iMENTORS

SEVENTH FRAMEWORK PROGRAMME

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D3.2 Requirement analysis and specifications for the Decision-Support System

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Abstract: D3.2 reports on the selection of output indicators and associated criteria for the multi-criteria evaluation framework for ICT4D initiative and e-infrastructure project evaluation. The document discusses the design and specification of the multi-criteria framework for evaluating initiatives in a multi-stakeholder fashion since each initiative may be subject to many assessments and evaluations. It also explains how each criterion contributes to successful e-infrastructure projects by exploiting the data retrievable from the online platform with database complemented with stakeholder input.

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List of abbreviations

Acronym/ Abbreviation	Explanation
API	Application programming interface
CEENET Engine	Central and Eastern European Networking Association
CORDIS	Community Research and Development Information Service
CRS	Creditor Reporting System
D	Deliverable (of the project)
DAC	Development Assistance Committee
DG	Directorate-General
DG CONNECT	European Commission Directorate General for Communications Networks, Content and Technology
DoW	Description of Work (of the project)
DSV	Department of Computer and System Sciences of Stockholm University
EC	European Commission
EFTA	European Free Trade Association
e-IRG	e-infrastructures Reflection Group
ESF	European Science Foundation
ESFRI	European Strategy Forum on Research Infrastructures
EU	European Union
EUR	EUROS
FP7	Seventh Framework Programme
Gov2u	Government To You
HEIs	Higher Education Institutes
HIV	Human Immunodeficiency Virus
HQ	Headquarters
HPC	High Performance Computing
IATI	International Aid Transparency Initiative
ICT	Information and Communication Technology
ICT4D	ICT for Development
i.e.	That is
IGAD	Intergovernmental Authority on Development
iMENTORS	e-infrastructure monitoring evaluation and tracking support system
IT	Information Technology
M	Month (of the project)
MCA	Multi-Criteria Analysis
NGO	Non-Governmental organization
NO	Number
SED	Social and Economic Dimensions

Executive Summary

The overall objective of iMENTORS is to enhance the coherence and effectiveness of international actors involved in e-infrastructures development projects and initiatives in Sub-Saharan Africa, based on the results and recommendations of previous studies and reports.

This document constitutes the Deliverable 3.2 of the iMENTORS project. The deliverable focuses on the selection of output indicators and associated criteria for the multi-criteria evaluation framework for ICT4D initiative and e-infrastructure project evaluation, which constitute the core of the Decision-Support Module.

The purpose of this document is to discuss the design and specification of the multi-criteria framework for evaluating initiatives in a multi-stakeholder fashion since each initiative may be subject to many assessments and evaluations, and a discussion of how each criterion contributes to successful e-infrastructure projects, by exploiting the data retrievable from the online platform with database complemented with stakeholder input.

The basis for understanding ICT4D assessments is the value chain model, which is based on the standard input-process-output model linking resources and processes to systematically analyze the stages an ICT initiative traverses over time. The output indicators are categorized into three divisions. In relation to the value chain impact components, these are the ***outputs*** since they are the direct changes associated with the technology and consist of accessing information, enabling interactions, and performing transactions. ***Outcomes*** are the direct benefits in terms of measurable (both quantitative and qualitative) benefits as well as costs associated with the outputs. For instance, reduction in transaction costs is an outcome resulting from performing online transactions like sending mobile money. Finally, ***development impacts*** refer to the broader ICT contribution the broader development goals, they are less tangible.

The evaluation model consists of three (3) sets of dimensions; the socio-economic development dimensions, the infrastructure dimension and the project performance dimension. The infrastructure and project performance dimensions are prerequisites for the socio-economic development dimensions which facilitate the realization of development. In relation to the value chain, these two dimensions are more closely related to the deliverables and are one-dimensional without sub-dimensions or indicators. Under social and economic dimensions, the sub-dimensions are the outcomes as defined above, while the outputs consist of ICT opportunities generally categorized as accessing information, enabling interactions, and performing transactions. Indicators will be defined for each of these categories based on the initiative.

Infrastructure Dimension focuses on assessing the efficiency and quality of the infrastructure. Focus is on infrastructures that provide connectivity, computing or processing, as well as data storage. Indicators here will be in terms of the quality of the access link, no. of people using the infrastructure etc. It is assumed that indications of an efficient infrastructure contribute to the realization of social and economic development.

Project Performance Dimension focuses on establishing whether a project actually meets its goals in terms of timeline, deliverables etc. It is assumed here that a successfully delivered project should have some contribution towards the realization of social and economic development.

Social and Economic Dimensions investigates people's perception of the role of ICT towards their well-being. It established that perception of importance also determined how people benefited from the initiative. ICT-related development has been defined in terms of the opportunities ICT offered; i.e. those things that people were able to be and do given an ICT4D

initiative. The evaluation criteria which consisted of three dimensions and several indicators were developed through a literature study as well as empirical studies. These classifications are corroborated by other similar studies within the developing country context.

1 Introduction: What is this deliverable?

After giving a small description of iMENTORS and of the work package, this section defines the scope and methodology of the deliverable. Finally, the relation of the deliverable to other deliverables is explained, with a brief paragraph to describe its intended audience.

1.1 The project: iMENTORS

The overall objective of the project is to enhance the coherence and effectiveness of international actors involved in e- infrastructures development projects and initiatives in Sub-Saharan Africa, based on the results and recommendations of previous studies and reports.

The project will:

- Provide policy support by identifying and monitoring all on-going e-infrastructure projects in Sub-Saharan Africa, and perform benchmarking, impact assessments.
- Enhance aid coordination and collaboration by providing insight on e-infrastructure development projects and through the platform's collaborative features (knowledge sharing) for development of new e-infrastructure development projects.
- Promote of e-infrastructures of common interest to Europe and Sub-Saharan Africa through extensive dissemination activities (workshops, conferences, communication).

Specific objectives:

1. **Build:** Create a virtual observatory, acting as one-stop-shop data warehouse providing up-to-date information on all e-infrastructure related development programmes and initiatives of the past five years in Sub-Saharan Africa to enhance the effectiveness and coherence of national and EU research policies and international cooperation in the field of research infrastructures:
   a. Identify and collect informational assets (data and sources): Identify and connect with key stakeholders, Gather and analyze relevance of all past and ongoing e-infrastructure development and ICT projects in Sub-Saharan Africa, Populate the virtual observatory.
   b. Create the virtual observatory (platform), User interface Decision support system.
2. **Develop a community of practice** for support to policy development and programme implementation by creating a social hub facilitating interaction and knowledge sharing, to improve collaboration among different stakeholder groups, and offer them opportunity to create synergies and plan future projects.
   a. Launch a space for Collaboration.
   b. Position iMENTORS as the knowledge broker.
   c. Decision support to policy development enabling users to produce queries across several online databases, and to evaluate e-infrastructure proposals from multiple perspectives in a structured manner.
3. **Sustain**: Build and maintain a strong stakeholder ecosystem around the iMENTORS project, which will ensure long-term viability of the project and will enhance the development of e-infrastructure in Sub- Saharan Africa.
   a. Community awareness.
   b. Standardization of practice.
   c. Political and Institutional support.

iMENTORS is a project funded by the European Commission's DG CONNECT under the Seventh Framework Programme (FP7). For more information visit: www.iMENTORS.eu

1.2 The Work package (subset of the project)

The objective of WP3 is to design and customize a web platform capable of storing, analyzing and displaying information relevant to past, current and potential e-infrastructure projects in Sub-Saharan African countries and to integrate the platform with a decision support system to provide impact assessment data.

1.3 The Deliverable (scope, objectives, methodology)

This deliverable outlines the iMENTORS decision support features, and in particular the suggested approach to perform multi-criteria evaluations of e-Infrastructure projects. The deliverable focuses on how to enable the use of a common assessment form and translate the resulting assessment into a formal multi-criteria model that can be evaluated by exploiting methods from decision analysis in imprecise domains.

1.4 Intended audience of this document

Group of readers	Reasons for reading
iMENTORS site visitors	To understand how the multi-criteria evaluations of projects is carried out, and what information that is needed in order to enable such evaluations.
iMENTORS data entrants	To understand how the multi-criteria evaluations of projects is carried out, and what information that is needed in order to enable such evaluations.
iMENTORS administrator	To understand the technical integration of the multi-criteria module with the platform.
The European Commission (EC)	To inform the Project Officer, the reviewers and other interested stakeholders from the EC, about project's dissemination plan, progress so far and anticipated activities regarding dissemination for the following period of the project.

Table 1: Intended Audience of D3.2

2 Assessing ICT4D Initiatives

Large investments in Information and communication Technology (ICT), especially in the developing country context, are motivated by the notion that ICT actually contributes to development. Despite high diffusion and uptake of ICT over the years, the high rates of failure of ICT4D initiatives raised scepticism as to whether ICT was actually contributing to development.

This resulted into the need for assessments to establish whether ICT was contributing to development. Therefore, assessments of the ICT contribution to development are essential for post hoc or ex-post assessment to establish what has been achieved from investments; pre hoc assessment of future investments, such as proposals to forecast potential impacts; as well as accountability to enable investors be accountable for their ICT4D investment (Heeks 2010 pg 628). It is however a subject of great concern that the contribution these investments have made towards development is still elusive despite the diversity in approaches evaluating the effectiveness of ICT for development (ICT4D) initiatives (Gomez 2012).

Existing approaches range from international, regional, national as well as project specific evaluation exercises. Over the years ICT4D evaluations have mostly focused on assessing the diffusion in terms of availability, access and use of ICT in terms of for example tele-density, number of computers etc. (Heeks 2010). While these are prerequisites to establishing whether ICT actually contributes to development, they do not highlight or report on the real benefits; what ICT has enabled people do, or how it has transformed their lives. This accounts for the increased attempts as well as call for studies into measuring the contribution of ICT on development in general (Best et al. 2009; Heeks and Molla 2009; Chew et al. 2010; Blake and Garzon 2012) or the more application specific e.g. e-infrastructure evaluation endeavours (Horlings et al. 2012; Leimbach et al. 2012 *Development of impact measures for e-Infrastructures, European Commission*; Passani et al. 2012 *Socio-Economic Impact Assessment for e-Infrastructures Research Projects ERINA+*).

However, the assessment of the ICT contribution to development involves various complexities that determine what is assessed and how it is assessed. Principal among these is attributing developmental impact to a single intervention, given that impacts might be realised later, even after the lifetime of the project. Moreover, Gomez (2012) and Heeks (2010) highlight the lack of well-formulated theoretical foundations to devise appropriate impact indicators that guide data collection as well as analysis.

In the developing country context this is further complicated by institutional barriers to data access where it exists. In other instances proper impact evaluations are also affected by the lack of baseline studies to allow for systematic impact assessments (e.g. Batchelor et al. 2003; Pather and Uys 2010). Ideally, impact assessments should be achieved through longitudinal studies to establish the before and after implementation states of the development recipient. However, this is inhibited in cases where the need for such evaluations becomes apparent once implementation has been done. Finally, attempts aimed at realizing generic evaluation indicators are also affected by the heterogeneity of initiatives with different target goals.

ICT4D comprises of two components; technology and development. The technology, ICT consists of the new and old technologies that facilitate by electronic means the creation, storage management and dissemination of information; as well as communication (Digital Opportunities Task Force 2002). Development on the other hand can be variously defined, however in this context it is a multi-dimensional concept, consisting of socio-economic dimensions such as health, education, governance that serve the needs of people in

developing countries. ICT4D initiatives therefore range from the underlying infrastructure to the applications that involve activities aimed at realizing socio-economic development.

2.1 The iMENTORS ICT4D evaluation framework

The basis for understanding ICT4D assessments is the value chain model (Adamali and Lanvin 2005; Heeks 2009). It is based on the standard input-process-output model linking resources and processes to systematically analyze the stages an ICT initiative traverses over time, see Figure 1 below. An ICT4D intervention-the input with fulfilled prerequisites which may include policies and implementation skills will result into a successful deliverable e.g. a telecentre. These deliverables once exploited by the target beneficiaries result into outputs, which result into outcomes and ultimately impacts. The realization of outcomes from outputs as well as impact from outcomes is affected by various contextual factors such as skills, institutional barriers and cultural or personal beliefs etc.

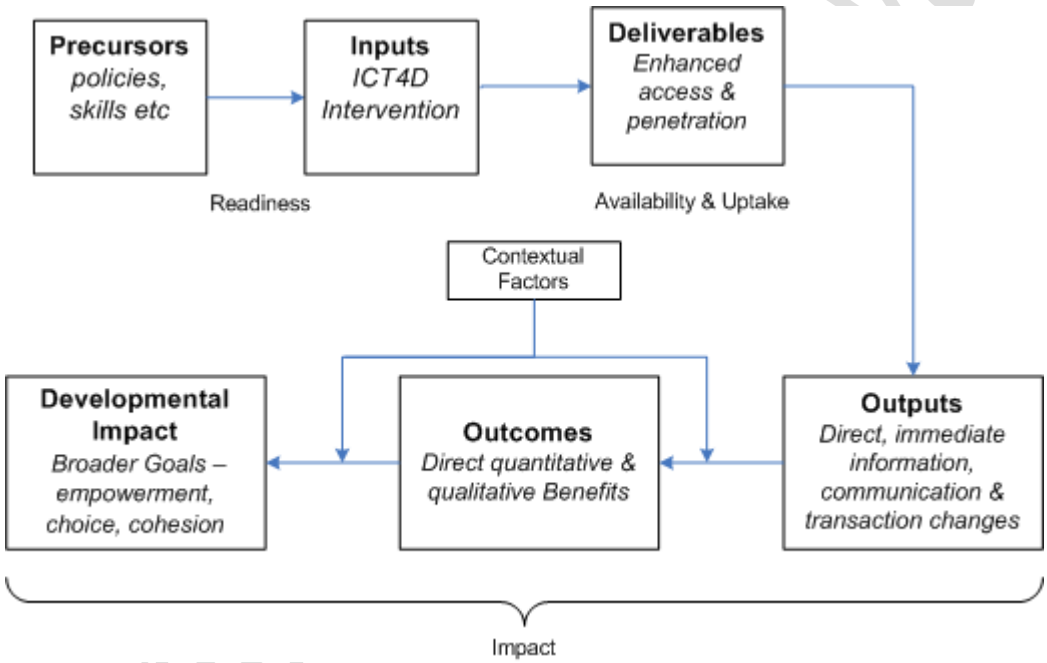

Figure 1: ICT4D Impact Evaluation Framework adapted from (Heeks 2009)

Over the years interest in the domains along the value chain has shifted from readiness and availability towards development impact (Heeks 2010; Gomez 2012). The shift in focus mainly arises from the need for ICT4D initiatives to demonstrate that they ultimately have a development impact in terms of social and economic development. This calls for focus on impact assessment which involves the evaluation of outputs, outcomes and development impacts of an investment as the value chain illustrates.

Development in this case is synonymous with Sen's (2007) definition i.e. comprising of a principal means with instrumental value, as well as an ultimate end of intrinsic value. It consists of both things people can do as well as what they become given an ICT4D initiative. Focus here is on the opportunities ICT offer It is also important to note that in taking a non-technology-centric view towards assessment, focus shifts from the resource i.e. ICT to its characteristics; which include communication; production, processing and distribution of information; and generation and dissemination of knowledge. In relation to the value chain

impact components, these are the ***outputs*** since they are the direct changes associated with the technology and consist of accessing information, enabling interactions, and performing transactions. ***Outcomes*** are the direct benefits in terms of measurable (both quantitative and qualitative) benefits as well as costs associated with the outputs. For instance reduction in transaction costs is an outcome resulting from performing online transactions like sending mobile money. Finally ***development impacts*** refer to the broader ICT contribution the broader development goals, they are less tangible (Gomez 2012; Leimbach et al. 2012)

From an analytical perspective, the outputs will then realize the direct benefits, the outcomes which report on the improvements the initiatives have had on people's lives. Such measures are of strategic value and are the building blocks of the broader social and economic development goals (Pather and Uys 2010 pp 9). These broader goals, i.e. the impacts are achieved from a range of outcomes in combination with various contextual factors, thus being more complex to define and evaluate.

2.2 Defining indicators for assessing ICT4D initiatives

Given the various interactions among the evaluation framework elements, a hierarchical structure as shown in Figure 2 below is proposed to facilitate a structured analysis. While the ultimate goal of any ICT4D initiative is the realization of social and economic development, this will be assessed at different levels, thus the diversity in evaluation dimensions.

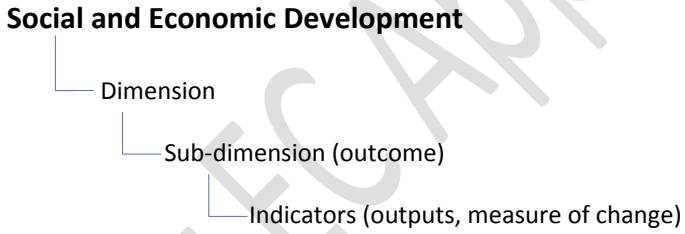

Figure 2: Hierarchical representation of dimensions and indicators

2.2.1 Evaluation dimensions

The evaluation model consists of three (3) sets of dimensions; the socio-economic development dimensions, the infrastructure dimension and the project performance dimension. The infrastructure and project performance dimensions are prerequisites for the socio-economic development dimensions which facilitate the realization of development. In relation to the value chain, these two dimensions are more closely related to the deliverables and are one-dimensional without sub-dimensions or indicators. Under social and economic dimensions, the sub-dimensions are the outcomes as defined above, while the outputs consist of ICT opportunities generally categorized as accessing information, enabling interactions, and performing transactions. Indicators will be defined for each of these categories based on the initiative.

Infrastructure Dimension: This focuses on assessing the efficiency and quality of the infrastructure. Focus is on infrastructures that provide connectivity, computing or processing, as well as data storage. Indicators here will be in terms of the quality of the access link, no. of people using the infrastructure etc. It is assumed that indications of an efficient infrastructure contribute to the realization of social and economic development.

Project Performance Dimension: This one focuses on establishing whether a project actually meets its goals in terms of timeline, deliverables etc. It is assumed here that a successfully

delivered project should have some contribution towards the realization of social and economic development.

Social and Economic Dimensions (SED): This is adapted from (Kivunike et al. 2008; Kivunike et al. 2011) which investigated people's perception of the role of ICT towards their well-being. It established that perception of importance also determined how people benefited from the initiative. ICT-related development was defined in terms of the opportunities ICT offered; i.e. those things that people were able to be and do given an ICT4D initiative. The evaluation criteria which consisted of three dimensions and several indicators were developed through a literature study as well as empirical studies. These classifications are corroborated by other similar studies within the developing country context (Ndiwalana et al. 2010; Gomez 2012).The three dimensions are the following:

- Social opportunities: which refer to arrangements society makes available to enable an individual to live a better life. From the capability perspective, this focuses on the capabilities related to social well-being like health, education, physical, emotional and personal development. Opportunities such as being able to contact a doctor, being able to obtain health information, staying in touch with family and friends etc. are the output indicators proposed in this dimension.
- Economic facilities: these refer to the opportunities that individuals enjoy to utilize resources for the purpose of consumption, production or exchange. The capabilities-focused indicators developed in this dimension included the ability to send and receive money, as well as the possibility to access information on markets, good farming practices and job opportunities.
- Political freedoms: the opportunities to exercise political rights e.g. being able to participate in local election, community development programmes, and so on.

2.2.2 Selection of indicators for assessing ICT4D initiatives

Given the above reasoning, impact assessments thus involve the assessment of outputs, outcomes and development impacts of an investment as the value chain illustrates. Outputs are the direct and observable changes associated with the technology in terms of new communication patterns, the new information and transactions. Outcomes are the direct benefits in terms of measurable (both quantitative and qualitative) benefits as well as costs associated with the outputs although they might not be observable; and finally development impacts refer to the broader ICT contribution the broader development goals, they are less tangible (Gomez and Pather 2012; Leimbach et al. 2012). It is important for an impact assessment exercise to consider all three aspects because outputs and outcomes are prerequisites for impacts to occur.

In certain instances outputs are defined as the quantifiable, tangible results (cf Gomez and Pather 2012). It is argued here though that these are deliverables assessing availability and uptake and while these are prerequisites for impact assessment, several standards already exist (ITU 2010). Just like for any other investment, ICT4D impact assessments aim to establish i) whether an investment has achieved results (post-ante assessment), ii) will achieve the envisaged results (ex-ante assessment) or is a means of accounting for the investment (Heeks and Molla 2009).

While the ICT4D value chain facilitates the definition of the components of the impact assessment stages, the capability approach provides an understanding of their interactions towards the attainment of social-economic development. Consequently the realization of any development impact from an initiative is strongly affected by the contextual factors has highlighted above and are therefore key aspects in an evaluation exercise. Based upon the

value chain view on project impact and on the properties of ICT4D initiatives, the following three sets of output indicators is suggested for the iMENTORS multi-criteria evaluation of ICT4D initiatives.

2.2.2.1 Infrastructure output indicators

Sub-Dimensions	Indicators
Quality	• Quality of (access/connectivity, processing, storage) infrastructure • Infrastructure Capacity/capability (Mbps, Gbytes, etc.) • Provisions for infrastructure expansion • Existence of redundancy options
Uptake & Usage	• Ease of use of infrastructure • Frequency of use of infrastructure • No. of infrastructure users • Level of utilization of infrastructure
Maintenance & Support	• Ease of maintenance of infrastructure • Existence of skilled support staff • Existence of maintenance budget

Table 2: Infrastructure output indicators

2.2.2.2 Project performance indicators

Sub-Dimensions	Indicators
Customer Satisfaction	• Quality of deliverables • Level of customer participation in project design & implementation
Schedule Management	• Deviations in original project schedule • Milestones completion
Cost Management	• Changes in project capital costs • Changes in project personnel costs
Human Resource Management	• Quality of project personnel • Rate of project personnel turnover • Deviations from original project manpower
Risk Management	• Existence of project risks? • Whether risks were mitigated or not?

Table 3: Project performance indicators

2.2.2.3 Social and economic development output indicators

Dimensions	2.2.3	**Sub-dimensions (Outcomes)**	***Outputs and Indicators***
Social Opportunities	Education 2.2.4	Research innovations	***Accessing information*** • Accessibility to relevant online resources • Frequency of access to online resources • Quality of relevant online resources ***Enabling interaction and communication*** • Quality of collaboration • No of collaborating institutions • Length of collaboration • Frequency of collaboration ***Innovative Performance*** • Existence of innovations (patents, research standards) • No. of new/improved innovations • No. of innovation publications • Frequency of use of innovations, research standards, patents (requested and issued) • No of users of innovations, research standards, patents (requested and issued)
		Quality of research	***Accessing information*** • Frequency of access to online resources • Quality of online resources • No. of online resources users (projects, researchers, institutions ***Enabling interaction and communication*** • Quality/type of research collaboration i.e. academic institution and industry, among academic institutions alone, regional etc • No of collaborating institutions • Frequency of collaboration ***Research quality*** • No. of research publications produced • Reduction in research completion life-

			span • Research quality institutional ranking • Frequency of use of research outputs e.g. external citations Start-ups resulting from initiative
		Improvements in education System	***Accessing information*** • Frequency of access to new pedagogical resources • Extent of adoption of new pedagogical techniques • Existence of new online courses • No. of participants in new online courses • Ability to enroll and participate in online or distance education programs • Availability of staff training programs e.g. online or distance training courses, PhD, masters, exchange opportunities etc.
	Health	Improvements in health delivery	***Accessing information*** • Existence of new approaches to share health information e.g. awareness of good health practice, immunization, awareness on pandemics etc • Existence of relevant online resources • Frequency of access to relevant online resources • No. of users of relevant online resources ***Enabling interaction and communication*** • Existence of facilities to support remote consultation and diagnosis • Frequency of remote consultation and diagnosis with healthcare providers e.g. through phone calls, video calls etc.
		Breakthrough innovations in health	***Accessing information*** • Availability of relevant medical online resources • Frequency of access to relevant online resources ***Enabling interaction and***

			communication • Existence of collaborations between relevant stakeholders • Frequency of participation in relevant collaborations ***Health Innovative Performance*** • Existence of health-related innovations • No. of new/improved health innovations • No. of health innovation publications • Frequency of use of innovations
		Improved Health services administration and management	• Existence of health management information systems e.g. Drug tracking and dispensing systems, patient records management systems; • Frequency of use of health management information systems
	Personal wellbeing	Improved self-esteem	• Individual recognition in terms of a prize, title, promotion or nomination resulting from works done
		Empowerment	• Improved levels of self-confidence resulting from participation in ICT4D initiatives, or skills obtained
		Entertainment and fun	• Entertainment e.g. listen to music, watch movies, play games • Obtain News (local, national, international and sports)
	Relational wellbeing	Improve family and social ties	• Accessibility/ownership to relevant applications e.g. social media applications, mobile phones • Frequency of use of relevant applications to contact Family/friends
Economic Facilities	2.2.5	Productivity	• Existence of information on product quality improvement • Frequency of access to relevant online resources • Existence of new goods/services produced (type and value) • Existence of new patents • Frequency of use of new goods/services
		Reduction in	• Existence of platforms to support

		transaction costs e.g. operational, transport	money transfer transactions • Existence of platforms to support online transactions e.g. e-commerce, e-tax • Frequency of use of these platforms
		Creation of new employment or income generation opportunities	• Existence of information on new employment opportunities, stocks, investment opportunities • Frequency of access of relevant information • Existence of information on economic related issues e.g. Market information, farming/agricultural practices • No. of new employment opportunities etc. obtained through the initiative
Political Freedoms	2.2.6	Promote political participation	• Existence/availability of relevant online platforms e.g. e-voting, community/national websites • Being able to participate in local/community or national political matters e.g. elections, debates • Frequency of use of relevant platforms • No. of users of relevant platform(s)
		Increase National/Institutional transparency	• Existence/availability of relevant online resources e.g. budgets on community/national websites, citizen online database etc. • Frequency of access to relevant online resources • Ability to report fraud online • Ability to question or comment on issues • Accessibility to personal records and entitlements e.g. identity, land titles etc. • No. of users of relevant platforms
		Promote local cultures and values	• Ability to create local content
		Promote citizen security	• Ability to contact people e.g. local leaders in case of an emergency

Table 4: Social and economic development output indicators

2.3 The iMENTORS multi-criteria evaluation model

The multi-criteria evaluation model of iMENTORS aims to provide a common model for evaluation of ICT4D initiatives, enabling for inter-project comparisons in terms of estimated impact and project performance relative to project objectives and what socio-economic dimensions that benefitted from the project.

Although the assessment of output indicators according to Table 1 yields an apprehension of the performance of an ICT4D initiative in terms of its contributions to the social and economic dimensions, it will not provide a basis for comparing initiatives in a decision support system manner since different projects have different precursors and objectives.

The multi-criteria evaluation model consists of three different entities. The first entity is the "Assessment form", in which evaluators enter statements referring to the observable indicator outputs of an initiative. The second entity is the criteria tree, which is the tree representation of the hierarchical structure Dimensions – Outcomes – Output as presented in Table 1. In this hierarchical tree, the outputs are modeled as leaf nodes, the Dimensions are the children of the root node, and the Outcomes are intermediate nodes in between the Dimension-nodes and the Output-nodes. Finally the third entity is a set of "output-to-outcome functions" mapping the observable change from an output to an estimated level of the benefit derived from this change.

2.3.1 Assessment form

The assessment form serves as the front-end to evaluators and stakeholders who enter output indicator data for a given ICT4D initiative to the platform. The assessment form should provide means for the evaluator to provide assessments for the set of output indicators feasible for the initiative/project under consideration. Further, the assessment form is to be web based and part of the iMENTORS platform. Of importance is that we foresee that both complete and precise assessments may be difficult to conduct, and part-filled assessment forms will be accepted by the multi-criteria evaluation module.

Imprecise and qualitative assessments will also be accepted, since the system should not force an assessor to stipulate precise quantitative assessments of output indicators if such cannot be done and due to that a majority of output indicators are qualitative by nature. Due to this, a multi-criteria evaluation engine supporting incomplete and imprecise information with the capability of aggregating with qualitative measures will be utilized in the iMENTORS evaluation procedure.

2.3.2 Output-outcome functions

The set of output-outcome functions is an artifact implemented in a middle-layer between the assessment form and the multi-criteria model. Technically, they will be implemented in an API taking assessment forms as inputs and delivering evaluation results from the evaluation engine. Its purpose is to provide the multi-criteria model with the performance measures of the ICT4D initiative which can be used for equitable evaluations of the initiative.

More specifically, an output-outcome function map a given output assessment from the assessment form from onto an estimated level of the outcome or outcomes related to that output. These will, for all output-outcome functions, share range for all outputs although they will be defined in different ways depending on the nature of the assessment. For instance, if the assessment is purely quantitative, its scale and unit, if it is binary like 'yes'/'no' or if it is a

qualitative ordering etc. In general, each output-outcome function can be viewed as a parametric function where parameters may be supplied by the evaluator but a default parameter setting will be suggested. This work will be conducted throughout Task 3.5 and reported on in Deliverable 3.3.

However, an output-outcome function for an output indicator is defined as a function taking as arguments the value of the output x and a set of parameters $p_1, p_2, \ldots, p_3$

$f(x, p_1, p_2, \ldots, p_n) : D_i \rightarrow [0,1]$

where D_i is the domain for the i:th output indicator. General parameters for an output-outcome function include:

p_1 : the objective of the output

p_2 : a threshold, or minimum requirements put on the output

p_3 : the priority level of this output

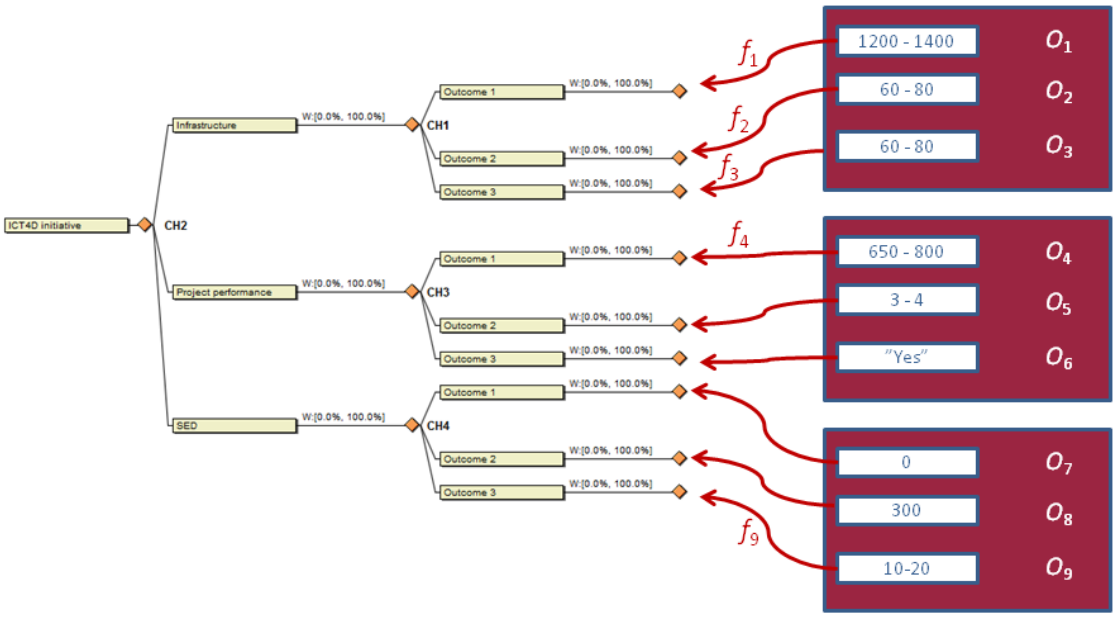

Figure 3: Outline of the evaluation process

Figure 3 outlines the evaluation process, with assessment form holding nine different fields for assessing outputs partitioned into the three evaluation dimensions, nine output-outcome functions $f_1 - f_9$ and a criteria tree that can be formally represented in order to conduct multi-criteria evaluations. Image of criteria tree is from the decision modeling software *Decide*IT.

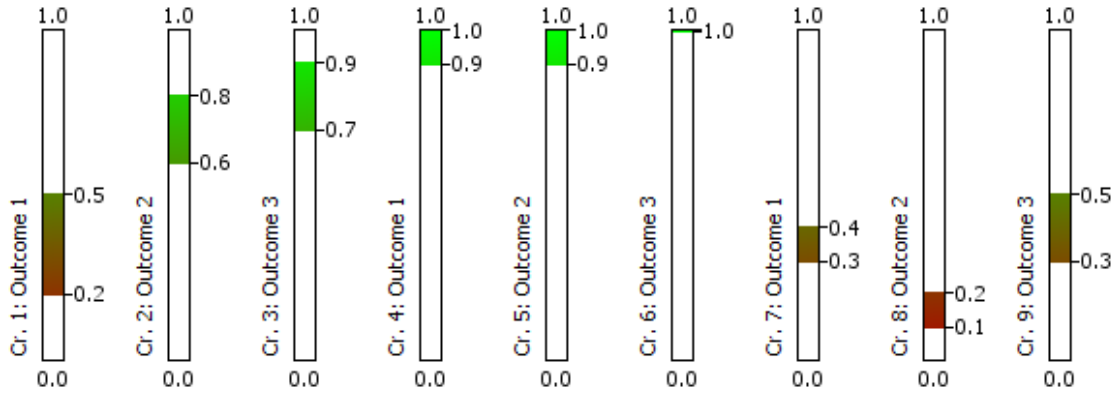

Figure 4: Example of resulting interval-valued outcome levels

Figure 4 is an example of resulting interval-valued outcome levels, from at present state undefined output-outcome functions $f_1 - f_9$ in a so called value profile. In this example the project performance (the middle three bars) executed well, but the SED impact is evaluated to be rather low (rightmost three bars). The image is taken from the decision modeling software *Decide*IT.

2.3.3 Multi-criteria model

The methods of appraisal of projects are developed in various scientific fields, one such being multi-criteria analysis (MCA), commonly called multiple criteria decision analysis when the aim is to compare decision alternatives. The primary feature of MCA is that different variables can be considered together. Although there are many different methods for MCA, they share the feature of providing aid in the clarification of what is to be assessed, how they contribute to meeting the stated criteria (sometimes referred to as objectives or attributes), and that they enable for evaluators or decision makers to expresses their values and preferences.

Sometimes it is argued that it does not really matter which method to employ, the most important is to actually use an MCA method and thereby conform to a systematic approach. For instance, (Huang et al 2011) show that when different MCA methods are used assessing the same issue, the outcome is quite similar. In this project we have chosen to use the Delta MCA method that supports imprecise information and criteria trees. The Delta method is the basis for the graphical decision analysis tool *Decide*IT which we use for multi-criteria model design purposes in this project.

Underlying a multi-criteria analysis is a formal multi-criteria model that serves as a formal representation of an ICT4D initiative assessment. The formal representation is needed in order to perform evaluations enabling for classification of projects into overall performance classes and to provide inter-project comparable results with respect to the social and economic dimensions that benefit from a project such that the comparison is fair, taking project size and objectives into account.

The use of a similar multi-criteria model, using the same evaluation technologies as the iMENTORS approach, for evaluating ICT projects has been discussed in (Kivunike et al. 2008). Note that the criteria tree does not have to be visualized when using the iMENTORS platform, i.e. it is not a front-end to evaluators (that is the assessment form). The multi-criteria model is, however, represented formally in the evaluation engine used which is to be accessible from the platform through an API taking a representation of an assessment form as input and

providing evaluation results given output indicator values and performance value function parameters.

In the formal multi-criteria model, the overall aggregated value of a project can be obtained from a weighted sum. Let ${}^{k}v_i$ denote the outcome value of a project P_i with respect to the k:th outcome, and let w_k be a numerical and normalized weight for the k:th criterion, then the expression $\mathbf{\Sigma}_k\, w_k \cdot {}^{k}v_i$ is the aggregated value of P_i when considering all criteria. The weights can be retrieved in different ways, either from the priority level parameter of the performance value function or from the actual stakeholder performing the evaluation, see, e.g., (Riabacke et al. 2012). By delimiting the summation $\mathbf{\Sigma}_k\, w_k \cdot {}^{k}v_i$ to include criteria subsets belonging to a specific dimension of social and economic development, it is possible to investigate what dimensions that benefits from the project being evaluated.

Furthermore, the aggregated value can be used as a basis for MCA classification, that is, the initiative is assigned to a class based upon the assessed outputs and the outcome levels they lead to for a specific initiative. The reason for assigning objects to classes is that class membership provides more meaning to the evaluation result than pure quantitative evaluation results. A feasible classification method for the iMENTORS domain is the UTADIS approach to classify objects based upon multiple criteria (Zopounidis and Doumpus 2002).

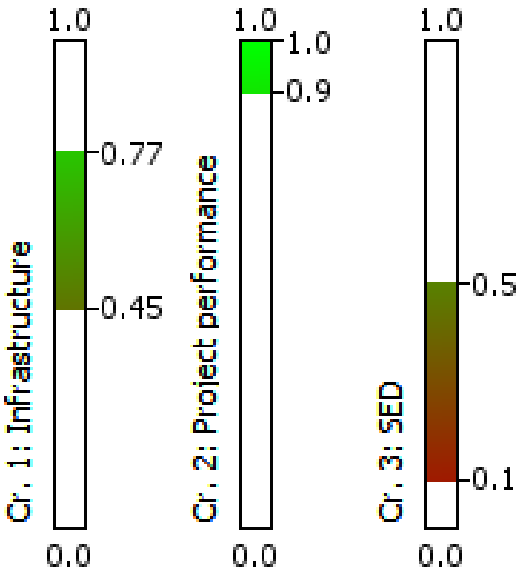

Figure 5: Example of interval-valued dimension levels

Figure 5 is an example of interval-valued dimension levels obtained from aggregating the outcome levels Figure 4 in a value profile. The image is taken from the decision modeling software *Decide*IT.

2.3.3.1 The evaluation method

With respect to multi-criteria methods supporting imprecise input statements, a number of implemented methods have been developed such as WINPRE supporting the preference programming approach (Salo and Hämäläinen 1995), Interval SMART/SWING, (Mustajoki et al. 2005), PRIME Decisions (Salo and Hämäläinen 2001), and RICH Decisions (Salo and Punkka 2005). However, the focus of these tools has been primarily on elicitation of subjective preferences rather than providing different means for evaluations and comparisons of objects (Danielson et al. 2007).

The DELTA method employed in iMENTORS focuses on the evaluation aspects and incorporates sensitivity analyses and means for evaluating parts of a multi-criteria problem such as a subset of criteria. The method is based on standard concepts of values and criteria weights (and probabilities if desired) since these concepts are well-established and therefore have been more easily accepted by decision-makers.[1]

The method takes as its starting point the use of interval-statements, but extends the ideas to the use of comparative or ordinal statements as well. It is also possible to stipulate template intervals or template fuzzy set representations associated with qualitative statements which often occur in project appraisals (Kulak et al. 2005). The method does not force the use of interval or comparative statements, but supports precise inputs as well, so that the evaluator may be as deliberately imprecise as he/she wishes to be.

The method is implemented in the Delta library, being a static C library. This library must be wrapped in a C# or Java layer enabling for method invocation so that the MCA evaluations can be called from the server hosting the iMENTORS platform, regardless of the evaluation engine being physically located on the platform server or not. For instance, the *Decide*IT decision software utilize a Java wrapper of the Delta library customized for user interaction with respect to building criteria tree and decision tree models. With respect to iMENTORS, the wrapping layer will provide a customized API for the domain at hand, being multi-criteria evaluation of ICT4D initiatives. Notably, this layer will hold the implementation of the output-outcome functions, taking as input an assessment form and returning evaluation results.

[1] For details on the representation of a multi-criteria evaluation problem and computational issues when evaluating with imprecise information, see, e.g., (Danielson 2005, Larsson et al. 2005, Danielson and Ekenberg 2007).

3 Integrating the MCA framework with iMENTORS

In this chapter we outline the technical specifications on how to enable the multi-criteria model and integrate it with the iMENTORS platform in order to enable the above approach. We categorize the requirements into three different categories:

1. Web GUI requirements,
2. Database requirements, and
3. Decision method requirement.

The deployment diagram blow shows how the platform interacts with wrapped Delta library and its evaluation API and the Delta multi-criteria evaluation engine.

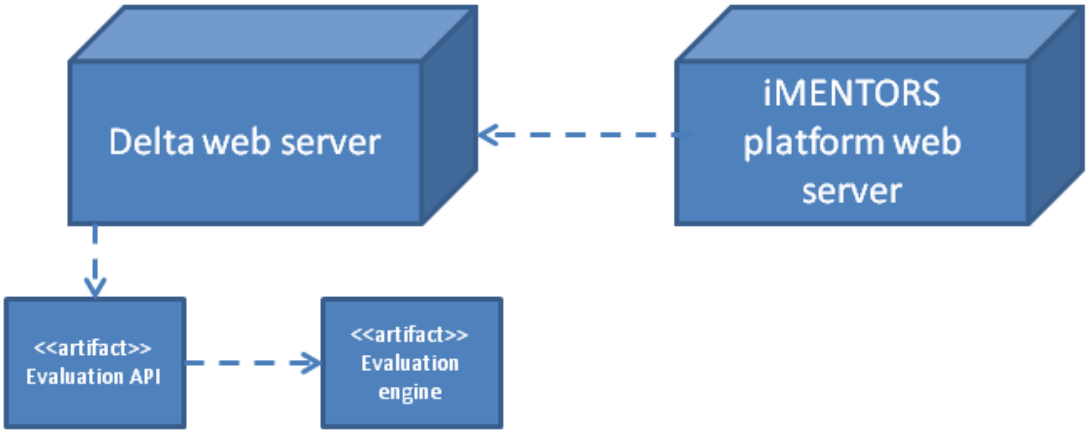

Figure 6: Simple deployment diagram for multi-criteria evaluation feature of the iMENTORS platform.

3.1 Web GUI requirements

These requirements stem from that the evaluators must be able to provide output assessments for any given project. The assessment form will therefore be designed for web-based usage.

Users assigned to a project (by updating the respective project or the user's profile) will be given the rights to perform an assessment by filling out the assessment form.

Template assessment forms feasible for the type of project being assessed will be developed as part of Task 3.3 and Task 3.5.

3.2 Database requirements

The requirements put on the database is due to that MCA evaluation results and output assessments for any project should be retrievable through the platform and that queries based upon assessments and evaluations should be enabled. Hence, a one-to-many relationship between an ICT4D initiative entity and an assessment entity should be present in the iMENTORS database.

Adequate fields for the database and specifications of the assessments and evaluation results entities are to be specified as part of Task 3.5.

3.3 Decision method requirements

The requirements put on the decision method are derived from the needed features of the MCA methodology outlined in chapter 2 of this document.

The requirements include:

1. Capability of representing a criteria hierarchy,
2. Capability of handling imprecise information and conduct evaluations with such,
3. Possibility to utilize the decision methods through a customized API implementing the output-outcome functions.

These requirements are met by the Delta library evaluation engine. Technically, the decision method implemented in the Delta library is made available through remote calls to the API wrapping the evaluation engine.

The software development needed for the multi-criteria evaluation is restricted to the wrapping layer and its API since the Delta library already exists.

3.4 Next Steps: Development Plan

This section contains a straightforward step-by-step outline of the artifacts that need to be developed in order to realize the integration of the decision analytical framework and the iMENTORS platform. Item 1-2 and 3-4 can be done in parallel. Item 3 is partly dependent on item 2 since the output-outcome functions are to be implemented in the wrapping library.

1. A web-based assessment form on the iMENTORS platform with a database entity for an assessment relative to an ICT4D initiative.
2. Definition and implementing the output-outcome functions as part of the wrapping library.
3. An iMENTORS wrapper library for the multi-criteria engine in order to enable cross language interoperability, i.e. the platform can invoke evaluation methods passing an assessment form as argument.
4. A call API for the wrapping library adapted for the iMENTORS multi-criteria model
5. The classification scheme for the evaluation results. This need only be tentative to perform the integration.

Conclusions

In this document, we have outlined an approach for assessing and evaluating ICT4D initiatives by using linking the value chain model to a multi-criteria evaluation method. In relation to the value chain components, the objective of the evaluation is to link observable outputs of an ICT4D initiative to foreseen benefits and to what broader areas of development these contribute to. Consequently, we make the following distinctions between elements part of an ICT4D initiative assessment.

- The ***outputs*** are the direct changes associated with the technology and consist of accessing information, enabling interactions, and performing transactions.
- The ***outcomes*** are the direct benefits in terms of measurable (both quantitative and qualitative) benefits as well as costs associated with the outputs. For instance reduction in transaction costs is an outcome resulting from performing online transactions like sending mobile money.
- The ***development impacts*** refer to the broader ICT contribution the broader development goals, they are less tangible.

The multi-criteria evaluation model consists of three fundamental dimensions;

1. the infrastructure dimension,
2. the project performance dimension, and
3. the socio-economic development dimensions.

The infrastructure and project performance dimensions are prerequisites for the socio-economic development dimensions which facilitate the realization of development. In relation to the value chain, these two dimensions stipulate output and are more closely related to project deliverables and lack sub-dimensions or indicators. Under social and economic dimensions, the sub-dimensions are the outcomes, while the outputs consist of ICT opportunities generally categorized as accessing information, enabling interactions, and performing transactions.

Immediate steps include defining the assessment scales and indicators for each of these categories based on the initiative and provide usable templates for web-based entering of assessment data from evaluators, as well as defining reasonable output-outcome-functions enabling for evaluating upon the social and economic dimension. In parallel, a wrapping library skeleton is developed. Given a definition of the output-outcome functions these are to be implemented as part of the wrapping library.

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