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National Strategic Implementation plan for using Cloud Computing in Education in Arab Countries

January 2018

The Arab League Education, Culture and Science Organization (ALECSO) is a Tunis-based specialized institution working under the umbrella of the League of Arab States. It is essentially concerned with the development and coordination of the activities related to education, culture and science in the Arab world.

The International Telecommunication Union (ITU) is the United Nations specialized agency for Information and Communication Technologies – ICTs. The ITU Arab Regional Office in Egypt provides the support to ITU Members in the Arab Countries under several activities related to ICT development and deployment of telecommunication/ICT infrastructure and services.

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Executive Summary

Technological development and globalization, the corollary of which is the competition in all sectors, have not spared the higher education today called to be part of the generalized movement of transformation. The university is called not only to adapt to the digital age but also to seize the opportunities that digital technologies offer to accomplish its mission in a world where the physical boundaries of access, dissemination, and knowledge production fade.

Cloud computing is one of the most important vectors of the current and foreseen transformations in higher education. To foster its adoption in Arab countries, ALECSO and ITU have published in 2016 a detailed report entitled "Guidelines to improve the use of Cloud Computing Technology in Education in Arab Countries". This first report focused mainly on:

- Developing specific guidelines for migrating to the cloud which take into account several parameters and national contexts for the Arab countries;
- Delivering a cloud migration policy for decision makers;
- Defining a roadmap to develop and deploy cloud infrastructures and platforms for education and research.

In addition to this first report, Alecso and ITU have launched a second study aimed at furthering the design and implementation of a migration strategy towards cloud computing in education. and especially universities in Arab countries.

This second report therefore aims at guiding participants in the elaboration of their own vision and national strategy for mass adoption of cloud computing in higher education. The development of a vision and strategy for migration to the cloud requires a structured approach that considers different facets of cloud computing and the context in which Higher Education Applications' migration will be implemented. To meet such requirements, a general model of the Digital University (DU) as well as a contextualization approach and tools for designing and implementing the cloud migration strategy have been developed.

This report is structured in 5 chapters:
- the first chapter presents an updated summary of the ALECSO-ITU "Guidelines to improve the use of Cloud Computing Technology in Education in Arab Countries"
- Chapter 2 presents the vision and model for the Digital University
- Chapter 3 customizes the digital university model
- Chapter 4 contextualizes the vision for the cloud
- Chapter 5 builds migration/implementation strategies.

The report ends with a general conclusion.

Updated summary of the ALECSO-ITU "Guidelines to improve the use of Cloud Computing Technology in Education in Arab Countries"

This chapter begins by presenting the state of the art in cloud adoption and cloud technologies. It recalls the 3 service models IaaS, PaaS, SaaS, the 4 deployment models (private cloud, community cloud, public cloud and hybrid cloud) as well as the policy guidelines that are:

- Key policy 1: Give to investment in a high quality network (intranet+access to INTERNET) the highest priority
- Key policy 2: Always Public cloud first.

This policy consists in encouraging the use of public cloud as the first choice wherever possible which enable educational institutions fast access to advanced IT and helps catching up with international practice.

- Key policy 3: “Cloudify” the existing local infrastructures and applications at institutional level.

This policy aims at facilitating and speeding up cloud migration through “cloudification” solutions to be adopted to improve the management of the existing IT infrastructure without disrupting the operation of the applications used by educational institutions.

- Key policy 4: Adopt a cloud friendly governance model for IT.

This policy aims at providing ease of use and flexibilityof IT cloud resources for users and proposes the establishment of an intermediary entity which should facilitate relationships between suppliers and customers.

The chapter also recalls the main supports necessary for the migration to the cloud in the countries of the Arab world and insists on two fundamental aspects: capacity building and cultural change. It also presents use cases for three migration scenarios : SaaS Migration, IaaS and PaaS Migration, Cloud Service Brokerage for IaaS and PaaS Migration.

The second part of the chapter presents the State of ICT and cloud computing in education in the Arab World. Global ICT Indicators of Arab countries have been updated and countries have been classified into four groups. In addition, a new indicator has been introduced which is the number of Facebook subscribers. To better understand the state of cloud computing in education in the Arab World, the main results of the survey conducted on the adoption of the cloud in educational and research institutions in the Arab countries were recalled.

The third part of the chapter is devoted to the presentation of country experiences related to cloud computing in education. The cases presented are those of Morocco, Jordan, Saudi Arabia, Bahrain, Tunisia, Sudan, Djibouti, Comoros and Mauritania. An update on the status of the transnational meta-cloud for Higher Education, RosettaHUB, is also provided.

The review of countries’ experiences confirms that cloud adoption is a movement that is gradually spreading and gaining momentum within the higher education institutions of the Arab world. Bahrain has developed the most comprehensive national strategy for cloud computing adoption in e-government which encompasses Education. However, most Arab countries haven’t yet developed their own national strategies. It is timely to provide tools to support those countries in building such strategies as well as practical measures for their implementation and thus help them succeeding their migration to the cloud.

Vision and model for the Digital University

This chapter summarizes and reuses substantial parts from "An Avalanche Is Coming, Higher Education And The Revolution Ahead" [16] and "Digitizing Higher Education To enhance experiences and improve outcomes" [17] .

Higher Education is facing growing challenges. The global economy is changing. Both in commercial terms and at a standard level, the value of university degrees is falling. The internationalization of Higher education and the ever-growing global student opportunities are confronting universities with unprecedented and furious competition. Globalization is enhancing the number of potential students who "shop" globally for the best higher education offerings. This trend will accelerate as public funding for higher education around the world is reduced and replaced by private funding such as loans or direct payments.

Universities will have to rethink their business model and embrace massively innovative educational technology: They have to cater for a generation connected from birth which uses massively social media and evolve seamlessly within globalized digital communities.

Moreover, universities are struggling as all their costs are growing. There is an urge to review and optimize governance and administration and to rationalize the use of staff members, physical resources, buildings, etc. The forces that have brought about these changes in higher education are the very tools we need to solve them. University has to adapt to the digital age; higher education has to change its very DNA while keeping what is most essential to its mission. The essence of the university can not only survive but also thrive in the new digital age.

A digital University is one in which, all staff, academics and students use technology tools on a day to day basis. A digital University is also one that runs all aspects of its business with digital technology at its heart to achieve academic excellence, enhance brand, interact and work closely with ecosystems, perform internationally recognized research and achieve financial stability and efficiency.

The development of a vision and strategy for migration to the cloud requires the definition of a structured approach that takes into consideration different facets of cloud computing and the context in which it will be implemented. To meet such requirements, a general model of Digital University (DU), a contextualization approach and tools for designing and implementing the cloud migration strategy have been developed.

The basic principle behind the development of the DU and all the tools for designing and implementing the strategy is the adaptability to the diverse countries' contexts in the Arab world.

Our model of the Digital University DU is built upon six components, two transversal and four vertical ones. The four vertical pillars are the “Digital Campus Management”, the “Digital Teaching & Learning”, the “Digital Research” and the “Ecosystem digital links”. The two transversal layers are “the Digital Strategy & Vision layer” and “The IT service delivery Platform”. Each of the first 5 components includes specific objectives. Achieving objectives requires a set of specific IT applications in addition to common IT applications.

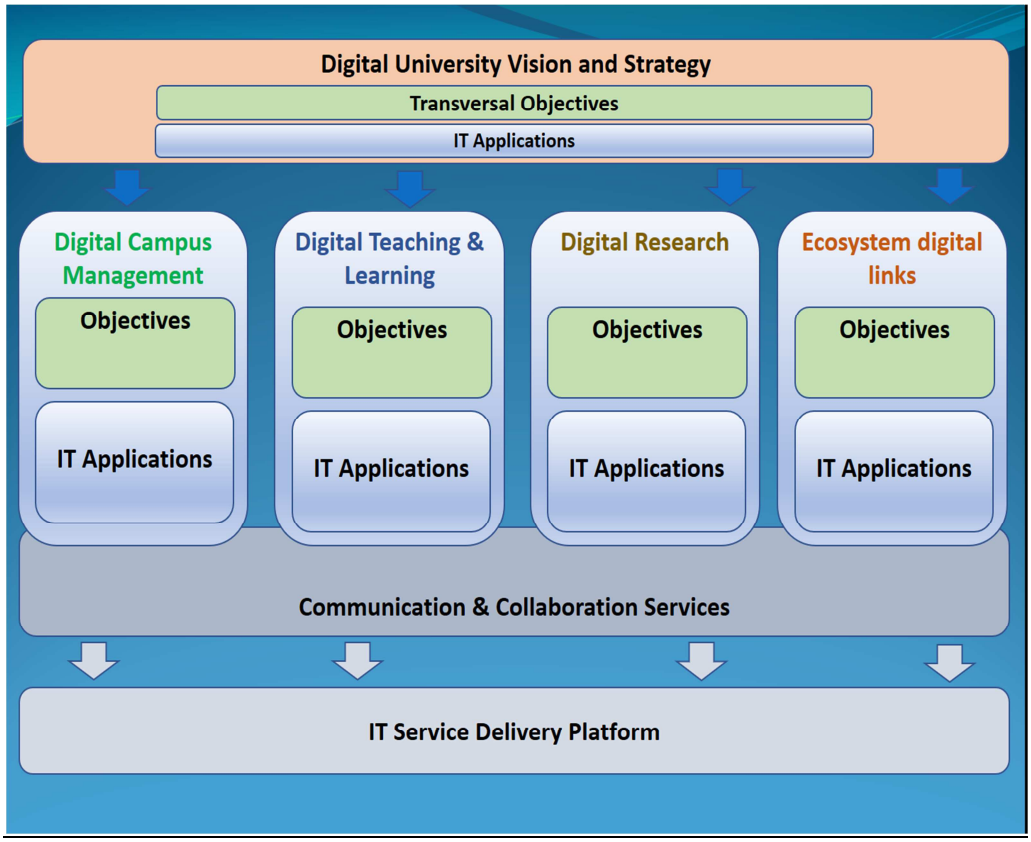

Fig. 1 Digital University high-level model

The general model in Figure 2 specifies the set of objectives and applications for all components of the DU. However, their adaptation at countries and universities levels are required.

Customized digital university model

Among the objectives and applications mentioned in Figure 2 of the DU general model, each ministry of education and / or each university may, depending on its resources and skills and other specific conditions, define strategic objectives for each DU component and choose, using the tools developed in this report, the applications most likely to help achieving those objectives.

A subset of IT applications has been selected and prioritized according to their respective contributions to the objectives for each DU pillars and for the “Vision and strategy” transversal layer.

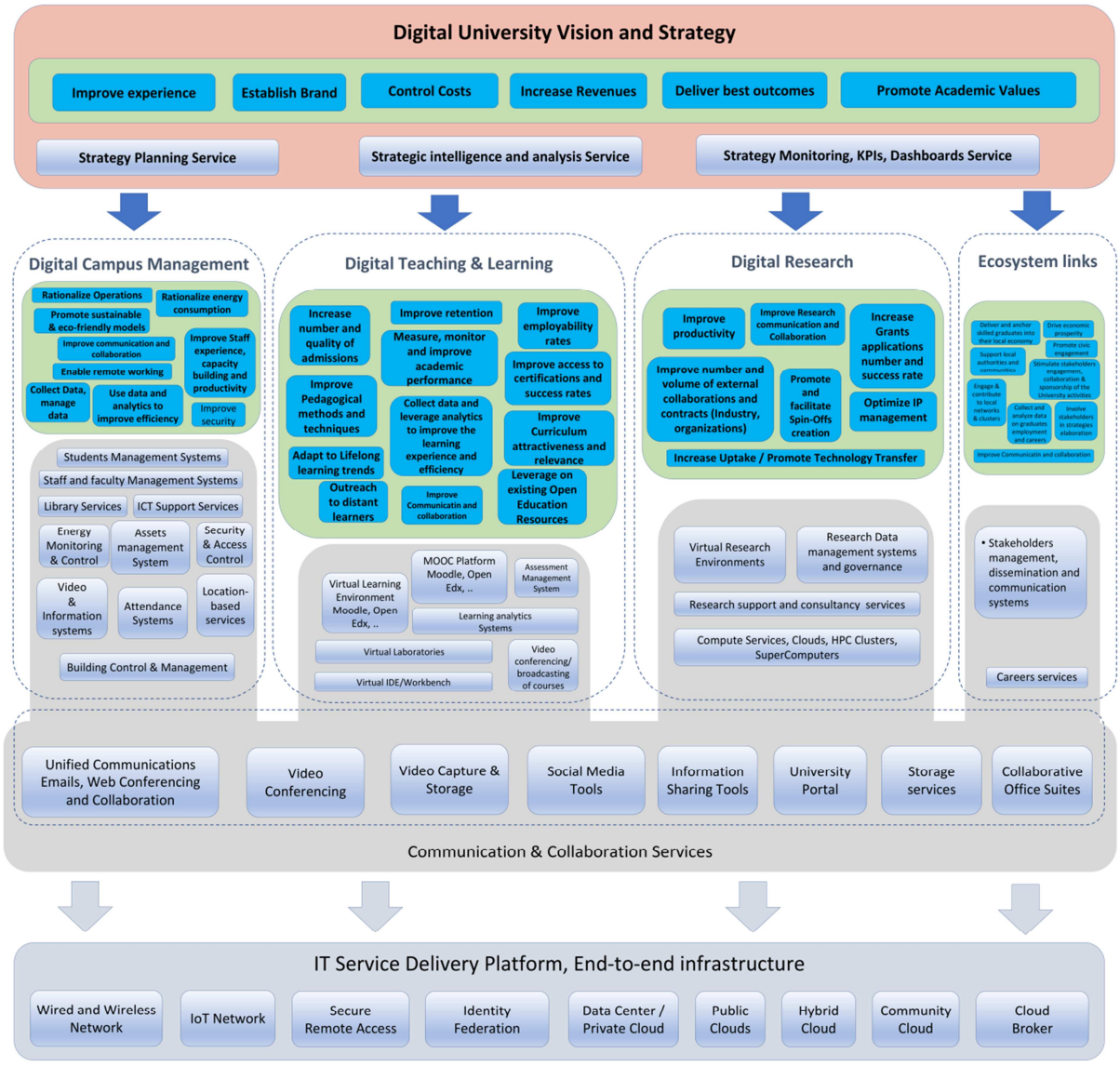

Fig. 02 Expanded Digital University Model (DU Model)

To guide the project team in defining the vision for the DU, a three-layered decision-making model has been proposed. Three typical layouts for strategic decision making and choices of macro objectives and IT Applications are considered: Ministry only decides, Ministry and University decide, the three actors decide. The 3 cases are defined alongside with examples.

Contextualized vision for the cloud

This chapter will focus on the "IT service delivery platform and end-to-end infrastructure" layer and will lead to the elaboration of a contextualized vision for the cloud.

The elaboration of a cloud vision is based upon the choice of the type of cloud to use. This choice should be well informed and should leverage the cloud adoption policy guidelines presented in the 2016 report and especially Key Policy Guideline 2: Always Public cloud first.

The policy to be adopted consists in encouraging the use of public cloud as the first choice wherever possible and hence enabling educational institutions fast access to advanced IT and

catching up with international practice. It is recommended to consider Always SaaS first and Use Pubic PaaS/IaaS instead of local infrastructures. Software-as-a-Service should be considered first, it entirely delegates all the unwanted complexity to a service provider and empowers users through seamless access to tailored and effective Web User interfaces. PaaS and IaaS (public if possible or private otherwise) should then be considered as the way to go when it comes to the provisioning of custom applications and capabilities, they expose more complexity but can be harnessed thanks to APIs and automation frameworks. Existing on-premise applications that (i) have critical constraints or (ii) wouldn't benefit from public or private clouds or (iii) can't be cloudified should continue operating on-premises.

The elaboration of a cloud vision should also take into consideration cloud-type-specific SWOT analysis for the pre-chosen cloud types. Identification of SWOTs is important because they can inform later steps while planning to achieve the objective. A catalog of possible SWOT factors for each of the four dimensions (opportunities, threats, strengths and weaknesses) is proposed. The decision making bodies as well as all the different impacted stakeholders should contribute to the SWOT analysis and should help defining the factors belonging to the four quadrants. What is required is not to simply enumerate factors but also to fully identify them, assess their importance and prioritize them in a rational manner. The outcome of the SWOT analysis makes the choice the type of cloud to adopt easier.

The migration to the cloud requires a change in IT governance models and practices. For instance, the model should enforce two main requirements for the services to be made available to users : ease of use and flexibility. The model should consider the introduction of an intermediary entity which facilitates relationships between suppliers and customers. It is recommended to adopt a cloud friendly governance model for IT.

Building migration/Implementation strategies

This chapter aims at helping the project team define migration plans for the retained IT applications. The feasibility and the complexity of the migration depends on many critical factors, for example the existence of a high-speed internet access.

In the first part of the chapter, we define a list of critical factors. Critical factors are pre-requirement for migrating IT Applications to the cloud. Without them, migration might not be feasible at all or might have a high risk of failure. That's why it is essential to check how well the institution fulfills those factors before deciding to migrate. However, critical factors are not equally important, a few are essential, others might be relevant only to a few IT applications. We propose a tool to quantify both the cross-applications criticality level for the different factors and the "Migration Difficulty Score » for IT applications. The factors that expose a high cross-applications criticality level should be prioritized accordingly. IT Applications with a low "Migration Difficulty Score » should be first to consider for migration.

The second part of the chapter provides typical migration scenarios for the different pillars as well as a tool for elaborating detailed plans. Its aim is to help defining the objectives of each

application that could potentially be migrated to the cloud and to translate the sub objectives into activities and sub-activities. Then, it helps estimating the required resources, the team structure and size and the timeline to achieve each activity. It helps considering planning and monitoring aspects such as resources, stakeholders, KPIs, etc. Each migration scenario starts by providing

- The DU pillar it belongs to
- Its target cloud style (IaaS, PaaS, SaaS)
- Its target cloud type (Private, Public, Hybrid, Community, Cloud Broker)
- The vendor of the technology it migrates to
- Whether it relates to an existing application or a new one
- The nature of the application being migrated (legacy, open source, etc.)

Five typical migration scenarios are provided.

Scenario 1, "Migration to a private cloud with OpenStack"
Its objective is to deploy a legacy Students Management System on an OpenStack-based private cloud

Scenario 2, "Migrating Moodle to AWS"
Its Objective is to deploy a Virtual Learning Environment / LMS based on Moodle on Amazon's public cloud

Scenario 3, "Migrating Research Computing Services to the cloud using a cloud broker, AWS, Azure and Google Cloud Platform (GCP)"
Its objective is to **deploy** a Cloud broker and a collaboration portal to access compute and storage capabilities for research on AWS, Azure, GCP and Open Nebula-based research cloud in order to provide each researcher and each PhD student with a managed /monitored personal public cloud account**.**

Scenario4, "Migrating SharePoint-based portal to Azure 365"
Its objective is to **deploy** a Stakeholders management, dissemination and communication portal/CMS based on Microsoft SharePoint on Azure.

Scenario 5, "Migrating communication and collaboration services to G Suite for education"
Its objective is the use G Suite for education for communication (GMAIL, HANGOUTS) Collaboration (G Docs) Courses management (G Classroom) and cloud computing/big data education.

Conclusion
The key principle behind the development of the DU and all the tools for designing and implementing the strategy is the adaptability to the diversity of contexts of Arab countries. These tools are designed so that the main actors within the ministries and / or universities

can, through discussion and dialogue, not only reduce / add elements composing these tools, but also review and update their degree of importance in acting on the weights. This process is initiated by the contextualization of the tools that allow an exchange based on the argumentation of the actors. As a result, the process and the tools that underpin it bring views together and foster the emergence of a shared vision and a consensus around goals, their priorities, and the means to achieve them. This creates the right conditions for the acceptance, commitment, and involvement of the actors.

The migration of universities to the cloud is not limited to its technological dimension. It involves a set of actors including decision makers, beneficiaries and teams involved in the implementation of change. The latter is to be interpreted as a dynamic process of material and immaterial transformations, including the culture of the university. This process is part of a proactive strategy of permanent renewal with regards to technological evolutions and modes of work and collaboration.

The success in migrating to the cloud in Higher Education is conditioned by the adoption of a participatory approach that puts emphasis on the development of the university's capacity to change and adapt. It is essential to conduct and steer change in a way that enables the greatest autonomy of the different actors while respecting key guidelines and preserving core strategic objectives.

Introduction

Just as globalization and technology have transformed huge sectors of the economy in the past 20 years, higher education faces today radical transformations. It is urged to adapt to the digital age and change its very DNA. Universities have to overcome the compelling challenge of preserving their soul and keeping what is most essential to their mission while thriving in the new digital age. Cloud computing is one of the most important vectors of the current and foreseen transformations in higher education. To foster its adoption in Arab countries, ALECSO and ITU have recently published a detailed report [1] and proposed a set of key policy guidelines. As a follow-up to this valuable study, both partners agreed to launch in 2017 a specific program with the aim to offer their assistance to Arab countries in order to develop their national implementation strategies on using cloud computing in Education. The first event of the new program consisted of a 2-day workshop supported with the publication of a new report on "National Strategic Implementation plan for using Cloud Computing in Education". The event welcomed decision makers from Ministries of ICT and higher education, experts in ICT and Arab universities faculty members using or foreseeing the use of cloud computing in teaching or research.

The report aims at guiding participants in the elaboration of their own vision and national strategy for mass adoption of cloud computing in higher education. It explains, synthesizes, and complements the 2016 report. Key aspects covered will be:

- project the overall digital strategy into a digital university model and leverage instruments for elaborating the contextualized strategy and conceiving the tools for its implementation
- Analyze current challenges and trends in Higher Education and present an overall vision aiming at promoting the digital university concept in the Arab World.
- Provide an up-to-date status of ICT in the Arab World
- Explain the foundation of cloud computing and its key applications in Higher Education
- Present and explain the rationale behind the “Alecso-ITU Guidelines to improve the use of Cloud Computing Technology in Education in Arab Countries”
- Propose country-customizable templates for SWOT Analysis, strategy design and actions planning to help participants in elaborating their own vision and national strategy for an effective migration to the cloud of their higher education institutions.

The 2-day workshop or inception meeting combined presentations, discussions, group brainstorming activities and the drafting of national implementation strategies by participants. The workshop familiarized participants with the different concepts involved, explained the trends of HE digital transformations and highlight the key role of cloud computing in those transformations. It outlined the current status of ICT adoption in Arab countries and enriched that overview with participants’ contributions and discussions. Most importantly, the workshop described and explained the different proposed instruments and templates that were

used by participants during the group brainstorming sessions to elaborate their own vision and to draft their customized national strategies. The workshop also guided them towards translating those strategies into action plans while taking into consideration all management, resources allocation, monitoring and evaluation aspects.

Participants used the templates, slides and spreadsheets provided during the workshop to elaborate their own strategies drafts which were presented as slides and filled in templates to their colleagues and discussed.

Chapter 1
Updated summary of the ALECSO-ITU "Guidelines to improve the use of Cloud Computing Technology in Education in Arab Countries"

The objective of this chapter is to remind readers of the main facts, ideas and outcomes of the 2016ALECSO-ITU"Guidelines to improve the use of Cloud Computing Technology in Education in Arab Countries"Report (to be named from now on the 2016 Report, [1]).

It updates and complements the state of the art and elaborates further on the relevance of cloud computing for Higher Education. It also updates and complements the State of ICT and cloud computing in education in the Arab World. This includes an update of some ICT indicators. Finally a reminder of Cloud Adoption policy guidelines is also provided.

The2016 report is structured as follows:

- The first part deals with the state of the art of cloud adoption and cloud technologies; It explains the concepts, introduces some initiatives, and surveys focusing on cloud computing in education and research and sketches technical elements of the cloud ecosystem in order to characterize the main tools used in production around the world;
- Chapter 2 classifies the Arab countries according to their level of development in the ICT field; It also presents the methodology adopted to conduct a survey on cloud computing in the Arab countries as well as the survey's results;
- Chapter 3 outlines the policy recommendations taking into account the findings related to current state of cloud adoption worldwide, particularly in educational and research as well as the outcome of the survey and the state of ICT in the Arab world;
- Chapter 4 provides a practical guide to help educational institutions and information technology (IT) managers plan and operate application and workload migration to the cloud. It provides a detailed roadmap that covers a list of technical steps for migration.

1.1 State of the Art in Cloud Adoption and Cloud Technologies

Cloud computing is a delivery model for applications, platforms and infrastructures over the Internet. It brings substantial value and benefits in terms of cost, performance and agility and enables ubiquitous, reliable and collaborative access to data and applications. It democratizes access the high-end infrastructures and innovative software technologies like never before.

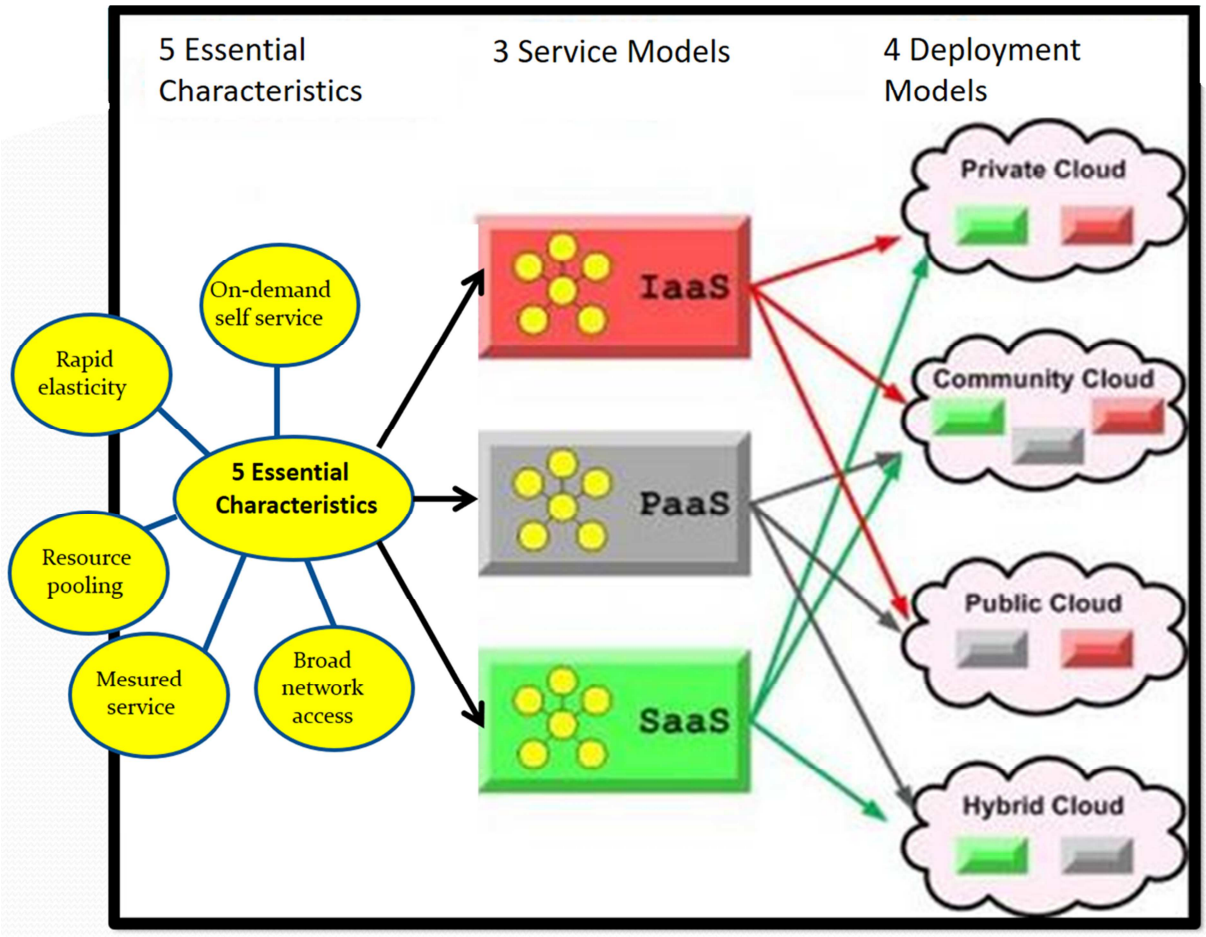

Fig. 3 Cloud computing characteristics and deployment model [2]

Software as a Service (SaaS), represent the largest cloud market and are still growing quickly. SaaS uses the web to deliver applications that are managed by a third-party vendor and whose interface is accessed on the clients' side. Most SaaS applications can be run directly from a web browser without any downloads or installations required, although some require plugins. SaaS in Higher Education has come a long way. One of the most successful example is **Google Apps for Education.**

Fig. 4 Google Apps for Education [3]

Google Apps for Education consists of a complete suite of communication and collaboration cloud applications. Included in the suite are Gmail, Calendar, Drive, Sites, Groups, Google+, and Hangouts. Google Drive includes "The Docs Editors": Docs, Sheets, Forms, Slides, and Drawings. This is a power suite of applications that are heavily integrated with one another for rapid communication and collaboration in the cloud. Google Apps for Education Anticipated to Reach 110 Million Users by 2020 [4].

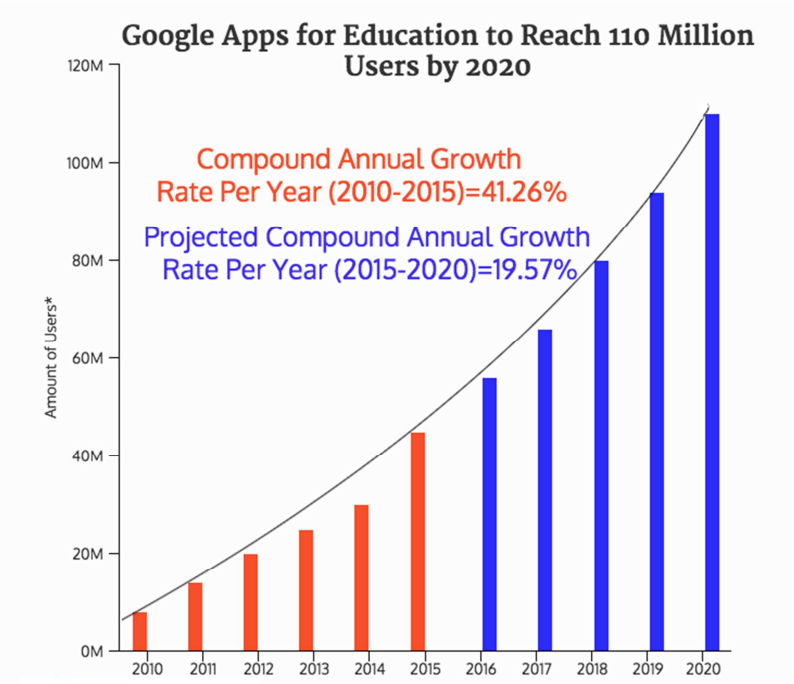

Fig. 5 Google Apps for education growth [5]

Office 365 delivered from the Microsoft cloud is also a very widely used SaaS for Higher Education It consists of similar services to the Google for Educations ones.

Fig. 6 Office 365 [6]

Platform as a Service (PaaS), are used for applications, and other development, while providing cloud components to software. What developers gain with PaaS is a framework they can build upon to develop or customize applications. PaaS makes the development, testing, and deployment of applications quick, simple, and cost-effective. With this technology, enterprise operations, or a third-party provider, can manage OSes, virtualization, servers, storage, networking, and the PaaS software itself. Developers, however, manage the applications [7].

Infrastructure as a Service (IaaS), are self-service models for accessing, monitoring, and managing remote datacenter infrastructures, such as compute (virtualized or bare metal), storage, networking, and networking services (e.g. firewalls). Instead of having to purchase hardware outright, users can purchase IaaS based on consumption, similar to electricity or other utility billing [7].

The cloud resources can be public, private or hybrid. The **public cloud** is defined as computing services offered by third-party providers over the public Internet, making them available to anyone who wants to use or purchase them. They may be free or sold on-demand, allowing customers to pay only per usage for the CPU cycles, storage, or bandwidth they consume. The **private cloud** is defined as computing services offered either over the Internet or a private internal network and only to select users instead of the general public. A **hybrid cloud** is a computing environment that combines a public cloud and a private cloud by allowing data and applications to be shared between them [7].

Mimicking public clouds on private infrastructures shrinks the spectrum of benefits. The economic advantage is reduced as capital investments are required. The technological agility is reduced as scalability can't happen beyond the limits of the provisioned computers. Private cloud restricts access to innovation both in the hardware and software spaces. It became clear today that the most viable approach is the hybrid one: Use the public cloud wherever possible and keep applications with strict legal or privacy constraints on premises, eventually on an infrastructure that is virtualized and automated the cloud way [7].

The Main global trends in the cloud market and the state of adoption [1] are summarized as follows:

- The cloud infrastructure will be available as affordable services part of the ambient environment, and as a commodity;
- The public cloud market has experienced a tremendous growth over the past few years. The Saas segment will continue to outrun the IaaS and PaaS segment with about 60% of total market in 2018;
- Cloud applications will account for 90% of worldwide mobile data traffic by 2019, compared to 81% at the end of 2014;
- Major providers in public cloud are Amazon (AWS), Microsoft (Azure) and Google (GCP). AWS dominates the public cloud.

RightScale's recent survey (2015) on a sample of 930 organizations belonging to various sectors of activities shows that:

- Cloud is a given and hybrid cloud is the preferred strategy of the respondents.
- Scalability, faster access to infrastructure, and availability are the top three benefits experienced using cloud, whereas "security" and "lack of cloud resources and expertise" are the top 2 challenges.
- Central IT teams are increasingly offering self-service portals as a central hub to broker cloud services to the enterprise

The NSF-XSEDE cloud adoption survey (2012-2013) conducted in higher education and research institutions across a wide variety of scientific areas and the humanities, arts, and social sciences, found that:

- The cloud benefits identified by the survey participants were: flexible pricing model, lower costs, compute elasticity, data elasticity, Software as a Service, Education as a Service, broader use, scientific workflows, rapid prototyping, and data analysis;
- The cloud challenges identified included the learning curve, the variability in bandwidth, the lack of private/public cloud interoperability, the security, the data movement and cloud computing cost and the funding availability.

Given the importance of the cloud phenomenon, the European Commission and the National Science Foundation (NSF) launched major initiatives in cloud computing. The EU adopted strategy in 2012 for "Unleashing the potential of cloud computing in Europe". It also adopted cloud computing among the research priorities in the H2020 research and innovation funding program. The Commission announced the launch of a cloud for research data – the 'research

open science cloud'. The 'European Open Science Cloud' aims to create a trusted environment for hosting and processing research data to support EU science in its global leading role.

In August 2014, The NSF has announced the funding of several projects to create cloud computing test beds “to enable a new future for cloud computing”. It aims at **transforming** the current US research environment by supporting research infrastructure, enabling transformative research at the frontiers of computing.

In addition to these initiatives, several universities have adopted and actually migrated a certain number of applications such as distance learning and / or scientific research applications to the public cloud.
Among the universities that have migrated educational applications to the public cloud, the examples of Anhanguera in Brazil, The Khan Academy, The Tokyo University of Technology, the AMP Lab at the University of California Berkeley, The University of Hawaii at Manoa, the University Sorbonne Paris Cité are noteworthy.

- Anhanguera one of the largest universities in Brazil and in the world supporting distance learning, Anhanguera is one of the largest users of Moodle, an e-learning platform for collaborative learning, migrated Moodle to Amazon AWS ;
- The Khan Academy posts a vast collection of free educational online. Students answer some 1.5 million practice questions per school day all served through Google App Engine.

- The Tokyo University of Technology (TUT) has opted for a full shift of its ICT environment to the Azure cloud.

Among the universities that have migrated scientific applications to the public cloud, the following examples are worth mentioning:

- The Algorithms, Machine, and People (AMP) Lab at the University of California Berkeley leverages AWS to quickly scale the compute resources needed to apply analysis algorithms to genomic data;
- The Collaboration project MSSNG Autism Speaks adopted Google to migrate and scale up its database to hold information from the whole genomes of 10,000 individuals, making it the world’s largest single repository of autism-related DNA sequencing data.

In addition to these experiences with the public cloud, educational institutions have adopted private or community cloud models. Two case studies are to be mentioned:
- The University of Hawaii at Manoa (UHM) College of Education (COE) located on several remote islands adopted the open source cloud platform OpenStack to virtualize its infrastructure;

- In 2015 the University Sorbonne Paris Cité (USPC) decided to renovate and to federate its research infrastructure through the launch of a community cloud based on the Open Nebula open source technology.

1.2 Cloud adoption: Policy guidelines

Policy recommendations presented are based on the findings related to cloud adoption in the world and particularly in educational institutions [1]. They also refer to the state of infrastructure and ICT development in the Arab world as well as to the rate of cloud adoption or intentions and preferences with regard to cloud migration for a sample of educational institutions

The development of the key policies presented below is also the result of a literature review and of intensive exchanges and debates between the experts of the project.

Four key policies are proposed. These policies are structured according to major stakeholder's profiles: ministerial departments, universities and educational institutions.

Key policy one: high quality network

Arab countries whose ICT Development Index scores are average or weak need to accelerate the development of their network infrastructure in order to foster and succeed in migrating to the cloud. The first key policy principle is: ***Give to investment in a high quality network (intranet+access to INTERNET) the highest priority***. To this end:

- **Ministries** in charge of higher education and research should negotiate contracts' frameworks and SLAs at national level with Telecom operators to provide a best of breed network access to all institutions regardless of their locations and size. Bandwidth should be appropriately sized and should be upgraded on a regular basis.
  It is essential to coordinate with the different ministries in order to implement a framework of incentives promoting universal access to the internet. Students, teachers and researchers should be able to have access to a reliable internet connection not only on campus but also at home (anywhere anytime).
- **Universities/ higher education institutions** have to allocate the right budgets to deploy a redundant/reliable high-quality intranet, properly sized and supported.
  Wireless access should be provided and campus-wide coverage should be optimal and permanently monitored and supported. Wired connections should be available in all the rooms where learning and practical activities requiring maximum reliability and bandwidth are taking place.
  It is recommended to negotiate with hardware providers to lower the barrier for acquiring laptops and negotiate with Telecom operators to lower the barrier for gaining 3G/4G internet access on mobile devices to all students, teachers and researchers.

Key Policy 2: Always Public cloud first

Public Cloud computing offers computing capacity and storage as well as a wide range of services and scientific applications that can be used as needed. It offers flexibility, efficiency

and enables users to benefit from developments made by suppliers. Services are accessible via the Internet everywhere all the time.

The policy to be adopted consists, therefore, in encouraging the use of public cloud as the first choice wherever possible and hence enabling educational institutions fast access to advanced IT and catching up with international practice: ***Always public cloud first*** is the second key policy

It is recommended to consider Always SaaS first and Use Pubic PaaS/IaaS instead of local infrastructures. Software-as-a-Service should be considered first, it entirely delegates all the unwanted complexity to a service provider and empowers users through seamless access to tailored and effective Web User interfaces. PaaS and IaaS (public if possible or private otherwise) should then be considered as the way to go when it comes to the provisioning of custom applications and capabilities, they expose more complexity but can be harnessed thanks to APIs and automation frameworks. Existing on-premise applications that (i) have critical constraints or (ii) wouldn't benefit from public or private clouds or (iii) can't be cloudified should continue operating on-premises.

- **Ministries** in charge of higher education and research should negotiate contracts' frameworks with the key global and local cloud providers. Engage in ambitious partnerships with those players (such as Google, Microsoft, Amazon, etc.) in order to make the use of cloud in education part of a larger framework of cooperation, promotion of innovation and adoption of cutting-edge IT solutions throughout their countries.
  Ministries should also put in place communication strategies contributing to a mindset shift about pervasiveness of cloud solutions.
- **Universities/ higher education institutions** should review all services and applications in use, benchmark existing SaaS alternatives and migrate if a mature and satisfactory solution exists which also respects the different constraints and legal rules of the institution.
  For PaaS/IaaS migration, IT departments should train their members on technologies such as containers and clouds automation APIs and tools. They should expose self-service portals to the end user and automate user interaction with tools and applications as much as possible.

Key policy 3: "Cloudify" the existing local infrastructures and applications at institutional level

To speed up cloud migration, intermediate solutions may be adopted to improve the management of the existing IT infrastructure without disrupting the operation of the applications used by educational institutions. It is recommended to "***cloudify" the existing local infrastructures and applications at institutional level***. To this end, 2 options are available:

a- Use containers for applications deployment;
b- Use a mature open source cloud toolkit (OpenStack, OpenNebula). Eventually with virtual machines running Docker Engines (or a similar container engine). Avoid proprietary virtualization technologies and use open source hypervisors (KVM, Xen) wherever possible.

Option (a) alone represents an easier option than (b)

- **Ministry** in charge of higher education and research should put in place a program for pilot projects to show case the cloudification using containers and cloud toolkits of typical institutions' infrastructures. It is also necessary to publish and disseminate results, know-how and lessons learned.
- **University/higher education institution**'s IT departments should train their members on technologies such as containers, virtualization technologies and clouds toolkits. Pilot projects must be put in place to help making informed decisions about the specific container orchestration technology and cloud toolkit that would best fit the needs of the institution.

Key policy 4: Adopt a cloud friendly governance model for IT

The migration to the cloud requires a change in IT governance models and practices. First, the offer to be made available to users must meet two main requirements: ease of use and flexibility. Secondly the establishment of an intermediary entity should facilitate relationships between suppliers and customers. It is recommended to ***adopt a cloud friendly governance model for IT***.

Applying the above policy choices requires to overcome many **barriers to cloud adoption**. Among the most significant barriers that have been identified are: "security issues", "Integration with existing systems", "data protection and privacy concerns". To be able to meet the challenges of cloud migration, institutions need support. The main support demands requested by institutions are related to "cost benefit analysis" and "security and privacy".

Capacity building is key to a successful transition to cloud. **I**nstitutions must make investment in the governing structures, organization processes, people and their skills required to make cloud technology an essential element in how the organization services are managed. IT managers need to understand what capabilities are offered and how they can be combined with internal resources, and develop a plan to leverage these combined resources.

Cultural change is also essential and it cannot be achieved without a substantial educational effort. Cloud experimentation by IT specialists and users would greatly facilitate culture change; workshops to share the knowhow and experiences cross-institutions would also be needed. One needs to keep in mind that outsourcing arrangement or a technical platform are not enough. Institutions must plan for cloud computing as a **strategic choice** and the elaborated strategies should be adapted to the institution's specific environment and use cases. Cloud migration should be used as a vector for transformation and improvement. For instance, new curricula need to be addressed in parallel with the deployment of cloud technologies. The curricula may concern the teaching of cloud technologies-related skills or

may leverage the capabilities of the cloud to provide more effective education. This applies to all data science related curricula for example.

1.3 Cloud migration: Implementation and guidelines

The objective is to provide a practical guide to help educational institutions and information technology (IT) managers to plan and operate applications and workloads migration to the cloud. It provides a detailed roadmap that covers a list of technical steps for migration [1].

Three scenarios for migrating applications, services and workloads to Cloud Computing infrastructures are considered:

- **SaaS Migration**: Consists in replacing in-house applications with new SaaS applications;
- **IaaS and PaaS Migration**: deals with migrating in-house applications and workloads to private or public IaaS/PaaS Clouds;
- **Cloud Service Brokerage for IaaS and PaaS Migration**: describes the Usage of cloud brokers to manage the delivery of cloud services and negotiate relationships between educational institutions and private or public Clouds providers.

A migration use case is also presented for each scenario:

SaaS Migration: Many schools, colleges and universities have moved their email, collaboration and communication services to the cloud. The objective is to completely replace in-house applications and services with new SaaS capabilities. Email, Video Conferencing, Storage, Social Network, Office tools are all eligible applications for migration. Both Google and Microsoft offer such educational tools in SaaS mode for free in many countries. The Amazon Educate global initiative provides students and educators with AWS credits for use in courses and projects. The Amazon's cloud powers various innovative SaaS offerings for eLearning. Echo360 for example is an AWS-backed active learning platform; its SaaS classroom capabilities replace several classroom learning technologies that are neither scalable nor designed to support the diversity of modern faculty/student interaction.

Domain administrators in charge of moving their students, faculty and staff members to Google Apps for Education or to Office 365 for Education or to AWS will find in the report references to guides with a step-by-step outline for completing the technical aspects of the deployment. The outlines include relevant help center's articles and videos for the three cloud providers.

Migration to an IaaS /PaaS: The major technical steps for migrating in-house applications and workloads to public or private IaaS/PaaS Clouds are: (i) Elaborate a cloud migration project plan (ii) Set up the cloud environment (iii) Set up the Applications in the cloud (iii)Set up a pre-migration prototype (iv)move to the production cloud.
These steps are outlined in the report; their detailed description is beyond the scope of this executive summary

Two migration use cases are presented one public cloud case and one private cloud case.

The first one deals with a public cloud migration of an institutional Moodle to AWS, a typical multitier dynamic web application. Amazon provides a set of whitepapers targeted at architects and technical decision makers looking to build a cloud migration strategy. The actual migration steps described for this use case are: (i) Cloud Assessment (ii) Proof of concept (iii) Data migration (iv) Application migration (v) Co-existence phase (vi) Optimization.

The second use case deals with the set up of an open stack based private cloud environment and the migration process as implemented by ENIS (school of engineering at Sfax University). ENIS is expected to achieve the following objectives:

- Migrate business applications (e.g. office order, timetable, mailing service, web service, etc…) to the private cloud;
- Replace traditional PCs deployed in practical work classrooms with thin clients connected to a private cloud based VDI (Virtual Desktop Infrastructure);
- Offer virtual machines as a service for researchers to deploy their scientific workloads;
- To offer a self-service portal for administrators to allocate virtual servers (to run applications) and for end users (teachers, students, researchers, etc.) to access their own virtual desktops and virtual machines.

Cloud service brokerage for IaaS and PaaS Migration: Cloud service brokerage acts as a middle man between educational institutions and public cloud providers (like Amazon AWS, Google Compute/App Engine, Microsoft Azure) by aggregating and offering multiple cloud resources and services that best suit their needs. The broker represents a single interface for interacting with multiple public and private clouds. The broker may be deployed on premises, within one institution data center or in a community fashion, under the supervision of supra-institutions entity (e.g. ministry of research and education) or as a paid external service.

Cloud broker can manage multiple public clouds through their APIs (Application Programming Interfaces). In order to avoid vendor lock-in and to ensure services' portability and interoperability, it is recommended to deal with public clouds offering extensive and well documented APIs. Clouds allowing virtual artifacts to be easily exported are to be preferred.

Cloud brokers are often made accessible through self-service portal which act as a central hub within the organization. The portal allows users to seamlessly provision, access and share the IT capabilities and services they need without having the IT administrators directly involved.

A few examples of cloud brokerage platforms are presented: RosettaHUB, CloudSelect broker, CompatibleOne and JellyFish.

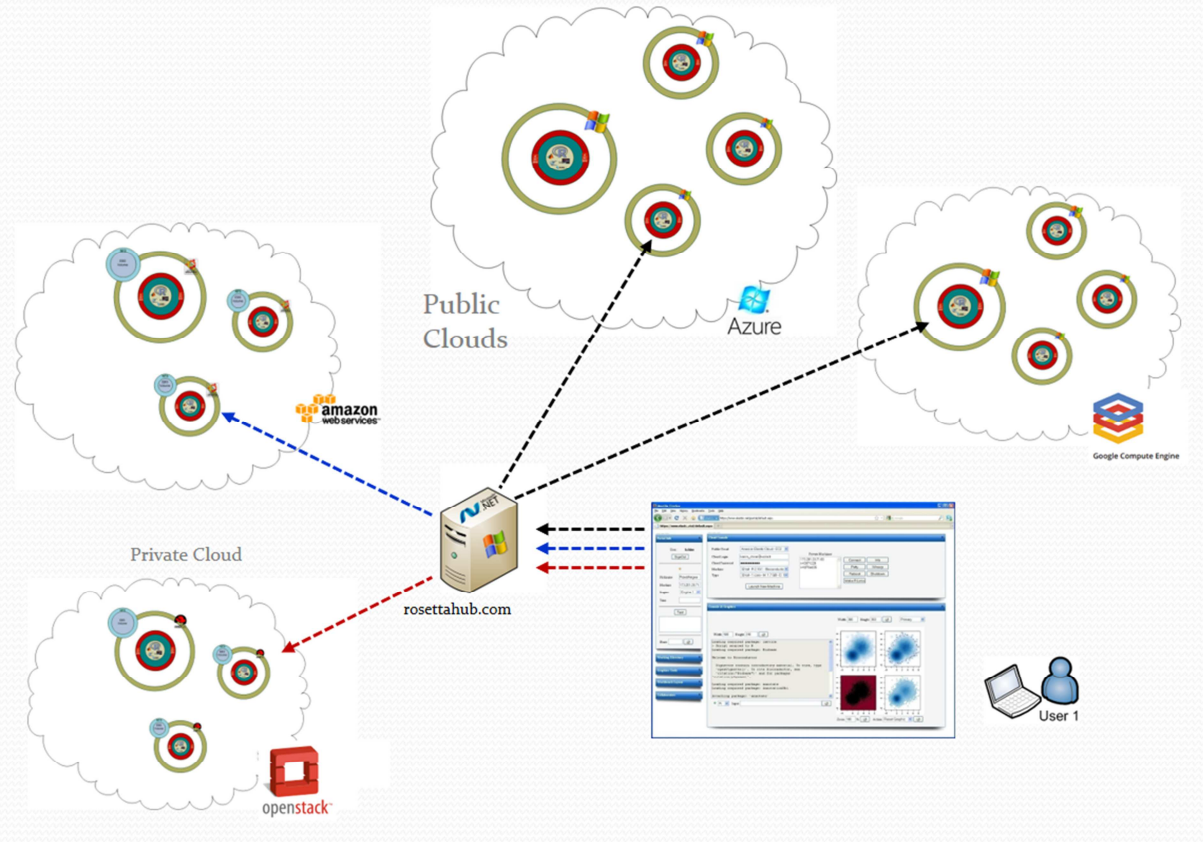

Fig. 7 Cloud brokerage (meta-cloud) through RosettaHUB [8]

RosettaHUB [www.rosettahub.com] is an innovative eScience and eLearning platform. It provides researchers, teachers and students with a streamlined experience in their day-to-day interactions with (i) clouds, HPC clusters and supercomputers which are made accessible through one easy-to-use web console(ii) data science environments, tools and libraries which are interconnected and exposed in the browser as collaborative services the Google Docs way(iii) data storage capabilities which are mapped to an easy-to-use interactive framework and next to which compute capabilities are created and remotely controlled (iv)big data frameworks such as Spark(v) Local Desktop tools such as Excel and Word which become clients to remote advanced cloud-based data processing capabilities (vi) Local applications and code which can leverage the RosettaHUB libraries to programmatically provision and use cloud resources and tools for scientific computing and data analysis (vii) peers and collaborators with whom real-time collaboration in the browser can be engaged.

Various other open source technologies can be used as brokerage building blocks for the institutional one-stop access portal such as the CloudSelect broker, the CompatibleOne broker and JellyFish. Some of them are based on open standards such as OCCI (Open Cloud Computing Interface).

1.4 State of ICT in the Arab World

1.4.1 ICT status in the Arab world

The 2016 ITU-Alecso report [1] gives the 2015 ranking of 16 Arab countries according to ITU ICT Development Index (IDI). The 16 Arab countries are ranked from 27 to150 out of 162 classified countries. They all achieved some progress as compared to 2010. They may be divided into three classes: the first one which consists of 7 countries is above the world average of 5.03; two countries of this class even exceed the average of the most advanced countries (7.35); the second class is made up of four countries that are close to the world average with an IDI varying between 4.75 and 4.40. The last class consists of 5 countries with an IDI has varying between 3.71 and 2.07.

The figure below shows the IDI scores of the Arab countries as well as their positioning relative to the world average, the Arab countries, the developed and developing countries averages.

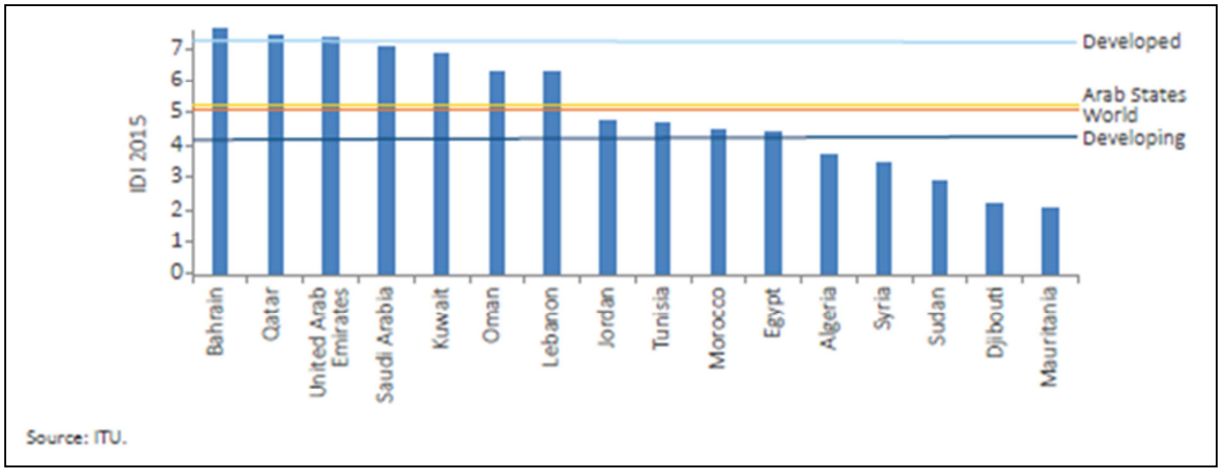

Fig. 8 IDI by country compared with global averages, 2015 [9]

The average IDI of Arab countries slightly exceeds the world average.

For the purposes of the study, the section below presents an update of some IDI indicators considered as prerequisites for the implementation of a cloud strategy in higher education. Two sets of indicators are considered, ICT Access Indicators and Pervasiveness of social networks indicators.

1.4.2ICT Access Indicators

ICT Access Indicators include, the number of mobile cellular telephone per 100 inhabitants, the number of fixed broadband subscriptions per 100 inhabitants, the Proportion of households with computers, the percentage of individuals using the Internet. The evolution of the percentage of individuals using the Internet will also be presented. Source of Updated Data ITU 2016 [10].

- *Mobile-cellular telephone*

According to data from the ITU (2016), the number of mobile phone subscribers in the 22 Arab countries shows great differences. Thus, in 12 countries the number of subscribers exceeds 100%, while it varies in the 10 remaining countries between 96 and 38%. The 22 countries are classified into four groups as shown in the figure below.

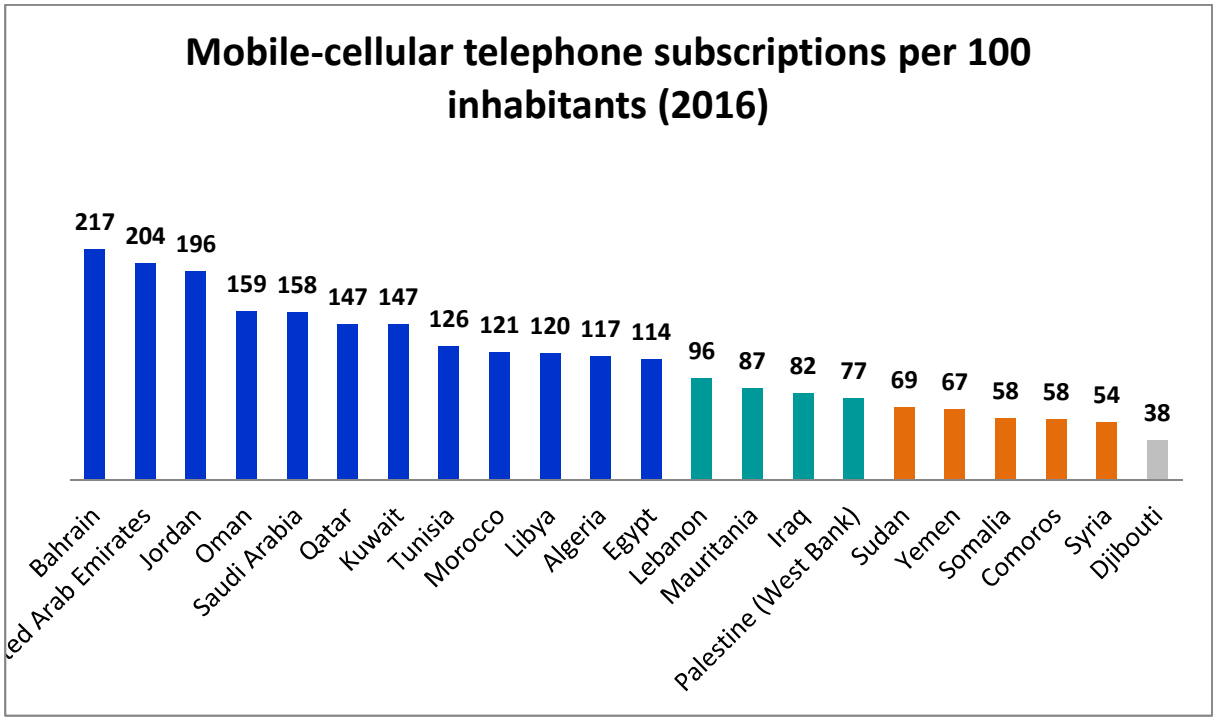

Fig. 9 Mobile-cellular telephone subscriptions per 100 inhabitants

- *Fixed-broadband subscriptions per 100 inhabitants*

As shown in the figure below, the number of fixed-broadband subscriptions per 100 inhabitants also shows significant differences between countries. Countries were also classified into four groups. It is interesting to note that two countries (Lebanon and Mauritania) that are part of Group 2 for the number of mobile phone subscribers are ranked at the top of the list. Libya, Kuwait and Morocco who are in the first group are here in the third group. Overall rates are relatively low.

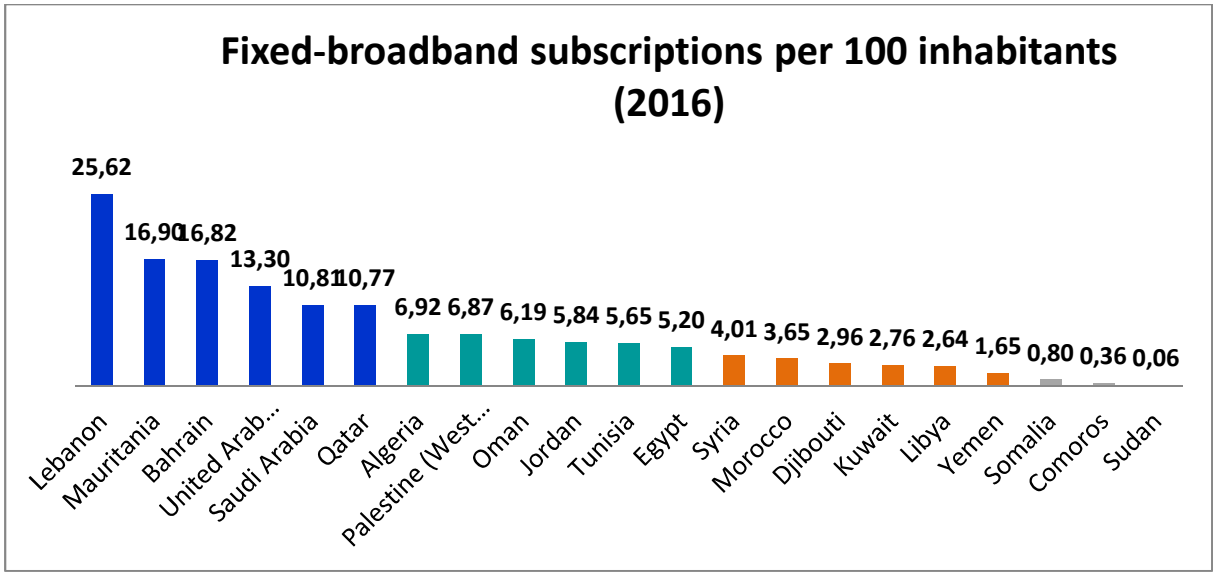

Fig. 10 Fixed-broadband subscriptions per 100 inhabitants

- *Percentage of Individuals using the Internet (2016)*

In only 6 countries does the connection rate to the Internet exceed 70%. We find here 5 countries of golf and Lebanon. For the vast majority of countries the rate varies between 70% and 20%. Djibouti, Comoros and Somalia have very low rates respectively 13%, 8% and 2%...

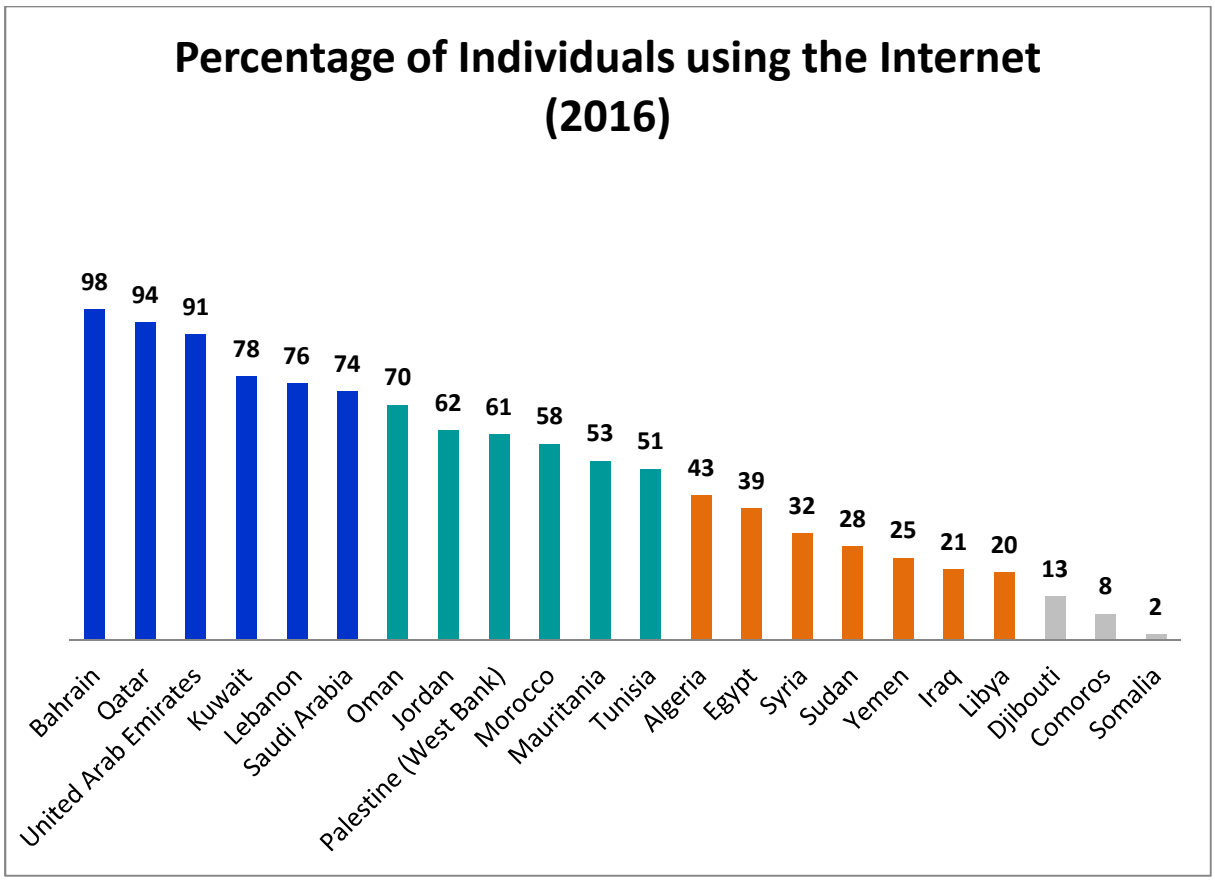

Fig. 11 Percentage of Individuals using the Internet

As shown below, the evolutions of the rates of individuals using the internet are also very different. For example, Bahrain has fairly high and continuous growth rates. On the other hand, Tunisia and Egypt have followed a slower pace of growth.

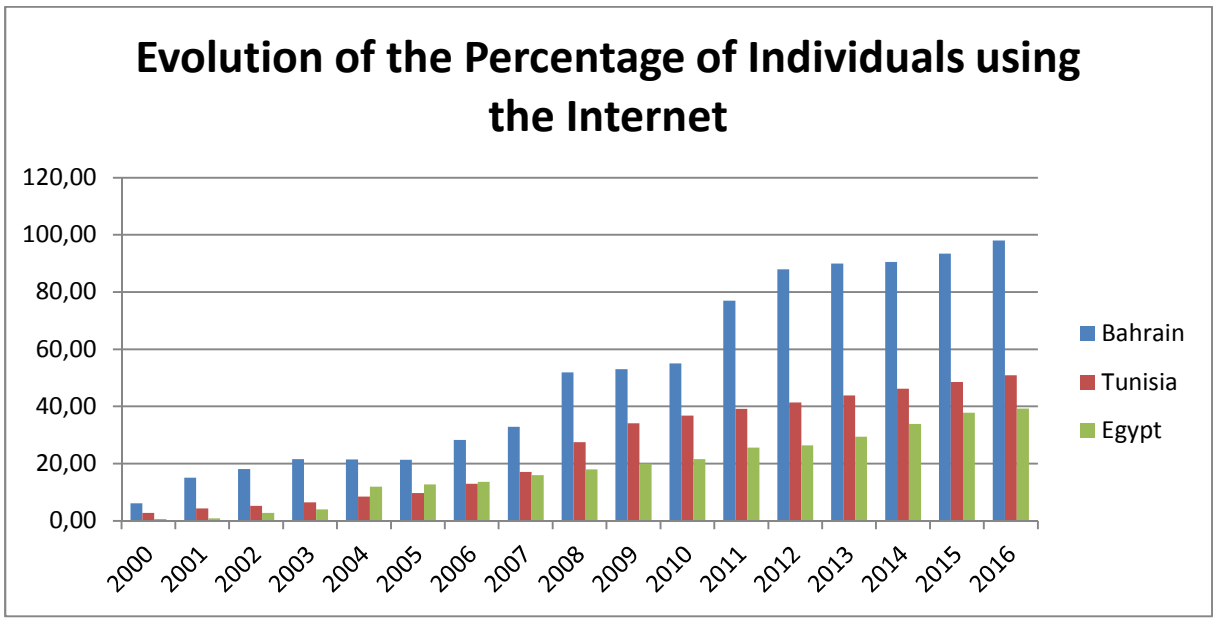

Fig. 12 Evolution of the Percentage of Individuals using the Internet

- *Proportion of households with computer (2015)*

The proportion of households with a computer is also highly variable. Rates vary between 95% and 5%. Almost half of the 18 countries have a rate of less than or equal to 50%. . It should be noted that data are only available for 18 of the 22 Arab countries.

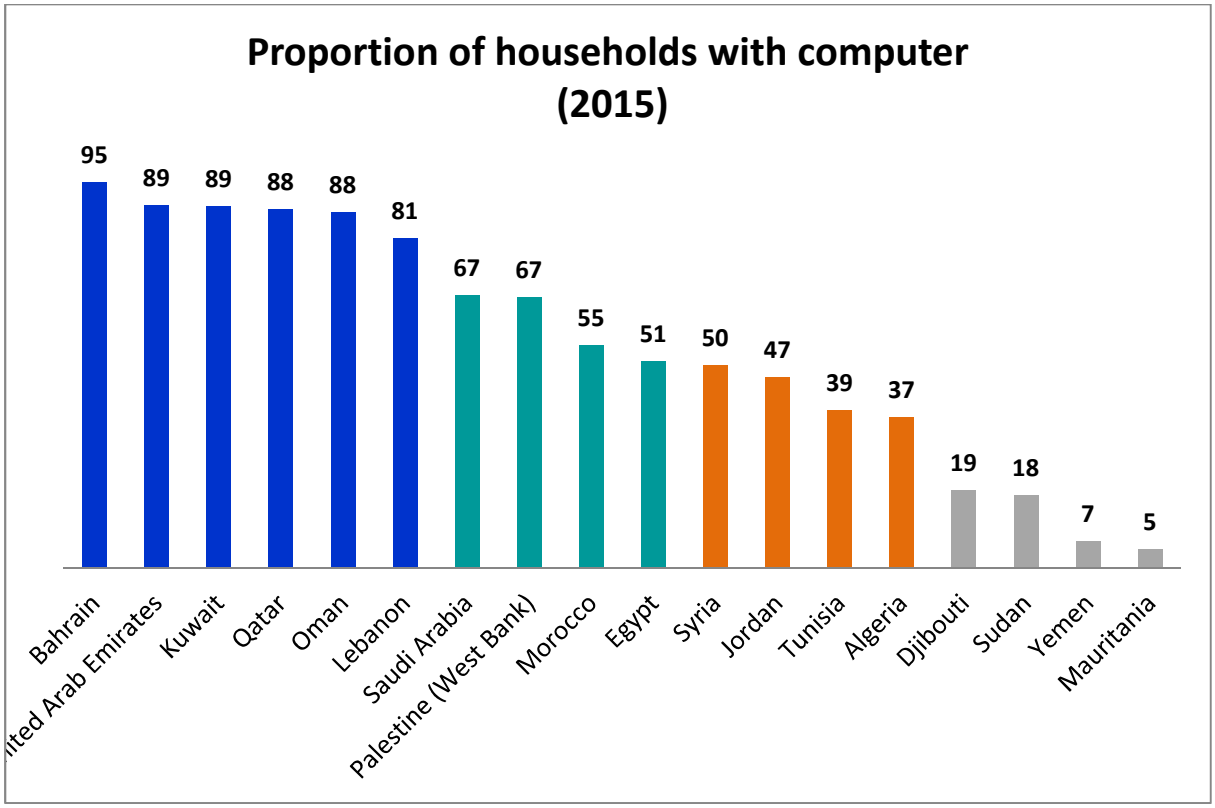

Fig. 13 Proportion of households with computer

1.4.3 Pervasiveness of social networks

Currently the most used social network in the world is Facebook. Its use has spread to all Arab countries. In 7 countries 50% of the population or more have a Facebook account. In only 6 countries, less than 21% of the population has a Facebook account.

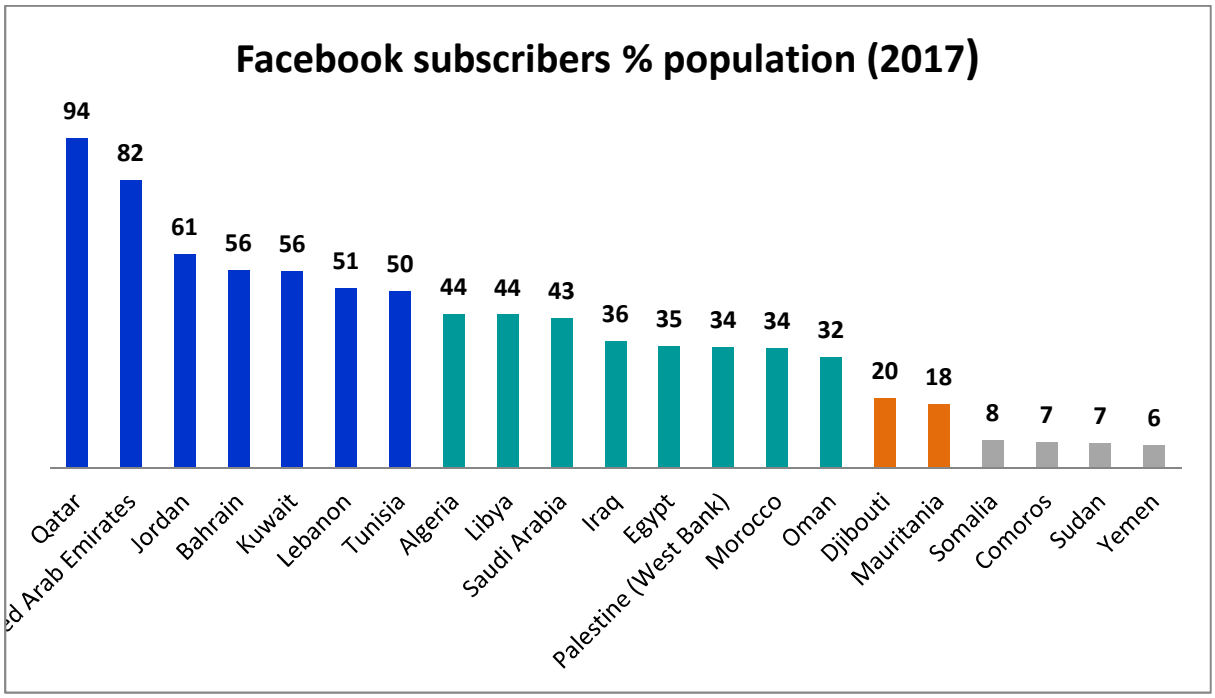

Fig. 14 Facebook subscribers % population [11]

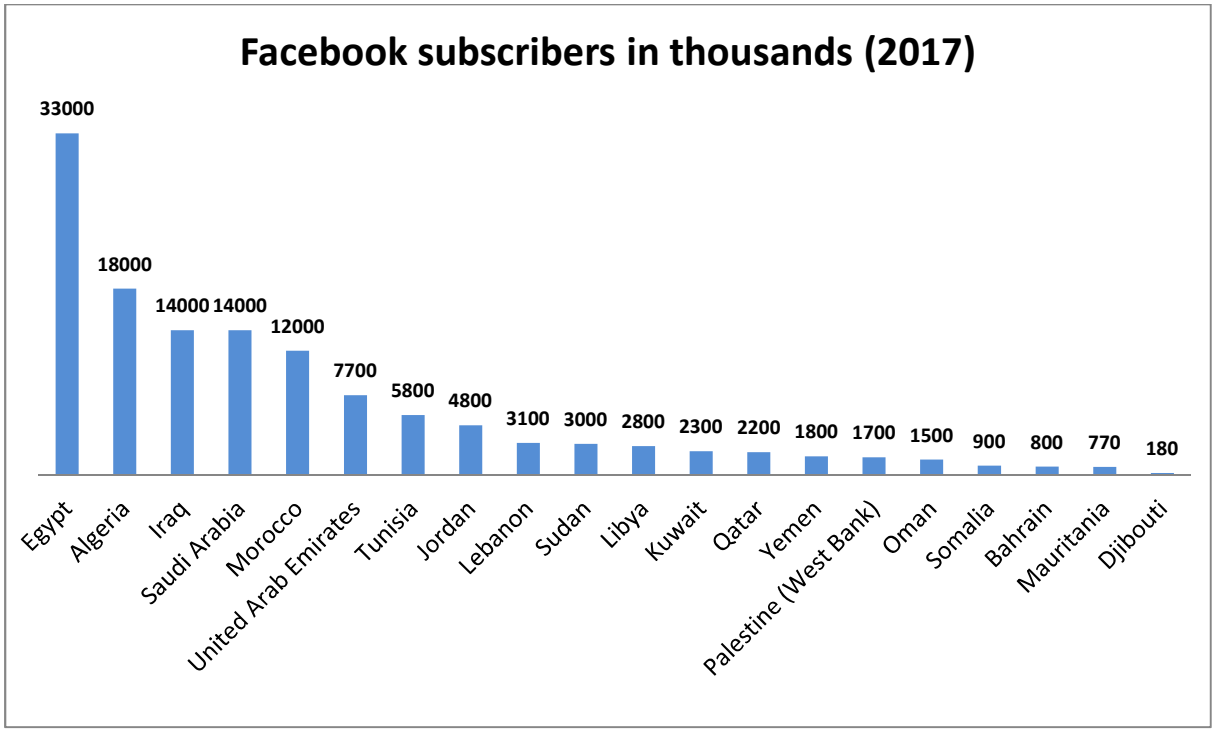

Fig. 15 Facebook subscribers in thousands [11]

1.5State of the cloud computing in education in the Arab World

This section presents the main outcomes of the survey conducted between August and November 2015 and presented fully in the 2016 Alecso-ITU report [1] in order to make this report more comprehensive and self contained. The objective of the survey was to collect data on cloud adoption in educational and research institutions in the Arab countries. The survey was aimed at government departments, engineering schools, faculties and research centers, and data centers.

The objective of the survey is (i) to make an inventory of ICT use in Arab institutions (ii) to understand how those institutions perceive the benefit and applicability of the cloud to their use cases and whether and how they plan to use it (iii) to understand the barriers and risks they currently apprehend. The outcome will be used to elaborate recommendations for triggering or catalyzing Arab institutions' migration to the cloud.

65 questionnaires were completed online, but only 40 were valid. 25 were rejected because of lack of information or multiple responses from the same organization or unrealistic data. 10 Arab countries participated in the survey.

Tab.1 Breakdown of respondents by country

Countries	**Number of respondents**
Algeria	1
Sudan	1
Morocco	1
Tunisia	6

United Arab Emirates	1
Jordan	11
Palestine	1
Kuwait	7
Qatar	1
Bahrain	9
n.a.	1
Total	**40**

The majority of institutions surveyed (85%) own a data center. The majority of students have an email address; however the number of students with a laptop is relatively low.
Institutions use different types of IT applications and services with the highest concentrations on Administrative and operational services applications (98%), collaborative applications (95%), storage (93%) and office suite (90%).

As regards cloud adoption 40% of the respondents indicated that they are either at production (12%) or implementation stage (28%). If we add the percentage of institutions in the trial stage then the total reaches 52%.

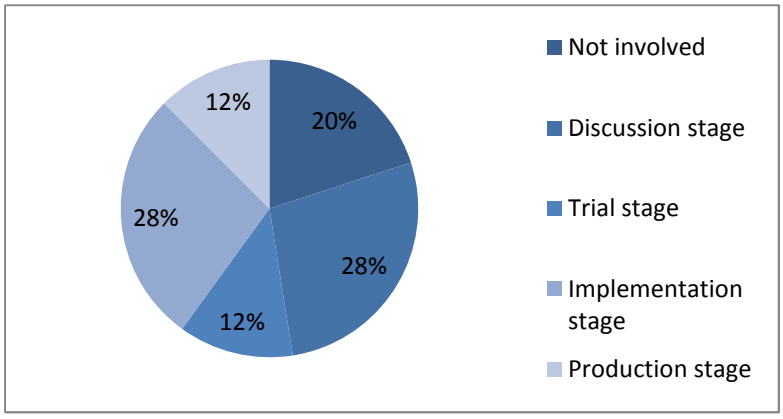

Fig. 16 Cloud utilization in institutions

1.5.1 Survey outcome for institutions that do not use the cloud

Thirty five respondents are not in production stage. They are the non-users of the cloud. The main results concerning them are presented in the following.

The most important benefits perceived by the highest percentage of respondents are "disaster recovery capabilities" followed by "hardware cost saving" and "reliable data storage". More than 50% of respondents consider that all the other benefits are very important except for "convenience for the development team" (43%).
The vast majority of respondents perceive the use of the cloud as easy or very easy.
Despite this positive perception of the benefits and the ease of use of the cloud, a number of barriers to cloud adoption were identified by respondents. Among the more significant barriers we find "security issues", "Integration with Existing systems", "data protection and / or privacy Concerns". Overall, all the barriers mentioned in the questionnaire are perceived by the majority of respondents as important / very important.

Despite these perceived barriers, 55% of respondents formally introduced cloud computing in their strategy or are in a formal discussion stage to make it part of their strategies. This confirms the trend noted above.
In case of migration, according to a time frame, the preferred applications to migrate to the cloud during the first year are « collaborative application » with 46% of respondents, followed by storage service (34%) and scientific applications (29%).

Intention of migration IT applications and services to the cloud

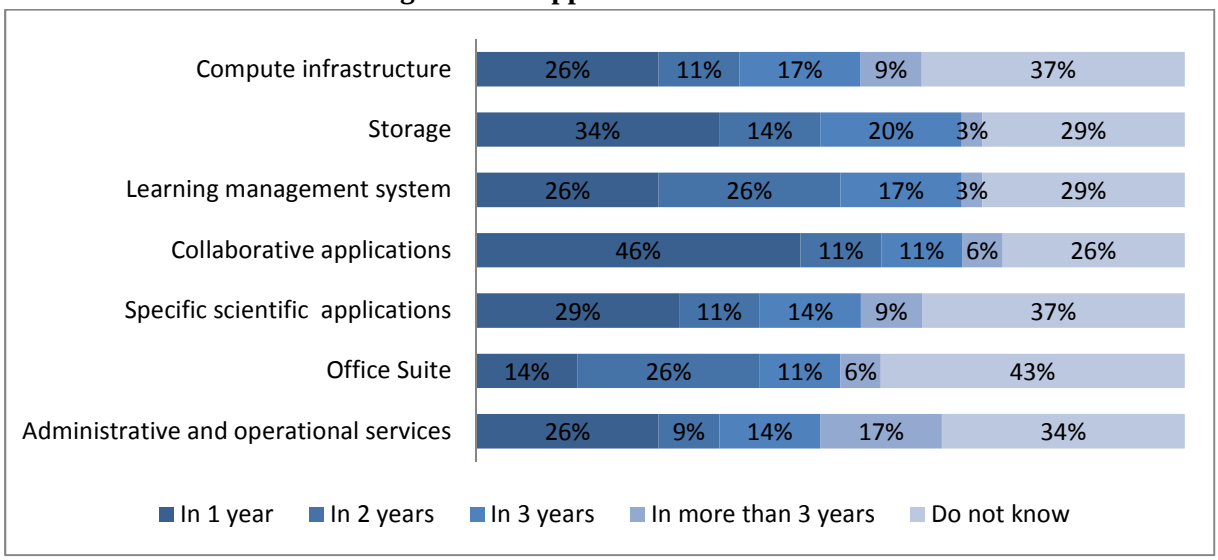

Fig. 17 Intention of migration IT applications and services to the cloud

In order to remove barriers and facilitate cloud migration, respondents expressed their needs for support as given in the following figure:

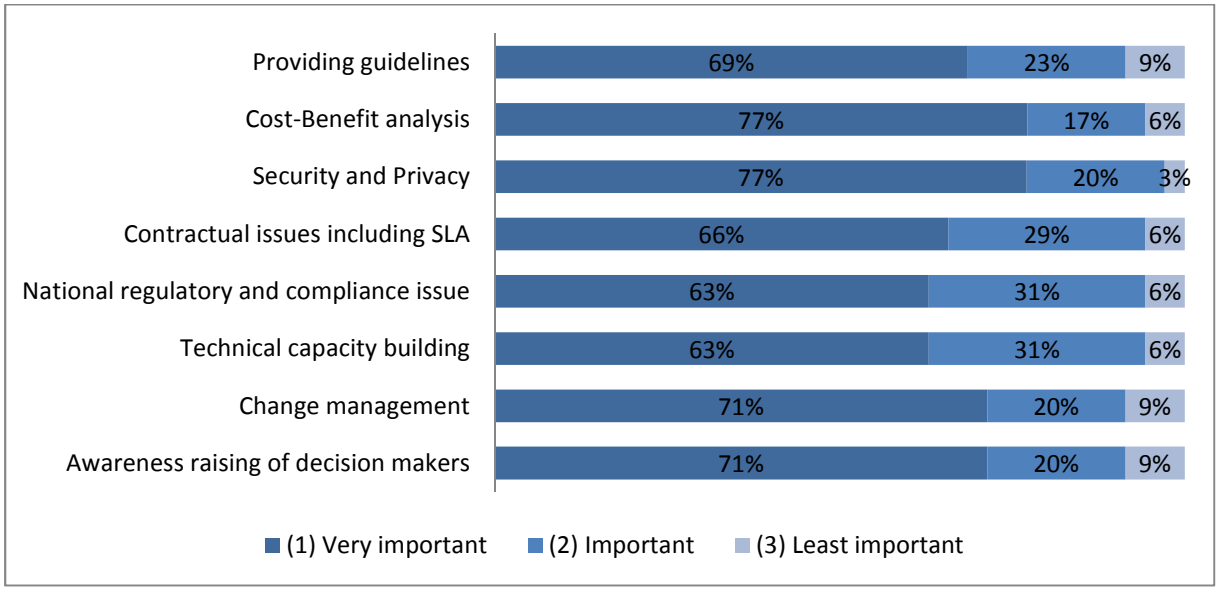

Fig. 18 Following areas need support regarding decision to migrate to the cloud

All proposed support items received a “very important” score from more than 60% of respondents. The highest support demands are related to « cost benefit analysis » and « security and privacy ».
The following figure shows 49% all respondents are just familiar or beginning to familiarize themselves with cloud computing. Given that the majority of respondents belong to IT departments this suggests that there is a strong need for support in raising awareness and capacity building.

1.5.2 Survey outcome for institutions that use the cloud

The number of institutions in the sample using the cloud, in production stage, is 5.
The five institutions have migrated more than 75% of their collaborative applications to the cloud. Three of them have migrated more than 75% of "specific scientific" and "office suite" applications to the cloud. Only one institution has migrated more than 75% of "Learning Management Systems" application to the cloud.

Applications and services for which the respondents intend to pursue migration or plans to migrate to the cloud are given below:

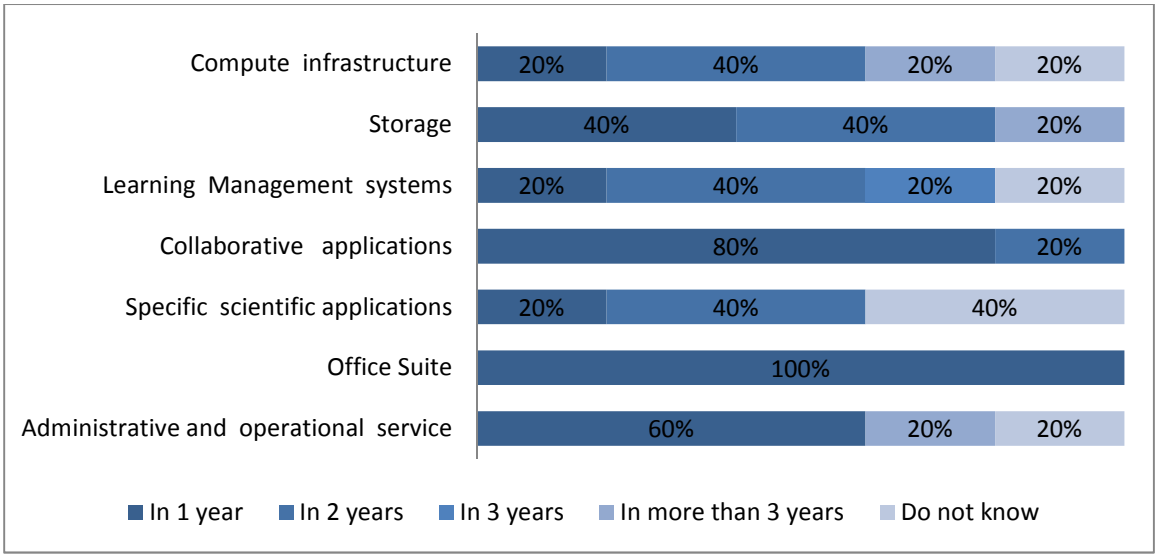

Fig. 19 Applications and services for which the respondents intend to pursue migration or plans to migrate to the cloud

In one year, five institutions intend to migrate "office suite" applications to the cloud, and «collaborative applications" (or rather what remains of them since they have already migrated more than 75%) for 4 them.

Four institutions recognize that the "Ability to scale up and scale down IT" is a very important benefit. Only one institution considers that "Convenience for the IT development teams" is a very important benefit. Similarly, only one institution considers that the "Reduction of capital expenditure" benefit is very important.

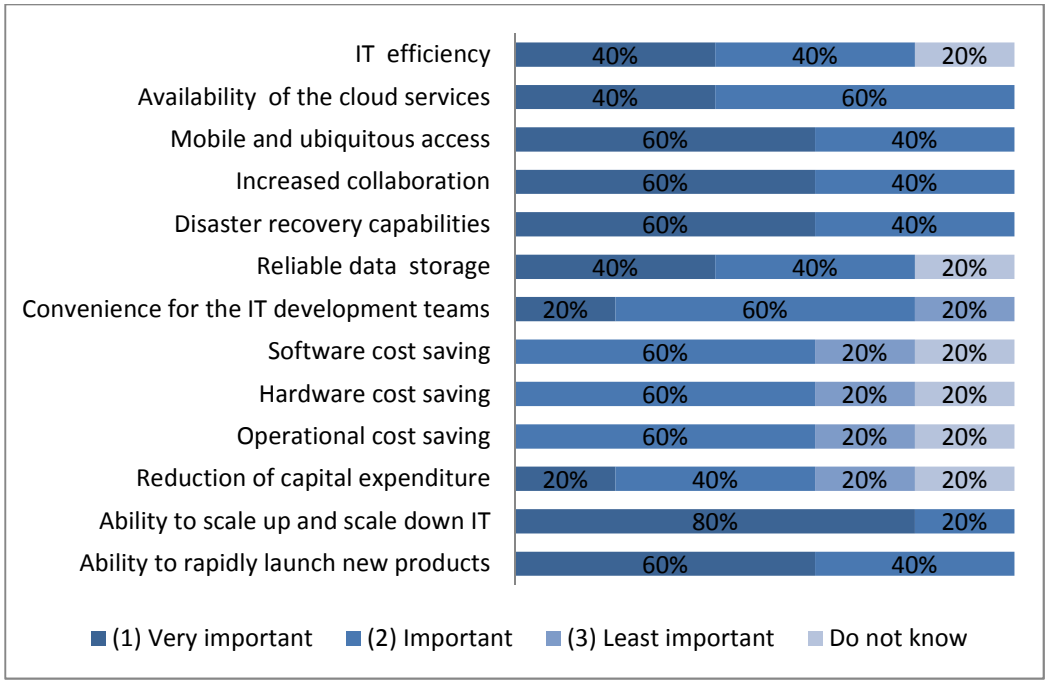

Fig. 20 Benefits that have been made in moving to the cloud

The main barriers that institutions encountered when migrating to the cloud are particularly: the "Lack of control over IT infrastructure", "security issues", "Data protection and/or privacy concerns", "Decision makers are not fully aware of the benefits the technology can deliver". For 4 respondents the existing infrastructure was a major barrier in the migration process.

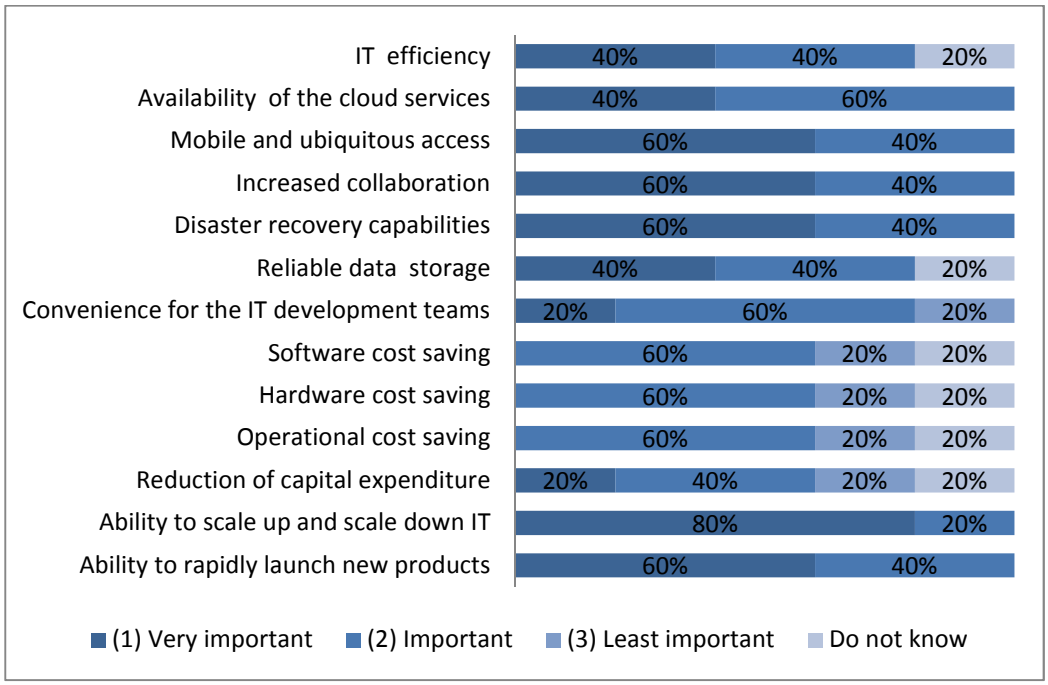

Fig. 21 Benefits that have been made in moving to the cloud

Most respondents (4) adopted change management in the cloud migration process.

According to the respondents the main actions to be taken to boost cloud migration are especially the needs for increased transparency in pricing and technical capacity building.

1.5.3 Trends outlined by the survey

Strong trends emerged from the survey of the 40 institutions of higher education in the Arab world:

- **A clear move toward cloud adoption**: 52% of surveyed institutions are either in the production, implementation or test phase;
- **A positive perception of cloud benefits by non cloud adopters (not in production phase)**: the most important benefits perceived by the highest percentage of respondents are "disaster recovery capabilities" followed by "hardware cost saving" and "reliable data storage".
- **Applications to migrate to the cloud for non cloud adopters**: « collaborative application » with 46% of respondents, followed by storage service (34%) and scientific applications (29%) are the preferred applications during the first year. They are followed by «learning management system» for the first couple of years (26% the first year and 26% the second year).
- **Perceived barriers for cloud adoption for non cloud adopters** Among the most significant barriers are "security issues", "Integration with Existing systems", "data protection and / or privacy Concerns".
- **Support needed to migrate to the cloud**: the highest support demands by non **cloud adopters** are related to « cost benefit analysis » and « security and privacy ».
- Most cloud adopters (4/5) engaged in change management to overcome cloud adoption barriers.
- **Cloud adopters expressed their satisfaction with cloud utilization.**

It is to be reminded that the results of the survey should be considered with caution since the survey sample is not representative enough. They give however some clear indication as to the growing cloud adoption in many Arab countries

1.6 Cloud computing in education, Countries' experiences

The goal of this part is to recall a couple of experiences [1] and to provide additional information given the recent data and also the presentations made during the Bahrain workshop which concerns Bahrain, Tunisia and the use of Rosetta Hub, Mauritania, Sudan, Comoros and Djibouti.

- **Morocco**

Morocco seems to be among the leaders in Africa in cloud computing adoption. Indeed universities of IbnZohr (Agadir), Chouaib Doukkali (El jadida), Sidi Mohammed Ben Abdellah (Fès), Ibn Toufail (Kénitra), Cadi Ayad (Marrakech), Moulay Ismail (Meknès), Mohammed 1er (Oujda), Mohammed V de Souissi (Rabat), Abdelmalek Essadi (Tetouan/Tanger), Hassan II (AinChok- Casablanca), Sultan Moulay Slimane (Beni Mellal) et Hassan II adopted « Google Apps For Education » as a service for their students, faculty members and administrative staff.

Morocco has also decided to use the cloud in vocational training: OFPPT, a public institution for vocational training, adopted Microsoft Office 365. OFPPT provides training in 327 training institutes across the country for 500,000 students in 35 fields of study [5].

- **Jordan**

In Jordan 2 universities have adopted the cloud: Jordan University of Science and Technology (Jordan) and Princess Sumaya University for Technology.

- **Saudi Arabia**

In Saudi Arabia, two universities have also adopted the cloud: King Abdallah University of Science and Technology and King Abdulaziz University

- **Bahrain**

The Bahrain Information and eGovernment Authority (iGA) published on April 24, 2017 a report outlining its Cloud First Policy [12]. The Cloud First Policy states that:
« The Bahraini Government is committed to modernizing government information and communication technologies (ICTs) and will lead by example in using cloud computing services to reduce costs, increase security, increase productivity, and develop excellent citizen services,
The Kingdom of Bahrain will adopt a Cloud-First approach with the aim of:

- Reducing the cost of government ICT by eliminating duplication of solutions and fragmentation in the technology environment, and leveraging the efficiencies of on-demand provisioning of ICT services;
- Increasing security by using accredited platforms;
- Increasing productivity and agility, and thus improving citizen services.

In order to achieve this, all government agencies of the Kingdom of Bahrain will evaluate cloud-based services when undertaking all ICT procurements. The decision on the appropriate ICT delivery model will be based on an assessment of each application, incorporating fitment of purpose, cost benefit analysis and achieving value for money over the life of the investment. This assessment is best achieved by using any of the well-established tools available in the market, either from the identified cloud service provider and/or a non-attached third party »
The report further indicates that **iGA** will

- Act as the interface between cloud service provider and government entities.
- Ensure relevant SLAs are defined for the applications based on the entity requirements.
- Monitor and govern SLAs agreed with cloud service provider.
- Provide support and guidance to entities in assessment and identification of applications to move to the cloud.
- Provide technical support to modify applications and get them cloud ready. »

As a consequence of the Cloud First Policy all HE education institutions are migrating to the cloud. An educational portal has been deployed on the cloud, as shown in the figure below which illustrates on one side the various users and on the other side the services provided.

Fig. 22 Bahrain Edunet [13]

- **Tunisia**

Tunisia has 2 IT centers, one is dedicated to primary and secondary education (CNTE) and the other to higher education (CCK). The 2 centers provide IT infrastructure, collaborative tools such as email, and specialized software, they also play the role of Internet providers to all the concerned institutions.

To our knowledge, Tunisia has not developed a cloud strategy for education. However, many initiatives have been launched by institutions of higher education. However a certain number of HE institutions adopted « Google Apps For Education ». A couple of institutions adopted Microsoft Azure Cloud and a few institutions adopted an open stack based Private Cloud

A certain number of HE Institutions gained access to the **IBM Educational Private Cloud Environment.**

Some institutions, such as the Faculty of Medicine of Tunis adopted Google apps for all faculties, staff &Students and deliver a digital version of their courses at the beginning of the academic year.

Furthermore, the most notable phenomenon is the big interest shown by the researchers for access to AWS Educate (Amazon Web Services) via Rosetta Hub. This demonstrates an important need for researchers to access large-scale cloud resources. Hence more than 20 HE institutions adopted **Rosetta Hub** to access AWS Educate .The 2016 report presented Rosetta Hub as an example of a cloud broker below a status update is provided.

The figure below illustrates how **SESAME University is providing** access to its students, faculty and personnel to several clouds taking advantage of free offers for education of AWS

via Rosetta Hub, Google and IBM. SESAME University has its own data center but is gradually migrating all its IT to public clouds.

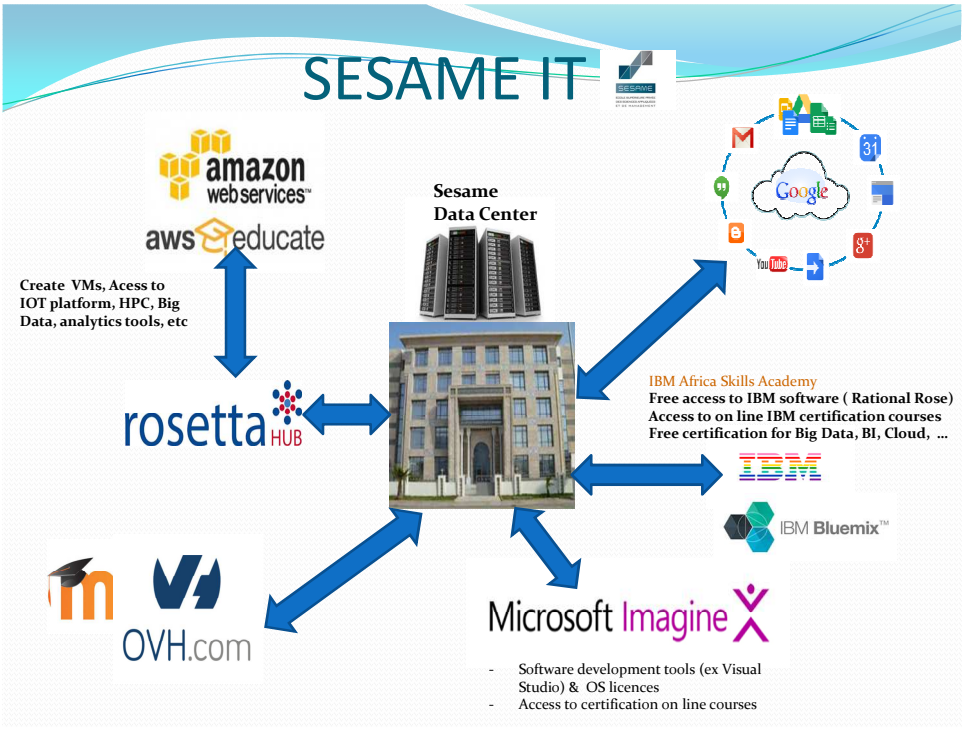

Fig. 23 Sesame University IT Platform [14]

- **Rosetta Hub Update**

The 2016 report presented Rosetta Hub as an example of a cloud broker. Rosetta Hub facilitates access to Amazon's offerings for education and, as such, enjoys a steady increase in penetration in many countries. As of December 2017 [15], over 50higher education institutions and research Labs including UCL, Imperial College London, Trinity College Dublin, Paris-Dauphine University, Ecole Polytechnique, UOB, Bahrain Polytechnic, about 20 HE institutions in Tunisia, etc. are using Rosetta Hub. More than **12000**researchers, educators and students had access to more than 1,000,000 USD of AWS credits renewable every year (out of which 250,000 USD for Bahraini universities). Students, educators and researchers access **the full spectrum of AWS cloud computing, big data, machine learning and IoT Services.**

RosettaHUB also provides **credit aggregation**, full flexibility on how to manage the institution's budget as well as safeguards that protect individual users from depleting their budgets. RosettaHUB acts as a social **Meta cloud** where educators and students can easily share cloud artifacts.

- **Sudan**

The Ministry of Communications and Information Technology mandated the National Information Center to form a national committee to develop a strategy for the country in the cloud computing. (Ref Bahrain Workshop [13])

- **Djibouti, Comoros and Mauritania**

The three countries have not yet introduced neither experimented cloud computing in education but showed a great interest to move to cloud computation and take a leap forward [13].

Conclusion

To conclude, the review of countries' experiences confirms that cloud adoption is a movement that is gradually spreading and gaining momentum within the higher education institutions of the Arab world. Bahrain has developed the most comprehensive national strategy for cloud computing adoption in government ICT including Education. However, most Arab countries haven't yet developed their own national strategies and it is timely to provide tools to support those countries in building such strategies as well practical measures for their implementation and thus help them succeeding their migration to the cloud.

Chapter 2
Vision and model for the Digital University

The following chapter summarizes and reuses substantial parts from "An Avalanche Is Coming, Higher Education And The Revolution Ahead" [16] and "Digitizing Higher Education To enhance experiences and improve outcomes"[17].

Just as globalisation and technology have transformed other huge sectors of the economy in the past 20 years, universities will be subject to radical metamorphosis. The old models that have been followed by higher education are mostly broken, urgent and deep transformation is required. The march towards the digital university has begun with no going back and cloud computing is one of its main pillars.

2.1 The modern challenges of Higher Education

Higher Education is facing growing challenges. The global **economy is changing**, the playing fields are being leveled, growth became more dependent on the quantity, quality, and accessibility of the information rather than on classic means of production: knowledge and technology became the cornerstones the new economy. This new economic reality produced and will continue producing across the globe mass unemployment especially among young people. Artificial Intelligence's unstoppable rise and foreseen ubiquity can only sharpen the employment challenge as automation will obsolete millions of jobs across all economic activities.

Both in commercial terms and at a standard level, the **value of university degrees** is falling. Not only University do not hold exclusive awarding power but also its ability to open the doors of a globalized job markets decreased in facts and in perception by the general public. Providing content is not any more a key added value as content became ubiquitous. It is provided over the internet mostly freely and without control by a variety of stakeholders and contributors. In this new content/knowledge ecosystem, the power of the academy is getting diluted.

The **internationalisation** of Higher education and the ever-growing global student opportunities are confronting universities with unprecedented and furious competition. Globalisation is enhancing the number of potential students who "shop" globally for the best higher education offerings. This trend will accelerate as public funding for higher education around the world is reduced and replaced by private funding such as loans or direct payments.

Universities will have to rethink their business model and embrace massively cutting-edge educational technology: They have to cater for a **generation connected from birth** which uses massively social media and evolve seamlessly within globalized digital communities. That generation will be confronted with an ever-changing market where the nature and pattern of demand for skills and knowledge in the workforce is shifting.

The demand for well-educated, imaginative, collaborative, confident people who take personal responsibility, leverage the best-in-class digital technologies, and go the extra mile is increasing across all economic sectors. Tomorrow's workforce is expected above all to be agile, to be able to learn, adapt, cross the borders between disciplines and navigate in complex environments where digital technologies often play an important role. The rise of Data science, Big Data, AI and IoT is creating an important skill gap, existing curricula must be upgraded and new curricula need to be created to close the gap and unleash the tremendous economic potential of the new trends and technologies. Those new trends require access to highly sophisticated and scalable digital infrastructures that most universities don't have.

The universities are struggling as all their **costs are growing**. There is an urge to review and optimize governance and administration and to rationalize the use of staff members, physical resources, buildings, etc. The cost of research is also growing. Maintaining internationally competitive research laboratories is getting harder and harder. The cost of research is not the only challenge to maintaining a high-quality faculty, the new trends and practices in research made proximity unnecessary, **globalized academic communities** do not perceive any geographical or institutional boundaries. Competition is also coming from Industry's big players whose influence is growing day after day.

The forces that have brought about these changes in higher education are the very tools we need to solve them. University has to adapt to the digital age, higher education has to change its very DNA while keeping what is most essential to its mission. The essence of the university can not only survive but also thrive in the new digital age.

2.2 A model for the digital university

A digital University is one in which, all staff, academics and students use technology tools on a day to day basis. A digital University is also one that runs all aspects of its business with digital technology at its heart to achieve academic excellence, enhance brand, interact& work closely with ecosystems, perform internationally recognized research and achieve financial stability and efficiency.

Our model of the Digital University, as represented in figure 24, is built upon six components two transversal and four vertical ones. The four vertical pillars are the "Digital Campus Management", the "Digital Teaching & Learning", the "Digital Research" and the "Ecosystem digital links". The two transversal layers are "the Digital Strategy & Vision layer" and "The IT service delivery Platform». Each component includes specific objectives. Achieving objectives requires a set of specific IT applications in addition to common IT applications

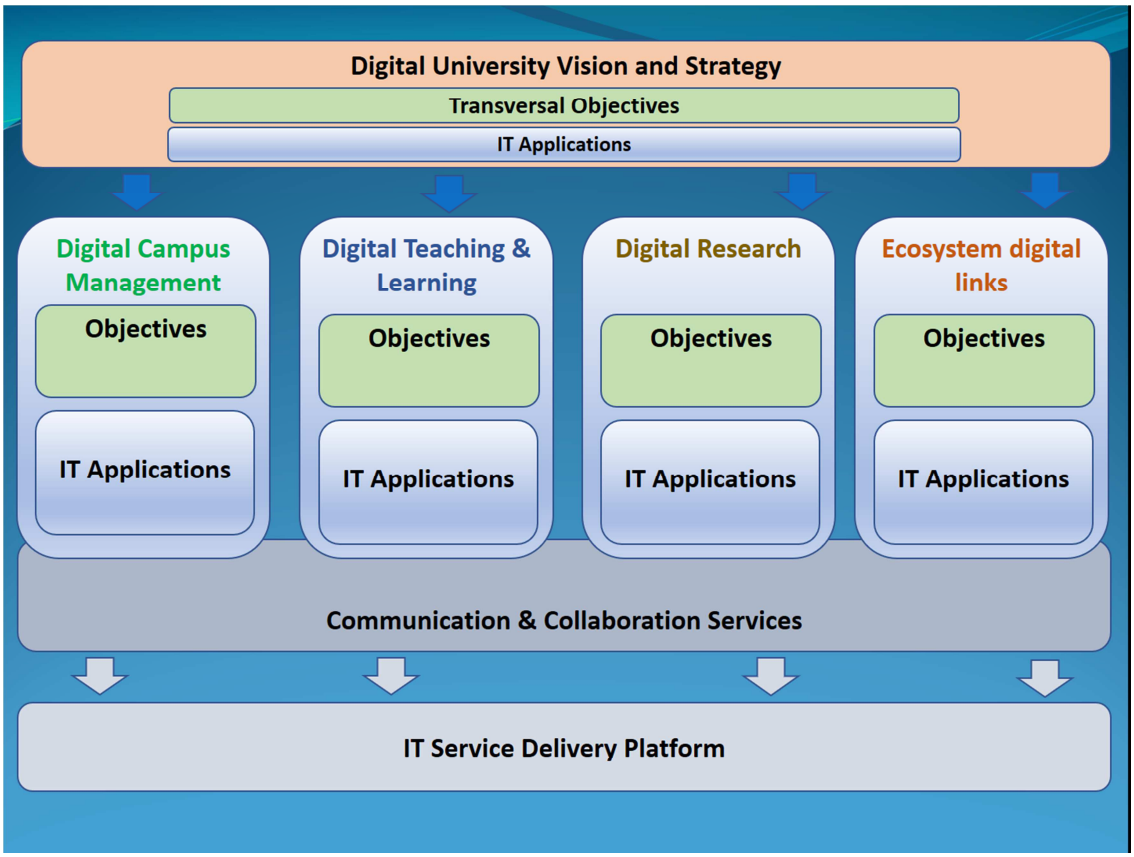

Fig. 24 Digital University high -level model

2.3 Pillars of the Digital University

2.3.1 Digital Campus Management

Modern universities should place digital technologies at their very heart, achieve the fullest exploitation by staff, academics and students of those technologies and create the conditions for the university to operate from a Digital Campus. Universities have had to adopt a more business-approach by maintaining a sharp focus on **brand**, **financial stability** and **academic excellence**. Digital technologies can be instrumental to each of those core objectives and can play a key role in rationalizing and optimizing the university's main cost centers.

For *staff and academics*, an end-to-end IT infrastructure fully supported by network security and mobility services can enable **location-independent working** as the first step towards changing ways of working and work styles, and can drive direct savings and efficiency through increases in productive time.

Such infrastructure would also help **optimizing the use of *Campus Buildings*** as much as it supports the new work styles and the new teaching and learning settings. Digital technologies can play a key role in implementing a more sustainable and cost effective model in relation with use of *energy and resources*: they can monitor, control and help managing the use, hence cost, of all utility services. For instance, significant energy-saving benefits can be derived from IT consolidation and virtualization of infrastructure and services.

The adoption of new sourcing and financing models including **cloud, managed and shared services** would drastically reduce the capital and operational costs significantly besides improving the overall technical, financial and process agility of the institution.

Digital technologies can help implementing ***n***ew, collaboration-enabled operational processes. Within a digital university, all staff and academics should have the confidence and skills to use technology tools on a day to day basis. Real-time communications and collaboration services further develop the value of location-independent working by enabling virtual meetings and virtual information sharing. These capabilities act as the essential catalyst for the development of new collaboration-enabled processes, and for new ways of accessing content, applications and services.

A digital university should recognize the full value of the resources and facilities provided by its **physical campus**. A well-designed physical campus, fully incorporating digital technology, is essential for building the brand of a university - by enhancing the student experience, and delivering the right settings and facilities for teaching, learning and research. On such a digital campus, technology not only reduces operational costs but also enhances safety and security and provides information tools for staff, academics, students and researchers. These benefits deliver real value – both to university operations, and to the experience of students and researchers.

The technology platform supporting the digital campus should provide network connectivity, mobility and security for all applications and services across the campus and should also incorporate a wide range of Internet of Things (IoT) applications supporting the core activities of the university, enabling new teaching and learning practices, and delivering a good student experience. The wireless network has a key role to play within the digital campus and so must be designed for robustness and to meet the high-density demands of a modern university. Modern wireless networks are also capable of providing location information on users which can be used by the university to build up a picture of campus use and patterns of individual use.

2.3.2 Digital Teaching and Learning

Universities have long recognized the ability of technology to disrupt teaching, learning and assessment. Further technology disruption is essential if a modern university is to differentiate its student offer so increasing admissions, improving retention and, critically, delivering better outcomes. Preparing confident students for the world of work is complex. It requires strong academic leadership, access to a high-quality curriculum and content, and the exposure of students to the effective use of business technology. Furthermore, high quality teaching and learning must seek to support the learning style of each individual student; whether it be peer group learning, individual learning or ‘learn-by-doing.’ This approach encourages students to take ownership of their own learning, seen as an essential step towards achieving the best outcomes.

2.3.2.1 Virtual Learning Environments

A global approach for digitalizing teaching, learning and assessment requires the use of a modern web-based platform for all the digital aspects of courses of study: a Virtual Learning Environment or VLE. The VLE typically (i) allows participants to be organized into cohorts, groups and roles (ii) presents resources, activities and interactions within a course structure (iii) provides for the different stages of assessment reports on participation (iv) has some level of integration with other institutional systems such as the federated identity management systems. The VLE is articulated around five core capabilities: content management, curriculum mapping and planning, learner engagement and administration, communication and collaboration, real-time communication. Moodle and Open Edx are typical widely acclaimed and widely used VLEs. Making them accessible ubiquitously, anytime, anywhere to thousands of students is a challenge for the university digital infrastructure. Moreover, they present a fluctuating usage pattern with sharp picks at exam times and concurrent labs that's why public clouds constitute an environment of choice for such VLEs.

2.3.2.2 Analytics-based education

Advanced analytics is transforming what universities can do for students, professors and tutors. A wealth of data is now being collected from a range of internal systems and external sources such as mobile and wearable devices that can be analyzed and presented back to the user in an interactive and highly visual fashion. Universities that are able to harness the potential of data by analyzing it intelligently and using it to deliver outcomes, such as improved academic performance, employability rates or student retention, will give themselves a considerable advantage.

2.3.2.3 Virtual labs

The growing importance of numerical simulations and data analysis in a large number of scientific and engineering subjects such as (bioinformatics, astrophysics, climate studies, civil engineering, civil engineering, etc...) require the introduction of new digital capabilities for learners in the form of virtual labs running on advanced and scalable infrastructures. Data science for instance which is a new discipline that relies on computers and mathematics, particularly statistics to extract information from data relies often on Cloud computing as the key technology to implement algorithms and data processing and visualization techniques.

Data science curricula have been added by thousands of universities around the globe. The data science, big data and IoT-related subjects typically need tight integration with large infrastructures and advanced software and services. A new generation of VLEs is emerging to fill in the technology gap. The new VLEs act both as brokers to public and private clouds and as social portals exposing virtual educational appliances, catalogs of educational and research services that can be built on-the-fly based provisioned templates.

2.3.3 Digital Research

2.3.3.1 Science and 4th paradigm

Increasingly, scientific breakthroughs are being powered by advanced computing capabilities that help researchers manipulate and explore massive datasets. “One of the greatest challenges for 21st-century science is how we respond to this new era of data-intensive science. This is recognized as a new paradigm beyond experimental and theoretical research and computer simulations of natural phenomena—one that requires new tools, techniques, and ways of working.” (Douglas Kell).

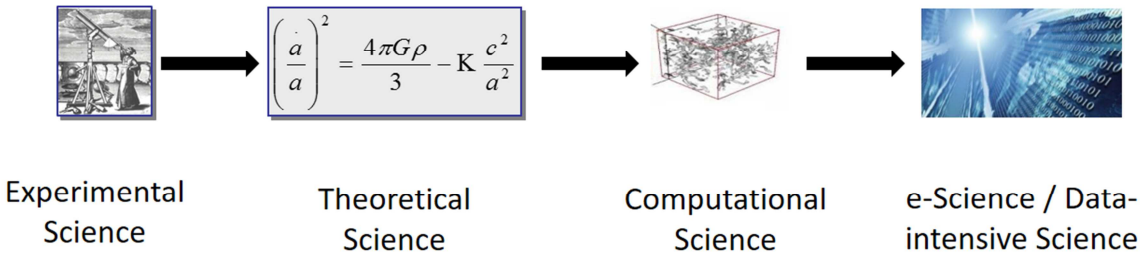

Fig. 25 The 4thParadigm [27]

2.3.3.2 Collaborative Research

Technology plays an important role in leading-edge research; both by increasing the success rates of research programme bids and by delivering better research outcomes. But, once again, technology disruption is essential for a modern university. Technology can allow a modern university to successfully differentiate its research offer, and so increase the number of research programmes and partnerships, and enhance its brand. Research has always been very dependent on IT. And having the right compute and storage for high performance and ‘big data’ computing, supported by robust research data management, is still at the heart of research. But there are other, increasingly important, factors that need to be addressed by research leads. Security and information governance must be a key focus to ensure intellectual property is protected, and research data can be accessed over whatever retention period is demanded by a programme. And, collaboration tools are also critical. Research is fundamentally a collaborative process and providing the right tools to get the very best out of individual researchers, team structures and peer organizations is now of critical importance.

2.3.3.3 Open Science

Open science is the movement to make scientific research, data and dissemination accessible to all levels of an inquiring society, amateur or professional. It encompasses practices such as publishing open research, campaigning for open access, encouraging scientists to practice open notebook science, and generally making it easier to publish and communicate scientific knowledge (Wikipedia).

2.3.4 Ecosystem Digital Links

Universities should exploit connectivity, communications and collaboration to maximize the value of university partner communities, anchor its activities to its digital stakeholders and catalyze its exchanges and collaborations with them.

For many universities links to external stakeholders and stakeholder groups are becoming ever more important. This is particularly the case for ‘place-centered’ universities with the mission to deliver educated and skilled graduates into their local economy, thereby supporting local authority drives for economic prosperity and political devolution. For such universities, there are key partnerships with the local Public Sector (local authorities, Medical Trusts and colleges, schools and academies) and with local businesses (start-up and established businesses) to further local economic activity including apprenticeships, placements and research activity. Typically, up to six external stakeholder groups can form an integral and essential part of university life. This includes:

- Alumini
- Government Funding Bodies
- Local, Regional and National Research Partners (to capture funding, progress research programmes and exploit intellectual property
- Local and regional businesses (to provide educated and skilled staff and for apprenticeships
- Local colleges, schools and Academies
- Local Authority, Local Medical Services and other public sector (to provide educated and skilled staff and pursue economic prosperity.

To be successful in delivering its model of education and research, and achieving its regional ambitions, University should make each stakeholder group operate as a thriving digital community. Technology plays a key role in allowing each stakeholder group to be supported by the ability to connect, communicate and share information.

Chapter 3
A customized digital university model

This chapter aims at defining a model for the digital university based on which a country-level cloud migration strategy can be elaborated. Starting from this model, a multi layered approach is proposed to define the guiding principles of the decision making process supporting the strategy to be elaborated.
Indeed, a cloud strategy for education must be derived from the country's digital strategy for education. The digital strategy makes it possible to define a vision, objectives to meet and relevant IT applications enabling objectives' achievement at country, university or institution level. In the absence of an overall digital strategy, the proposed multi-layered approach makes it possible for the project team to contextualize the main guiding principles.

This chapter is structured in three parts, the first focuses on the elaboration of customized Digital University model, the second will present the multi-layered decision making model and how to contextualize it as well and the third part deals with the contextualization of the governance model.

The starting point is the **Digital University high-level model** proposed in chapter 2 (figure 24). The DU high level model has 6 components: two transversal layers and 4 vertical pillars. The Digital Strategy & Vision layer includes **global objectives** and each of the pillars includes **specific objectives.** Achieving those objectives requires a set of specific **IT applications** in addition to common IT applications, as shown in Fig…. .The IT service delivery Platform layer is a support layer.

3.1 Expanded digital university model

The objectives and the IT applications of the Digital University are derived from the different proposals and views expressed in Chapter 2: vision and model for the Digital University.

The figure below represents a detailed and comprehensive view of the proposed Digital University model. (Expanded DU model to be called DU model in what follows). The objectives and IT application are proposed for the DU's four pillars and for the DU's "vision and strategy layer"

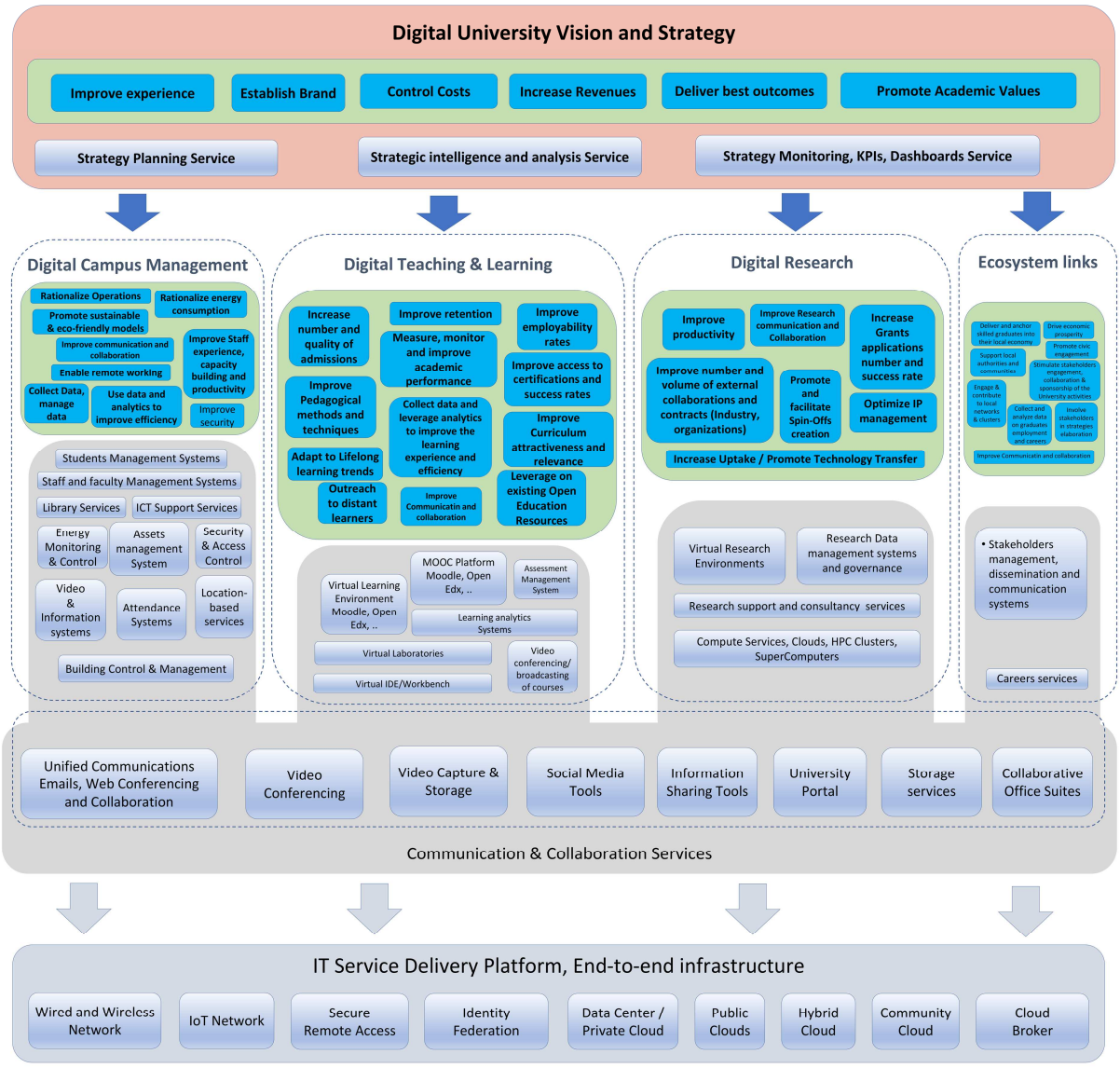

Fig. 26 Expanded Digital University Model (DU Model)

3.1.1 Expanded digital university model Objectives

The DU model objectives are:

- **Digital University Vision and Strategy, Transversal/Global Objectives**
    - Establish Brand
    - Deliver best outcomes
    - Promote Academic Values
    - Improve experience
    - Control Costs
    - Increase Revenues
- **Digital Campus Management Objectives**
    - Rationalize Operations

    - Improve communication and collaboration
    - Enable remote working
    - Improve Staff experience, capacity building and productivity
    - Use data and analytics to improve efficiency
    - Improve security
    - Rationalize energy consumption
    - Promote sustainable &eco-friendly models
- **Digital Teaching & Learning Objectives**
    - Increase number and quality of admissions
    - Improve retention
    - Improve employability rates
    - Measure, monitor and improve academic performance
    - Improve access to certifications and success rates
    - Improve Pedagogical methods and techniques
    - Improve Curriculum attractiveness and relevance
    - Leverage on existing Open Education Resources
    - Adapt to Lifelong learning trends
    - Outreach to distant learners
    - Collect data and leverage analytics to improve the learning experience and efficiency
    - Improve Communication and collaboration
- Digital Research **Objectives**
    - Improve productivity
    - Improve Research communication and Collaboration
    - Increase Grants applications number and success rate
    - Improve number and volume of external collaborations and contracts (Industry, organizations)
    - Promote and facilitate Spin-Offs creation
    - Optimize IP management
    - Increase Uptake / Promote Technology Transfer
- Ecosystem digital links **Objectives**
    - Deliver and anchor skilled graduates into their local economy
    - Drive economic prosperity
    - Support local authorities and communities
    - Stimulate stakeholders engagement, collaboration & sponsorship of the University activities
    - Promote civic engagement
    - Engage & contribute to local networks & clusters
    - Collect and analyze data on graduates employment and careers
    - Involve stakeholders in strategies elaboration
    - Improve Communication and collaboration

3.1.2 Expanded digital university model IT applications

For each set of objectives defined in the pillars or in the "vision and strategy" transversal layer, a set of IT applications is proposed to achieve those objectives. Those applications are either standard ones or have been derived from the analysis conducted in chapter 2.
The IT applications are as follows:

- **Digital University Vision and Strategy, IT Applications**
  - Strategy Planning App
  - Strategic intelligence and analysis App
  - Strategy Monitoring, KPIs, Dashboards App
  - Communication & Collaboration Services
- **Digital Campus Management, IT Applications**
  - Students Management Systems
  - Staff and faculty Management Systems
  - Security & Access Control
  - Assets management System
  - Library Services
  - ICT Support
  - Video & Information systems
  - Attendance Systems
  - Location-based services
  - Building Control & Management
  - Services Energy Monitoring
  - Communication & Collaboration Services
- **Digital Teaching & Learning, IT Applications**
  - Virtual Learning Environment / LMS, Moodle, Open Edx etc.
  - Virtual Laboratories
  - Virtual IDE/Workbench
  - MOOC Platform Moodle, Open Edx,..
  - Assessment Management System
  - Learning analytics Systems
  - Video conferencing/broadcasting of courses
  - Communication & Collaboration Services
- **Digital Research, IT Applications**
  - Virtual Research Environments
  - Research Data management systems and governance
  - Location-independent access to research data and other content;
  - Research support and consultancy services
  - Compute Services, Clouds, HPC Clusters, Super Computers
  - Communication & Collaboration Services
- **Ecosystem digital links, IT Applications**
  - Stakeholders management, dissemination and communication systems
  - Careers services

- Communication & Collaboration Services

« **Communication & Collaboration Services** » are supportive of the four pillars as well as of the « vision and strategy » transversal layer. They include the following:

- Unified Communications Emails, Web Conferencing and Collaboration
- Video Conferencing
- Collaborative Office Suite
- Video Capture & Storage
- Social Media Tools
- Information Sharing Tools
- University Portal
- Storage services

3.2 Customization of the digital university model

The DU contextualization means selecting the objectives and IT applications which are relevant to the context of the country for which the strategy will be elaborated. We propose a two-step contextualization methodology. The first step leads to objectives contextualization, the second step is about IT Applications contextualization.

3.2.1 Step 1: Objectives Contextualization

The country's or institution's digital strategy -if one has been enacted- guides the selection of objectives. Otherwise, the project team should select objectives after engaging with key decision makers.

The project team will choose among the proposed objectives in the DU model. The list objectives can't be exhaustive and the project team should introduce any missing objective which would meet any specific concerns or needs. The DU tools enable the project team to discard irrelevant objectives.

The DU tool (http://bit.ly/bahrain-du)

The DU tool is based on Fig xx. Expanded Digital University Model (DU Model) based on which the project team can retain or discard objectives. The choice of objectives is a critical task and should be discussed at length among stakeholders.

The outcome is a **DU model with contextualized objectives** (example of a Tunisian University is represented in fig xx which includes selected objectives as well as IT applications as defined in the next section).

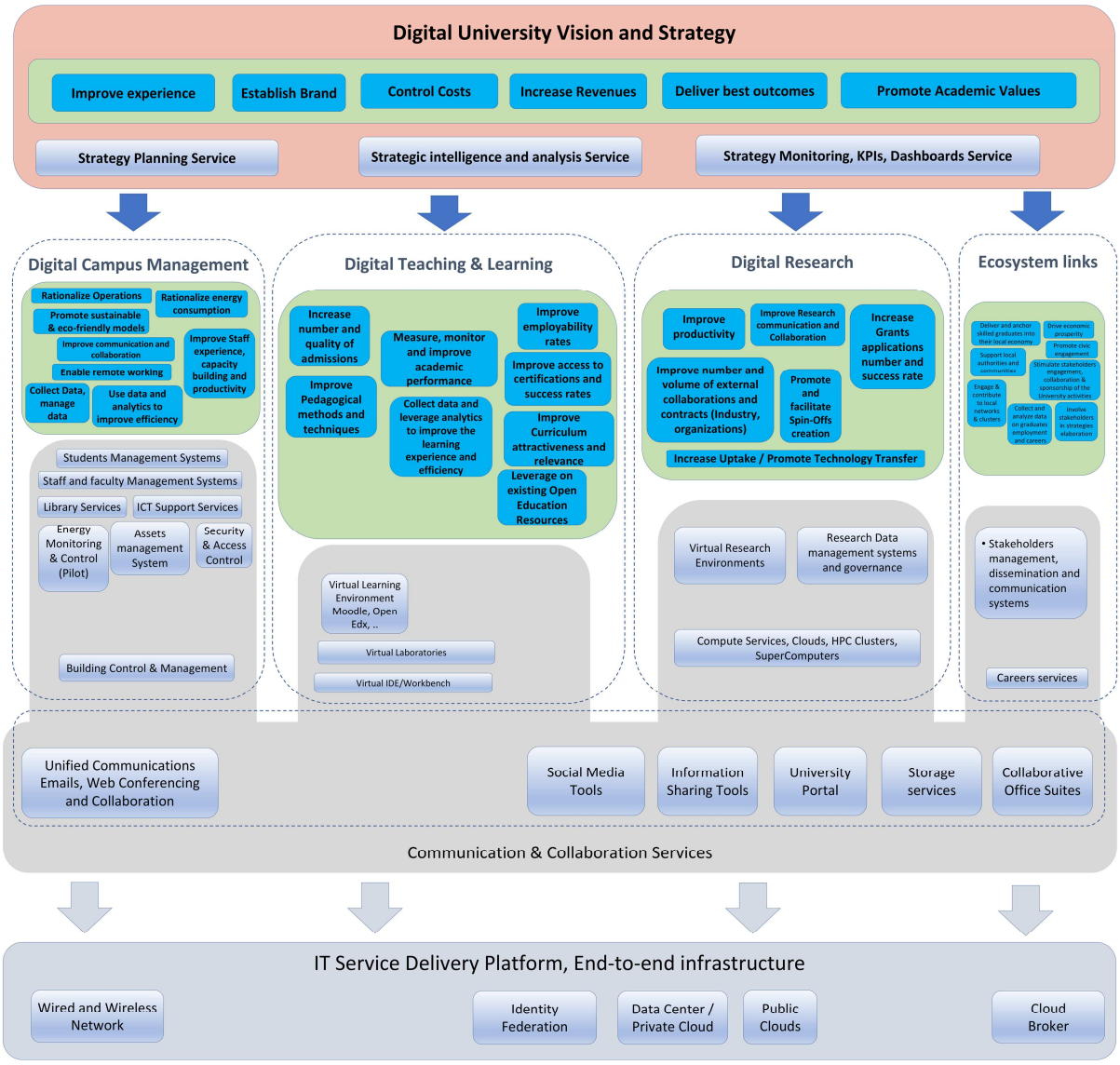

Fig. 27 Example of a contextualized digital university model

3.2.2 Step2: Contextualization of the IT Applications

The selection of IT Application is done using the OAPP tool. The starting point is the DU model with contextualized objectives.

The OAPP tool

The excel document has 4 sheets corresponding to the 4 DU pillars: Campus, Education, Research and Ecosystem (Note that a sheet maybe easily added in similar way for the top layer). Each sheet represents a matrix with IT applications as rows and objectives as columns. IT applications include the pillar-specific ones and the cross-pillars ones

A row of weights reflects the importance of the corresponding objective for the institution.

Each cell has a score corresponding to the contribution of the IT application (row) to the objective achievement (column).

The right column represents the sum of the contributions of the application to the weighted objectives. The higher is the value, the more the application contributes to achieving the set of defined objectives. This helps in setting priorities for the choice of applications to migrate first.

The bottom row represents the sum of the (ratios of (contribution) by (objective weight)) of all the applications to achieving one specific objective.

For each pillar, the project team should:

(i) Update the objectives and keep only those retained in the contextualized DU model

(ii) Define weights for the objectives in the corresponding row

(iii) Define a score (1 to 5) which estimates the contribution of the IT Application to achieving an objective

(iv) retain the IT applications which have the highest scores in the last column (score column) of the pillar-dedicated sheet in OAPP

(v) Discuss the contribution of all the IT Applications to the achievement of each specific retained objective using the scores in the last row of the pillar-dedicated sheet in OAPP

To illustrate the approach, here is an example of the "Digital Research" Sheet where all the objectives have been set to 1

Tab.2 Objectives-application Matrix Digital Research 1

Digital Research	Improve productivity	Improve Research Collaboration	Increase Grants applications number and success rate	Improve number and volume of external collaborations and contracts	Promote and facilitate Spin-Offs creation	Optimize IP management	Increase Uptake / Promote Technology Transfer	Score
Weights (Objectives importance for the university) [1-5] higher value means more importance	1	1	1	1	1	1	1	
Virtual Research Environments	3	3	0	2	1	0	0	9
Research Data management systems and governance	3	3	0	2	1	0	0	9
Research support and consultancy services	2	1	4	3	2	3	3	18
Compute Services, Clouds, HPC Clusters, SuperComputers	5	5	0	3	1	0	0	14
Unified Communications Emails, Web Conferencing, etc. (*)	2	3	0	3	0	0	0	8
Video Conferencing	1	3	0	1	0	0	1	6
Video Capture & Storage	0	0	0	0	0	0	0	0
Social Media Tools	0	0	0	1	0	0	2	3
Information Sharing Tools	1	1	0	1	0	0	1	4
University Portal	0	0	3	2	0	1	3	9
Storage services	3	0	0	1	0	0	0	4
Collaborative Office Suite	3	3	1	2	0	0	2	11
	23	22	8	21	5	4	12	

One can notice that the applications « research support & consultancy services » has the highest score (18) followed by « compute services, clouds, HPC Clusters, Super computers » which has a score of 14.By examining the last row, it appears that the objective « improve productivity » has the highest score (23) which means that this objective is the one to which the IT applications contribute the most.

A different choice of weights would produce different scores and can potentially change the priority ranking if IT Applications. By attaching a weight of 5 to «Improve productivity" and "Increase Uptake / Promote Technology Transfer**",** the "compute services…." IT Application gets the highest (44).

Tab.3 Objectives-application Matrix Digital Research 2

Digital Research								
	Improve productivity	**Improve Research Collaboration**	**Increase Grants applications number and success rate**	**Improve number and volume of external collaborations and contracts (Industry, organizations)**	**Promote and facilitate Spin-Offs creation**	**Optimize IP management**	**Increase Uptake / Promote Technology Transfer**	**Score**
Weights (Objectives importance for the university) [1-5] higher value means more importance	5	3	1	1	1	1	5	
Virtual Research Environments	3	3	0	2	1	0	0	27
Research Data management systems and governance	3	3	0	2	1	0	0	27
Research support and consultancy services	2	1	4	3	2	3	3	40
Compute Services, Clouds, HPC Clusters, Super Computers	5	5	0	3	1	0	0	44
Unified Communications Emails, Web Conferencing, etc. (*)	2	3	0	3	0	0	0	22
Video Conferencing	1	3	0	1	0	0	1	20
Video Capture & Storage	0	0	0	0	0	0	0	0
Social Media Tools	0	0	0	1	0	0	2	11
Information Sharing Tools	1	1	0	1	0	0	1	14
University Portal	0	0	3	2	0	1	3	21
Storage services	3	0	0	1	0	0	0	16
Collaborative Office Suite	3	3	1	2	0	0	2	37
	23	22	8	21	5	4	12	

The following table shows the scores of the IT Applications for the « Digital Learning and Teaching » pillar. Objectives weights are all set to 1. « Virtual Learning Environment / **LMS, Moodle**, Open Edx" gets the highest score.

Tab.4 Objectives-application Matrix Digital Learning & Teaching

Digital Learning & Teaching												
	Increase number and quality of admissions	Improve retention	Improve employability rates	Measure, monitor and improve academic performance	Improve access to certifications and success rates	Improve Pedagogical methods and techniques	Collect data and leverage analytics to improve the learning experience and efficiency	Improve Curriculum attractiveness and relevance	Adapt to Lifelong learning trends	Outreach to distant learners	Leverage on existing Open Education Resources	Score
Weights (Objectives importance for the university) [1-5] higher value means more importance	1	1	1	1	1	1	1	1	1	1	1	
Virtual Learning Environment / LMS, Moodle, Open Edx etc. (*)	3	4	2	2	2	5	3	2	3	4	4	34
Virtual Laboratories	1	3	2	0	2	3	3	2	3	4	4	27
Virtual IDE/Workbench	0	1	2	0	2	3	3	2	3	4	4	24
MOOC Platform Moodle, Open Edx, ..	3	3	2	2	3	3	3	2	3	4	4	32
Assessment Management System	1	2	2	4	0	1	3	4	3	2	2	24
Learning analytics Systems	3	5	3	4	1	1	5	4	3	2	2	33
Unified Communications Emails, Web Conferencing, etc. (*)	1	2	1	0	1	1	0	0	2	3	1	12
Video Conferencing	0	2	0	0	1	1	0	0	1	3	1	9
Video Capture & Storage	0	0	0	0	0	4	0	0	0	2	1	7
Social Media Tools	4	2	3	0	0	0	1	1	0	1	1	13
Information Sharing Tools	0	2	2	0	0	1	0	0	1	1	1	8
University Portal	4	2	2	0	0	0	0	0	0	1	0	9
Storage services	0	0	0	0	0	0	4	0	0	3	0	7
Collaborative Office Suite	0	0	0	0	0	3	0	0	1	2	1	7
	20	28	21	12	12	26	25	17	23	36	26	

Given their common nature, the « Communication & Collaboration Services » IT Applications' scores should be aggregated across all DU pillars.
The outcome is a contextualized DU model, in line with the national digital strategy, with contextualized objectives and pertinent/prioritized IT Applications to achieve the objectives

3.3 The multi Layered approach

As a matter of fact, the elaboration of a vision for the Digital University should rely on the national digital strategy complemented by the strategies and guidelines set at Higher Education Ministry level.

The elaboration of the vision should take into consideration several distinct levels of decision making which vary according to the autonomy level of the universities and the Higher Education individual institutions. It also depends on the existing instruments and institutions whose role is to implement the national digital strategy or to deliver IT capabilities at national or regional level. For example, in "Bahrain", the "cloud first" national strategy enforces a "cloud first" strategy for all universities and their HE institutions. Nonetheless, the migration

strategies and migration plans have been left to the universities and HE institutions to define and implement. iGA is the Bahrain organism who designed the “cloud first” national strategy and is responsible for its application across Governmental bodies, entities and HE Institution. In Tunisia, Centre de Calcul Khawarizmi (CCK) is the IT service provider for all Tunisian Universities and the HE institutions they manage. It is responsible for institutional emails, web hosting, network maintenance and bandwidth allocation, research compute resources federation, etc. The Tunisian Virtual University (UVT) has its own data centers and also provides HE IT Applications (such as Moodle access) at national level. Not all relevant HE IT Applications are provided by CCK or UVT. Both have explored private clouds but none has adopted public cloud at scale. The DU vision for Tunisia will very much depend on the evolution of CCK and UVT and on the levels of autonomy that will be given to Universities and to their HE institutions.

Different scenarios can be envisaged. In order to guide the project team in defining the vision for the DU, a multi-layered decision-making model has been proposed as well as a dedicated tool: bahrain-gsv.

The 3-layered-approach Model

3 types of actors and 3 hierarchical layers of decision making are considered: Ministry, University, Institutions according to the degree of autonomy. In this case we consider the ministry in charge of HE, the universities that report to that ministry and for each university the institutions that report to it. Typical institutions are school of engineering, faculty of sciences, faculty of humanities, school of medicine, etc.) .

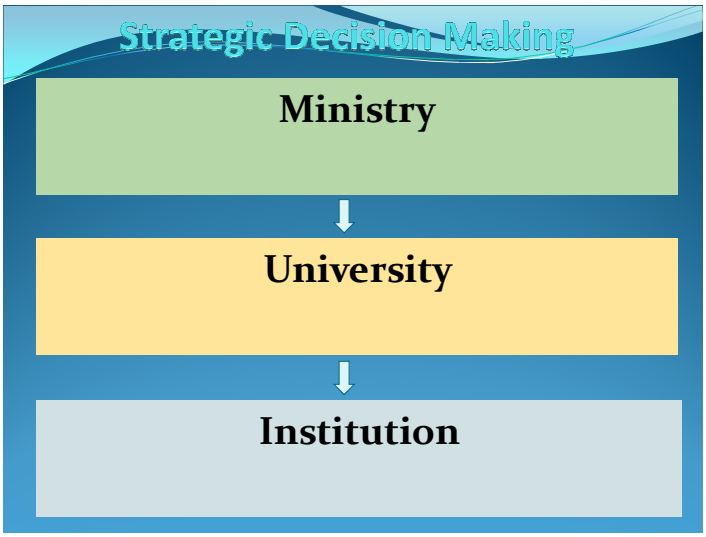

Fig. 28 The 3-layered-approach Model

The model doesn’t take into consideration national organisms in charge of the national digital strategy. It doesn’t take into consideration neither any existing federated infrastructure for HE at national level.

3 typical layouts for strategic decision making and choices of macro objectives and IT Applications are considered: Ministry only decides, Ministry and University decide, the three actors decide. The 3 cases are defined alongside with examples in what follows.

- **Ministry only decides**

In this case the Ministry elaborates strategies. The Universities reporting to the Ministry strictly follow the Ministry strategy. Institutions of a university strictly follow the University strategy.

The figure below gives an example where the ministry decided for common set of objectives and IT applications for the 4 pillars of a DU. With regard to DU1 the Digital Campus Management pillar 3 objectives are selected denoted by DU1-OBJ1, DU1-OBJ2, DU1-OBJ3and 2 Applications to support those objectives denoted DU1-APP1 end DU1-APP2. Similar notations are used for DU2 the Digital Teaching & Learning, DU3 the Digital Research pillar and DU4 the Ecosystem digital links pillar.

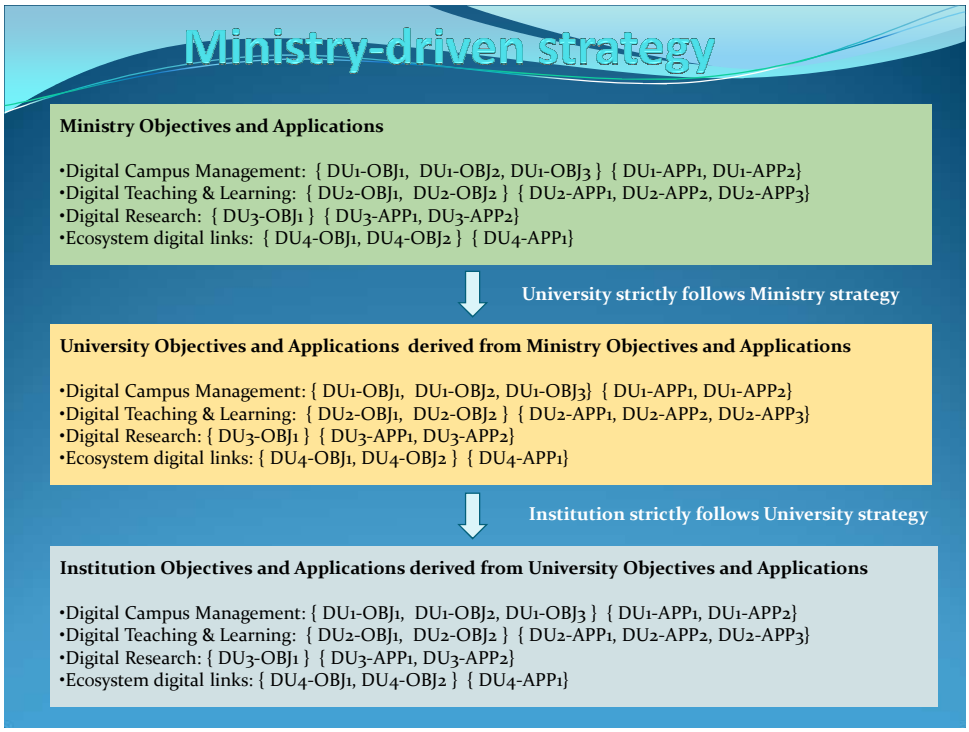

Fig. 29 Ministry-driven Strategy

Note that Universities adopt exactly what Ministry defines and similarly institutions adopt the same set of objectives and applications per pillar defined by their university. It is a top down approach which actually facilitates a SAS approach for the common applications and may be a common community cloud if the option to the move to the public cloud is not adopted.

- **Ministry and University decide**

In this case the Ministry enforces a subset of common objectives and applications. A University defines a subset of specific objectives and applications. Institutions strictly follow their University strategy. In other words, the ministry allows their universities to add some

objectives according to their specificities. This approach facilitates a SAS approach for the common applications.

The figure below gives an example where the ministry decided for common set of objectives and applications for the 4 DU pillars. The University added some specific objectives and IT applications. In bold are all specific objectives and applications. For example, in the second layer, the university layer in DU1 the Digital Campus Management pillar: **DU1-OBJ3**is a university specific objective and **DU1-APP2** a specific university application.

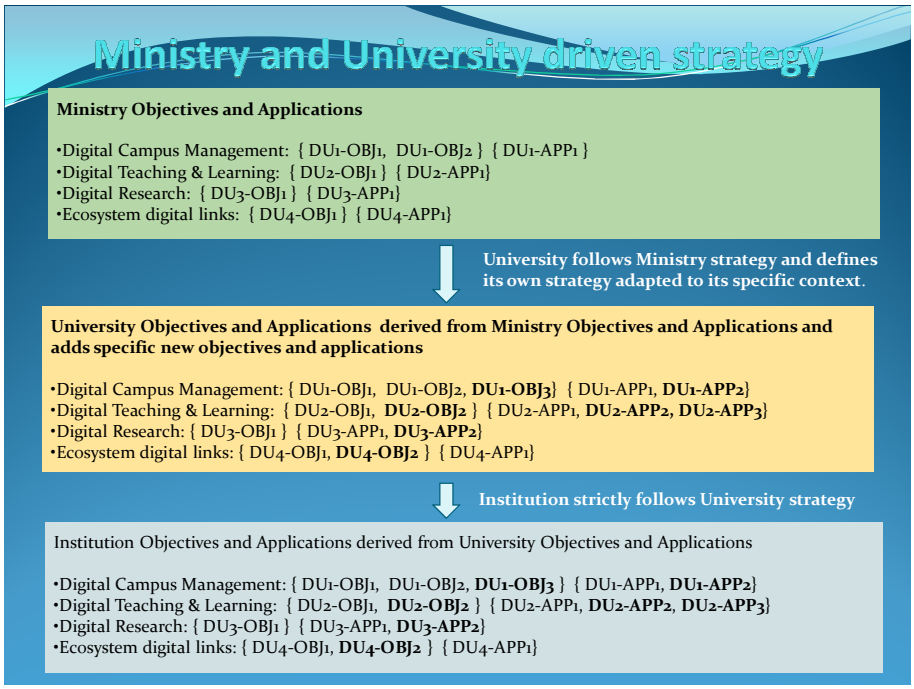

Fig. 30 Ministry and University driven Strategy

- **The three actors decide:**

The Ministry enforces subset of common objectives and applications. The University defines a common subset of specific objectives and applications. Institutions define an extra subset of specific objectives and applications.

The figure below gives an example where the ministry decided for common set of objectives and applications for the 4 DU pillars. The University adds some specific objectives and IT applications common for all its institutions. The institution added some specific objectives and IT applications and adopted of course all objectives and applications decided at the university level.

In bold are all specific objectives and applications at the university level and in purple all specific objectives and applications at the institution level. For example in DU1 the Digital Campus Management pillar of the institution a specific IT application **DU1-APP3 was** added.

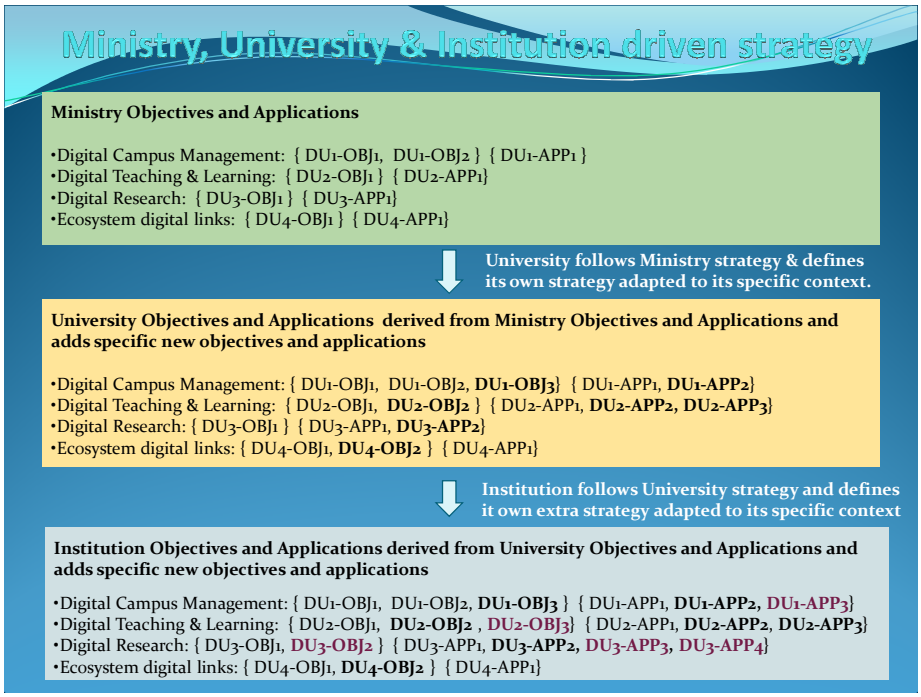

Fig. 31 Ministry, University and Institution driven Strategy

Chapter 4
Contextualized vision for the cloud

In Chapter 4, a contextualized Digital University model and the decision making process have been developed.

The contextualized DU shows IT applications pertinent to achieving the retained objectives. This chapter will focus on both the IT service delivery platform and end-to-end infrastructure layer and the elaboration of a contextualized vision for the cloud.

The approach here is similar to the one adopted in the previous chapter: What will be achieved is a contextualized IT Service Delivery Platform layer represented in the DU diagram and isolated in the figure xx below.

Fig. 32 IT service delivery platform layer

IT service delivery platform includes the network infrastructure, secure remote access, identity federation as well as various types of IT infrastructures.

The capacity of the wired and wireless network should be in line with the retained IT applications and the number and usage pattern of the end users. It is important to emphasize the critical importance of a high-quality network for any cloud migration strategy.

The IoT network is required only in case IT applications such as Attendance Systems, Location-based services, Building Control & Management, Services Energy Monitoring are chosen. All those IT applications belong to the digital campus management pillar. The capacity of the IoT network should be in line with the selected applications. Identity federation and secure access services are a pre-requirement for such applications.

When it comes toIT infrastructure resources, different models are considered such as Data Center/Private cloud, Public clouds, Hybrid Cloud, Community cloud and Cloud Broker.

The **public cloud** is defined as computing services offered by third-party providers over the public Internet, making them available to anyone who wants to use or purchase them. They may be free or sold on-demand, allowing customers to pay only per usage for the CPU cycles, storage, or bandwidth they consume.

Unlike private clouds, public clouds can save institutions from the expensive costs of having to purchase, manage, and maintain on-premises hardware and application infrastructure - the cloud service provider is held responsible for all management and maintenance of the system. Public clouds can also be deployed faster than on-premises infrastructures and with an almost infinitely scalable platform. Every member of the institution can use the same application from any office using their device of choice as long as they can access the Internet. While security concerns have been raised over public cloud environments, when implemented correctly, the public cloud can be as secure as the most effectively managed private cloud implementation if the provider uses proper security methods, such as intrusion detection and prevention systems (IDPS).

The **private cloud** is defined as computing services offered either over the Internet or a private internal network and only to select users instead of the general public. Also called an internal or institutional cloud, private cloud computing gives institutions many of the benefits of a public cloud - including self-service, scalability, and elasticity - with the additional control and customization available from dedicated resources over a computing infrastructure hosted on-premises. In addition, private clouds deliver a higher level of security and privacy through both the institution firewalls and internal hosting to ensure operations and sensitive data are not accessible to third-party providers. One drawback is that the institution's IT department is held responsible for the cost and accountability of managing the private cloud. So private clouds require the same staffing, management, and maintenance expenses as traditional datacenter ownership.

A **hybrid cloud** is a computing environment that combines a public cloud and a private cloud by allowing data and applications to be shared between them. When computing and processing demand fluctuates, hybrid cloud computing gives the institution the ability to seamlessly scale their on-premises infrastructure up to the public cloud to handle any overflow - without giving third-party datacenters access to the entirety of their data. HE Institutions gain the flexibility and computing power of the public cloud for basic and non-sensitive computing tasks, while keeping critical applications and data on-premises, safely behind an institution firewall.

Using a hybrid cloud not only allows institutions to scale computing resources, it also eliminates the need to make massive capital expenditures to handle short-term spikes in demand as well as when the need to free up local resources for more sensitive data or applications arises. Institutions will pay only for resources they temporarily use instead of having to purchase, program, and maintain additional resources and equipment that could remain idle over long periods of time [Source: Microsoft Azure Overview]

A Cloud Broker provides a single point of entry to manage multiple cloud services. The two important unique features of a cloud broker are the ability to provide a single consistent interface to multiple differing cloud providers and the clear visibility that the broker allows into which company is providing the services in the background.

In general, cloud brokers provide services in three categories:

- Aggregation: A cloud broker combines and integrates multiple services into one or more new services. The broker provides data integration and ensures the security of data in transition between the cloud consumer and multiple cloud providers.

- Arbitrage: Service arbitrage is similar to service aggregation, except that the services being aggregated are not fixed. Service arbitrage means a broker has the flexibility to choose services from multiple Providers, depending upon the characteristics of the data or the context of the service.

- Intermediation: A cloud broker enhances a given service by improving some specific capability and providing value-added services to cloud consumers. The improvement can be managing access to cloud services, identity management, performance reporting, enhanced security, etc.

Benefits of using a cloud broker include the following:

- Cloud interoperability - Integration between several cloud offerings.
- Cloud portability - Move application(s) between different cloud vendors.
- Increase business continuity by reducing dependency on one cloud provider.
- Increase SLAs by leveraging multiple cloud providers.
- Cost savings - Most IaaS clouds offer significant volume discounts to those who have purchased a large number of instances. For example, Amazon provides 20% or even higher volume discounts in Amazon Elastic Compute Cloud (EC2). Due to the sheer volume of the aggregated demand, the cloud broker can easily qualify for such discounts, which further reduces the cost of serving all the users.
- Pay for what is needed: Cloud brokers provide a selected assortment of services required by the consumer.

There are also concerns related to the use of a cloud broker. The greatest drawback in using a cloud broker is reliance on the broker to be continuously up to date on new cloud technologies, options and offerings. Using a cloud broker also adds complexity in maintaining an organization's security requirements throughout the entire delivery chain as the broker adds a layer between the cloud service providers and the organization. There are potential conflicts of interest, so the organization needs to ensure that the broker is consistently representing its best interests when recommending cloud offerings. [Source Wikipedia]

The elaboration of a cloud vision is based upon the choice of the type of cloud to use. This choice should be well informed and should leverage the Cloud adoption policy guidelines presented in the 2016 report and especially ***Key Policy guideline 2: Always Public cloud first.***

The policy to be adopted consists in encouraging the use of public cloud as the first choice wherever possible and hence enabling educational institutions fast access to advanced IT and catching up with international practice. It is recommended to consider Always SaaS first and Use Pubic PaaS/IaaS instead of local infrastructures. Software-as-a-Service should be considered first, it entirely delegates all the unwanted complexity to a service provider and empowers users through seamless access to tailored and effective Web User interfaces. PaaS and IaaS (public if possible or private otherwise) should then be considered as the way to go when it comes to the provisioning of custom applications and capabilities, they expose more complexity but can be harnessed thanks to APIs and automation frameworks. Existing on-premise applications that (i) have critical constraints or (ii) wouldn't benefit from public or private clouds or (iii) can't be cloudified should continue operating on-premises.

4.1Contextualized SWOT Analysis

SWOT analysis (or SWOT matrix) is an acronym for strengths, weaknesses, opportunities, and threats and is a structured planning method that evaluates those four elements of an organization, project or business venture.

The elaboration of a cloud vision should also take into consideration cloud-type-specific SWOT analysis for the pre-chosen cloud types.

Identification of SWOTs is important because they can inform later steps in planning to achieve the objective. First, decision-makers should consider whether **the objective is attainable**, given the SWOTs. If the objective is *not* attainable, they must select a different objective and repeat the process. [Wikipedia]

We to propose to SWOT-analyze cloud migration involving part or all of the following cloud types:

- Data Center/Private cloud
- Public clouds
- Community cloud
- Hybrid Cloud
- Cloud broker

Cloud types that are not compatible with the actual context of the institution should be skipped.

"SWOT analysis aims to identify the key internal and external factors seen as important to achieving an objective. SWOT analysis groups key pieces of information into two main categories:

1. Internal factors – the *strengths* and *weaknesses* internal to the organization
2. External factors – the *opportunities* and *threats* presented by the environment external to the organization

Analysis may view the internal factors as strengths or as weaknesses depending upon their effect on the organization's objectives. What may represent strengths with respect to one

objective may be weaknesses (distractions, competition) for another objective. The factors may include all of the 4Ps as well as personnel, finance, manufacturing capabilities, and so on.

The external factors may include macroeconomic matters, technological change, legislation, and socio cultural changes, as well as changes in the marketplace or in competitive position. The results are often presented in the form of a matrix as shown in the Figure below. [Wikipedia, https://en.wikipedia.org/wiki/SWOT_analysis]

Fig. 33 SWOT Matrix

The four dimensions of SWOT are defined as follows:

- **Strengths :**characteristics of the project that give it an advantage to achieve objectives
- **Weaknesses :**characteristics of the project that place it at a disadvantage for achieving objectives
- **Opportunities :**elements in the environment that the project could exploit to its advantage
- **Threats :**elements in the environment that could cause trouble for the project

As a matter of fact, the decision making bodies as well as all the different impacted stakeholders should contribute to the SWOT analysis and should help defining the factors belonging to the four quadrants. What is required is not to simply enumerate factors but also to fully identify them, assess their importance and prioritize them in a rational manner.

To help the project teams in elaborating their different SWOT analysis, catalogs of factors have been added as part of the "SWOT" tool (http://bit.ly/bahrain-swot):

Strengths and weaknesses factors

Political engagement/vision

Digital strategy/vision at Ministry level

University pedagogy Innovation strategy/programs
Education and research community's motivation/engagement
Existence of a centralized center/facilities for HE IT services
Flexible and proactive IT governance
Broadband Internet connection
Local area network infrastructure
IT prevalence at universities and institutions levels
Cloud computing services experience at universities and institutions levels
IT services cloud computing skills
Financial resources availability

Opportunities factors

Cloud computing technologies penetration/ pervasiveness
Funding bodies support
Diversity and accessibility of cloud computing offerings/capabilities
Enabling legal framework for data privacy
Enabling legal framework for cloud services
Mobile penetration
Collaboration enablement
Disaster recovery capabilities
Data storage infrastructure availability, scalability and reliability
Reduction of capital expenditure
Compute infrastructure scalability
Reduced time-to-market for new services deployment
Reduced overall infrastructure cost for new services
Increased technical agility
Increased financial agility

Threats factors

Lack of support from government
Lack of support from international funding bodies
Limited involvement of external stakeholders
Current state of the country's Internet / telecom infrastructure
Universities / institutions technologically lagging behind
Lower quality of education
Lower employability
Lower attractiveness for students, teachers and researchers
Higher vulnerability to cyber attacks of HE Information Systems
Lower ranks in international HE rankings

From the strengths factors, weaknesses factors can be derived in a straightforward manner.

The SWOT tool also includes the SWOT analysis' four quadrants.

The tasks to be addressed by the project team include:

- Discussing and choosing from the catalogs the strengths, weaknesses, opportunities and threats specific to their countries, ministries, universities, etc.
- Completing the quadrants with the selected factors and with new factors identified as relevant by the project team and not present in the catalogs.

Outcome: Contextualized cloud-type-specific SWOT matrices

The project team and decision makers may now reach a decision on the type of cloud to be adopted.

4.2 Contextualized vision for the IT governance

The migration to the cloud requires a change in IT governance models and practices. First, the offer to be made available to users must meet two main requirements: ease of use and flexibility. Secondly the establishment of an intermediary entity should facilitate relationships between suppliers and customers. It is recommended to ***adopt a cloud friendly governance model for IT***. Hence it is advisable to:

a- Allow end users (Teachers, students, researchers, staff) to make informed choices about the specific services they may want to experiment with or use on the long run. Redefine the role of the IT department to become a service and support provider without limiting the scope of initiatives that users may want to take;

b- Create an entity at national, regional or institutional level that deals with brokerage and procurement in a centralized way. That entity's major missions would be to:

(i) Negotiate the SLAs and the general terms and conditions with both Network providers and Global/national public clouds providers when possible/applicable. Make sure the terms and conditions are compatible with all the legal frameworks to which the institutions are subject;

(ii) Centralize the procurement of public cloud resources;

(iii) Operate the cloud broker and the self-service portal;

(iv) Take responsibility for a federated/consistent data strategy and data management plan;

(v) Act as a single point of information for IT/data security and privacy policies/rules.

The Ministry in charge of higher education and research should

- study the different options for the intermediate entity and short-list those which are compatible with existing rules and procurement processes;
- arbitrate between public and private entity options and if the latter option is chosen, select a company based on the legal rules in place;
- Otherwise, arbitrate between the creation of a new public entity and the delegation of the new role to an existing one that has the operational capacity for that. Make sure that the entity is governed in a way that gives to the end users/institutions power to contribute to the strategical decision making.

If the Ministry decides not to operate an entity at national or regional level, the university should (i) create that entity or (ii) attribute its role to a team with in the IT department or (iii) contract with a company.
In case of (i) or (ii), Universities/ higher education institutions must make sure that

- all the required human resources and skills are available to meet the intermediation challenges at technical and legal levels;
- The entity is open to end users' contributions to the strategical decision making.

Chapter 5
Building migration/Implementation strategies

Chapter 4 led to the elaboration of a contextualized DU model. A subset of IT applications have been selected and prioritized according to their respective contributions to the objectives for each DU pillar and for the “Vision and strategy” transversal layer. Chapter 5 led to the elaboration of a contextualized vision for the cloud.

This chapter aims at helping the project team define migration plans for the retained IT applications. The feasibility and the complexity of the migration depends on a number of critical factors, for example the existence of a high-speed internet access.

In the first part of the chapter, we define a list of critical factors and we propose a tool to quantify both the cross-applications criticality level for the different factors and the “Migration Difficulty Score » for IT applications.

The factors that expose a high cross-applications criticality level should be prioritized accordingly. IT Applications with a low “Migration Difficulty Score » should be first to consider for migration.

The second part of the chapter provides typical migration scenarios for the different pillars as well as a tool for elaborating detailed plans. It helps deriving migration objectives and sub-objectives into activities and sub-activities as well as considering planning and monitoring aspects such as resources, stakeholders, KPIs, etc.

5.1 Critical factors identification

Critical factors are pre-requirement for migrating IT Applications to the cloud. Without them, migration might not be feasible at all or might have a high risk of failure. That’s why it is essential to check how well the institution fulfills those factors before deciding to migrate.
However, critical factors are not equally important, a few are essential, others might be relevant only to a few IT applications.

In order to better structure and apprehend the critical factors with regards to the IT Applications to migrate, three categories of actors as well as three families of factors have been considered.

The groups of actors are:

- Public Authorities
- Universities/Institutions
- Students, Educators, Researchers, and personnel of the University

The three families of factors are:

- The country context (defined by the political choices that have been made)

- The University/institution context and the different types of available resources
- The infrastructures and equipment available to Students, Educators, Researchers and Administrative staff.

Tab.5 Critical factors

Country Context	**University/Institution Context**	**infrastructures and equipment available to Students, Educators, Researchers and personnel.**
High-speed INTERNET	Local network	Personal laptop
Legal framework for personal or confidential data	Institutional Access devices (PC, terminal)	Personal Mobile phone/Tablet
Existence of public cloud access	Existence of an institutionnel portal	
	Existence an Identity Federation System	
	IoT Network	
	End devices for (sensors, actuators, RFID....)	
	IT governance and management skills	
	cloud migrations kills	
	Gouvernance for resources access	
	Financial resources availability	

The “factors” tool helps identifying the cross-applications critical factors (by DU component) as well as the easiest IT Applications to migrate. It is based on 5 matrices, each matrix includes all the critical factors as columns and all the IT applications as rows, grouped by DU component.

The four first matrixes are for DU pillars and the fifth matrix corresponds to the « Communication & Collaboration » common-IT applications.

IT Applications have been selected in the previous chapters. A weight is associated to each factor on a scale of 1 to 5 which characterizes the “difficulty-to-fulfill” the critical factor for the university or institution. The higher is the value, the more difficult it is to meet critical factor.

The sum on the last line of each matrix provides the criticity level of each factor for the migration of all the IT applications belonging to a DU component.

In each matrix, the last column provides a score for each IT Application weighed by the critical factors’ “difficulty-to-fulfill” coefficients. The higher is the score the more difficult is the migration of the corresponding application.

The last line of the Sheet represents the criticity of each factor for all the applications. The higher is the value, the more critical is the factor for whole set of applications (cross-DU-components)
The matrixes can be customized at four levels:

- The proposed factors can be removed, new identified factors can be added according to the context
- The weights characterizing the “”difficulty-to-fulfill” (for the university/institution) of the critical factors. the scale can be finer-grained than [1-5]
- The scores characterizing the importance of the critical factors (column) for the IT Application (row).The scale can be finer-grained than [1-5]
- The rows corresponding to IT applications which were not selected in the previous chapters should be removed. The IT Applications retained here can be only a sub-set of the selected IT Applications

Once applied, the « factors » tool makes it possible to order critical factors according to their level of criticity and to order IT Applications according to the difficulty of their migration to the cloud.

The following example associates an equal coefficient for « difficulty-to-fulfill » to all critical factors.

Tab.6 Applications Digital Campus Management-Critical Factors Matrix

	Local Network	Institutional Access device (PC, terminal)	Personal laptop	Personal Mobile phone/Tablet	High speed Internet Connection	Existence of a legal framweork for data privacy	Existence of public cloud offerings	Existence of an institutionnel portal	Existence of an Identity federation system	Financial resources availability	Gouvernance for resources access	IT governance and management skills	Cloudmigrations kills	IoT Network	End devices for (sensors, actuators, RFID,...)	Migration Difficulty Score
Weights (difficulty level for the university to meet critical factor) [1-5] higher value means more difficult to meet critical factor	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	

Digital Campus Management																
Students Management Systems (*)	3	5	1	1	5	5	5	3	3	5	3	5	3			47
Staff and faculty Management Systems	3	5	1	1	5	5	5	3	3	5	3	5	3			47
Library Services	3	5	1	1	5	1	5	3	3	5	1	5	3			41
ICT Support Services	3	5	1	1	5		3	3	3	5	3	5	5			42
Energy Monitoring(pilot)	5	5			1	1	1			5	1	3	5	5	5	37
Security & Access Control (for labs with critical research)	5	1		1	1	1	1		3	5	1	3	5	3	3	33
Assets management System	3	5		1	3	3	3		1	5	1	5	5	1	1	37
Video& Information Systems	5	5			3	3	1		1	5	1	3	3	1	1	32
Attendance Systems	3	3		1	1	3	1	1	1	5	1	3	3	1	3	30
Location-based services	3	3		3	3	3	1	1	3	5	1	5	5	3	3	42
Building Control & Management	5	3		1	1	3	1			5	1	3	5	5	5	38
Pillar Digital Campus' factor criticity score	41	45	4	11	33	28	27	14	21	55	17	45	45	19	21	426

The last line of the above matrix shows that the critical factor which has the highest score is the « Financial Resources Availability" one. Therefore, that factor is the most critical for the entire set of retained IT Applications from the "Digital Campus Management" pillar.
This means that the university has to satisfy/fulfill this factor before considering the migration of IT Applications from the "Digital Campus Management" pillar.

The IT Applications "Students Management Systems" and "Staff and faculty Management Systems" have the highest score (47) which means that migrating them to the cloud is the hardest of all. Should the university decide to migrate them, it has to fulfill their key critical factors.
The different matrixes are provided below.

Tab.7 Applications-Critical Factors Matrix for the 4 DU-Pillars

	Local Network	Institutional Access device (PC, terminal)	Personal laptop	Personal Mobile phone/Tablet	High speed Internet Connection	Existence of a legal framework for data privacy	Existence of public cloud offerings	Existence of an institutionnel portal	Existence of an Identity federation system	Financial resources availability	Gouvernance for resources access	IT governance and management skills	cloud migration skills	IoT Network	End devices for (sensors, actuators, RFID,...)	Migration Difficulty Score
Weights (difficulty level for the university to meet critical factor) [1-5] higher value means more difficult to meet critical factor	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	
Digital Campus Management																
Students Management Systems (*)	3	5	1	1	5	5	5	3	3	5	3	5	3			47
Staff and faculty Management Systems	3	5	1	1	5	5	5	3	3	5	3	5	3			47
Library Services	3	5	1	1	5	1	5	3	3	5	1	5	3			41
ICT Support Services	3	5	1	1	5		3	3	3	5	3	5	5			42
Energy Monitoring (pilot)	5	5			1	1	1			5	1	3	5	5	5	37
Security & Access Control (for labs with critical research)	5	1		1	1	1	1		3	5	1	3	5	3	3	33
Assets management System	3	5		1	3	3	3		1	5	1	5	5	1	1	37
Video& Information Systems	5	5			3	3	1		1	5	1	3	3	1	1	32
Attendance Systems	3	3		1	1	3	1	1	1	5	1	3	3	1	3	30
Location-based services	3	3		3	3	3	1	1	3	5	1	5	5	3	3	42
Building Control & Management	5	3		1	1	3	1			5	1	3	5	5	5	38
Pillar Digital Campus' factor criticity score	41	45	4	11	33	28	27	14	21	55	17	45	45	19	21	**426**
Digital Teaching& Learning																
Virtual Learning Environment / LMS, Moodle, Open Edx etc. (*)	5	5	1	1	5	1	5	1	3	1	3	3	3			37
Virtual Laboratories	5	5	3	1	5	1	5	1	3	3	3	5	5	1	1	47
Virtual IDE/Workbench	5	5	3	1	5	1	5	1	3	3	3	5	5			45
MOOC Platform Moodle, Open Edx, ..	5	5	3	1	5	1	5	3	3	5	3	5	5			49

Assessment Management System	5	5	3	1	5	3	3	3	3	3	1	5	5			45
Video conferencing/broadcasting of courses	1				5		1	1		5	1	3	1			18
Learning analyticsSystems	5	5	3	1	5	3	5	3	3	5	3	5	5			51
Pillar :Digital Research' factor criticity score	**31**	**30**	**16**	**6**	**35**	**10**	**29**	**13**	**18**	**25**	**17**	**31**	**29**	**1**	**1**	**292**
Digital Research																
Research Data management systems and governance (pilot)	5	5	3	1	5	5	5	1	5	3	3	5	5	1	1	53
Research Computing Service, Clouds, HPC Clusters, Super Computers (*)	5	5	3	1	5	5	5	1	5	5	3	5	5	1	1	55
Virtual Research Environments	5	5	5	1	5	5	5	3	3	3	3	5	5	1	1	55
Research support and consultancy services	5	5	5	1	5	5	5	3	3	5	3	5	5			55
Pillar: Digital Research' factor criticity score	**20**	**20**	**16**	**4**	**20**	**20**	**20**	**8**	**16**	**16**	**12**	**20**	**20**	**3**	**3**	**218**
Pillar : Ecosystem digital links																
Stakeholders management, dissemination and communication systems (*)	5	5	3	3	5	1	5	5	1	3	5	3	1			45
Careers services	5	5	1	5	5	3	5	5	1	3	5	3	1			47
Pillar Ecosystem Links' factor criticity score	**10**	**10**	**4**	**8**	**10**	**4**	**10**	**10**	**2**	**6**	**10**	**6**	**2**	**0**	**0**	**92**
Communication & Collaboration Services																
Unified Communications, Emails, Web Conferencing and Collaboration , etc. (*)	1	1	3	5	5	3	5	1	1	1	1	1	1			29
Video Conferencing	1				5		1	1		5	1	3	1			18
Video Capture & Storage	1	3			5	3	3			5	1	5	1			27
Social Media Tools	1	1	3	5	5	1	5	1	1	1	1	1	1			27
Information Sharing Tools	3	3	3	3	5	3	5	3	3	1	1	3	3			39
University Portal	5	5	3	3	5	1	5		3	3	5	3	3			44
Storage services	5	5	3	3	5	3	5	3	3	3	3	3	3			47
Collaborative Office Suite	5	5	3	3	5	3	5	3	3	1	1	1	1			39
Pillar : common applications' factor criticity score	**22**	**23**	**18**	**22**	**40**	**17**	**34**	**12**	**14**	**20**	**14**	**20**	**14**	**0**	**0**	270
Overall factor criticity score	**124**	**128**	**58**	**51**	**138**	**79**	**120**	**57**	**71**	**122**	**70**	**122**	**110**	**23**	**25**	**1298**

The last line of the matrix shows that « High-speed INTERNET" received the highest score (138) which means that it represents the most critical factor for the entire set of retained IT Applications. It has to be fulfilled before any migration can be envisaged.

5.2 Typical migration scenarios for the different pillars.

This section presents the “migration” tool. Its aim is to help defining the objectives of each application that could potentially be migrated to the cloud and to translate the sub objectives into activities and sub-activities. Then, it helps estimating the required resources, the team structure and size and the timeline to achieve each activity.
The tool exposes four Sheets, each one specific to one of the DU pillars and one exemplifies a migration of an application from the communication and collaboration (IT applications common the four pillars).
Each migration scenario starts by providing

- The pillar it belongs to, its target cloud style (IaaS, PaaS, SaaS)
- Its target cloud type (Private, Public, Hybrid, Community, Cloud Broker)
- The vendor of the technology it migrates to
- Whether it concerns an existing application or a new one
- The nature of the application being migrated (legacy, open source, etc.)

The sheet also provides:

- The objectives and sub-objectives of the migration, sub-objectives correspond to the migration horizon: ST(Short-term), MT (Medium-term) or LT (Long-term)
- Resources, Leadership/team, timeline for completion by the project team in coordination with stakeholders.

5.2.1 Scenario 1: Migration to a private cloud with OpenStack
Objective: Deploy a legacy Students Management System on an OpenStack-based private cloud

Digital University Pillar	Digital Campus Management
Cloud Style	IaaS
Cloud Type	Private
Cloud Vendor	OpenStack
Application exists	Yes
Application type	legacy

Sub-objective: Migrate 100% of the legacy application to OpenStack

Activity	**Subactivities**	**Ressources**	**Stakeholders**	**Leader ship**	**Timeline**
Activities required to achieve the subobjectives		*Required resources (financial, human, IT, etc.)*	*Beneficiaries, other stakeholders*	*Who leads the activity*	*When should the activities start and end*

Choose hardware	Diagnosis of the existing infrastructure and services Financial assessment Compatibility Assessment Infrastructure size and topology assessment				
Choose the Hypervisor (Xen,KVM,MSHyper V,VmWare)	Deploy a first prototype Training for the IT staff				
Deploy OpenStack's cloud manager	Deploy a first prototype (devstack) Training for the IT staff				
Data Migration	Move all of the Students data into Swift, migrate databases to OpenStack machine instances, create new images, design a backup process				
Application Migration	Integrate the students management legacy application (on OpenStack) with existing institutional systems (identity federation, etc)				
Co-existence Phase	Migration monitoring				
Optimization	Adjust the number of the OpenStack virtual machine instances to the observed usage patterns. Evaluate the new service in terms of technical, functional and organizational aspects.				

5.2.2 Scenario 2: Migrating Moodle to AWS

Objective: Deploy a Virtual Learning Environment / LMS based on Moodle on Amazon's public cloud

Digital University Pillar	Digital Teaching and Learning
Cloud Style	IaaS
Cloud Type	Public
Cloud Vendor	AWS
Application exists	Yes
Application Type	Open Source

ST Sub-objective:
Deploy moodle for 20% of the existing curriculum

Activity	**Subactivities**	**Ressources**	**Stakeholders**	**Timeline**
Activities required to achieve the subobjectives		*Required resources (financial, human, IT, etc.)*	*Beneficiaries, other stakeholders*	*When should the activities start and end*
Cloud	Diagnosis of the existing			

Assessment:	infrastructure and services Financial assessment Compatibility Assessment Infrastructure size and topology assessment			
Proof of Concept:	deploy a first prototype training for the IT staff			
Data Migration	move all of the Moodle's static course material (video, audio, etc. files) into AWS S3			
Application Migration	integrate Moodle with existing institutional systems (identity federation, enrollment, support/ticketing, etc)			
Co-existence Phase	Training for the teachers about Moodle's use Review and update Grouping of courses into categories: classroom/distance/blended on moodle / off moodle Add more course and enable more Moodle capabilities			
Optimization	Adjust the size of the infrastructure to the observed usage patterns. Use Reserved Instances to reduce costs Evaluate the new service in terms of technical, functional and organizational aspects.			

MT Sub-objective:
Deploy Moodle for 50% of the existing curriculum

Activity	**Subactivities**	**Ressources**	**Stakeholders**	**Timeline**
Activities required to achieve the subobjectives		*Required resources (financial, human, IT, etc.)*	*Beneficiaries, other stakeholders*	*When should the activities start and end*
Cloud Assessment:	Financial assessment Infrastructure size and topology assessment			
Proof of Concept:	Align new team members cloud and moodle-related skills. Advanced training for the IT staff.			

Data Migration	Ingest more learning-related content			
Moodle-related capacity building	Training for a larger group of teachers about Moodle's use, organize more advanced courses for power users. Review and update Grouping of courses into categories: classroom/distance/blended on moodle / off moodle Add more courses and enable more Moodle capabilities			
Optimization	upscale the infrastructure in production for 100% of students /educators and 50% of courses Evaluate the new service in terms of technical, functional and organizational aspects.			

LT Sub-objective:
Deploy moodle for 80% of the existing curriculum

Activity	**Subactivities**	**Ressources**	**Stakeholders**	**Timeline**
Activities required to achieve the subobjectives		*Required resources (financial, human, IT, etc.)*	*Beneficiaries, other stakeholders*	*When should the activities start and end*
Cloud Assessment:	Financial assessment Infrastructure size and topology assessment			
Proof of Concept:	Align new team members cloud and moodle-related skills. Advanced training for the IT staff.			
Data Migration	Ingest more learning-related content			
Moodle-related capacity building	Training for a larger group of teachers about Moodle's use, organize more advanced courses for power users. Review and update Grouping of courses into categories: classroom/distance/blended on moodle / off moodle			

	Add more courses and enable more Moodle capabilities			
Optimization	upscale the infrastructure in production for 100% of students /educators and 80% of courses Evaluate the new service in terms of technical, functional and organizational aspects.			

5.2.3 Scenario 3: Migrating Research Computing Services to the cloud using a cloud broker, AWS, Azure and Google Cloud Platform (GCP)

Objective: Deploy a Cloud broker and a collaboration portal to access Compute and Storage for research on AWS, Azure, GCP and Open Nebula-based research cloud. Provide each researcher and each PhD student with a managed /monitored personal public cloud account**.**

Digital University Pillar	Digital Research
Cloud Style	Brokered IaaS
Cloud Type	Public|Private
Cloud Vendor	AWS|Azure|GCP|OpenNebula|RosettaHUB
Application Exists	No
Application type	Open Source | Proprietary

ST Sub-objective: Deploy the broker for enabling access to active & monitored AWS accounts for 100% Researchers and PhD students

Activity	**Subactivities**	**Ressources**		**Leadership**	**Timeline**
Activities required to achieve the subobjectives		*Required resources (financial, human, IT, etc.)*		*Who leads the activity*	*When should the activities start and end*
Join AWS Educate, AWS Academy and submit projects to AWS for research					

Proof of Concept:	Assess the quality of the institutional network infrastructures. Obtain approval for using the public cloud. Deploy an institution-dedicated brokerage infrastructure. Connect the broker to an institutional AWS root account. Map the institution departments and research laboratories to the brokerage portal's virtual sub organizations. Connect the institution PhD students and researchers enrolment pipelines to the brokerage portal Connect the brokerage portal to the identity federation systems, Connect the broker to the internal billing systems.				
Data Migration	Move non-sensitive research data sets and databases to AWS S3,AWS EFS, AWS Glaciere, AWS RDS, AWS RedShift (https://aws.amazon.com/products/storage/). Early-stage institutional research data lake				
Scientific Applications Migration	Build AMI (machine images) with the different research software needed. Build Docker images with research software. Register images and docker images with the brokerage portal.				
Optimization	Adapt the size of the brokerage infrastructure to the observed usage patterns. Use Reserved Instances to reduce costs Use Spot Instances where applicable to reduce costs Evaluate the new service in terms of technical, functional and organizational aspects.				

MT Sub-objective : Connect the broker to Azure and GCP for 100% Researchers and PhD students

Activity	**Subactivities**	**Ressources**		**Leadership**	**Timeline**
Activities required to achieve the subobjectives		*Required resources (financial, human, IT, etc.)*		*Who leads the activity*	*When should the activities start and end*

Proof of Concept:	Connect the broker to an institutional Azure root account. Connect the broker to an institutional GCP root account. Connect the institution PhD students and researchers enrollment pipelines to the brokerage portal Connect the broker to the internal billing systems.				
Data Migration	Move non-sensitive research data sets and databases to Azure storage services (https://azure.microsoft.com/en-gb/services/storage/). Move non-sensitive research data sets and data bases to GCP storage services (https://cloud.google.com/storage/). Early-stage institutional research data lake				
Scientific Applications Migration	Build virtual machine images with the different research software needed. Build Docker images with research software. Register images and docker images with the brokerage portal.				
Optimization	Adapt the size of the brokerage infrastructure to the observed usage patterns. Use Reserved Instances to reduce costs Use Spot Instances where applicable to reduce costs Evaluate the new service in terms of technical, functional and organizational aspects.				

LT Sub-objective: Connect the broker to internal Open Nebula-based private clouds and HPC clusters

Activity	**Subactivities**	**Ressources**		**Leadership**	**Timeline**
Activities required to achieve the subobjectives		*Required resources (financial, human, IT, etc.)*		*Who leads the activity*	*When should the activities start and end*
Proof of Concept:	Connect the broker to an institutional Open Nebula management tools and APIs.				

	Connect the institution PhD students and researchers enrollment pipelines to the brokerage portal Connect the broker to the internal billing systems.				
Data Migration	move research data sets to Open Nebula's storage system. Early-stage institutional research data lake				
Scientific Applications Migration	Build virtual machine images with the different research software needed. Build Docker images with research software. Register images and docker images with the brokerage portal.				
Optimization	Adapt the size of the brokerage infrastructure to the observed usage patterns. Evaluate the new service in terms of technical, functional and organizational aspects.				

5.2.4 Scenario4: Migrating SharePoint-based portal to Azure 365

Objective: Deploy a Stakeholders management, dissemination and communication portal/CMS based on Microsoft SharePoint on Azure

Digital University Pillar	Ecosystem digital links
Cloud Style	PaaS
Cloud Type	Public
Cloud Vendor	Microsoft
Application exists	Yes
Application type	Proprietary (MS) + Legacy content (existing portal)

ST Sub-objective: Deploy a Scalable Sharepoint on Azure and migrate all the on-premise Sharepoint infrastructure and data.

Activity	**Subactivities**	**Ressources**	**Leadership**	**Timeline**
Activities required to achieve the subobjectives		*Required resources (financial, human, IT, etc.)*	*Who leads the activity*	*When should the activities start and end*
diagnosis of the existing infrastructure and services			Project Coordinator	

training for the IT staff					
deploy a first prototype, integrate SharePoint with existing institutional systems (identity federation, enrollment, support/ticketing, etc)					
Evaluate the prototype, assess the scalability requirements.					
deploy a scalable infrastructure in production for 100% of stakeholders					
Evaluate the new service in terms of technical, functional and organizational aspects.					

MT Sub-objective:

Enable extra Social collaboration features in SharePoint.
Knowledge base for Alumni.
Directory service for Alumni
Directory of on-going research projects
Research projects outcomes

Subobjectives	**Activity**	**Subactivities**	**Ressources**	**Leadership**	**Timeline**
ST: Short-term MT: Medium-term LT: Long-term	*Activities required to achieve the subobjectives*		*Required resources (financial, human, IT, etc.)*	*Who leads the activity*	*When should the activities start and end*
MT: Enable extra Social collaboration features in SharePoint. Knowledge base for Alumini. Directory service for Alumini Directory of on-going reseach projects Research projects outcomes	diagnosis of the existing infrastructure and services			Project Coordinator	
	training for the IT staff				

	deploy a prototype for the features and services				
	evaluate the prototype, assess the scalability requirements.				
	deploy a scalable infrastructure in production for 100% of stakeholders				
	Evaluate the new services in terms of technical, functional and organizational aspects.				

LT Sub-objective :

Directory for skills and expertise.
Alumni success stories.

Activity	**Subactivities**	**Ressources**	**Leadership**	**Timeline**
Activities required to achieve the subobjectives		*Required resources (financial, human, IT, etc.)*	*Who leads the activity*	*When should the activities start and end*
Inventory of skills and expertises relevant for the stakeholders			Project Coordinator	
deploy a prototype for the features and services				

evaluate the prototype, assess the scalability requirements.				
deploy a scalable infrastructure in production for 100% of stakeholders				
Evaluate the new service in terms of technical, functional and organizational aspects.				
Evaluate impact of the new services				

5.2.5 Scenario 5: Migrating communication and collaboration services to G Suite for education

Objective: Use G Suite for education for communication (GMAIL, HANGOUTS) Collaboration (G Docs) Courses management (G Classroom) and cloud computing/big data education

Digital University Pillar	Communication and collaboration services
Cloud Style	SaaS
Cloud Type	Public
Cloud Vendor	Google
Application Exists	Yes (partly)
Application Type	Proprietary (Service)

ST Sub-objective:

Migrate 100% of the students, faculty members and staff to Gmail

Enable Google Drive for documents sharing

Enable Google Docs as the institutional on-line collaborative office suite

MT Sub-objective:

Enable Google Classroom and integrate it with 100% of courses

Enable Hangouts and integrate it with distance education programs

Enable Calendar and generalize its use for staff and faculty members

LT Sub-objective:

Apply to Google Cloud Platform Education Grants, Join GCP for education and integrate its use within Cloud Computing/Big Data/Data science related courses

Conclusion

This report complements the first report published in 2016 by Alecso and the ITU entitled "Guidelines to improve the use of Cloud Computing Technology in Education in Arab Countries". It aims at guiding project teams from Arab countries in the elaboration of their own vision and national strategy for mass adoption of cloud computing in higher education.

The development of a vision and strategy for migration to the cloud requires a structured approach that takes into account different facets of cloud computing and the context in which Higher Education Applications' migration will be implemented. To meet such requirements, a general model of the Digital University (DU) as well as a contextualization approach and tools for designing and implementing the cloud migration strategy have been developed.

The key principle behind the development of the DU and all the tools for designing and implementing the strategy is the adaptability to the multiple contexts of Arab countries. The DU model is built upon six components two transversal and four vertical ones. The four vertical pillars are the "Digital Campus Management", the "Digital Teaching & Learning", the "Digital Research" and the "Ecosystem digital links". The two transversal layers are "the Digital Strategy & Vision layer" and "The IT service delivery Platform». Each component except the "The IT service delivery Platform" includes specific objectives. Achieving objectives requires a set of specific IT applications in addition to common IT applications.

At the level of each target country, each ministry of education and / or university may, depending on its endowment of resources and skills, its specific conditions and its potential for development, defines strategic objectives for the different pillars and for the "Strategy and Vision" transversal layer. They can choose using the tools exposed in this report to select the applications most likely to achieve the retained objectives.
The strategic design tools connect objectives-applications and applications-critical factors. They translate objectives into operational plans and programs by choosing the cloud style, type and provider, and by defining sub-objectives, activities, sub-activities to be implemented and by identifying the resources to be allocated and the teams to be deployed.

These tools are designed so that the main actors within the ministries and / or universities can, through discussion and dialogue, not only reduce / add elements composing these tools, but also review and update their degree of importance in acting on the weights. This process is initiated by the contextualization of the tools that allow an exchange based on the argumentation of the actors. As a result, the process and the tools that underpin it bring views together and foster the emergence of a shared vision and a consensus around goals, their priorities, and the means to achieve them. This creates the right conditions for the acceptance, commitment, and involvement of the actors.

The migration of universities to the cloud is not limited to its technological dimension. It involves a set of actors including decision makers, beneficiaries and teams involved in the implementation of change. The latter is to be interpreted as a dynamic process of material and immaterial transformations, including the culture of the university.

This process is part of a proactive strategy of permanent renewal with regards to technological evolutions and modes of work and collaboration.

The success in migrating to the cloud in Higher Education is conditioned by the adoption of a participatory approach that puts emphasis on the development of the university's capacity to change and adapt. It is essential to conduct and steer change in a way that enables the greatest autonomy of the different actors while respecting key guidelines and preserving core strategic objectives.

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