

Research Article

A Framework and Case Example for Evaluating Cost-Effectiveness of Information Services Across Technologies

Faheem Hussain

faheem.hussain@auw.edu.bd
Asian University for Women
Chittagong, Bangladesh
Mobile: +88 01711614724
Web site: <http://www.asian-university.org/>

Rahul Tongia*

(On leave from Carnegie Mellon University)
tongia@cstep.in
Center for Study of Science, Technology, and Policy (CSTEP)
Raja Ramanna Complex
Raj Bhavan Circle, High Grounds
Bengaluru, 560 092
India
+91-80-4249-0000

Abstract

This paper introduces a framework to examine the relative effectiveness and cost-effectiveness of different information and communications technologies to deliver a range of social services, using a case example of rural Bangladesh. It focuses particularly on major sectors such as agriculture, education, disaster response and healthcare. An expert elicitation (using both local and international experts) on ICT effectiveness by service domains shows localization as the key determining factor for any technological intervention. Community-based radio broadcasting (CR) appears as the dominant option among the considered ICTs. Human intervention has been found to be crucial in both low (20%) and medium-high (60%) literacy populations. Our study also shows public funded terrestrial TV is more effective and has higher acceptability in providing information over privately owned satellite/cable TV channels. Literacy doesn't seem to significantly affect the relative effectiveness of information centers with Internet connection over print and TV-based options. In addition, an extensive techno-economic model for the various ICTs and stochastic evaluation of potential penetrations of the ICTs (reach) has also found CR to be the most cost-effective option. We conclude with a proposed set of policy and operating recommendations to enable effective technology-based information services for rural Bangladeshi development.

1. Introduction

Ensuring the availability of community-level information services is an important priority for the general population in developing regions. With the proliferation of information and communication technology (ICT) options for communication and broadcasting, the numerous positive impacts that community-based information services can contribute become more evident (Rajora, 2002). Community-based information services usually go beyond the traditional "one size fits all" information access model used by the incumbent regulators and policy makers, focusing primarily on the customized needs of the target communities (National Telecentre Database, 2009). Of course, not all ICTs are equivalent. Different technological solutions may better meet the needs of different service sectors. For example, an option that works well for agriculture-

**Managing Editor's note: This paper was selected by the Guest Editors based upon their review of ICTD2009 contributions and the ICTD peer reviews. The paper was then sent out for additional blind peer reviews. Dr. Tongia recused himself from editorial duties throughout this process.*

related information services may not be effective for disaster response, which requires greater timeliness and penetration. Yet comparatively little is known about the relative effectiveness of different technologies for different purposes. This paper therefore looks into the relative effectiveness and costs of different technologies to deliver different socioeconomic services, first through a general framework and then through specific application of that framework in rural Bangladesh, focusing on major development sectors such as agriculture, education, disaster response, health care, etc.

The primary objective of this study is to develop a framework that can help inform choices by policy makers, practitioners, development agencies, and the like, while also promoting better understanding of the applied efficiencies and relevance of different technologies in delivering information about socioeconomic development. We recognize this cannot be perfect or universal, especially given our subjective measure of effectiveness, and the wide variance in local conditions. Formal (pre/post)-type analyses for effectiveness across ICTs are rarely available, given that most studies consider only one technology at a time for effectiveness analysis. Given exactly such difficulties in comparing technologies, we believe expert elicitation with normalization is a useful starting point for such an analysis. This study does not claim to be definitive, but provides a foundation for further investigation, combined with economic analysis tools that can be useful for per-technology analysis.

This analysis has several components. First, expert opinions on ICT effectiveness by service domain (health, education, etc.) for various ICTs (TV, radio, print, telecenters, etc.) came from international and local (Bangladeshi) experts in communications and development. Opinions were gathered via expert elicitation surveys, taking care to manage anchoring and other biases (detailed subsequently). The elicitations were for low literacy (20%) and medium-high literacy (60%) populations. Second, we created a techno-economic model for each of the respective ICTs. Finally, we made estimates of potential penetrations of the ICTs (reach) to estimate the cost-effectiveness per user of the technologies for the particular service domain.

The focus here is largely on the delivery of socioeconomic services (supply side). Analysis of more political issues such as citizens' rights to information,

citizen participation in governance, etc., is beyond the scope of this paper.

2. International Experience and Literature on Community-Based Information Services

Over the last few decades, amid the disparity in access to information between the global North and South, the concept of alternative or community-based media has emerged. The New World Information and Communication Order, proposed by UNESCO in the late 1970s and early 1980s (MacBride, 1980), had the goal of beginning to balance this information divide (Rodriguez, 2001). Studies have shown that, with the introduction of new technologies, valuable information needed by any community becomes more accessible and affordable (Opubar, 1999). But at the policy and practice level, the question arises of which of the many new technology options to choose.

A significant amount of research has been done to assess the effectiveness of different technological interventions in various information service domains, e.g., education, disaster response, agriculture, etc. In the many cases evaluated, experts have found radio-aided services to be effective for different education or training purposes (Dock & Helwig, 1999; Holmes, Karmacharya, & Mayo, 1993; Pringle & David, 2003). The effectiveness and importance of visual broadcasting media has been supported in other studies (Bates, 1995; Hulsman, 2000).

While choosing an appropriate technology to enhance educational delivery or other socioeconomic services, issues such as access, cost, maintenance, interactivity, user-friendliness, availability, and speed should be considered (Bates, 1995). According to UNESCO, users and experts also focus on the specific abilities of the considered technologies in terms of delivering appropriate messages in a given domain. And technological efficiencies can vary in terms of outreach capability, flexibility, interactivity, etc. (Tobing, 2002). There are, thus, a variety of factors that need to be taken into account in judging relative effectiveness.

Taking the first, accessibility has tended to favor more traditional ICTs. As discussed below, these have had far greater penetration and accessibility rates than newer digital technologies. More recently, though, the importance of computer-aided,

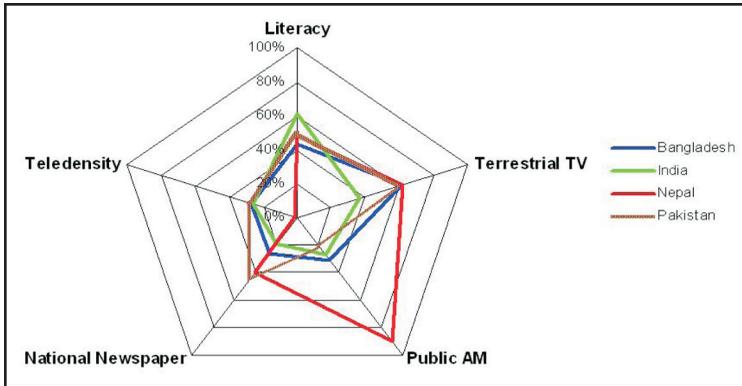


Figure 1. Relative accessibility of literacy and different communication media in South Asian countries (2004–2008).

Data Source: CIA—The World Factbook for India, Bangladesh, Nepal, and Pakistan (2010).

Internet-based, and wireless technologies has been emphasized (Iannella & Henricksen, 2007). In some ways, these ICT options often show superior performance in comparison with the alternatives, and lessons are starting to be learned. For example, with telecenters,¹ the lesson is the value of local content and the importance of affordability in ensuring effective and sustainable services (Kumar & Best, 2008; Proenza, 2001). Factors such as high cost, lack of training, lack of motivation, maintenance issues, and limited infrastructure often hinder the highest level of efficiency attainable by these relatively new technological interventions (Austin & Husted, 1998; Carnoy, 2004).

Finally, we are also seeing the emergence of ICT combinations. For example, the value of community radio (CR)² has been seen in a number of countries. Now CR is being used in combination with other technologies, such as telecenters, to help deliver web-based or email-derived information to listeners, and mobile phones to help audience members contribute to radio programs (Hussain & Tongia, 2007).

A. ICT Accessibility

As noted above, a key issue in evaluating ICT effectiveness is accessibility. Put bluntly, whatever its potential, an ICT is of limited value in delivering community information services if it is not accessi-

ble. As a background to our study, then, we reviewed accessibility rates, using South Asia generally and Bangladesh specifically as exemplars. From Figure 1, it can be seen that “traditional” ICTs are more dominant than telecommunications-based ICTs (though, see below, that picture is changing). We are also reminded that literacy is a second and important factor that will affect the utility of different information technologies.

Turning to the specifics of Bangladesh, there is tremendous potential for a variety of types of ICT-based information access points (Hussain, 2008a). However, that potential is limited by various issues. The national literacy rate is only 43.1% (CIA Factbook Bangladesh, 2010), and only around half of those classified as literate can properly read and write (Bangladesh Enterprise Institute, 2006). As a result of this, but also cost and coverage issues, a national media survey found that 28.5% of the total Bangladeshi population is in the “information dark” (Bangladesh Enterprise Institute, 2006), meaning they have never listened to a radio program, watched a TV program, read a newspaper, or had any similar means of getting valuable and current information needed for their livelihood and well-being. This situation is even worse in rural areas (35.9% of rural people had no access to any information service), where most of the people live.

Traditional media do, of course, reach significant numbers (see Table 1) but these are declining. For example, because of the absence of localized programming and participation, the only public radio broadcaster, Bangladesh Betar, has been losing its listener base rapidly (39% in 1998, 37% in 2000, 34% in 2002, and 23% in 2004) (Bangladesh Enterprise Institute, 2006). Only very recently has the Government of Bangladesh opened up the airwaves (on an experimental basis) for community-based low-power FM radio broadcasting.

1. Telecenters are shared premises where the public can access ICTs (Proenza, 2001).

2. Community radio is a subset of radio broadcasting, which is an inexpensive and popular medium for disseminating content (information, news, entertainment) that specifically focuses on the active participation of its listeners and tries to ensure access to information by all.

Table 1. Access status of different ICTs in Bangladesh.

Technology/Information Service Option	Penetration/Access (% Population)
Radio	30.4%
Terrestrial TV	61%
Satellite TV	12.4%
Newspaper	26%
Telecenters	1,061 (total number, nationwide)

Source: National Telecentre Database, 2009.

By contrast, the penetration level of cellular phones and Internet users is increasing. By early 2010, the teledensity of the country was 36%, with 54.1 million cellular phone and 1.7 million landline subscribers (BTRC, 2010). The Bangladesh Telecenter Network (BTN) has also undertaken initiatives to create 40,000 telecenters nationwide by 2011 (National Telecentre Database, 2009).

B. Significance of this Research

While much of the research described has focused (at least qualitatively) on the effectiveness and impacts of various technologies in multiple information service domains, there is a need for studies that examine the comparative effectiveness of a wide range of appropriate technologies across a set of information services in specific socioeconomic settings. The difficulties in conceptualizing the relative effectiveness of multiple types of interventions, taking into account a large set of application domains and the many factors described above, is clearly daunting. The objective of the present study is to develop a robust comparative cost-effectiveness analysis framework, which will enable concerned stakeholders (i.e., policymakers, practitioners, international and local development agencies, etc.) to have a better understanding of the applied efficiencies and relevance of different technologies in multiple information service domains. While the specific focus of the application is Bangladesh, this framework is general and can be used as a guideline in other developing regions with similar needs and aspirations.

3. Research Method

The principal research question we address is: What are the most effective technological interventions for providing community information services, using rural Bangladesh as a case example?

This required two selections to be made: The set of information services to be covered, and the set of technologies to be investigated. While recognizing the information services are interrelated and have some overlap in terms of target population, socio-economic objectives, and modes of communication, we selected seven based on population needs and assessed importance to the South Asian region within which Bangladesh sits (ADB, 2007):

- Agriculture: General extension service (especially educational and technical information)
- Agriculture: Market information
- Education (especially lifelong/adult)
- Disaster Response (especially related to flooding, drought, and cyclone/tsunami)
- Health Care: AIDS and STD (awareness and prevention)
- Health Care: Family planning (awareness)
- Financial Services (personal and community)

The second selection was of the technologies to be covered. These were selected on the basis of their availability (guided partly by the ICT accessibility data given above), their development potential (Hussain, 2008a), and evidence of actual benefits delivered. (Cellular phone-based options were not considered individually, but the impact and effectiveness of cell phones have been partially accounted for in the hybrid solutions of Information Centers as well as in person-to-person approaches.) In addition to the face-to-face (F-to-F) option, technological interventions selected for the survey were (in alphabetical order):

- Community radio (low-power FM)
- Development FM radio
- Local newspaper

- National newspaper
- Printed brochure
- Public AM radio
- Rural information center (RIC-1) equipped with computers, Internet connectivity, and one or more of the following: scanners, printers, digital cameras, cellular phones
- RIC-2 equipped similarly as RIC-1, but without any Web-based facilities
- Satellite radio
- Satellite/cable TV
- Terrestrial TV (privately operated for profit)
- Terrestrial TV (government operated)

A. Expert Elicitation

Given the paucity of cross-ICT comparative measures of effectiveness, let alone ones that measure effectiveness across different development domains, a quantitative, subjective expert elicitation was chosen as a means of capturing the effectiveness of the ICTs per-development domain. We chose a set of experts to gauge effectiveness because the dominant literature on effectiveness was usually on a per-technology basis, and also typically per development domain, e.g., studies on use of radio for education. Even cross-ICT comparisons for education (or any other domain) are limited, let alone comparisons across multiple development domains. If one attempted to measure absolute effectiveness as found in scattered studies, normalizing across the domains appeared nigh-on impossible, in part because of the variance in experience with and expenditures on different domains. Of course, our chosen methodology has a number of limitations, including the fact that experts' views will be subjective; not to mention it is unlikely they will have equal experience or expertise across the ICTs or the development domains. However, given the combined knowledge that was brought to bear, we believe that these views represent a reasonable proxy for actual (cost-)effectiveness.

To quantify the relative effectiveness of various technologies for delivering a variety of socioeconomic information services, we administered a survey to a group of international (American, Australian, Fijian, Guatemalan, Indonesian, Nepali, and Sri Lankan) and local (Bangladeshi) experts. These groups have had many years of experience in

the field of communication and development (specifically they were selected as well-known practitioners/researchers/evaluators in the telecommunications industry, community broadcasting, rural education, telecenters movement, etc.). In seeking their judgments, we explicitly asked the experts to ignore differences in cost. At the start, 20 international and 30 local experts were solicited to take part in this study. Ultimately, eight international and 14 local experts provided detailed responses. Even though traditional community broadcasting does not exist in Bangladesh, all the local experts of this study have decades-long experience in community-based media activism and exposure to the community media services in neighboring countries.

In this study, we defined "information" to be most useful—as shown in the literature—when it is delivered in the language of the community, addresses topics of interest and concern to the community, and is framed in a way that is clear and understandable to members of that community. We defined "community" as a group of a few hundred to several thousand people who live within a few tens of kilometers of each other in a developing country and share the same language and culture.

Experts were asked to assess the relative effectiveness of different ICTs for different types of information services in two types of communities: Ones with relatively high (60% or higher) and low levels (20% or lower) of adult literacy. We defined adult literacy to mean a recipient's ability to read at an intermediate level in his or her primary language. For each application, we asked the experts to first identify the communication option that they believed would be the most effective for a community with relatively high adult literacy and assign it a score of 100. They were then asked to assign a number to each of the other technology options to indicate how relatively less effective they believed that technology option would be for the specific information service identified. We also received qualitative information from the experts.

Although we did not adopt an iterative, Delphi-type approach, it nonetheless took roughly six months of correspondence using regular mail, Internet, and phone conversations to produce an effectiveness dataset from our experts on five continents. We then built a cost model for calculating costs and penetration information (using field-based South Asian datasets) through techno-economic

analysis per ICT. This portion extends the type of techno-economic analysis found in Hussain and Tongia (2007) to other ICTs, capturing issues such as capital costs, operating costs, lifespan, etc. (see also Hussain, 2008b). Finally, all the analyzed and calculated data were combined in a common platform to compare the relative effectiveness of the considered technologies in the various socioeconomic service sectors of this analysis. While the model we introduce for comparative cost-effectiveness analysis is a generic one, in this article, the data analysis and subsequent findings were based on South Asian (predominantly Bangladeshi) datasets. One additional (assumption-driven) set of calculations was the penetration any given technology would realize (expanded on later). Finally, as most of the experts were not so familiar with three of the technologies, development FM, satellite radio, and private terrestrial TV were omitted from further analysis.

B. Cost and Other Estimations

Our objective in estimating the costs of various delivery technologies is to provide descriptions or mechanisms by which to deliver services and estimate their costs in a way that would allow comparisons. In general, “cost per person per year” is estimated for each option, where “cost” is the monetary amount spent by the provider to deliver the information in a real-world setting and “person” is the generic term that covers target listener, viewer, reader, user, etc. (as appropriate for any particular technology/medium) within the community. Naturally, this assumes equivalence among all the persons. We recognize the potential for ambiguity with “person” instead of “listener” as a limitation—it is a model or analysis choice whether to use listener or simply a person who is a potential listener, i.e. (for the case of a radio), owns a radio and lives in an area with radio coverage. We chose the latter in the analysis, in part because there is limited data on actual listener profiles, let alone for specific development content.

For community-based information services, while calculating cost-per-person-year, both operational and amortized capital expenditure are considered. For the services with national coverage, we calculate a generalized cost-per-person-year (delivery and content development cost) that caters to numerous communities and issues. We assumed a base two-, five- and 10-year life cycle for the audio/video pro-

gram, RIC equipment, and CR station equipment, respectively, and used 7.5% as the interest rate for annualized capital expenditures (sensitivity analysis also considered 11% and 15%, but we used 7.5% as a baseline, a common rate for development/nonprofit projects in South Asia). This matches the stochastic cost modeling of CR management in Hussain and Tongia (2007). We also take into account stations’ or other facilities’ monthly operational expenditure, which may include staff salaries, utility bills, and space rental.

The variable literacy (20% vs. 60%) affected the analysis in two ways. First, the penetration would vary based on the specific technology. We also modified the multiplier slightly with literacy to capture (at a crude level) the link between literacy and economics (affordability), which affects the penetration of a technology. Stated another way, higher-literacy users were likely to be richer, which is more of an issue for some technologies than others. Lacking specific data on this, we made simplified assumptions mostly differentiating by technology. Figure 2 shows the likely achievable penetration in Bangladesh by the considered technologies. Bangladesh does not yet have CR broadcasting, so we used data from Nepal and India as a base, and set CR penetration at 68%.

For the technologies with a national presence (i.e., national newspaper, public AM, terrestrial TV, and satellite TV), we considered the literacy rates as the proxy of other major factors while determining probable access rates within any community. We assumed that higher literacy will result in higher access to certain technologies, but the rate may not be linear. In order to realistically calculate the penetration of these technologies in the high-literacy and low-literacy areas, we used the ratio of 60% and 20% respectively, compared to the national literacy rate (43.1%) (*CIA Factbook Bangladesh*, 2010), multiplied by the corresponding technology’s potential national penetration number and a technology-specific multiplier. The values of all the multipliers considered were estimated based on the respective technology’s dependence on literacy for mass proliferation. For example, to estimate the penetration of a national newspaper in a community with 20% or lower literacy, we multiply the national newspaper readership number (26%) by the literacy ratio (20%:43.1%) and a multiplier. As the dissemination of newspapers is directly related to the literacy of a

target community, we estimate the baseline value of this technology's multiplier to be 1. Given the wide uncertainty in parameters (i.e., cost, penetration), we have used Analytica® parametric and stochastic modeling software to estimate a distribution in the total yearly cost for each media outlet.

The Appendix gives more details on the cost calculations for the various technologies; full details on assumptions of capital and operating expenditures per technology are available from the authors. Given the wide variance in numbers per technology, it is beyond the scope of this paper to display these in a succinct manner. Below are a few of the key issues for the calculations, either per technology, or generalized. These go together to build Table 2, which shows the estimated cost calculations and penetration levels for all the considered information delivery methods.

Face-to-face (not discussed before, as this is not an ICT-based solution per se) assumed a provider was locally available and accessible (used the local language), and may be a salaried specialist. We assumed the cost for the face-to-face specialist was identical across all domains, except health care. Health care was assumed to be a one-on-one service, while things such as agricultural extension could be undertaken in groups.

We also needed to calculate population penetration rate: the likely percentage of the population reached by a particular technology. For CR, as noted above, we used Nepali or Indian data for penetration estimates because this technology is not yet

operational in Bangladesh, and derived the following equation:

$$\left(\frac{\text{Total Yearly Cost}}{\text{Number of Listeners}} \right) \times \left(\frac{\text{Societal Program}}{\text{Total Broadcast Time}} \right) \times \left(\frac{\text{Selected Service}}{\text{Total No. of Services}} \right)$$

or, $\left(\frac{\text{Total Yearly Cost}}{\text{Number of Listeners}} \right) \times \left(\frac{2}{3} \right) \times \left(\frac{1}{7} \right)$

Analogous calculations were done for the other technologies. One decision point was how much of a shared medium was used for development, e.g., TV. The Appendix spells out more of these factors and the numbers used. The penetration for face-to-face is shown as a hypothetical 100%, not because we expect 100% of the population is covered but because the costing model is modular, i.e., 100% of a small population is covered by a given face-to-face expert. If national 100% penetration is desired, the costs are assumed to scale relatively linearly, so for the cost comparison, we have chosen 100%. If the practical penetration is lower, this raises the costs accordingly, which are already the highest per "user" or beneficiary (Figures 5–6).

4. Comparative Effectiveness Analysis

Before we present the results of the expert elicitation, Table 3 shows a cross-technology comparison for three effectiveness characteristics—directionality, cognitive level, and access type—that are also important (and developed on the basis of field data and research findings [Bates, 1995; Hussain, 2008b]).

For the relative effectiveness data, both international and local (Bangladeshi) experts' opinions were initially considered. All the experts showed greater confidence in face-to-face intervention than in most of the technologies in almost all the application domains. Looking specifically at the ICTs then, according to both of the expert groups, CR turns out to be the most effective technology in both high-

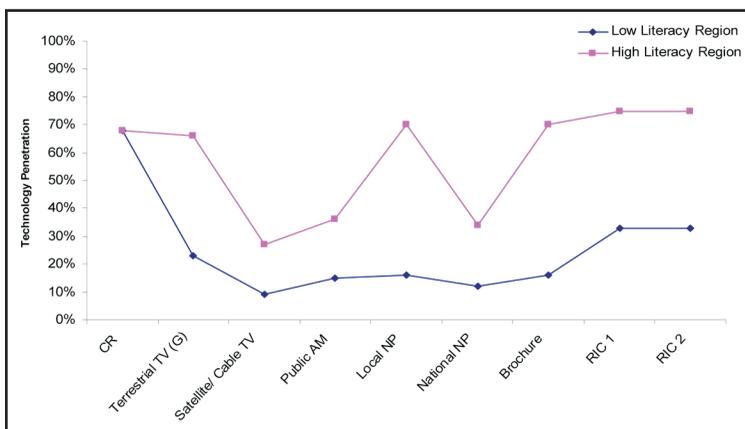


Figure 2. Cross-technology comparison of likely achievable penetration in Bangladesh.

EVALUATING COST-EFFECTIVENESS OF INFORMATION SERVICES ACROSS TECHNOLOGIES

Table 2. Calculated cost estimations.*

Delivery Option	Information Service Sector	Cost-Per-Person-Year (US cents)*		Population Penetration Level*	
		≤20% Literacy	≥60% Literacy	≤20% Literacy	≥60% Literacy
CR	<i>For any of the considered service sectors</i>	1.1	1.1	68%	
Public AM		0.25	0.1	14%	36%
Terrestrial TV		0.45	0.15	23%	67%
Satellite TV		0.8	0.3	9%	26%
National Newspaper		0.4	0.14	12%	34%
Local Newspaper		35	8	16%	70%
RIC-1		86	38	33%	75%
RIC-2		17	23	33%	75%
Printed Brochure	<i>Agriculture: General Extension</i>	35	23	16%	70%
	<i>Agriculture: Market Information</i>	55	43		
	<i>Education</i>	36	24		
	<i>Disaster Response</i>	35	23		
	<i>Health Care: AIDS and STD</i>				
	<i>Health Care: Family Planning</i>				
	<i>Financial Services</i>				
Face-to Face	<i>Agriculture: General Extension</i>	159		Ideally, 100% of the target population can be covered by face-to-face from an availability perspective; usage and uptake may be lower. From a "supply" perspective, we take a parametric range (high to low) to do the cost estimates. ³	
	<i>Agriculture: Market Information</i>	159			
	<i>Education</i>	167			
	<i>Disaster Response</i>	99			
	<i>Health Care: AIDS and STD</i>	245			
	<i>Health Care: Family Planning</i>	245			
	<i>Financial Services</i>	163			

*We varied the parameters (for both cost and penetration data) as part of sensitivity analysis, but the results were qualitatively the same, e.g., changing the cost of a radio tower by 30% would not change the cost-effectiveness calculation by nearly as much given the variety of other input parameters, including other capital costs, operating costs, etc. Even when penetration was varied, the general findings remained robust.

literacy and low-literacy scenarios (Figures 3 and 4)⁴ (although there was much less familiarity with CR, and thus higher variation, in the responses of the Bangladeshi experts). This is not surprising: From the data given above, CR has been found to be a highly

accessible technology that enables two-way, participation-based communication in a single or shared environment.

As with CR, the international experts considered public AM to be an effective medium. The ordinal

3. This challenge is similar to radio or other media, where signal availability is necessarily only one measure, actual listening time being a separate and lower measure.

4. These figures consider average effectiveness values of different technologies across all service domains in both high-

Table 3. Cross-technology comparison for multiple effectiveness characteristics.

Technology Intervention	Directionality	Cognitive Level	Access Type
CR	Two-way,* Participatory	Low	Single / Shared
Public AM	One-way	Low	Single / Shared
Terrestrial TV	One-way	Low	Single / Shared
Satellite TV	One-way	Low	Single / Shared
National Newspaper	One-way	High	Mostly individual
Local Newspaper	One-way	High	Mostly individual
Printed Brochure	One-way	High	Mostly individual
RIC-1	Two-way	Medium**	Shared
RIC-2	Two-way	Medium**	Shared

*Through the participation of the local community via alternative (though sometimes asynchronous) media, such as word-of-mouth and cell phones.

**With the help of intermediaries (information intermediaries).

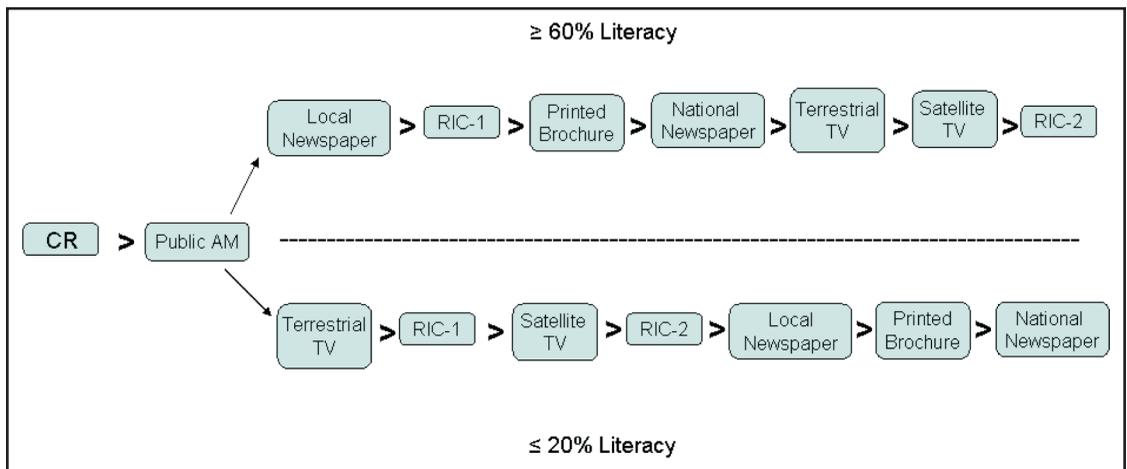


Figure 3. Effectiveness ranking of different technologies (according to international experts).

effectiveness rankings of technological interventions diverge after this point. Localized print-based options (local newspaper and printed brochure) show clear dominance over the visual broadcasting options (terrestrial TV, satellite TV) in a higher literacy area. On the other hand, as expected, visual media are considered more effective than print media in communities with lower literacy. In both

cases, the Rural Information Center with Internet connection (RIC-1) has been ranked in the middle and demonstrated statistically insignificant differences in its usefulness as a community intervention with respect to other technologies, a promising aspect for a relatively new information service option.⁵

The Bangladeshi experts' perception about the

literacy and low-literacy regions. Individually, the experts have shown higher variance in effectiveness estimations (details in Section V).

5. Paired T-tests were performed on the effectiveness scores of international experts in high (between local newspaper and RIC-1) and low (between terrestrial TV and RIC-1) literacy, regions. Both times, the difference was statistically small (with t-stat of 0.1068 and p-value of 0.459 in 60% literacy, and t-stat of 3.277 and p-value of 0.0084 in 20% literacy) between the experts' perception about relative effectiveness. T-tests with a small number of experts (both international and local) have limited value; we report the p-values despite not being significant only to indicate some comparative figures.

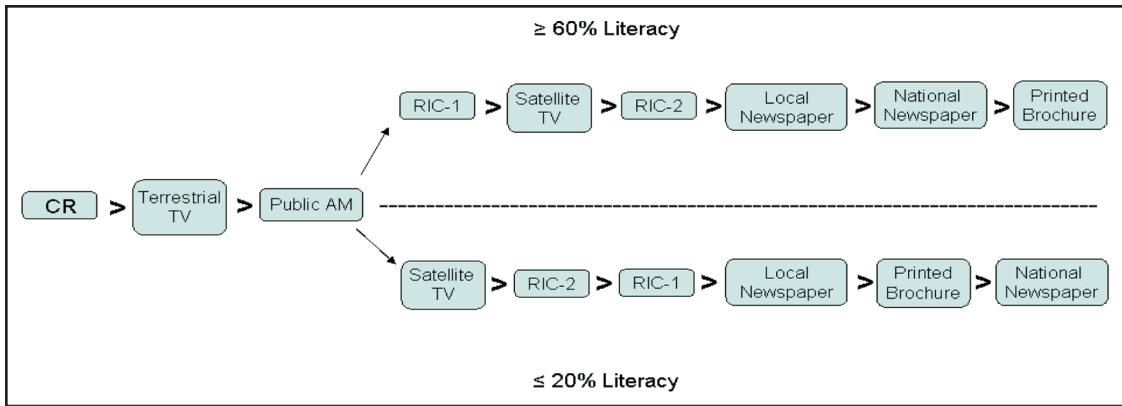


Figure 4. Effectiveness ranking of different technologies (according to local experts).

relative effectiveness of some of the technological options is significantly different from those of the international experts, which was something we wanted to investigate. This becomes important when we consider other technologies and other regions in a generalized model, where there may be technologies not locally present, thus requiring reliance on global experiences with appropriate modifications. CR remains the top choice, but in a higher-literacy area the difference in effectiveness between terrestrial TV and CR was less pronounced but still measurable.⁶ Unlike the views of international experts,⁷ local experts rank terrestrial TV and public AM broadcasting high in both types of literacy regions. Print-based options generally were considered highly ineffective, a contrast with the international findings. According to the local experts, RIC-2 (the information center without Internet facility) is more effective than RIC-1 in low literacy regions,⁸ significantly dissimilar from the views of the international set of experts.⁹

5. Service Sector-Specific Preliminary Observations

For the in-depth analysis of the relative effectiveness data (both technology and information service

domain), we focused on the international experts' judgment, which captures the technology for development experiences in multiple developing regions. The primary reason for this decision is the Bangladeshi experts' absence of substantial field experience with the effectiveness of a number of technology options (i.e., CR, RIC-1, RIC-2, public AM, local newspaper, etc.) due to regulatory obstacles (CR); poor program management (public AM); high Internet costs, lack of human resources, and poor funding (RIC); and the absence of press freedom and effective representation of local issues (local newspaper). The Bangladeshi sample also has much greater variance than the international sample, especially for technologies not yet in use in Bangladesh (Rahman, 2008).

For each information service domain, we created a graphical representation of comparative cost-effectiveness data. Space constraints mean not all of these can be shown, but Figures 5 and 6 show examples, drawn from a sample application domain (agriculture: general extension). In these figures, the Y and X axes represent the effectiveness scores and plausibly achievable technology penetration, respectively. The spread of effectiveness scores given by individual experts for various delivery systems (from

6. A paired T-test between the effectiveness scores of terrestrial TV and CR by the local experts found the difference statistically significant for both low and higher literacy (with t-stat of 4.44 and p-value of 0.002 in a 60% literacy area, and for the 20% literacy case t-stat was 10.14 and the p-value 2.7×10^{-05}).

7. Two-sample T-tests were performed between the effectiveness scores of the two groups of experts in high- and low-literacy region. Both times, we found a statistically significant difference (with t-stat of -10.04 and p-value of 7.6×10^{-07} in 60% literacy, and t-stat of -12.54 and p-value of 9.6×10^{-08} in 20% literacy) between the experts' opinions.

8. With a t-stat of -22.7 and p-value= $2.39E-07$ in a paired T-test.

9. With t-stat of -8.36 and p-value= $-7.92E05$ in a two-sample T-test.

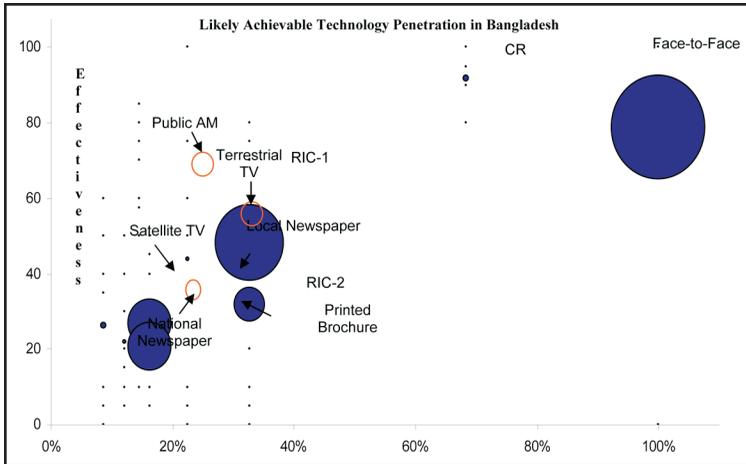


Figure 5. Cross-technology comparison for providing agriculture-based (general extension) information service in a high literacy ($\leq 60\%$) area (international experts).

Note: CR is the most cost-effective technology-based option here, with tradeoffs of penetration, cost, and effectiveness between the next choices of face-to-face, rural Information Center with Internet connection, and local print media.

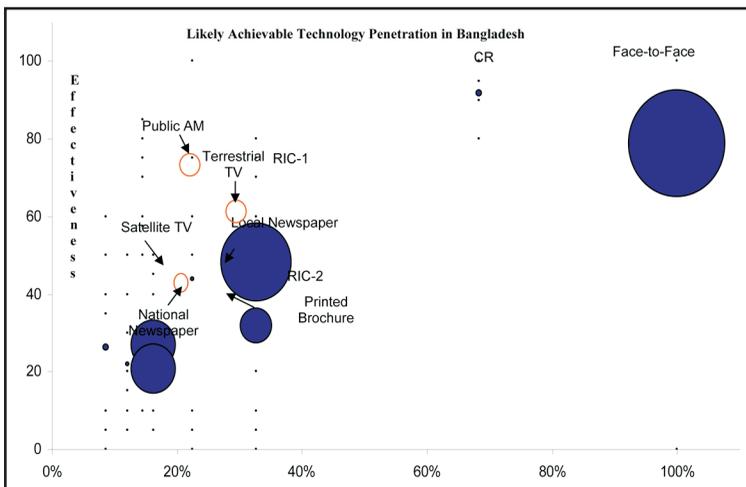


Figure 6. Cross-technology comparison for providing agriculture-based (general extension) information service in a low literacy ($\leq 20\%$) area (international experts).

Note: CR is the most cost-effective technology-based option here, with tradeoffs in cost, penetration, and effectiveness in the next choices of face-to-face, public AM, and RIC with Internet connection.

pendent of the potential differing technology penetration or cost scenarios in Bangladesh.

We integrate all these types of data in a single graphical display for each information service domain and in two types of literacy-based scenarios to: (1) have a comprehensive look at the relative effectiveness of several technologies as information service providers in the target service sectors, and (2) examine their present positioning in terms of plausible local or national penetration level.

A. Domain-Specific Key Observations

To find out the relative effectiveness of different technologies to deliver a range of information services, we first focus on the service sector-specific performance in both high- and low-literacy scenarios. The “observations” are limited to being based on the data set and analysis, and we do not claim these to be universal facts. Instead, these are manifestations as observed.

Observation 1: For **agriculture general extension**, CR was ranked as the most effective technological intervention, independent of the literacy rate within any community. For high-literacy regions, print-based options dominate broadcasting alternatives. RIC-1 is ranked third overall in effectiveness, followed by local newspaper, public AM radio, national newspaper, and others. For communities with low literacy, public AM turns out to be the

second most effective way to deliver general extension information among the less literate population, followed by RIC-1, terrestrial TV, RIC-2, local newspaper, etc.

0 to 100 on the Y-axis) can be seen as multiple dots together with the highlighted ones representing average values. The size of the average value data points corresponds to the cost-per-person-year for each considered delivery technology. According to our assumptions, the effectiveness scores are inde-

Observation 2: For **agriculture market information**, CR remains the top choice. For high-

literacy areas, public AM radio is considered to be next most effective, followed by technological options with higher localization options (RIC-1, local newspaper, printed brochure). In low-literacy areas, broadcasting options (public AM, terrestrial TV, and satellite TV) dominate the effectiveness ranking, followed by RICs and print-based options.

Observation 3: In **education**, apart from CR, in higher-literacy areas, given its wide range of options available using the Internet and multimedia, RIC-1 is considered to be the second most effective delivery technology, followed by public AM, local newspaper, printed brochure, RIC-2, and the other broadcasting alternatives. For low-literacy regions, broadcasting options overwhelmingly lead the relative effectiveness ranking.

Observation 4: Radio broadcasting (CR, public AM) and TV (terrestrial and satellite) are considered to be the most effective technologies with which to develop an efficient **disaster response** infrastructure in both high- and low-literacy communities.

Observation 5: In the **health care sector**, for both service types, experts emphasize the higher effectiveness of proactive face-to-face interventions by local health care workers. CR remains the most effective information service option in all literacy and service sector scenarios.

Observation 6: According to the experts, CR alongside localized print-based options are more suitable in providing information related to **financial services** among the more literate population. For a low-literacy community, broadcasting options are considered to offer superior information services.

B. Technology-Specific Key Observations

Examining which technology works best for which information service provides the basis to further examine the effectiveness trends for different types of technologies, their potential impact in the future proliferation of certain information services, the regulatory and policy implications of certain technology usage, etc. Here technologies have been classified within broader groups to come to some general observations.

1) Broadcasting-Based Information Service Options

Observation 1: Radio broadcasting dominates the technology-based service delivery mechanism with its literacy-independent potential in localized and participatory communication.

Observation 2: CR leads in cost effectiveness in all service sectors through ensuring localization and community participation.

Observation 3: Broadcasting-based information service options are the key behind any effective disaster response mechanism.

Observation 4: Publicly funded terrestrial TV shows higher effectiveness and acceptability in providing information when compared to privately owned satellite/cable TV channels.

Discussion: In this research, we assume that higher literacy closely correlates with higher economic affluence, an indicator for people to opt for “better” communication technologies. In Bangladesh, satellite/cable TV is less popular (and has lower penetration) than terrestrial TV (BCCP, 2002). It shows the positive externality that a nation’s broadcasting regulations can create through mandating the incumbent public broadcasting service to air social service information programs. Generally, private satellite channels have fewer regulatory obligations to abide by and little or no financial incentives in airing socioeconomic service programs, let alone localized versions. Satellite also has greater challenges of localization than many other technologies based on its very wide footprint.

2) Print-Based Information Service Options

Observation 5: Local print-based options are more effective than national ones.

Discussion: The general population can be effectively reached with locally published newspapers or printed brochures in comparison with the big newspapers with nationwide circulations. Community ownership, localization of content development and easy accessibility are reported as some of the key factors responsible for this trend.

Observation 6: Print-based options can be used as effective auxiliary mechanisms for socioeconomic services that require personalized attention.

Discussion: In lifelong learning, financial service advising, health care, and agriculture-based information services in any high-literacy region, community-based print options are more effective than the visual broadcasting media, according to the effectiveness ranking and comments of the international experts. Usually, non-governmental organizations and development agencies in the field use this type of intervention as a supporting tool in addition to their broader door-to-door personalized campaigns.

3) Rural Information Centers

Observation 7: Literacy rates do not affect the relative effectiveness of RIC-1 over print- and TV-based options.

Observation 8: RICs without Internet can still be used as a successful tool for providing community education.

Discussion: According to the experts in this research, on average in both high- and low-literacy scenarios, the RIC-1 centers are (or, we feel, perhaps, can be?) more effective than some major TV broadcasting and locally published print-based options. Especially with the help of its information intermediary (“informed intermediary”) mechanism, local database and cellular phone applications, RIC-1s have a lot of growth potential as a relatively new technological option (Köhler, Reitmaier, & Schulz, 2007). As we have found in this research, RICs without Web-enabled facilities (RIC-2) are less effective than RIC-1s as well as the majority of the other interventions in both high- and low-literacy communities. But in the education domain, RIC-2 shows higher effectiveness than national newspapers and satellite TV. Based on discussion with the development experts in South Asia, we found that the relatively lower demand for updates in lifelong learning curricula is considered to be one of the main reasons behind RIC-2’s better performance in this specific service sector.

6. Recommendations for Effective Information Services

While this is a comparative analysis, in all technologies, availability of local, relevant, right-language content is a key challenge, one for which the costs can and do vary enormously. Based on the relative effectiveness analysis through expert elicitation, stochastic cost modeling, literature review, personal discussions with practitioners, and anecdotal evidence, we make the following recommendations for effective technology-centric information services deployment. These findings are based just on a single case country—Bangladesh—but we will largely phrase them in general terms since they may well have universality, though of course all this must be framed within an understanding of the limitations of the specific case data and of the expert elicitation process.

- Direct human involvement should be an integral part of any “communication for develop-

ment” initiative. Experts’ overwhelming preference for “face-to-face” interventions and research findings related to the importance of human interaction justifies its importance at least as an auxiliary medium for any technology-based information service options.

- As the majority of rural populations lack access to effective information services, participatory radio-based broadcasting options can play important roles as socially sustainable development mechanisms. Both sets of experts identified this as a highly effective tool, and our cost estimates showed this to be relatively inexpensive.
- Over-the-air TV broadcasting has wider appeal, both as a source of entertainment and socioeconomic communication among the general population, irrespective of their literacy and economic status. Airing a greater number of development-oriented programs, opening up education channels, and ensuring participation of the local population in regional TV stations are some of the ways to develop an effective TV-based information service network.
- Especially for a disaster-prone country such as Bangladesh, where latency in getting weather updates from a single (centralized) point has resulted in the loss of thousands of lives, decentralized emergency warning systems and response mechanisms might be worth establishing. In addition to the traditional satellite-based initiatives, community-based micro-broadcasting systems with local participation can be developed for a sustainable disaster response infrastructure beyond the initial warning.
- Ideally dominant in higher literacy areas, print media remains the backbone of education systems, one of the most important service sectors considered in our analysis. The success of print-based options as a part of any integrated delivery mechanism (Hussain, 2008a) makes it an important element for any viable communication for development option.
- With literacy-independent access efficiency, RIC-1 can provide a platform for sustainable information (this implicitly assumes the use of intermediaries). Following the successful example of Nepal (UNESCO, 2006), a balanced inte-

gration of face-to-face-, CR-, print-, and Internet-based multimedia activities may be able to address the majority of the information service needs. This follows from our analysis that there is no easy “winner” when it comes to technologies, so hybrid solutions might be important. In addition, all the technologies would benefit from government support, whether for financing, tax incentives, licensing norms, etc.

- Efforts to demystify the technologies used for information service centers can lead to greater efficacy with technology and wider participation by the general population. For example, low-cost CR options such as the “suitcase radio” can be used in the field for on-the-spot broadcasting and human resource development purposes.
- Both the literature review and collected field data identified “scarcity of trained human resources” as one of the major roadblocks toward establishing an effective information service network (CBAA, 2009; Fraser & Estrada, 2001). Experiences from South America and from Nepal showed the effectiveness of decentralized support and resource centers for training information service providers on technical issues, content development, management, etc. (Fraser & Estrada, 2001; Nepal Forum of Environmental Journalists, 2010). Regular in-service training for personnel and resource pooling in remote places (i.e., sharing of content, technicians, etc.) can also ensure the operational sustainability of any information service center. This is vital for long-term sustainability beyond the initial period.

Additional Policy Suggestions

These draw from literature and suggestions from the surveys, while not drawing directly from the preceding analysis:

- Information service providers engaged in socio-economic development work need separation from competing commercial entities. The absence of such separation mechanisms can result in unfair competition, pressure on service providers to overlook societal commitment for greater commercial success and, at times, the abrupt closure of such initiatives (Pringle & Subba, 2007).

- A “Development Information Service Fund” can be created to provide monetary help for establishing information infrastructure in underserved communities. All the commercial broadcasting and communication enterprises can contribute to this fund. This type of mechanism is the backbone for parallel policies worldwide on universal service for telephony (FCC, 2008).
- On modeling and comparing program and labor costs of community-based information service providers in isolated versus more collaborative environments, we find that national, regional, and local cooperation in terms of program and resource sharing should be encouraged officially, in addition to pooling resources for learning, training, troubleshooting, etc. (given labor is a significant fraction of operational costs [Hussain & Tongia, 2007]).
- Convergence of media and digitization imply that governments should encourage such integration, instead of more traditional “silo”-based regulation. As the work has hinted, hybrid solutions between technologies, including face-to-face and mobiles, might offer the most promise. This implies that policies and regulations should not be constrained by technology but, rather, facilitate such convergence.

7. Further Work and Discussion

The findings and recommendations in this article draw from a combination of the analysis and the expert comments, and will thus vary region-to-region. We also recognize other significant limitations, such as the fact that some experts may have been subconsciously thinking of affordability (cost) when considering effectiveness, despite an explicit request to separate costs, since the framework in this paper involves separate cost calculations. With these limitations, we believe the framework can nonetheless provide a useful tool for similar cross-technology analyses in various regions.

We know intuitively that different technologies always behave differently and have different costs. This paper attempts to give structure (and numerical values, based on an example) to these. One side finding was the divergence between international and domestic experts when it came to selected technologies but agreement over some ICTs such as

Table 4. ICT feature list.

<i>Directionality</i> , aka "Cast"	(broadcast, unicast, multi-cast [selected users], etc.)
<i>Content creation ease</i>	(high, medium, low) Will be subjective, especially depending on training and equipment
<i>Content ownership/control</i>	(centralized, decentralized, hierarchical, etc.) Some of this may not be transparent to end users.
<i>End-user marginal cost</i>	(quantifiable)
<i>Total costs per user</i>	(quantifiable, in theory) Depends on the reach or penetration, e.g., for radio, is this per "listener" or per radio capable of receiving (or even population covered)?
<i>Speed of dissemination</i>	(instant, delayed by "x" time, etc.) Delays may need to be averaged or typical values
<i>Richness</i> (multimedia)	(textual, audio, video, etc.) Effectiveness may vary in this dimension based on end-user literacy levels
<i>Trust</i>	(subjective, qualitative) Measured both from an end user's perspective and from a security of design perspective. These can be separated, e.g., the Internet may not be safe, but that fact may not be recognized. Alternatively, an official, secure, hardened Web site (like that of a bank) may be secure, but people may not realize it is secure.
<i>Robustness</i>	(Reliability measures, congestion measures, etc.) Can one rely on the technology?

community radio, despite no major deployment in the local area (Bangladesh).

How does one choose among technologies? This article presents a cost-effectiveness framework, which can be one tool. However, is it possible to make explicit trade-offs between technologies and their effectiveness for a respective sector or development domain?

While leaving the details for further research, we introduce a *preliminary* generic technology framework, which can be used to map functionality to effectiveness (Table 4). Essentially, this identifies how accessible, prompt, interactive, secure, etc., a technology is. That can then be mapped to the needs of different domains, e.g., disaster response prioritizing speed more than other domains. This is an extension of Table 2.

The Table 4 feature list attempts to convert the above characteristics into more specific ones that can be examined qualitatively, if not quantitatively. Of course, one challenge arises when there are overlaps or hybrid technologies; for example, many mobile phones popular in developing countries now include an FM radio.

Based on qualitative (if not quantitative) assess-

ments of a technology for a given application, perhaps through interviews with experts, literature, etc., one could then use such an analysis for guiding future policy as well as technology development. In particular, one might focus on identifying gaps in a given solution, and options for a *hybrid* solution (e.g., one that combines a mobile phone with broadcast radio and community ownership), particularly helping to suggest combinations of technologies with complementary features.

One challenge, of course, is the subjective nature of some of these technologies. In addition, technology (or prices) changes rapidly, sometimes faster than policy frameworks. As an example, the emergence of "femto-cells"¹⁰ as a technology means anybody with a broadband connection can now house a mobile mini-tower. However, the technology is today still a closed system, in part due to the regulations on spectrum use.

Summarizing some of the findings of the article, effectiveness analysis using experts' judgment and financial data modeling have shown the strength of radio-based information service options as useful and applied tools for development activities.

Although we and our experts specifically focused on

10. Femto-cells are small mobile towers (low-range) being marketed to consumers for installing in their premises to provide coverage inside the home; areas where the carrier signal may not penetrate. With estimated prices (late 2009) of about \$150 or so, these rely on the broadband uplink of the consumer for call completion. This is in contrast to unified wireless, which can use a wi-fi signal to directly connect a phone to the landline system, on wi-fi-enabled phones, which is another alternative technology design.

Table 5. Parameters for public AM programming.

Duration of a Program	30 min
Number of Programs per Week	2
Number of Programs (yearly)	96
Duration of Total Program Time	48 hours

Bangladesh, we believe that there should be a similar argument in other regions. Rural Information Centers with Internet connections also turn out to be very promising as *hybrid* information access points (under the assumption of intermediaries for extending their reach). We find awareness is a challenge in choosing technologies, given the differences between international and local experts—this implies dissemination of data and best practices to be of value. Given the enormous differences in cost, effectiveness, and penetration, often with a tradeoff (there is rarely a single dominant solution), policy-makers will need to decide how to prioritize technologies through the enabling environment.

Regulatory and policy decisions can strongly impact the relative costs of technologies, as well as their penetration. Nonetheless, the broad portfolio of technologies available for information services for development implies great potential for developing countries, with relatively low costs per beneficiary for all the technologies (under \$1 per person-year in scale).

Appendix: Cost Calculation Details

1) Community Radio (CR)

For the CR cost estimation, we included both monthly operational and yearly capital expenditure cost (amortized). The lifetime of radio transmission equipment was assumed to be 10 years. The listener base was calculated in terms of CR penetration among typical South Asian communities in India and Nepal (there is virtually no community radio in use in Bangladesh), which usually ranges from 60% to 90% (Nepalnews.com, 2001). After deriving the total yearly cost, we can calculate a set of cost-per-listener-year" values, depending on the probable population (density) of any community, the potential CR listener base, transmission range, etc. Our observation of global CR practices shows that approximately two-thirds of total broadcast time is dedicated to societal issues (Radio Lumbini, 2009;

Radio Sagarmatha, 2010). Of those blocks of time, we assume an equal distribution of air time among the seven information services. Thus, the final cost-per-listener-year for any CR-based service is computed as per the equation shown in the main text. Table 2 showed the calculated cost-per-person-year and penetration levels for all the technology-based information services in the target community. Costs of CR broadcasting have been normalized considering the market price (including taxes) for equipment and human resources (a number of commercial and public FM stations are working in Bangladesh, and their costs are comparable to the ones from Nepal and India, where CR is deployed).

2) Public AM

In South Asian nations, most public AM stations cover the whole country. This centralized and one-way broadcasting doesn't have the flexibility to air localized programs nor does it have the means to incorporate grassroots participation. Considering everything, our assumptions for cost-per-listener-year then focused only on specific program production and transmission costs, which in turn can be divided among the potential listener base nationwide. Empirical studies support the practice of airing twice-a-week programs on any particular societal issue. The assumptions for any radio program's broadcasting time and frequency in a public AM station for a certain year are stated in Table 5.

In this study, we assumed that, to distribute community-based information services, we needed a series of audio programs and to buy the airtime from Bangladesh Betar or the regulator to broadcast it, using the cost structure available in Bangladesh. The radio listenership data also took into account the shared usage practice by the Bangladeshi population.

3) Terrestrial TV (Public) and Satellite TV

Here the majority of the assumptions regarding program frequency, cost-per person-year, access to programming, etc., are similar to those for public AM.

Table 6. Assumptions for a newspaper-based societal ad campaign.

Space bought in the front page of any national newspaper	1/16th of the full page (Standard newspaper page with 36"x24" dimension)
Duration of the ad (per year)	100, 300, and 350 days (varied parametrically)
Target population	Total community population x national newspaper readership (%) (BCCP, 2002)

We used the cost of video production and TV transmission pricing (both terrestrial and satellite). For calculating access level, national terrestrial TV penetration rate (BCCP, 2002) has been used alongside the literacy ratio and a variable multiplier.

4) Face-to-Face (F-to-F)

Ideally, face-to-face service delivery should involve one-to-one contact between a facilitator and a person who is a member of the target population. But in most cases, this is not feasible or cost effective. F-to-F mechanisms actually vary, depending on the type of information being provided. The development costs of content in all the services are either insignificant in comparison to the calculated delivery cost or external to the system. The total cost has been estimated for a year-long program. In general extension and market information sectors, the percentage of people nationally involved in agriculture has been used as the base percentage in estimating the range of agro-related population within the considered community. We assume that a group of 50 people (varied parametrically) meets with an agricultural extension worker on a regular basis. In the education sector, the national literacy rate was considered for estimating community illiteracy. For disaster response and financial services, community-based estimations were used for calculating the target population. Each F-to-F group's base population and other estimations are similar to the ones used in the agriculture sector. Due to the sensitive nature of health care information services, we assumed monthly one-on-one interaction between public health field workers and the target community population.

5) National Newspaper

We assume that a relevant entity procures ad space to publish specific communication material pertaining to one of the seven information service dimensions defined in this research. The assumptions for any national newspaper's social ad campaign and publishing frequency are stated in Table 6.

6) Local Newspaper

The frequency of ad publishing is assumed to be similar to that of the national newspaper with relatively cheaper ad rates. We also took into account high- and low-literacy scenarios for calculating potential readership within the target community. We assumed the reader ceiling of 20% for the low-literacy region and 60% in a high-literacy community.

7) Printed Brochure (PB)

Designing printed brochures and pamphlets for any target community audience has long been a basic strategy used by local non-government organizations for distributing social service information. Readership and target community estimations are similar to local newspapers. The development cost of educational materials has been estimated to be relatively higher than the rest of the information domains for PB (Haiplik, 2004).

8) Rural Information Center-1 (RIC-1) and Rural Information Center-2 (RIC-2 = no Internet)

Rural Information Centers (RICs) house computers with various information resources and, possibly, Internet access. The cost estimation of RICs is based on data collected mainly from Bangladesh, Nepal, and India. The RIC model considered in our research has the following basic facilities: computers, Internet connection (available in RIC-1 and absent in RIC-2) and facilities for basic computer training, and printer/cellular phone/fax for commercial usage. The Pallitathya Kendra (PK) model, used by the NGO D.Net in Bangladesh, has been emulated in designing RIC-1's and RIC-2's working infrastructure. A PK-type RIC usually has an outreach service, where the RIC field workers or an informediary will personally go from house to house within any target community and address their information needs by connecting users through cell phones to the pre-selected expert panel or the locally developed database (Pallitathya, 2010). For the penetration estima-

tion of RICs, we assume that RIC usage will be greater in regions with high literacy, resulting in the need to develop multiple RICs within those areas, all within walking distance of all community members (2 or 3 km radius). For a low-literacy region, we estimate less usage and the presence of a single RIC for the whole community. Also, the proactive approach taken by the RIC field workers certainly has some positive impact, at least among the literate community population and beyond. We moreover assumed that the content development and distribution cost for any information service will be similar for any RIC. ■

References

Asian Development Bank (ADB). (2007). *South Asia economic report—Social sectors in transition* (pp. 23–48). Philippines: Asian Development Bank.

Austin, L. S., & Husted, K. (1998). Cost-effectiveness of television, radio, and print media: Programs for public mental health education. *Psychiatric Services, 49*, 808–811.

Bangladesh Enterprise Institute. (2006). *Media in development: Linkages between poverty reduction, social development and diversified media in Bangladesh*. Dhaka, Bangladesh.

Bates, A. W. (1995). *Technology, open learning and distance education*. London: Routledge.

BCCP. (2002). *National media survey 2002*. Dhaka: Bangladesh Center for Communication Programs. Retrieved December 9, 2008, from <http://www.bangladesh-ccp.org/NationalMediaSurvey.htm>

BTRC. (2010). *PSTN & mobile phone users*. Dhaka: Bangladesh Telecommunication Regulatory Commission. Retrieved February 15, 2010, from <http://www.btrc.gov.bd/>

Carnoy, M. (2004). *ICT in education: Possibilities and challenges*. Barcelona: Universitat Oberta de Catalunya.

CBAA. (2009). *Community Broadcasting Association of Australia*. Sydney. Retrieved November 9, 2009, from <http://www.cbba.org.au/>

CIA *Factbook Bangladesh*. (2010). Washington, DC: Central Intelligence Agency. Retrieved March 6,

2010, from <https://www.cia.gov/library/publications/the-world-factbook/geos/bg.html>

CIA *Factbook India*. (2010). Washington, DC: Central Intelligence Agency. Retrieved January 17, 2010, from <https://www.cia.gov/library/publications/the-world-factbook/geos/in.html#People>

CIA *Factbook Nepal*. (2010). Washington, DC: Central Intelligence Agency. Retrieved January 17, 2010, from <https://www.cia.gov/library/publications/the-world-factbook/geos/np.html#People>

CIA *Factbook Pakistan*. (2010). Washington, DC: Central Intelligence Agency. Retrieved January 17, 2010, from <https://www.cia.gov/library/publications/the-world-factbook/geos/pk.html#People>

Dock, A., & Helwig, J. (Eds.). (1999). An overview of IRI experience to date. *Interactive Radio Instruction: Impact, Sustainability and Future Directions*. Washington DC: World Bank.

Federal Communications Commission (FCC). (2008). *Universal service* (USA). Retrieved March 29, 2008, from http://www.fcc.gov/wcb/tapd/universal_service/quarter.html

Fraser, C., & Estrada, S. R. (2001). Features and functions of community radio. *Community radio handbook* (pp. 15–24). Paris: UNESCO.

Haiplik, B. (2004). *The BRAC education program teacher training and development system quality improvement initiative: Report #2, monthly refresher training for BRAC teachers*. Dhaka, Bangladesh: BRAC.

Holmes, D. R., Karmacharya, D. M., & Mayo, J. K. (1993). Radio education in Nepal. In H. Perraton (Ed.), *Distance education for teacher training* (pp. 136–195). New York: Routledge.

Hulsmann, T. (2000). Costing open and distance learning. *Commonwealth of learning* (pp. 27–39). Vancouver. Retrieved January 5, 2009, from the Commonwealth of Learning Online Database.

Hussain, F. (2008a). Community broadcasting in South Asia: Hybrid solutions for localized information access points (A Bangladeshi case study).

- 26th scientific conference on the international association for media and communication research: *Media and global divides (IAMCR 2008)*. Stockholm.
- Hussain, F. (2008b). Effectiveness of technological interventions for education and information services in rural South Asia. *ProQuest® Dissertations and Theses* (3342721). Retrieved January 14, 2010, from ProQuest® Online Dissertations and Theses database.
- Hussain F., Morgan, M. G., & Tongia, R. (2008). *Technological interventions for BRAC's in-service teacher training program: A comparative analysis*. Working Paper. Pittsburgh, PA: Department of Engineering and Public Policy, Carnegie Mellon University.
- Hussain, F., & Tongia, R. (2007, December 16). Community radio for development in South Asia: A sustainability study. *2nd international conference on information and communication technologies and development (ICTD2007)*. Bangalore, India.
- Iannella, R., & Henricksen, K. (2007). Managing information in the disaster coordination centre: Lessons and opportunities. In B. Van de Walle, P. Burghardt, and C. Nieuwenhuis (Eds.), *4th International ISCRAM Conference*. Delft, The Netherlands.
- Köhler, T., Reitmaier, M., & Schulz, G. J. (2007, September 25–27). Telecenters as instrument for bridging the digital divide in rural areas. *EBRF (Research forum to understand business in knowledge society) 2007 Conference*. TU Dresden, Finland.
- Kumar, R., & Best, M. (2008). Social impact and diffusion of telecenter use: A study from the sustainable access in rural India project. *Information Technologies & International Development*, 4, 31–45. Retrieved June 8, 2009, from *ITID Journal Online Database*.
- MacBride, S. (1980). *Many voices, one world*. Lanham, MD: Rowman & Littlefield Publishers, Inc.
- National Telecentre Database. (2009). *Bangladesh Telecentre Network*, Dhaka, Bangladesh. Retrieved March 14, 2010, from <http://www.mission2011.net.bd/>
- Nepal Forum of Environmental Journalists. (2010). Community radio support center. Kathmandu: NFEJ. Retrieved February 2, 2010, from <http://www.nefej.org/en/crsc>
- Nepalnews.com. (2001). *Future tense of dailies*. Kathmandu: Nepalnews.com online. Retrieved June 25, 2009, from <http://www.nepalnews.com/contents/englishmonthly/businessage/2001/aug/cover.htm>
- Opubar, A. E. (1999). If community media is the answer, What is the question? In A. Gumucio-Dagron & T. Tuftte (Eds.), *Communication for social change, anthology historical and contemporary readings*. South Orange, New Jersey: CFSC.
- Pallitathya. (2010). *Pallitathya Kendra*. Dhaka, Bangladesh. Retrieved March 8, 2010, from <http://www.pallitathya.org/index.php>
- Pringle, I., & David, M. (2003). The Kothmale model: Using radio to make the Internet visible. In B. Girard (Ed.), *The one to watch: Radio, new ICT and interactivity*. Rome: FAO.
- Pringle, I., & Subba, B. (2007). *Ten years on: The state of community radio in Nepal*. UNESCO. Retrieved December 6, 2008, from http://portal.unesco.org/geography/en/files/7991/11966615215State_of_Community_Radio_in_Nepal_abridged.pdf/State%20of%20Community%20Radio%20in%20Nepal_abridged.pdf (pp. 19–21).
- Proenza, F. J. (2001). Bridging the rural knowledge gap: Information systems for improved livelihoods. *Telecenter sustainability—Myths and opportunities*. Rome: FAO.
- Radio Lumbini. (2009). *Program description Radio Lumbini 96.8 MHz*. Retrieved June, 2009, from <http://www.radiolumbini.org/programdescription.asp>
- Radio Sagarmatha. (2010). *Program radio Sagarmatha*. Retrieved March 23, 2010, from <http://www.radiosagarmatha.org/en/programm-list-with-grid>
- Rahman, S. (2008). *Bangladesh ICT Indicator*, Bangladesh. (Online mailing group in KY, USA.) Accessed

EVALUATING COST-EFFECTIVENESS OF INFORMATION SERVICES ACROSS TECHNOLOGIES

- February 16, 2009, <http://www.banglait.org/banglaict.htm>
- Rajora, R. (2002). *Bridging the digital divide: Gyandoot—The model for community networks*. New Delhi: Tata McGraw-Hill.
- Rodriguez, C. (2001). From alternative media to citizen's media. In A. Gumucio-Dagron & T. Tufte (Eds.), *Communication for social change, anthology: Historical and contemporary readings*. South Orange, New Jersey: CFSC.
- Tobing, L. (2002). *How to do community radio: A primer for community radio operators*. New Delhi: UNESCO.
- UNESCO (2006). *Madanpokhara CMC extends its network to village schools*. Retrieved January 12, 2010, from http://portal.unesco.org/ci/en/ev.php-URL_ID=21853&URL_DO=DO_TOPIC&URL_SECTION=201.html