Health Technology Management in Less-Developed Countries: An Untold Success Story

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INTRODUCTION

In 1982, Project HOPE convened an international conference at its Millwood, Virginia campus to discuss the transfer of appropriate healthcare technology to developing countries, with representatives of several countries, medical equipment manufacturers, and international agencies, as well as experts from academia and non-government organizations (NGOs)[2].

The conference was organized in response to growing concerns over many failed technology transfer projects in the previous two decades, resulting in a large amount of inoperable sophisticated equipment and unmet healthcare needs in spite of significant financial investment. Soon after the deliberations began, it became clear that the main cause of these failures was not inappropriateness of technology transferred—i.e., a mismatch between the needs of the population and the capability of the technologies—but a combination of inadequate acquisition planning and lack of maintenance support (Russell, 1982). The conclusions of the 1982 conference was echoed and reinforced in subsequent meetings and reports coordinated by international organizations (WHO, 1987; WHO, 1990; PAHO, 1993a) and NGOs (Halwachs GTZ, 1989; Temple-Bird GTZ, 1991; Judd & Issakov GAME 2008).

Actually, several years prior to the Millwood conference, the Pan American Health Organization (PAHO), had recognized the dire condition of healthcare equipment in its member countries and obtained funding to invest in health technology management (HTM) centers in some countries (e.g., Jamaica and Venezuela) and started technical cooperation programs in several others (e.g., Argentina, Brazil, Colombia, Costa Rica, Cuba, Ecuador, Mexico and Peru). While initially successful, their equipment services were limited to the capital cities and only a fraction of the trainees were retained by the Ministries of Health (MOHs). These initiatives were unable to self-sustain and eventually succumbed to the economic crisis of 1980s (PAHO, 1985; PAHO, 1989; PAHO, 1991, PAHO, 1995; PAHO, 2011).

In 1988, WHO organized a virtual international roundtable with input from experts around the world and published the discussion in World Health Forum (Bloom, 1989). The roundtable not only confirmed the two challenges identified earlier - acquisition planning and maintenance, but also pointed out fundamental underlying issues. First and foremost is the fact that unlike drugs and vaccines, medical equipment requires continual outlay of funds, on order of 6-15% of original acquisition price, for the life of equipment, often up to 10-20 years after acquisition[3]. Thus, it is

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[2] See a list of abbreviations used in Table 1.

useless for NGOs and financing organizations to provide equipment donations or investment loans if the recipient countries cannot pay for recurrent expenses, even if adequate planning and maintenance are available. Another serious deficiency is the lack of a framework for proper HTM in most developing countries. Without a framework defined and supported by policies, procedures, defined responsibilities, and earmarked resources for HTM, it is difficult to perform technology planning in harmony with the country's health policies and priorities, ensure appropriate human and material resources necessary to operate the equipment, and maintain it in safe and operational conditions.

Another important landmark is a study commissioned by the World Bank in 1998 on the appropriateness, effectiveness, fairness, and efficiency of the medical equipment loans it made to developing countries totaling about US$10 billion for a decade ending in 1997. This study (World Bank, 1998) concluded while the appropriateness of the technology acquired by developing countries was occasionally an issue, significant improvements were desired in the areas of need analyses, adoption of international standards, user training, after-sales support (for supplies, maintenance, software updates, and service), and cost of ownership considerations. Without these improvements, the study concluded, many of the loans will not achieve their goals and the World Bank could stand to be accused of lack of transparency, poor financial stewardship, and contributing to poor health conditions in developing countries.

Using the recommendations collected from the meetings, reports, and discussions, several global initiatives were launched.

- WHO, PAHO, and ORBIS International organized a series of Advanced HTM Workshops (typically 1-week seminars) beginning in 1991 with the support of the American College of Clinical Engineering (ACCE) to raise awareness and provide management methodologies to public and private health leaders and managers in developing countries (Hernandez A, 2002).
- Simultaneously, PAHO fostered several HTM initiatives with multilateral partners focused on Central American countries (PAHO, 1993b).
- The World Bank Institute (WBI) created in 1997 a health technology module in its Flagship program focused on providing basic HTM concepts to planning and finance authorities of countries that were seeking loans from the Bank (WBI, 2011).
- A global HTM listserv Infratech was created by WHO-PAHO-ACCE in 1999 (Gentles et al 2011).
- WHO with its partners developed equipment donation guidelines (WHO, 2000 & updated 2010).
- The World Bank and WHO also organized a high-level forum in Washington in 2003 to review and identify strategies and policies to improve the planning, acquisition, operation and disposal of medical technology in client countries, with contributions from international development agencies, NGOs, and the private sector (Wang, 2003b).
- In 2007, the World Health Assembly issued a resolution directing WHO's Director-General to create a number of initiatives to improve HTM in developing countries (WHO, 2007) in 2010.
    - Baseline Country Survey on Medical Devices (WHO, 2010a)
    - First Global Forum on Medical Devices September in Bangkok, Thailand (WHO 2010b).

In spite of these and other initiatives, some key leaders in international organizations and NGOs, including some mentioned above, have openly expressed skepticism about the merit of such investments, citing the large amount of equipment that still remains idle in developing countries, wasting precious, limited resources and not providing vital services or impacting the health outcomes. A few had even argued that the current status of HTM in each country is simply a reflection of that

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[3] Actually, a more rigorous analysis of the total cost of ownership (TCO) of shows that most medical equipment is costlier to operate and maintain over its life cycle than its initial investment, often by a factor of 4-5 times. This is analogous to an iceberg that has only about 20% of its mass visible about the water line (David & Judd, 1993; Wang, 2003b).

country's overall economic and societal development, so it is useless to try to promote HTM or improve healthcare if the country and its people are not ready for it. An even more radical view is that all development aid programs are inherently bad and only perpetuate dependency (Moyo, 2009). Fortunately, such "political-realist" arguments have been refuted by scientific, randomized evaluations conducted by development economists who proved that, while throwing money at problems is often not the best solution, certain free services and small incentives can produce outcomes that far exceed normal expectations (MIT Poverty Action Lab, 2010).

To gain better insight into factual gains achieved in the last three decades, as well as the reasons for the lack of progress in some cases, an informal, international survey was conducted in 2010 by the authors. This article provides a summary of the survey results, with a critical analysis of the essential elements for success and an in-depth discussion of the root causes of the challenges detected and the potential solutions.

CONCEPTUAL FRAMEWORK

As HTM evolved through somewhat different paths in each country, it is helpful to lay a conceptual framework that covers HTM's main components, its relationship with other areas of health system, and its primary stakeholders who have their own interests and perspectives. *Figure 1* provides a succinct visual summary of the HTM framework (Wang, 2003a). Although technology includes drugs, biologics, devices, procedures, and organizational and managerial systems (OTA, 1980), the emphasis of this article is on equipment due to the challenges and unique requirements mentioned above. From *Figure 1*, it is clear that the international conferences and discussions conducted in the last three decades were focused on the core elements of HTM and, thus, it is not surprising that most of the initiatives—and successes—have been in capacity strengthening, e.g., training of managerial and technical staff. In the meanwhile, the stakeholders and their powerful and continual influence on HT and its management have seldom been addressed properly. As discussed later, many of the remaining obstacles to lasting solutions are caused by factors that are outside of the HTM block within this figure.

METHODS

In parallel to the WHO Baseline Country Survey (WHO, 2010a), the authors invited key HTM leaders in developing countries to submit detailed accounts of HTM progress in their countries. Since a formal, broad, and comprehensive geographical survey was already being conducted by WHO, the emphasis was on the accomplishments, challenges encountered, and insights into potential root causes.

Responses were received from 40 countries on 5 continents. In addition, information was gathered through presentations and posters presented at the 20-Year Review of Advanced HTM Seminars held in March 2010 in Atlanta, Georgia and the WHO First Global Medical Device Forum held in Bangkok (WHO, 2010b, Cordero 2010), as well as email exchanges and verbal communication received from various country leaders. *Figure 2* provides a visual summary of the countries providing information.

RESULTS (OR ACHIEVEMENTS)

The information obtained from the informal survey responses received and other communication was synthesized to provide a concise summary by country and continent, and is presented in alphabetical order. This section is focused on achievements made by individual countries and continents, while the challenges are analyzed later in the **Discussion** section. This separation is helpful because the achievements were often unique to each country, while the challenges seem to be universally shared by all developing countries. Individual country results are shown in *Tables 2-5* by Region.

Africa

With the exception of the Republic of South Africa (RSA), African countries have been dependent on donations of devices and supplies for several decades. While this dependency persists, many African

countries have made significant progress in HTM in the past 20-30 years (see *Table 2*). Most HTM initiatives started with external investments and assistance but signs of self-sustaining efforts are clearly visible. For example, HT policy has been established in Ethiopia (Mulegeta, 2010), Ghana (Zienaa, 2010), RSA (Quville, 2001), and Uganda (Wanda, 2010); a regional perspective on HT policy is also noted (Issakov 2011). HTM training programs exist in at least eight countries, with graduate-level programs in RSA (Kalaf, 2010 and Poluta, 2011); associations of CE professionals have been created in at least five countries; and wider access to Internet and cellular telephones has facilitated ongoing sharing and exchange of technical information and expertise, resulting in more timely medical equipment support solutions.

Asia

Wealthier Asian countries (e.g., Korea, Singapore, and Taiwan) have deployed CE professionals in their hospitals for more than two decades, even though there is still strong dependence on OEM service contracts for complex equipment. Less wealthy countries (i.e., Myanmar, Nepal, Philippines, Vietnam, etc.) are catching up rapidly, sometimes with international assistance. (The Peoples Republic of) China is the country that showed the most impressive growth. In less than 15 years, the number of CE professionals has grown from a few dozens to over 100,000. Its CE professional association has organized 11 consecutive annual national events attended by greater than 1,000 persons through 2010 (Zhou, 2010). India is not as evolved but gaining momentum rapidly, with two international workshops attended by more than 200 persons conducted in the last two years (Khambete, 2011). Malaysia is the first country in the region that decided to outsource the CE services of all its public hospitals to a small number of private companies independent of OEMs (Hamid, 2010). See *Table 3*.

Latin America and The Caribbean (LA&C)

Undoubtedly, LA&C as a whole have provided the most impressive growth of HTM of all continents. While the merit goes to individual countries, PAHO deserves special recognition for its strong support for over 30 years. In spite of failures in initial programs, PAHO leaders persisted in encouraging and supporting initiatives that have borne fruit. Key aspects in development have been active participation of academic centers in organizing BME/CE programs and the creation of national and university-based HT centers. Although almost all countries made impressive progress (Dyro, 2004), Brazil leads not only in size but also high quality of its programs, i.e., officially a WHO collaborating center (two other centers exist in Colombia and Mexico). Brazil also has a large CE association with several hundred members and more than 10 annual conferences (Garcia, 2010; Calil, 2010). Mexico deserves special credit for its high-level and robust HT center with significant influence on HTP and decisions through MOH (Velazquez, CENETEC, 2008). Peru has also developed a university-based HTM center (Vilcahuaman & Rivas CENGETS, 2010). Once known for its best-structured national program, Cuba is not as effective now but still has the largest group of trained HT professionals in the hemisphere. See *Table 4*.

Southern & Eastern Europe, Middle East & Central Asia

This group has had a very uneven distribution of progress in HTM, probably due to vastly diverse cultural and economic environments. Wealthy Middle Eastern countries have good HTM programs at hospital level but generally weak programs at national level, with some exceptions. In spite of limited resources, Jordan managed to create one of the best national programs with strong high-level political support, earning the status of a WHO collaborating center (Mobarek & Dalo, 2010). Eastern European countries are starting to make significant progress, limited by local economical and political realities, i.e., Georgia and Albania (Jaliashvilli, 2010; Picari, 2010). Spain has substantially grown its CE professional contingent through a combination of national regulations and strong local support in the hospitals. However, the most spectacular case belongs to Italy, where a modest, university-based CE program became a multi-million Euros private company with hundreds of workshops in 12 European countries in about 15 years (Bravar, 2010). See *Table 5*.

DISCUSSION (OR CHALLENGES)

Collective Challenges

From the summary above, it is evident that significant progress has been made in the last three decades in most less-developed countries, even though the speed and maturity of their HTM programs vary widely. Notwithstanding the numerous inherent differences among countries and cultures, some of the challenges identified by the HTM professionals are shared universally, even in developed countries (Derrico et al., 2010). All countries continue to struggle with the following challenges:

1) Lack of competent staff. This is not limited to the insufficient number of engineers and technicians who understand the technology and can maintain the equipment, but skill sets are needed for interpreting HTA and multi-year life cycle HTM, i.e., participating with clinicians in technology planning and acquisition, managing sophisticated technology distributed over wide areas, and maintaining delicate relationships with clinicians, manufacturers, and administrators. It also has been difficult to retain the small amount of trained staff in low-paying government positions.

2) Limited access to technical documentation and spare parts. Even when competent maintenance staff is available, it is impossible for them to support the technology if they do not have access to documentation (including manuals and software) and parts. Although some manufacturers are willing to provide these items, local distributors are often unwilling to share them in order to retain the profitable after-sales support services. The lack of open-market competition, long delays and cumbersome processes in importation, and manufacturers' reluctance to alienate their distributors make this challenge difficult to overcome.

3) Poor planning and lack of commitment. Few less-developed country officials have learned how to use HTA in their health equipment and facility planning. Often, equipment is purchased solely based on physician requests, without careful consideration for its need, safety, efficacy, and support costs. As mentioned above, unlike drugs, vaccines, and implants, devices requires utilities, consumables, and maintenance to keep them usable. The high recurring costs mean long-term political and financial commitment is needed. Typically, politicians are eager to be inaugurate health facilities but loath to spend money on operating those facilities for the long term.

4) Irrational technology incorporation processes. As health services in most developing countries are managed by government or non-profit organizations, they are subject to public regulations on procurement. These regulations are often inappropriate for investments that have recurring costs much higher than the initial purchase price[4], because most bidding rules require the decision-makers to award the bid to the vendor with the lowest price, regardless of higher eventual total cost of ownership (TCO). Furthermore, as a significant portion of the investment funds are provided by international agencies as loans or donations, the recipient country are forced to open the bidding process to vendors who may never have sold anything into that country and, thus, often do not have the necessary infrastructure to support the equipment afterwards.

Essential Elements for Success

According to the survey responses, many creative solutions for the challenges described above have been found by developing countries. For example, academic institutions in Latin America have created many two-year university and post-graduate HTM programs to produce competent professionals for their countries (WHO, 1990). Many of the leaders of these programs were trained in the seminars sponsored and coordinated by PAHO and WHO mentioned above. Even though many of

[4] See footnote #3.

the trained public employees quickly migrated to the private sector, these programs have been able to supply replacements continually, thus avoiding significant gaps. Some countries, i.e., Brazil (Wang, 1990) and Jordan (Mobarek et al., 2005), realized that they needed to stop the brain drain by adopting some unorthodox approaches such as a career ladder for HTM professionals within the government and the creation of a separate joint venture.

The battle for documentation and replacement parts continues to be difficult but some innovative approaches have been reported. One is to seek help from industrialized countries where there are numerous organizations specialized in offering training and alternate-source parts at much more competitive prices. The ever increasing reach of the Internet and email have also helped HTM professionals in remote areas to access colleagues in more advanced regions who are very willing to help troubleshoot problems and suggest solutions. Some manufacturers have also posted their service manuals online, allowing the HTM professionals to bypass local distributors.

To improve equipment procurement, many have started adopting TCO as the primary bid evaluation criteria instead of the purchase price. Furthermore, more stringent and neutral technical specifications have helped to make the procurement process more transparent and hold the vendors responsible for after-sales support. Several countries have shared those specifications among themselves to reduce the need to "reinvent the wheel" (Wang, Coe & Chi, 1992).

All the early solutions above share some common essential elements that are worth to be studied and emulated by those who are still struggling with the similar challenges. These elements are listed below in decreasing order of importance:

a) A leader who has the vision, determination, and courage to challenge and change status quo.

b) Strong political support from high-level decision-makers who are equally committed to improve health services while risking his or her own prestige and political future.

c) Regional and international assistance in the form of guidance, training, information exchange, encouragement, and mentoring.

d) Enlightened vendors who understand and appreciate the fact that HTM will be eventually beneficial not only to the health sector but also to them in the long run.

Root Causes of Challenges

Reports received from developing countries suggest that in spite of the successes achieved and the creative solutions developed, there are many remaining obstacles or even relapses. Closer examination of these obstacles suggests that they are actually the root causes of the HTM problems in all countries, even in some developed ones. If the root causes listed below are not addressed, it is not possible to achieve sustained successes.

1) Lack of training, experience, awareness, and influence with decision-makers regarding HTM. Traditional curricula for health professionals and administrators seldom cover health infrastructure, especially the fundamental difference of equipment from drugs, vaccines, and other nondurable products. This deficiency accounts for most of poor planning practices and lack of commitment to operational funding, as well as interruptions and even destruction of successful HTM programs during political transitions. Similar lack of understanding also exists—albeit at much lower level—in many international agencies and NGOs. The consequences are easily detected in failed international medical equipment financing projects and donations of used equipment.

2) Equipment is often considered a status symbol instead of a service production tool. Rather than purchasing items that would adequately meet the needs of patients, many doctors insist on

acquiring equipment that fascinates them, regardless of price, performance, and, often, real efficacy and safety. These same doctors would never acquire the same sophisticated, maintenance-intensive equipment for their own clinics or hospitals, but would not hesitate to waste public resources on "the latest and greatest" as marketed by the producers.

3) Greed and short-sightedness of manufacturers and distributors. This is evident in the aggressive marketing of excessively sophisticated equipment to hospitals and countries that do not have the technical and financial resources necessary to operate, maintain, and update it and, often, even genuine need. This is probably the most significant cause of the "white elephants" found in developing countries.

4) Selfishness of some "aid," "cooperation," and "donation" programs that are actually sales-promoting schemes or publicity stunts. Many industrialized countries offer grants, and attractive loans that require the recipient countries to buy products manufactured in those countries with little or no regards to need, operational capacity, and ability to support the technology later. Many donation programs are nothing but gimmicks to transfer trash from developed countries to less-fortunate ones, while gathering publicity and sympathy for fund raising. These programs have also contributed abundantly to the "white elephant" population growth.

5) Lack of vision and courage among HTM professionals. In spite of the achievements described above in many countries, HTM professional in some countries are still unwilling to lead their colleagues to solve their own problems with their own resources and creativity. They keep citing the challenges described above as the reasons for their lack of success and blame others for not helping them to overcome those challenges.

Can HTM succeed?

Some skeptics have been questioning the promotion of HTM, claiming that there is no evidence that HTM has improved health outcomes to people, especially in less-developed countries. These HTM critics have argued that if drugs and vaccines can go through clinical trials to prove benefits in terms of lives saved, number of years of life extended, or quality-adjusted life year (QALY), then HTM should be subject to the same rigorous scientific tests before wide adoption. This extremely narrow view of HTM is very unfortunately because while HTM itself is a type of health technology (OTA, 1980), it is very difficult, if not impossible, to link HTM directly to health outcomes and measure its impact. This is because HTM is nothing but a tool that needs competent users and appropriate environment for it to be able to produce the desirable outcomes. By itself, it does not cure patients or prolong life.

An analogy with air transportation may help clarify this point. Health systems are service organizations like commercial airlines; the former treat patients while the latter transport passengers. Health systems use medical equipment while airlines use aircraft (and other equipment). Probably no one would argue good management and maintenance of aircrafts are important to ensure safe arrival of the passengers, as well as the reputation and financial viability of an airline; however, no one can say that aircraft management and maintenance alone guarantee safe flights and profitable airlines.

Likewise, good HTM is essential for patient care and safety, as well as patient satisfaction, even though it is not possible to measure directly the impact of HTM on clinical outcomes. Just like no one would willing to stop managing and maintaining aircraft to prove its importance, it would be immoral to prove the need and benefit of HTM by stop providing it for some time until disastrous consequences occur. It would be equivalent to denying drugs to patients after the initial results of a clinical trial have produced conclusive proof that the drug is effective. The progresses reported above prove that HTM must have been valuable for the health systems that have invested in it in the last 30 years; otherwise, those systems would have dismantled the HTM infrastructure and dispersed the people they hired and

trained. Furthermore, in all countries where private—and sometimes for-profit—health services coexist with public services, the former have typically invested more in HTM than the latter, including raiding trained talents aggressively from the latter.

Critics may also argue that HTM cannot be imposed from outside or even be sustained by short-term political decrees unless the country has reached adequate economical growth. However, examples from Brazil, China, Jordan, and Uganda show that they were able to promote HTM well before improvements in their national economy, relying mostly on political will and a critical mass of CE leaders. Granted, severe economical downturns can destroy good HTM initiatives, witness what happened in Cuba. On the other hand, it is unquestionable that HTM depends on social, economical, and political maturity for it to flourish and sustain.

Finally, it should be emphasized that HTM promotion is fundamentally different from donations and financial aid. While the latter are akin to "giving fish to hungry people," the former is analogous to "teach people how to fish." As President Obama declared (Obama, 2010),

> "The purpose of development … is creating the conditions where assistance is no longer needed."

HTM promotion by international agencies and NGOs aims at strengthening sustainable improvement of health services to millions of people in less fortunate countries.

CONCLUSIONS

The collective experience accumulated in less-developed countries in the last three decades provide convincing evidence that proper HTM is not only possible but already well established in many of those countries. However, it is too early to declare victory because many of them are still struggling with HTM challenges.

An important side effect of established HTM: Increasingly, developing countries that successfully create a HTM platform provide their leaders with the capability to "leap-frog" other countries' experiences and provide timely solutions to pressing healthcare needs. Three notable examples are HTM leaders helping Venezuela implement a public health EMR in one year (Silva & Lara-Estrella, 2010), Cameroon attracting investors in IT and telecommunications to rapidly enhance their healthcare system (Kwankam & Ningo, 2010), and the HTM Center in Mexico facilitating cabinet-level decision-making regarding HTA and clinical practice guidelines (Velazquez, 2008 & Gonzalez, 2010).

It is especially critical that international agencies and NGOs stop questioning the validity of promoting HTM. Such vacillations could unsettle the confidence of political leaders and, thus, affect their commitment to HTM in their respective countries. Actually, the root-cause analysis above shows that it is essential for international organizations to avoid focusing solely on capacity strengthening but invest equally in enhancing awareness at the highest levels. Donors, bilateral aid agencies, and international financing organizations need to change their approach from providing only investment resources to helping the recipient countries to assume gradually more responsibilities for the recurring costs, thus reducing the population of "white elephants."

Manufacturers and distributors need to take a wiser and long-term view of their international market, so their reputation will not be tarnished and become undesirable when those countries gain better economic conditions. At the same time, less-developed countries need to assume more responsibility for their own fate and actions. As mentioned above, many of the root causes can only be resolved by their own leaders abandoning their comfortable status quo and addressing the challenges directly. When the stakeholders shown on *Figure 1* can align their goals and respect each other's interests, it is possible—as demonstrated by the reported successes—to advance HTM to the same level that it already enjoys in industrialized nations.

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ILLUSTRATIONS

Table 1 – List of acronyms and abbreviations used in this article.	
ABBREVIATION	**FULL NAME**
ACCE	American College of Clinical Engineering
BME	Biomedical Engineering
CE	Clinical Engineering or Clinical Engineers
CM	Corrective Maintenance (or repairs)
EMR	Electronic Medical Record
GHTF	Global Harmonization Task Force
HT	Health Technology
HTA	Health Technology Assessment
HTM	Health Technology Management
HTR	Health Technology Regulation
IT	Information Technology
MOH	Ministry of Health
NGO	Non-Government Organization
OEM	Original Equipment Manufacturer
PAHO	Pan American Health Organization
QALY	Quality-adjusted life year
SM	Scheduled Maintenance (also known as Preventive Maintenance – PM)
TCO	Total cost of ownership
WBI	World Bank Institute
WHO	World Health Organization

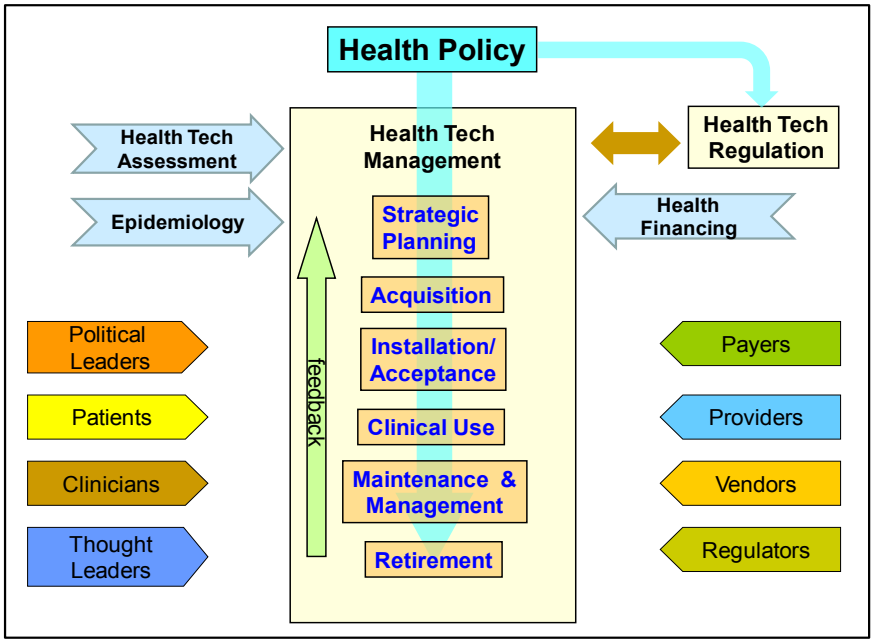

Figure 1 – A graphical representation of the main elements of HTM and how it relates to other areas of health system. Being a capital investment, equipment needs to be managed from its incorporation (strategic planning, acquisition, and installation and/or acceptance) until retirement, always guided by the country's or system's health policy. During its useful life, proper maintenance and management are essential to ensure safe, efficient, and cost-effective patient care. Often neglected, feedback provided by users and maintainers are essential to improve continually HTM within the country or system, avoiding mistakes made previously. HTM is intimately related to but distinct from technology regulation, as the later is focused on safety and efficacy, with little concern on costs and management challenges. Health technology assessment (HTA), epidemiology, health financing, and medical sciences provide the foundation for successful incorporation planning and subsequent use. The stakeholders offer perspectives based on their vantage points, as well as defend their own interests, thus affecting HTM in various manners throughout the equipment's lifecycle.

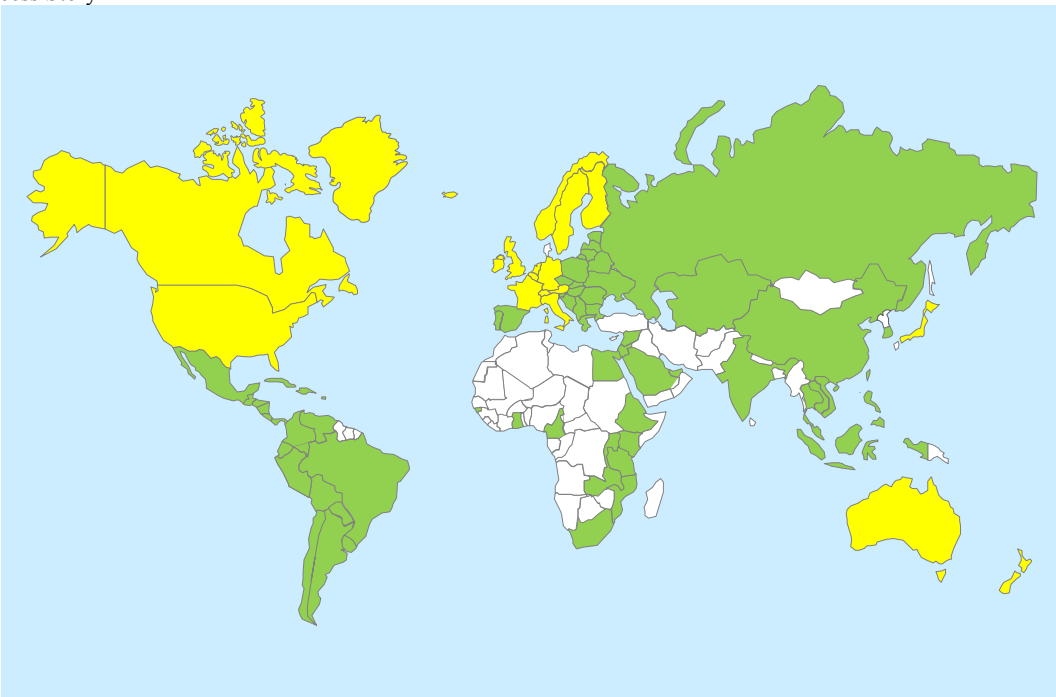

Figure 2 – A visual representation of the countries from which information was received on progress in health technology management (HTM) in the last three decades (countries colored in green). Countries that had established HTM programs before 1980 and were not included in the survey are shown in yellow. Countries shown in white are those for which no information was obtained on their HTM progress.

Table 2 – Examples of Major Accomplishments in **Africa**

COUNTRY	MAJOR ACCOMPLISHMENTS	REFERENCES
Cameroon	• HTP drafted and validated waiting to be implemented • HTM unit created in health districts and staff trained	• Kwankam, 2009, 2011 • Ngaleu-Toko, 2010
Ethiopia	• HTP developed with assistance from NGOs • Training programs with >100 trained professionals • National CE professional society since early 2000's	• Barragan, WHO 2009b • Mulegeta, 2010 • Hailemariam, 2010
The Gambia	• Model service/training organization established with UK assistance • Supporting other West African countries through service and training	• Nyassi & Mullaly, 2010
Ghana	• HTP, including donations, established by MOH • National CE professional society being created	• Zienaa & Adjabu, 2010 • Teninty & Malkin 2009
Kenya	• >350 MOH staff trained with external assistance since 1980's • 6 regional MOH service centers; 3-Year HTM training programs	• Owino & Anyango, WHO 2009b
Malawi	• HTM training started in 2006 with external assistance • MOH has trained technical staff performing equipment SM & CM	• Muigai, 2010
Namibia	• 1 national and 4 regional HTM service centers • No hospital based CEs and technicians or HTM training centers	• Nghipandulwa, 2009b and 2010
Senegal	• Had GTZ HTM training program; created National MOH HTM center • Created HTP in the 1990s; sustainability has been an issue	• Mbaye, 2010 • WHO, 2001
Republic of South Africa (RSA)	• CE programs in key hospitals and national CE society since 1970's • National HTP established 1990s; iHTP developed for MOH late 1990s • High-level HTM training programs in universities	• Kalaf, 2010; Quvile 2001 • Heimann , 2001 • Poluta, 2011
Tanzania	• HTM training provided at national and provincial levels • Equipment service training provided by NGOs and OEMs • National CE professional society created recently	• Mkwizu & Masanja, 2010 • Wear, 2009
Uganda	• HTP created in 2009 for all levels of care • HTM training program established in a university • National CE professional society well established	• Wanda, 2010

Table 3 – Examples of Major Accomplishments in **Asia**

COUNTRY	MAJOR ACCOMPLISHMENTS	REFERENCES
Peoples Republic of China (and Hong Kong)	• >1000 CE professionals practicing in public, private, military hosp. • The Chinese CE society has organized 11 national conferences • HT regulatory agency established and participating in GHTF • High-level HTM training programs established in universities	• Zhou, 2010 • Derrico et al., 2010
India	• High-level HTM programs in private hospitals and public hospitals • University and graduate-level programs being started • Two international workshops conducted	• Srinivasan & Poornachandran, 2010 • Khambete, 2011
Korea	• Nationally HTM closely linked with HTA efforts • Most hospitals have their own HTM teams	• Kim, 2009, 2011
Laos	• HTP begun by MOH in 2001, assisted by Luxembourg and JICA	• Insal, 2010
Malaysia	• HTM in all public hospitals have been outsourced to 5 companies • BME/CE graduates are in high demand	• Hamid, 2010
Myanmar	• A high-quality HTM program was created at the Department of Medical Research and is serving as a model for MOH and hospitals	• Gyi, 2010
Nepal	• Developed HTM policy 2004; have ongoing HTM project with GTZ • 2-year HTM training course established	• Porter & Schmitt, 2010
Philippines	• Training programs established with external assistance • Technical colleges in process of establishing degree programs	• Peralta, 2011
Singapore	• Solid HTM programs in almost all hospitals	• Koh, 2011
Taiwan	• Most hospitals have their own CE teams supporting the equipment • OEM contracts for complex equipment being gradually reduced	• Liu & Tu, 2011
Vietnam	• HTM gaining attention of MOH officials • The MOH central training program is being revitalized	• Pham, 2008

Table 4 – Examples of Major Accomplishments in **Latin America and the Caribbean (LA&C)**

COUNTRY	MAJOR ACCOMPLISHMENTS	REFERENCES
Argentina	• Solid CE programs in leading hospitals • Several university-level CE program in place, one of which is >10 yrs.	• Giles & Primic, 2010
Brazil	• > 5,000 CE professionals growing steadily since 1980's seek licensure; CE listserv for >8 years; CE association national meetings >10 years • HTR agency also controls hospital maintenance • Strong academic programs on BME & CE.	• Garcia, 2010 • Calil, 2010 • Painter, 2009
Colombia (COL)	• Numerous professionals trained by the National Hospital Fund before it was discontinued in 1991after 20 year of operations • Solid CE programs in leading hospitals; HTM training programs provided by universities and COL Association of Clinics and Hospitals	• Villamil & Molina, 2010 • Clark, 2010
Chile	• MOH centralized procurement encouraging better HTM at its hospitals • Solid CE programs in leading hospitals, particularly military ones • Training programs provided by two universities	• Diaz, 2010; • Acevedo, 2010
Costa Rica	• Strong HTM in Social Security hospitals • MOH trained equipment users and maintenance staff >15 years • Training programs provided by one university	• Murillo & Ingeana, 2010
Cuba	• Had >1,000 staff HTM unit in MOH earlier; large training programs with numerous HTM professionals working in Cuba and elsewhere	• Llanusa & Denis 2011
Dominica	• Implementing MOH equipment procurement policy • Implementing equipment management software	• Williams, 2010
Dominican Republic	• HTM training programs being offered by one university • MOH developing HTP; CE programs in some key public/private hosp.	• Hernandez D, 2010
Ecuador	• HTM policy established by MOH in 1982 • Isolated solid CE programs in leading public and private hospitals	• Yapur, 2007
El Salvador	• HTM established in some hospitals; training programs at university • MOH has started to license HTM staff	• Escobar, 2008 • Juarez, 2010
Jamaica	• MOH developing HTP policies • Anchored international HTM workshops for Caribbean region	• Richards, 2010; Batts, 2003; Boyd, 2003

Mexico	• MOH HT center created in 2004 for cabinet-level decision makers • >500 CE professionals participate in the national association • Solid CE programs in leading hospitals	• Gonzalez, 2010 • Velazquez, 2008
Nicaragua	• MOH effort re HTM training • Working with WHO and Luxembourg) to strengthen CE/HTM	• Lacayo. 2008
Panama	• Solid CE programs in leading hospitals in the MOH & Social Security • HTM training programs being offered by a university	• Guerra & Soriano, 2011
Paraguay	• Training programs at college and technical school levels created • MOH has started to license HTM staff	• Galvan, 2010
Peru	• A university-based HTM program was created with the support and recognition of MOH; the program assisted by on-line HTM training • Solid CE programs in leading hospitals	• Vilcahuaman & Rivas, 2010 • Clark, 2010
Puerto Rico	• Has advanced HTM programs as in the USA	• Misla, 2011
Uruguay	• Solid CE programs in leading hospitals • MOH supporting HTM Programs	• Ambrosi, 2011
Venezuela	• A Vice Ministry of Health Resources was created within MOH to manage facilities, drugs, medical devices, and HTM • Training programs at universities for MOH and Social Services staff	• Lara-Estrella & Silva, 2010

Table 5 – Examples Major Accomplishments in **Southern & Eastern Europe, Middle East & Central Asia**

COUNTRY	MAJOR ACCOMPLISHMENTS	REFERENCES
Albania	• HTP established and being implemented by HT unit within MOH • Training of graduate engineers accomplished with external assistance • CE units being created in regional hospitals	• Picari. 2010
Georgia	• Medical Device unit created within MOH • HTM training organized with assistance of WHO	• Jaliashvilli, 2010
Egypt	• Solid CE programs in a few leading hospitals	• Abdel-Moneim, 2011
Italy	• A university-based program evolved into the largest, independent service company serving over12 European countries • Training programs, including graduate ones, at several universities	• Bravar, 2010
Jordan	• MOH established a separate entity (Directorate) with a non-profit organization to provide national HTM services • Directorate nominated to become a WHO Collaborating Center • Training is provided by the Directorate, universities, and OEMs (as part of equipment purchase contracts)	• Mobarek et al., 2005 • Mobarek et al, 2010
Kosovo	• National CE group in MOH developed by ACCE & International Aid • Ongoing assistance by WHO and NGOs	• Boshnjaku , Ramiqi, Hashani, 2010 • Teninty & Malkin 2009
Kyrgyzstan	• National Maintenance Center created by MOH with special funding • Developed national equipment database & standards for primary care • Utilized EHTP 2001-2004 (now iHTP, integrated Health Technology Package) to link MOH HTM and health resource planning processes	• Agibetov, 2010 • Heimann, 2001 • Judd, 2009
Kingdom of Saudi Arabia	• Solid CE programs in many hospitals, some of which are outsourced • CE professional association created	• Madani, 2011
Lebanon	• Solid CE programs in a few leading hospitals • HTM training programs offered by universities	• Tabshouri, 2010
Spain	• Strong CE association has sponsored 9 national conference till 2010 and a vibrant Internet listserv • HTM professionals regulated by MOH • Solid CE programs in most hospitals	• Bravar, 2010