005)

*5.3 Combating HIV/AIDS, malaria, and other diseases*

In recent years, the majority of OR work on infectious diseases in developing countries has concentrated on HIV. This is one of the major issues of the 21st century and so perhaps this comes as no surprise. Nonetheless, it seems a shame that OR has not been used to help with some of the other, possibly less fashionable diseases.

There has been limited work in the area of optimal resource allocation and epidemic control (Brandeau et al.*,* 2003) and we found little work on general resource allocation problems in health care for developing countries, where infectious diseases are particularly important in governing the healthiness of a population. Lasry et al*.* (2007) consider the general problem of resource allocation for HIV where they compare an equity-based allocation of resources with the optimal allocation. More recent work looks at a more practical application (Lasry et al*.,* 2008), where a decision support tool named S4HARA is described.

There has been a considerable amount of modelling of HIV since the early 1990s when it was first really recognised as being a serious problem. In fact, the number of modelling studies that repeat the same research suggests that it may even have been over-worked. One of the most successful models of the HIV epidemic is STDSIM. This was first described by van der Ploeg et al (1998), where it was applied to data from Kenya. The aim was always to develop a general model that could be used for decision support in developing countries. The model has since been reused to model the HIV epidemics in Botswana and India (Nagelkerke et al*.,* 2002), the results of a large community-based trial of STI treatment (Korenromp et al*.,* 2000) and to determine how best to focus condom distribution (van Vliet et al*.,* 2001). In recognition of the importance of social networks and individual behaviour in the transmission of HIV, the majority of models employ some form of discrete event simulation (DES). Two other well-known and well-used models for HIV are described in Bernstein et al.(1998): the US Interagency Working Group AIDS Model or iwgAIDS; and SimulAIDS.

Models in the core OR literature tend to be more focused towards operational decision support. The model by Harper and Shahani (2003) is a good example of this, with an emphasis on usability of the model and practical outcomes, such as the projected costs of the HIV epidemic. Costs are also taken into account by Flessa (2003) in his system dynamics model of control programmes for a general east African setting and by Rauner et al. (2005) who model mother-to-child transmission of HIV. Vieira et al. (2003) model mother-to-child transmission, again with an emphasis on usability.

It is hard to determine how much of an impact OR and related techniques have had on policy decisions related to HIV in developing countries, as policy makers tend to be influenced by a range of different information and rarely list what this is. For example, descriptions of large-scale HIV intervention programmes such as Avahan, the Indian AIDS initiative (Wilson and Halperin, 2008) suggest that OR has had little part to play where it could be most useful in countering the HIV epidemic and there is a need for more awareness among policy-makers in the developing world of what OR can do.

*5.5 Natural disasters, humanitarian logistics*

Natural and man-made disasters particularly afflict those living on the poverty line, bringing immediate needs of food supplies, clothing, shelter and medical aid. Development itself is delayed or destroyed until immediate needs can be satisfied. A recent survey (Altay & Green III, 2006) notes the lack of OR literature in the area of disaster planning: the lack of research specifically applied to developing countries is thus even more pronounced.

Routeing and scheduling of food aid planes in Angola is optimised by De Angelis et al. (2007). Yi and Özdamer (2007) provide a dynamic formulation of disaster relief modelling, with relocation of scarce medical resources, emergency vehicle flows and location of temporary medical centres. Earthquake relief in Istanbul is described as a case study. Other relevant studies include Datta (1993) and Peters et al. (2007).

**6. Discussion and Conclusion**

In this review of OR in developing countries, certain qualifications and reservations were pointed out. These reservations tended to focus on what is a developing country, whether OR in developing countries is different to OR in the developed countries, and whether a review of OR in developing countries is useful for the subject in general. It seems clear that OR can make important contributions to improved decision-making in developing countries, but there are a range of issues that have to be borne in mind. The first is it is very difficult to define a developing country and there will always be characteristics which confounds most attempts at a definition. Second, the definition of OR varies widely in the literature on OR in developing countries, which means it is almost impossible to evaluate the impact of OR in developing countries. Third, there are many theories of development and an appreciation of them helps in defining the boundary around what counts as OR in developing countries. In other words, it depends on a position on what counts as development. Clearly ambiguities will arise around our response to questions such as whether a "right to development" exists, and if so, what kind of development, and who defines it? We think these are worthy of examination in the context of a globalized world. Finally, we are aware that there are a range of outputs where material on OR in developing countries may appear in print and that many multi-nationals and non-governmental organisations (NGOs) do OR in developing countries and either do not write up the experience or if they do the work is not readily available for review. Thus, many possibly good examples of practice will go unnoticed. This last point stresses the need to support the development of national OR societies in developing countries.

In this review we have attempted to locate OR within the contemporary debates to development as poverty alleviation in the context of the MDGs. Here, there are many issues relating to this now widely accepted notion of development, which there is a dearth of OR application. From our review, we found that OR is not used to address the MDGS in any significant way. However, this is not to say there are no applications to the issues: we found a great deal of publications addressing health, the most significant area being HIV/AIDS. There seems to be many great problems for which OR would be of immense use in the developing countries.

**Acknowledgements**

This research has been partially funded by the EPSRC (grant EP/F033982/1).

**References**

Abayomi, A., Adomakoh, N. 2006. Responding to the HIV epidemic in the developing world. Capacity building and technology transfer for monitoring with HAART: A Caribbean experience. African Journal of Medicine and Medical Sciences, 35 Suppl, 19-24.

Adetoro, O.O., Adeyemi, K.S., Parakoyi, B., Oni, A., Akure, T., Ogunbode, O., 1991. The application of operational research procedures to maternal mortality from puerperal sepsis in a rural community. Social Science and Medicine 33, 12, 1385–1390..

Aggarwal, S.C., 1994. Practical applications of OR in an underdeveloped nation. European Journal of Operational Research 77, 3, 357–374.

Ahmed, M.A., Alkhamis, T.M., 2009. Simulation optimization for an emergency department healthcare unit in Kuwait. European Journal of Operational Research, 198**,** 936-942.

Ahsan, M.K., Bartlema, J., 2004. Monitoring healthcare performance by analytic hierarchy process: a developing country perspective. International Transactions in Operational Research, 11, 465-478.

Ahumada, O., Villalobos, J.R., 2009. Application of planning models in the agri-food supply chain: A review. European Journal of Operational Research, 195**,** 1-20.

Akinyosoye, V.O., 1995. Operationalizing the Data Banking Concept within a National Statistical and Information System: Problems and Prospects in Nigeria. International Transactions in Operational Research, 2**,** 375-385.

Al-Marsumi, M., 2005. Modelling some aspects of the maintenance management of the working refractory lining of small electric arc furnaces in the steel industry. Journal of the Operational Research Society, 56**,** 275-285.

Al-Rashdan, D., Al-Kloub, B., Dean, A., Al-Shemmeri, T., 1999. Environmental impact assessment and ranking the environmental projects in Jordan. European Journal of Operational Research, 118**,** 30-45.

Alphonce, C.B., 1997. Application of the Analytic Hierarchy Process in agriculture in developing countries. Agricultural Systems, 53**,** 97-112.

Altay, N., Green III, W.G., 2006. OR/MS research in disaster operations management. European Journal of Operational Research, 175, 475–493.

Bachmann, M.O., Barron, P., 1997. Why wait so long for child care? An analysis of waits, queues and work in a South African urban health centre. Tropical Doctor, 27, 34-38.

Bannister, G.J., Stolp, C., 1995. Regional concentration and efficiency in Mexican manufacturing. European Journal of Operational Research, 80**,** 672-690.

Bapna, R., Thakur, L.S., Nair, S.K., 2002. Infrastructure development for conversion to environmentally friendly fuel. European Journal of Operational Research, 142, 480-496.

Barr, D.A., 2007. A research protocol to evaluate the effectiveness of public-private partnerships as a means to improve health and welfare systems worldwide. American Journal of Public Health, 97, 19-25.

Bartholdi, J.J., 1986. Operations Research in China. Interfaces, 16(2), 24-30.

Batabyal, A.A., Beladi, H., 2002. A dynamic analysis of protection and environmental policy in a small trading developing country. European Journal of Operational Research, 143**,** 197-209.

Benavides, B.M., Jacoby, E.R., 1994. An operational evaluation of the community oral rehydration units in Peru. Health Policy and Planning, 9, 438-443.

Berg, C.J., 1995. Prenatal care in developing counties: The World Health Organization Technical Working Group on Antenatal Care. Journal of the American Medical Women’s Association, 50, 182-186.

Bernstein R.S., Sokal D.C., Seitz S.T., Auvert B., Stover J., Naamara W., 1998. Simulating the control of a heterosexual HIV epidemic in a severely affected East African city. Interfaces 28 (3): 101-126.

Bertrand, J.T., 1991. Recent lessons from operations research on service delivery mechanisms. In: Seidman, M., Horn, C.M. (Eds.) Progress in Clinical and Biological Research, vol. 371: Operations Research: Helping Family Planning Programs Work Better, pp19-44. Wiley-Liss, New York.

Bornstein, C.T., Rosenhead J., 1990. The role of Operational Research in less-developed countries - a critical approach. European Journal of Operational Research, 49, 156-178.

Bornstein, C.T., Rosenhead, J., Vidal, R.V.V., 1990. Special issue – Operational Research in developing countries. European Journal of Operational Research, 49, 155-155.

Brandeau M.L., Zaric G.S., Richter A., 2003. Resource allocation for control of infectious diseases in multiple independent populations: beyond cost-effectiveness analysis. Journal of Health Economics, 22, 575-598.

Brent, A.C., Rogers, D.E.C., Ramabitsa-Siimane, T.S.M., Rohwe, M.B., 2007. Application of the analytical hierarchy process to establish health care waste management systems that minimise infection risks in developing countries. European Journal of Operational Research, 181, 403-424.

Buor, D., 2003. Analysing the primacy of distance in the utilization of health services in the Ahafo-Ano South district, Ghana. International Journal of Health Planning and Management, 18, 293-311.

Chang, P.L., Hsieh, P.N., 2008. Bibliometric overview of Operations Research/Management Science research in Asia. Asia-Pacific Journal of Operational Research, 25, 217-241.

Chattopadhyay, D., 2001. Production and maintenance planning for electricity generators: modeling and application to Indian power systems. International Transactions in Operational Research, 8**,** 465-490.

Chen S.P., Wei T. S., 2002.  The practice of operational research in Taiwan.  Journal of the Operational Research Society.  53(12): 1330-1337

Chen, F.Y., Goh, M., Lee, J., Ou, J., Sharafali, M., Teo, C.-P., Goh, P.-G., Sivanathan, P., 2001. ST Logistics: distributing consumer goods in China. International Transactions in Operational Research, 8**,** 203-219.

Chen, J.H., Jan, T.S., 2005. A system dynamics model of the semiconductor industry development in Taiwan. Journal of the Operational Research Society, 56**,** 1141-1150.

Chen, X., Pan, X., Yang, C., 2001. On the study of China's grain output prediction. International Transactions in Operational Research, 8**,** 429-437.

Cruz-Rivera, R., Ertel, J., 2009. Reverse logistics network design for the collection of end-of-life vehicles in Mexico. European Journal of Operational Research, 196**,** 930-939.

Daniel, S.E., Diakoulaki, D.C. and Pappis C. P. 1997. Operations research and environmental planning. European Journal of Operational Research, 102, 248-263.

Datta P.,C., (1992) Facts and Figures about Operational Research Society of India, In Raghuram, G. (ed) OR In India: A Retrospective, 1992. Operational Research Society of India and Wiley Eastern Limited, New Delhi. pp. xi-xiii

Datta, S., 1993. Applications of OR in health in developing countries - a review. Social Science & Medicine, 37, 1441-1450.

Datta, S., Bandyopadhyay, R., 1994. Applications of operational research in industry and industrialization in the developing countries: A review. Omega, 22, 173-184.

De Angelis, V., Mecoli, M., Nikoi, C., Storchi, G., 2007. Multiperiod integrated routing and scheduling of World Food Programme cargo planes in Angola. Computers and Operations Research, 34**,** 1601-1615.

de Moraes, L., Garcia, R., Ensslin, L., da Conceição, M.J., de Carvalho, S.M., 2010. The multicriteria analysis for construction of benchmarkers to support the clinical engineering in the healthcare technology management. European Journal of Operational Research, 200, 607–615.

Deng, S., Li, Y., Chen, J., 1997. Evaluating foreign investment environment in China: A systematic approach. European Journal of Operational Research, 100, 16-26.

Dick, B., Ferguson, J., Chandra-Mouli, V., Brabin, L., Chatterjee, S., Ross, D.A., 2006. Review of the evidence for interventions to increase young people's use of health services in developing countries. World Health Organisation Technical Report Service, 938, 151-204; discussion, 317-141.

Doerner, K., Focke, A., Gutjahr, W.J., 2007. Multicriteria tour planning for mobile healthcare facilities in a developing country. European Journal of Operational Research, 179**,** 1078-1096.

Durstine, R.M., Davis R.G., 1969. Educational planning in developing countries - a possible role for Operations Research. Operations Research 17: 911-915.

Dutta, G., 2001. IFORS OR for Development Prize. International Transactions in Operational Research, 8, 427-428.

Dutta, G., 2004. IFORS OR for Development Prize 2002. International Transactions in Operational Research, 11, 589-592.

Epstein, R., Henríquez, L., Catalán, J., Weintraub, G.Y., Martínez, C., Espejo, F., 2004. A combinatorial auction improves school meals in Chile: a case of OR in developing countries. International Transactions in Operational Research, 11, 593-612.

Ferrantino, M.J., Ferrier, G.D., 1995. The technical efficiency of vacuum-pan sugar industry of India: An application of a stochastic frontier production function using panel data. European Journal of Operational Research, 80**,** 639-653.

Ferrelli, R., Serrano, C.R., Balladelli, P.P., Cortinois, A., Quinteros, J., 1997. Strengthening local health care management in Bolivian districts through participatory Operational Research. International Journal of Health Planning and Management, 12, 29-50.

Fiedler, J.L., Day, L.M., 1997. A cost analysis of family planning in Bangladesh. International Journal of Health Planning and Management, 12, 251-277.

Flessa, S., 2003. Priorities and allocation of health care resources in developing countries: A case-study from the Mtwara region, Tanzania. European Journal of Operational Research, 150, 67-80.

Fontanella, G.C., Morabito, R., 2002. Analyzing the trade-off between investing in service channels and satisfying the targeted user service for Brazilian internet service providers. International Transactions in Operational Research, 9**,** 247-259.

Galvão, R.D., Espejo, L.G.A., Boffey, B., 2002. A hierarchical model for the location of perinatal facilities in the municipality of Rio de Janeiro. European Journal of Operational Research, 138**,** 495-517.

Gavrilescu, M., 2008. Biomass power for energy and sustainable development. Environmental Engineering and Management Journal, 7, 617-640.

Gielen, D.J., Yagita, H., 2002. The long-term impact of GHG reduction policies on global trade: A case study for the petrochemical industry. European Journal of Operational Research, 139**,** 665-681.

Goldie, S.J., Goldhaber-Fiebert, J.D., Garnett, G.P., 2006. Public health policy for cervical cancer prevention: The role of decision science, economic evaluation, and mathematical modeling. Vaccine, 24, 155-163.

Griffiths, J.D., 1995. Queueing at the Suez Canal. Journal of the Operational Research Society, 46**,** 1299-1309.

Groves, G., le Roux, J., van Vuuren, J.H., 2004. Network service scheduling and routing. International Transactions in Operational Research, 11, 613-643.

Günes, E.D., Yaman, H., 2009. Health network mergers and hospital re-planning. Journal of the Operational Research Society. In press: doi:10.1057/jors.2008.165.

Gutiérrez-Nieto, B., Serrano-Cinca, C., Mar Molinero, C., 2009. Social efficiency in microfinance institutions. European Journal of Operational Research, 60, 104-119.

Gupta O.K., OR Conventions in India: A Retrospection, In Raghuram, G. (ed), OR In India: A Retrospective,1992. Operational Research Society of India and Wiley Eastern Limited, New Delhi. pp. 20-26

Haouari, M., Azaiez, M.N., 2001. Optimal cropping patterns under water deficits. European Journal of Operational Research, 130**,** 133-146.

Harper, P.R., Shahani, A.K., 2003. A decision support system for the care of HIV and AIDS patients in India. European Journal of Operational Research, 147, 187-197.

Hodgson, M.J., Laporte, G., Semet, F., 1998. A covering tour model for planning mobile health care facilities in Suhum District, Ghana. Journal of Regional Science, 38, 621-638.

Hyden, G., 2007. Governance and poverty reduction in Africa. Proceedings of the National Academy of Sciences of the United States of America, 104, 16751-16756.

Iachan R. 2009. A Brazilian experience: 40 years using operations research at Petrobras International Transactions in Operational Research **16 (5): 585 – 593**

International Monetary Fund, 2009. Country Composition of WEO Groups. http://www.imf.org/external/pubs/ft/weo/2009/01/weodata/groups.htm#oem, viewed online 2 Sep 2009.

Jaiswal, N., K., (1992) Operational Research and ORSI Publications, , In Raghuram, G. (ed), OR In India: A Retrospective, 1992. Operational Research Society of India and Wiley Eastern Limited, New Delhi. pp. xiv

Jan, T.-S., Hsiao, C.-T., 2004. A four-role model of the automotive industry development in developing countries: a case in Taiwan. Journal of the Operational Research Society, 55**,** 1145-1155.

Kao, C., Wu, W.-Y., Hsieh, W.-J., Wang, T.-Y., Lin, C., Chen, L.-H., 2008. Measuring the national competitiveness of Southeast Asian countries. European Journal of Operational Research, 187**,** 613-628.

Kemball-Cook, D., Wright, D.J., 1981. The Search for Appropriate OR - A Review of Operational Research in developing countries. Journal of the Operational Research Society, 32, 1021-1037.

Kemp, B.J., Yousef, D.A., 1995. OR in practice: Results of a survey in the United Arab Emirates. European Journal of Operational Research, 80, 25-33.

Kingsbury, D., Remenyi, J., McKay J., Hunt J., (Eds.), 2004. Key Issues in Development. Palgrave, Basingstoke.

Korenromp E., Van Vliet C., Grosskurth H., Gavyole A., van der Ploeg C., Fransen L., Hayes R., Habbema J., 2000. Model-based evaluation of single-round mass treatment of sexually transmitted diseases for HIV control in a rural African population. AIDS, 14, 573-593.

Kumbaroglu, G.S., 1997. A model for long-term global air quality prediction and development of efficient control strategies in Turkey. European Journal of Operational Research, 102**,** 380-392.

Kunsch, P.L., Theys, M. 2007. The importance of systems thinking in ethical and sustainable decision-making. Central European Journal of Operations Research, 15, 253-269.

Lasdon, L.S., 1980. Operations Research in China. Interfaces, 10(1), 23-27.

Lasry A., Carter M.W., Zaric G.S., 2008. S4HARA: System for HIV/AIDS Resource Allocation. Cost-Effectiveness and Resource Allocation, 6, 7.

Lasry, A., Zaric, G.S., Carter, M.W., 2007. Multi-level resource allocation for HIV prevention: A model for developing countries. European Journal of Operational Research, 180, 786-799.

Laverack, G., Sakyi, B.E. 1997. Participatory learning materials for health promotion in Ghana - a case study. Health Promotion International, 12, 21-26.

Lewis, H., Rudolph, M., White, L., 2003. Rapid appraisal of the health promotion needs of the Hillbrow Community, South Africa. International Journal of Healthcare Technology and Management, 5**,** 20-33.

Li, H., Wang, S., Xu, L.D., 2000. Management science and Operations Research in China. European Journal of Operational Research, 124, 221-223.

Li, J.-Q., Borenstein, D., Mirchandani, P.B., 2008. Truck schedule recovery for solid waste collection in Porto Alegre, Brazil. International Transactions in Operational Research, 15**,** 565–582.

Lu, W.-M., Lo, S.-F., 2007a. A closer look at the economic-environmental disparities for regional development in China. European Journal of Operational Research, 183**,** 882-894.

Lu, W.-M., Lo, S.-F., 2007b. A benchmark-learning roadmap for regional sustainable development in China. Journal of the Operational Research Society, 58**,** 841-849.

Maturana, S., Contesse, L., 1998. A mixed integer programming model of the logistics of sulfuric acid in Chile. International Transactions in Operational Research, 5, 405-412.

McMichael, P., 2000. Development and Social Change: a Global Perspective. Pine Forge Press Thousand Oaks, California.

Melgarejo, L., de Figueiredo, J.N., Fries, C.E., 2009. A decision support methodology for increasing public investment efficiency in Brazilian agrarian reform. International Transactions in Operational Research, 16**,** 25-48.

Nagelkerke, N., Jha, P., de Vlas, S., Korenromp, E., Moses, S., Blanchard, J., Plummer, F., 2002. Modelling HIV/AIDS epidemics in Botswana and India: impact of interventions to prevent transmission. Bulletin of the World Health Organization, 80, 89-96.

Nederveen, P.J., 2001. Development Theory: Deconstructions/Reconstructions. Sage, London.

Ng, Y.C., Chang, M.K., 2003. Impact of computerization on firm performance: a case of Shanghai manufacturing enterprises. Journal of the Operational Research Society, 54**,** 1029-1037.

Pamuk, S., Köksalan, M., Güllü, R., 2004. Analysis and improvement of the product delivery system of a beer producer in Ankara. Journal of the Operational Research Society, 55**,** 1137-1144.

Papageorgiou, J.C., 1994. The role of the public sector in introducing operations research/ management science within developing countries. Public Administration and Development, 14: 293-312.

Peniwati, K., Brenner, W., 2008. Multi-decisions rating model: establishing rescue policies for regional drinking water companies (PDAMs) in Indonesia. European Journal of Operational Research, 186, 1127-1136.

Peters, E., de Matta, R., Boe, W., 2007. Short-term work scheduling with job assignment flexibility for a multi-fleet transport system. European Journal of Operational Research, 180, 82-98.

Petraš, J.C.E., 1997. Ranking the sites for low- and intermediate-level radioactive waste disposal facilities in Croatia. International Transactions in Operational Research, 4**,** 237-249.

Phahlamohlaka, J., Friend, J., 2004. Community planning for rural education in South Africa. European Journal of Operational Research, 152**,** 684-695.

Pizzolato, N.D., Barcelos, F.B., Lorena, L.A.N., 2004. School location methodology in urban areas of developing countries. International Transactions in Operational Research, 11**,** 667–681.

Pizzolato, N.D., Guerrero, S.G.V., 1999. Production management practice in a developing country: a case study. International Transactions in Operational Research, 6**,** 623-637.

Porter, J.D.H., Ogden J.A., 2002. Lessons in integration - Operations Research in an Indian leprosy NGO. Leprosy Review, 73, 147-159.

Raghuram, G. (ed), 1992. OR in India: A Retrospective.   Operational Research Society of India and Wiley Eastern Limited, New Delhi

Raghuram, G., 2004. Logistics of tractor distribution in an agriculture-driven economy: an Indian case study. International Transactions in Operational Research, 11**,** 701-714.

Rahman, S.-u., Smith, D.K., 2000. Use of location-allocation models in health service development planning in developing nations. European Journal of Operational Research, 123**,** 437-452.

Rand, G.K., Tsoukias, A., 2002. Developing OR in Africa: Initiatives of IFORS and EURO. Presentation at IFORS 2002, Edinburgh.

Rand, G.K., 2004. Developing Countries O.R. for Developing Countries: the role of IFORS. Direct Connection to Developing Countires, Vol 12 (2): 3-5

Rapley, J., 1996. Understanding Development: Theory and Practice in the Third World. Lynne Rienner Publishers, Boulder and London.

Rauner, M., Brailsford, S., Flessa, S., 2005. Use of discrete event simulation to evaluate strategies for the prevention of mother-to-child transmission of HIV in developing countries. Journal of the Operational Research Society, 56, 222-233.

Rosenhead, J., 1993. Enabling analysis - across the developmental divide. Systems Practice, 6, 117-138.

Rosenhead, J., Tripathy, A. (eds), 1996. Operational Research for Development. New Age International, India

Sagasti, F.R., 1974. Operations Research in the context of underdevelopment: some case studies from Peru. Operational Research Quarterly, 25, 219-230.

Saranga, H., 2007. Multiple objective data envelopment analysis as applied to the Indian Pharmaceutical Industry. Journal of the Operational Research Society, 58**,** 1480-1493.

Saranga, H., 2009. The Indian auto component industry – Estimation of operational efficiency and its determinants using DEA. European Journal of Operational Research, 196**,** 707-718.

Sathye, M., 2003. Efficiency of banks in a developing economy: The case of India. European Journal of Operational Research, 148**,** 662-671.

Schuurman, F. (ed), 1993. Beyond the Impasse: New Directions in Development Theory. Zed Books, London.

Schweigman, C., Bakker, E.J. and Snijders T. A. B 1990. Operations Research as a tool for analysis of food security problems. European Journal of Operational Research, 49, 211-221.

Sharma, U.G., 1996. Integrating HIV/ AIDS care in family welfare services: The PSS experience. Health for the Millions, 22(6): 14-17.

Singh, N., Shah, J., 2004. Managing tendupatta leaf logistics: an integrated approach. International Transactions in Operational Research, 11**,** 683-699.

Sircar, B.K., Deb, B.C. 1991. An operational study on implementation of oral rehydration therapy in a rural community of West Bengal, India. Indian Journal of Medical Research Section A-Infectious Diseases, 93, 297-302.

Smith, D.K., 2008. A bibliography of applications of Operational Research in West Africa. International Transactions in Operations Research, 15, 121-150.

Smith, H.K., Harper, P.R., Potts, C.N., Thyle, A., 2009. Planning sustainable community health schemes in rural areas of developing countries. European Journal of Operational Research, 193**,** 768-777.

Srivastatava, S.K., 2008. Network design for reverse logistics. Omega, 36**,** 535-548.

Stewart, T.J., 1995. OR practice in South Africa. European Journal of Operational Research, 87, 464-468.

Stiglitz, J., 2002. Globalization and its Discontents. Penguin, London.

Sudhir, V., Muraleedharan, V.R. 1996. Integrated solid waste management in urban India: A critical Operational Research framework. Socio-Economic Planning Sciences, 30, 163-181.

Thunhurst, C., 2007. Refocusing upstream: Operational Research for population health. Journal of the Operational Research Society, 58, 186-194.

Tiwari, P., 2004. A policy mechanism for housing construction activity to achieve social and environmental goals: a case for India. International Transactions in Operational Research, 11**,** 645-665.

Tomson, G., Paphassarang, C., Jonsson, K., Houamboun, K., Akkhavong, K., Wahlstrom, R., 2005. Decision makers and the usefulness of research evidence in policy implementation - a case study from Lao PDR. Social Science and Medicine, 61, 1291-1299.

Tripathy, A., 1993 Using OR/MS in Third World Countries: Some Cases from India. Paper presented at IFORS XIII, Lisbon 1993.

UNDP, 2005. Human Development Report, 2005. United Nations Development Programme, New York

van der Ploeg, C.P.B., Van Vliet, C., De Vlas, S.J., Ndinya-Achola, J.O., Fransen, L., Van Oortmarssen, G.J., Habbema, J.D.F., 1998. STDSIM: A microsimulation model for decision support in STD control. Interfaces 28 (3), 84-100.

van Vliet, C., Meester, E.L., Korenromp, E.L., Singer, B., Bakker, R., Habbema, J.D.F., 2001. Focusing strategies of condom use against HIV in different behavioural settings: an evaluation based on a simulation model. Bulletin of the World Health Organization, 79, 442-454.

van Vuuren, J.H., Gründlingh, W.R., 2001. An active decision support system for optimality in open air reservoir release strategies. International Transactions in Operational Research, 8**,** 439-464.

Vieira, I.T., Harper, P.R., Shahani, A.K., de Senna, V., 2003. Mother-to-child transmission of HIV: a simulation-based approach for the evaluation of intervention strategies. Journal of the Operational Research Society, 54, 713-722.

Walsham, G. 1978. Education in Operational Research for developing countries. Journal of the Operational Research Society, 29, 299-306.

White, L., 1994. Development options for a rural community in Belize - Alternative development and Operational Research. International Transactions in Operational Research, 1, 453-462.

White, L., Lee, G.J., 2009. Operational Research and sustainable development: tackling the social dimension. European Journal of Operational Research, 193, 683-692.

White, L., Taket, A., 1997. Beyond appraisal: Participatory Appraisal of Needs and Development of Action (PANDA), Omega, 25, 523-534.

Willis, K. , 2005. Theories and Practices of Development. Routledge, London.

Wilson, D., Halperin, D., 2008. Know your epidemic, know your response: a useful approach, if we get it right. Lancet, 372, 423-426.

Wolf, M., 2004. Why Globalization Works. Yale University Press, New Haven.

World Bank, 2009(a). Data and Statistics. http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20421402~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html. Accessed October 2009.

World Bank, 2009(a). Global Monitoring Report. http://web.worldbank.org. Accessed July 2009.

Yasenovskiy, V.S., Hodgson, M.J., 2007. Hierarchical location-allocation with spatial choice interaction modeling. Annals of the Association of American Geographers, 97**,** 496-511.

Yi, W., Őzdamer, L., 2007. A dynamic logistics coordination model for evacuation and support in disaster response activities. European Journal of Operational Research, 179, 1177-1193.

Yousef, D., A., 2009. Current status of operations research/management science education at the United Arab Emirates business schools. Education, Business and Society: Contemporary Middle Eastern Issues. Vol 2 (3): 191 - 202

Żak, J., 1999. The methodology of multiple-criteria decision making in the optimization of an urban transportation system: case study of Poznań City in Poland. International Transactions in Operational Research, 6, 571-590.

Zavadskas, E.K., 2008. History and evolving trends of construction colloquia on sustainability and Operational Research. Technological and Economic Development of Economy, 14, 578-592.

Zhang, X.-S., Cui, J.-C., 1999. A project evaluation system in the state economic information system of China: An operations research practice in public sectors. International Transactions in Operational Research, 6**,** 441-452.

Zheng, F., Xu, L.D., Tang, B., 2000. Forecasting regional income inequality in China. European Journal of Operational Research, 124**,** 243-254.

Zulu, I., Schuman, P. 2004. Priorities for antiretroviral therapy research in sub-Saharan Africa - a 2002 consensus conference in Zambia. JAIDS-Journal of Acquired Immune Deficiency Syndromes, 36, 831-834.

Table 1: IFORS members (√ indicates a developing country defines by the World Bank)

|  |  |
| --- | --- |
| Argentina √ | Italy |
| Australia | Japan |
| Austria | Korea |
| Bangladesh √ | Lithuania √ |
| Belarus √ | Malaysia √ |
| Belgium | Mexico √ |
| Brazil √ | Netherlands |
| Bulgaria | New Zealand |
| Canada | Norway |
| Chile √ | Philippines √ |
| China √ | Poland |
| Columbia √ | Portugal |
| Croatia √ | Serbia-Montenegra |
| Czech Republic | Singapore |
| Denmark | Slovinia |
| Finland | Slovakia |
| France | South Africa √ |
| Germany | Spain |
| Greece | Sweden |
| Hong Kong | Switzerland |
| Hungary √ | Tunisia √ |
| Iceland | Turkey √ |
| India √ | United Kingdom |
| Ireland | United States of America |
| Israel | Uruguay √ |

Table 2: Developed countries methodologies used in developing countires

|  |  |
| --- | --- |
| DEA | (Saranga, 2007; 2009; Sathye, 2003; Lu and Lo, 2007a, 2007b) |
| Systems Dynamics | (Chen and Jan, 2005; Jan and Hsiao, 2004) |
| Optimisation | (Doerner, 2007; De Angelis et al., 2007 Ahmed & Alkhamis, 2009) |
| Locational analysis | (Rahman & Smith, 2000; Galvão et al., 2002; Pizzolato et al., 2004; Yasenovskiy & Hodgson, 2007; Smith et al., 2009) |
| “Soft” OR methods | (Lewis et al., 2003; Phahlamohlaka & Friend, 2004) |

Table 3 : MDG and OR practice

|  |  |
| --- | --- |
| **Eradicate extreme poverty and hunger**, | (Bornstein and Rosenhead, 1990; Schweigman et al., 1990; Datta, 1993; Hyden, 2007) |
| **Achieve universal primary education** | (Durstine and Davis, 1969; Walsham, 1978; Laverack et al., 1997; Phahlamohlaka & Friend, 2004) |
| **Promote gender equality and empower women** | (Bertrand, 1991; Datta, 1993; Sharma, 1996; Fiedler and Day, 1997; Smith et al., 2009) |
| **Reduce child mortality**, | (Adetoro et al., 1991; Sircar et al., 1991) |
| **Improve maternal health,** | (Adetoro et al. 1991; Berg, 1995; Fiedler and Day, 1997) |
| **Combat HIV/AIDS, malaria, and other diseases** | (Sharma, 1996; Porter et al., 2002; Harper and Shahani, 2003; Zulu et al., 2004; Abayomi et al., 2006; Barr, 2007; Lasry et al., 2007) |
| **Ensure environmental sustainability** | (Papageorgiou, 1994; Sudhir et al., 1996; Daniel et al., 1997; Kunsch et al., 2007; Gavrilescu, 2008; Zavadskas, 2008; White and Lee, 2009) |
| **Develop a global partnership for development** | (Porter et al., 2002) |

1. The World Bank has adopted the GNI as a replacement for the Gross Domestic Product in line with the 1993 System of National Accounts (SNA). GNI takes into account all production in the domestic economy (i.e., GDP) plus the net flows of factor income (such as rents, profits, and labour income) from abroad. [↑](#footnote-ref-1)