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Towards an Unified Information Systems Reference Model for Higher Education Institutions

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Abstract

Higher education institutions are currently facing many challenges that are making them to start compete strategically, like other not-for-profit firm. To adequately support such new approach, their information systems and business strategies should be totally aligned. However, the current existing landscape of heterogeneous information systems and applications deployed in many institutions can compromise such aim. Recently, reference architectures and models have emerged as instruments suitable to help company's decision-makers to cope with such tensions. However, whilst many of such architectural models already exist for several industries, little has been done so far in higher education. In this paper, we briefly review major existing developments in such way before to inductively derive a unified information systems reference model tailored for higher education institutions.

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1. Introduction and motivation

Higher education is one of the main engines of progress around the world through its well-known functions of mass tertiary education, academic training and research, and the provision of public service[1]. Although this sector still retains historical foundations that give continuity and support to its functions, modern higher education institutions (HEIs) are currently facing many environmental challenges, including internationalization and globalization processes, reduction of public funding, the emergence of new educational technology and new legal and quality assurance requirements derived from recent educational reforms boosted by the Bologna process[2,3]. To cope with such challenges, educational institutions have started to act like several other for-profit companies prioritizing not only their role of public good and service knowledge providers but also the development of adequate competitive strategies to improve their competitiveness [4]. Such trade-off places enormous pressures on HEIs in terms of operational efficiency[5,6], which furthermore, should be achieved without diminishing the quality of educational service provided[7]. Hence, HEIs "*must undergo a major shift in terms of their managerial approach*"[4], leading to a profound impact on how institutions manage their processes, services and structures; and making them to evolve into a framework where such elements become instruments of flexibility and innovation, rather than barriers to growth and development[8]. As the vast majority of HEIs can nowadays be viewed as both human- and knowledge-intensive organizations[9], Information Systems Architectures (ISAs) emerge as critical instruments in such kinds of operational change initiatives, as they play a critical role in supporting several different institutional educational processes, as well as providing users with appropriate data[10–12].

One the one hand, and at present, many information systems (IS) landscapes at HEIs are merely the ad hoc configuration of each organization mainly based in bespoke developments, sometimes mixed with functionalities resulting from external software products commonly arisen for other industrial sectors and later adapted and updated[13–17]. On the other hand, and in order to streamline their organizations' activities[18], HEIs need to take advantage of their ISAs, ensuring that resources invested in Information Technology (IT) systems are based on business strategic objectives. As a result, there is a continuous and increasing growing tension between business (requirements) of the educational institutions and their available technological capabilities, which should be managed holistically in an integrated and coherent way[19]. Hence, only "*when business and IT are perfectly aligned, firms are able to perform at a high level due to the close cooperation between business and IT departments and their mutual understanding*"[20].

Enterprise Architecture (EA) is considered as one of the major instruments for enabling companies to cope with such alignment tensions[5,6,21]. The significance and practical relevance of this topic has been historically highlighted by IT managers[22,23] as well as by HEIs IT Managers[24,25]. However, wilts EA management practices have been adopted in several industrial firms[26], they have not yet been pervasively used in higher education settlements[27,28]. This fact has been confirmed by several empirical studies[29], ranking business/IT alignment maturity in education as the lowest compared with several other industries. Hence, there is a clear need for more research on EA practices in higher education contexts[30], including "*the feasibility of formalized frameworks and components of EA specifically tailored to suit the structure of HEIs*"[31].

Over the last years, and drawing on principles of generalization and knowledge reuse[32],Reference Architectures (RAs) and Reference Models (RMs) have emerged as abstract artifacts suitable to increase the quality (i.e. the efficiency and effectiveness) of EA practices and designed architectures[19,33–36]. Hence, notable RMs and RAs have been developed for several specific industries, as BIAN[37] for the banking industry; the eTOM framework[38] for the telecommunications industry; or TOGAF[39] or CORA[40] for the IT industry, to cite a few. In contrast, little has been done so far in the higher education industry, although several initial interesting contributions[41–45] can already be identified (mainly) from the *grey literature*. However, and in general terms, it can be concluded that scientific research in RAs/RMs for HEIs is still in an embryonic stage.

In order to partially cope with the previous gap, we focalize in the concrete topic of IS and applications in HEIs. Hence, the main goal of this work is, to derive and propose a preliminary *IS Reference Model for Higher Education* contexts. In so doing, we also see the work at hand as an opportunity for creating awareness on the IS community about the need to foster and widespread such abstract models as a well-accepted research topic[46]. Besides, the resulting proposed artifact could be useful for several practical purposes, like as a support tool for decision making, planning or communication among stakeholders[35,47]. Therefore, we believe that the paper at hand could be of interest not only for the research community but also for higher education business and IT managers as wells as IS service consultancy companies or IT vendor providers.

The remaining of the paper is structured as follows: first, we briefly introduce the concepts of RAs and RMs – as main topics of the paper – and briefly discuss existing contributions tailored for HEIs. Next, we outline the methodological approach followed to generate the envisioned artifact to subsequently introduce and present it. Finally, we close up with a concluding section, which also highlights the main limitations of the research.

2. Background and previous work

As a starting point for this section, we turn first our attention to the definition of RAs and RMs, as they are terms frequently used interchangeably in the literature. Whilst a commonly accepted definition of RA could not be found in the literature[32], they can be seen as generic architectures for a class of systems based on best practices[48]. According to Lankhost [34], they are "*standardized architectures that provide a frame of reference for a particular domain, sector or field of interest (...) providing a common vocabulary, reusable designs and industry best practices (...)".* Hence, RAs are used for designing concrete solution architectures in multiple contexts, serving as a standardization tool[49]. Typically, RAs components include "*common architecture principles, patterns, building blocks and standards*"[34]. RMs (also referred as model patterns) usually are one of such RA's block components.

RMs provide (i.e. represent) a clear view of the domain of interest of the RA, incorporating best-practice solutions as reusable knowledge that can be posteriorly adjusted for context-specific needs[49,50]. RMs consist of a "*set of unifying concepts, axioms and relationships within a particular problem (...) independent of specific standards, technologies, implementations, or other concrete details*"[51]. According to Fettke and Loos, RMs are conceptual frameworks that facilitate the process of IS design by providing a reusable and adaptable blueprint for a class of domain[52,53].

The concept of *Enterprise Reference Architecture (ERA)* emerges as a particular subtype of RAs, when the targeted domain or class of systems is set to a "*class of enterprises*". Hence, ERAs are still abstract artifacts, but to a lesser extent than a (generic) RA. ERAs have been defined as "*a generic EA for a class of enterprises, that in a coherent whole of EA design principles, methods and models which are used as foundation in the design and realization of the concrete EA that consists of three coherent partial architectures: the business architecture, the application [i.e. IS] architecture and the technology architecture*" (emphasis added)[19]. As many existing EA frameworks, ERAs distinguish among several layers that capture domain of interest. Whilst accepting that there is no consensus on which ones should be such concrete partial domain layers, it can be accepted that ISAs are usually considered as one of them[10,21,54–56]. Moreover, ISAs sub-domain layer can be further decomposed into (i) *informational (or data) architecture layer* – representing the main data types that support a business – and (ii) the *application architecture layer* – defining the applications needed for data management and business support[56,57]. Finally, the term *blueprint or landscape* is also referred in the literature as an architectural description showing the dependences and interrelationships among concrete architectural objects that belong to different sub-domains architectural layers, (usually) through a bi-dimensional matrix[58]. For example, *application (or IS) landscapes* provide a transparent overview on how processes (business sub-domain) are supported by concrete applications (IS sub-domain)[59]. Thus, blueprints and landscapes can be viewed as a simplified form of RMs.

Research on RAs/RMs for HEIs has been scattered and rare. In Table 1 we have summarized some of the main contributions that we have been able to identify, which largely emerge from the practitioners and the grey literature. In general, an emphasis can clearly be detected in business domain layer oriented contributions, whether as autonomous business process RM proposals[16,44,60,61] or as part of an encompassing HEI-tailored ERA[41–43]. In many cases, such models arise as a result of a collaborative effort project, where the resulting artifact is built inductively as an agreed model that satisfies all requirements posed by the stakeholders involved in the initiative. Alternatively, other proposals have also been derived from a more or less rigorous literature reviews[44,60,61]. Finally, wide-range extensible architectural models can come up from in-depth case studies or experiences undertaken in a concrete university setting[45].

The latter also applies for the case of more IS domain layer oriented contributions[62–64]. But in general terms, contributions developed to cope with the IS domain tend to be less rigorous and with a lesser level of depth and profundity than business domain layer oriented contributions. For example, it is possible to find several application landscapes or blueprints tailored for HEIs and developed by diverse IS/IT vendor companies[65,66]. Whilst these contributions can certainly be interesting resources, caution should be taken with them due their (legitimate) implicit commercial nature and bias in promoting concrete technical solutions and/or services − the same can be argued for more IT domain layer oriented contributions[67,68] −.

Table 1. Existing contributions related with RAs and RMs tailored for higher education

	Contribution	Focus	Breadth	Scope
IS & applications /IT Generic RMs	Generic Reference Application Architecture[69]	IS	General	General
	Application Architecture Reference Blueprint Model[70]	IS	General	General
	CORA Reference Model[40]	IS / IT	General	General
Enterprise Reference Architectures for HEI	HORA Reference Architecture[41,71,72]	BU/IS/IT	Netherlands	HE
	RATL Reference Architecture[43]	BU / IS	USA	HE
	CAUDIT Reference Architecture[42,73]	BU / IS	Australia	HE
	TIER Reference Architecture[74]	BU / IS	USA	HE
	Cloud Computing Architecture for HE[75,76]	BU/IS/IT	General	HE
Business (Process) RMs for HEI	Value Chains for Higher Education[44,60]	BU	General	HE
	Charles Sturt Business Process Model[45]	BU	General	University
	HE-IUP Business Process Model[61]	BU	General	HE
	Business Process Reference Model for HE[16]	BU	General	HE
	Process bundle (Academic cycle) of campus management[77]	BU	General	HE
IS & applications / IT RMs for HEI	Information Systems (Conceptual) Model[62]	BU/IS	Croatia	HE
	Campus Information Systems Conceptual Model[78]	IS	General	HE
	e-education Application Framework[79]	IS	General	HE
	Univ. of Tras-o-Montes e Alto Douro of Multidimensional ISA[63]	IS	Portugal	University
	Ohio State Univ. Conceptual Reference Architecture Model[64]	IS/IT	US	University
	SAP Value Map for Education & Research[65,66]	IS	General	HE
	Eduventures 2017 Higher Education Technology Landscape[80]	IS	General	HE
	WSO2 Connected Education Reference Architecture[67]	IT	General	HE
	BROCADE Campus Network Infrastructure Reference Architecture[68]	IT	General	HE
Other EA generic artefacts tailored for HEI	EDUCAUSE Administrative & IT Systems Snapshot[13]	IS/IT	Generic	HE
	EDUCASE EDS ECAR Core Higher Education IS Catalog[81]	IS	Generic	HE
	ICT (Enterprise) Architecture Principles[28,82]	BU/IS/IT	Norway	HE
	Model for Evaluation of IS for an Integrated Campus Management[83]	IS	Generic	HE
	KARTTURI EA HE Adoption Maturity Model[84]	BU/IS/IT	Finland	HE
	Cost-Benefit Model for Campus Management Systems[77]	BU/IS		

Legend. BU : Business Layer | IS: Information System Layer | IT: Information Technology Layer

At this point, we certainly have to highlight the Dutch national HORA Higher Education RA[41,71,72] as not only provides a complete business process RM for HEIs but also specifies a complete landscape of IS applications that can be deployed in an educational settlement. However, and on the one hand, HORA has been specified using the Archimate notation standard – which could restrict its understanding by several non-IT stakeholders –, and on the other hand, it has been totally written in Dutch, which can be perceived as a barrier of access to knowledge. Other existing HEI-oriented ERA, as the TIER Reference Architecture[74], have been developed as a much more general RA – i.e. applicable to any type of HEI and not dependent on the concrete constraints or requirements of a country or regional zone– but offering a much lesser degree level of detail on the architectural objects than HORA. CAUDIT[42] and RATL[43] HEI-oriented ERAs also include an IS domain layer, but they only define the data sub-layer architecture (i.e. they do not offer concrete detail on IS or applications). Finally, contributions more focused on the IT architecture sub-domain layer tend to be less frequent, perhaps by the fact that the IT layer can be considered as much less context-dependent than business and IS architectural ones.

Besides the named references, several additional contributions can be found describing solution EA architectures deployed in concrete HEIs. However, thy usually are very context-dependent, and thus, do not suit well for being applied in other different institutions. In sum, all previous background seems to confirm the need for conducting further research on RAs/RMs for HEIs, an more concretely on contributions focussing on the IS/IT architectural domain layers. This fact clearly contrast with developments undertook in other industries like healthcare –traditionally considered as a not-for-profit business domain comparable with higher education for research purposes[4] – for which evidence shows that similar IS oriented RAs/RMs can be relatively easily identified[85–87].

3. Research Approach

In line with existing approaches for developing RAs/RMs in other domains[88–90], we adopt a rather inductive approach to build our intended artifact. As a reference starting point, we use Hrabe and Buchalcevova's[70,87] *Application Architecture Reference Blueprint Model* (see Table 1), which provides an abstract and homogeneous logical domain model for application architectures. The model is suitable to be tailored and instantiated for industry specific industry contexts, and according to the authors, they have already successfully done it for the public sector or healthcare industries[70,87]. The model is grounded on two basic (architectural) design principles:

- *architectural (layered) hierarchical decomposition*, which is operationalized through as a set of abstract logical model templates to be extended (i.e. instantiated) for the targeted industry domain encompassing 6 main layers (user access, composite application layer, knowledge, information and media layer, transactional processing layer, cross-sectional applications functions layer, and integration and SOA platform layer).
- *application alignment with stakeholder interests,* which allows to position concrete applications over the previous logical model templates on the basis of their content, functionalities and relations to with applications of the architecture.

However, Hrabe and Buchalcenova do not include in their contribution a normative procedure or method for instantiating the abstract logical model templates. To overcome such limitation, we inspired on Angelov, Grefren and Greefhorst's[49] theoretical procedure model for constructing RAs. Although originally conceived for creating software-oriented RAs, we believe that it can be useful for guiding the developing of more EA-oriented RAs/RMs. The original procedure consists of six sequential steps, but for the purposes of our desired artifact we only applied the four initial steps (*enabling variability* and *evaluation of the RA* steps were not applied and left for future research). We concretely applied the four initial steps of the method for constructing our RM as follows:

(i) *Defining a type for the RA.* RA's typology can be defined according to a classification framework provided by Angelov et al. in the same article of the procedural method[49]. It is based on three main dimensions: *context of application, goals and design specification*. In our case, we are constructing a RM and hence, the framework cannot be directly applied. However, we believe that our RM could be typified according to several parameters defined in the classification framework as a *facilitation* RM (i.e. providing support for the design of concrete IS landscapes), defined by an *independent organization* (in our case, just a researcher), for being used in *multiple organizations* and described in an *abstract or semi-detailed level*.

(ii) *Selecting of a design strategy.* As introduced at the beginning of the section, we opted for an inductive practice-based driven approach from the basis of major existing contributions identified in literature.

(iii) *Empirical acquisition of data.* For deriving our RM we selected 8 contributions from Table 1: (i) 3 of the 5 identified ERAs for HEIs[71,74–76] (we excluded CAUDIT and RATL as they do not specify and application domain level), (ii) 2 generic IS/applications HEI-oriented generic conceptual models[78,79], (iii) 2 IS/applications HEI-oriented generic catalogs[13,81], and (iv) an IS evaluation model for HEIs[83]. The main criterion for choosing them was their clarity, level of detail and potential applicability in different educational settlements.

(iv) Construction of the RA. We derived our intended RM by inductively homogenizing the IS and applications defined or suggested in the selected sources. Additional details are provided in the following section.

4. Application Reference Blueprint Outline

The resulting RM inferred is presented graphically in Figure 1. IS and applications have been organized and structured according to the architectural design principles mentioned in the previous section. In order to improve the comprehensibility on how the RM artifact has emerged, in Annex 1 we provide the detailed mapping among each IS and application included in the final model with respect to all the original sources. Minor adjustments were applied in the specific IS and applications' nomenclature used in each concrete source in order to homogenize and harmonize the resulting artifact. For the concrete case of the Dutch's HORA ERA, the more (national) context-dependent applications included in the original specification were not taken into account in our inductive process.

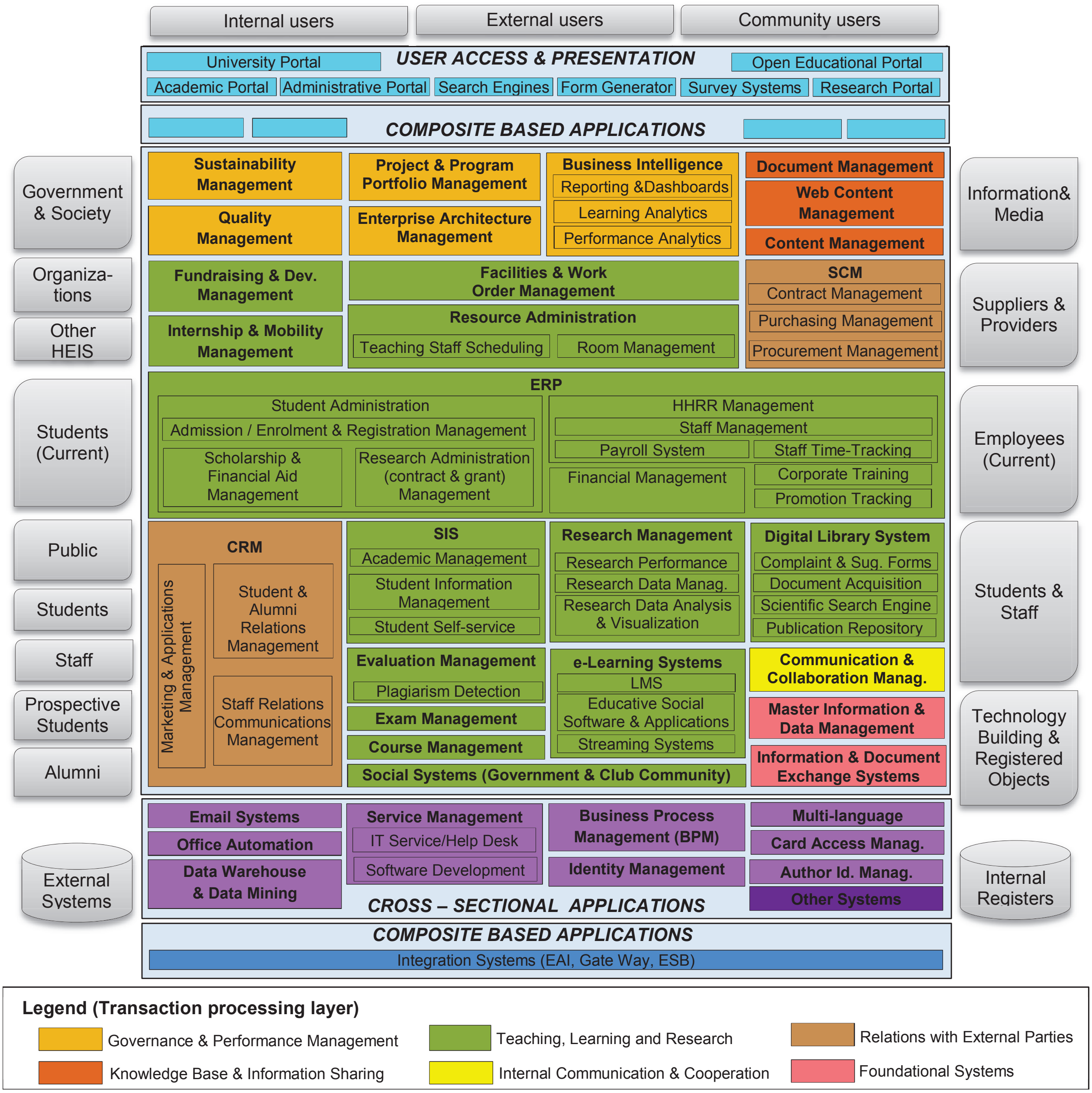

Fig. 1. The proposed IS RM for HEIs

The resulting IS RM can be of practical utility for HEIs practitioners in terms of providing high-level support and guidance for several IS and business related activities [16,19,33–36]. For example, it could be helpful for creating a repository or portfolio of the implemented IS, or as a communication tool for overviewing existing IS architecture to more non-technical stakeholders, or even as a support decision tool both for undertaking IS assessments and availability studies (i.e. AS-IS analyses) as well as defining scenarios for desired prospective IS architectures (i.e. TO-BE analyses and transition plans). In addition, it also could provide support for more concrete IS integration or acquisition projects or for assessing the contribution or impact of current IS in terms of internal quality assurance (IQAS) evaluation needs. Finally, it also can be used for establishing diverse types of mappings between IS and applications with concrete IT products (and services) provided by several market vendors.

4. Conclusion

This paper concentrated on RAs and RMs tailored for higher education settlements. On the basis of existing (similar) work, we contributed to knowledge by inductively generalizing and deriving a comprehensible and actionable IS RM for HEIs. The resulting instrument can be of practical utility as a communication and decision-making support-tool for several HEIs practitioners or stakeholders. Furthermore, the artifact constructed can also be considered as an instantiation of the original model proposed by Hrabe and Buchalcenova, in the sense that instantiating an abstract artifact can be viewed as a way of validating it them in terms of suitability.

However, we do not see our outlined RM as a definitive artifact, and thus, we believe that further research is needed to improve and refine it. In this sense, the relatively short sample of contributions used to derive the RM could be viewed as a first limitation. Hence, a more rigorous systematic literature review on HEI-oriented existing (similar) RAs/RMs contributions would have probably brought to light a more complete set of relevant sources from which infering a richer model. In addition, a more formalized and well-structured process for "inducting" and harmonizing identified IS and applications in each source would have probably also been useful. Finally, additional empirical studies in the form of use cases providing evidence on how the proposed artifact is effectively used in practice could be interesting future contributions, in order to validate the proposed RM. However, and given the objectives of the present paper, we believe that the artifact presented can be perceived as interesting and valuable by both IS higher education professionals and researchers.

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Appendix A. List of Information Systems/ Applications included in the IS Reference Model

Suggested Information Systems and Application Modules		Educause Core IS Catalog [81]	Educause IS Snapshot [13]	e-education Framework [79]	Campus Wide IS [78]	IS Evaluation Model [83]	HORA Ref. Archit. [41,71]	TIER Ref. Archit. [74]	Cloud HE Ref. Archit. [75,76]
Portals & User Access						√	√		
	University Web Portal			√		√	√		
	Administrative / Internal Portals								√
	Academic Portals								√
	Research Portal						√		
	Open Educational Portal						√		
	Search Engines						√		
	Form & Template Generator Systems						√		
	Survey Systems						√		
Administrative Enterprise Information System / Enterprise Resource Planning (ERP)		√		√					
	Student Administration *(can also be part of SIS)*	√	√			√	√	√	
	Admission /Enrollment/ Registration System	√			√	√			√
	Student Scholarship & Financial Aid Management System	√			√				
	Research Administration System (contracts & grants)	√	√				√		
	Financial Management System	√	√			√	√		√
	Payment Systems						√		
	Human Resource Management System	√	√	√		√		√	√
	Payroll System	√					√		
	Personnel (Staff) Management System	√					√		
	Staff Time–Tracking Registration System		√				√		
	Corporate Training System			√			√		
	Promotion Tracking System						√		

Suggested Information Systems and Application Modules		**Educause Core IS Catalog** [81]	**Educause IS Snapshot** [13]	**e-education Framework** [79]	**Campus Wide IS** [78]	**IS Evaluation Model** [83]	**HORA Ref. Archit.** [41,71]	**TIER Ref. Archit.** [74]	**Cloud HE Ref. Archit.** [75,76]
Student Information System (SIS)		√	√	√			√	√	
	Academic Management System		√			√			√
	Student Information Management System (course registration and grades, degree audit, housing, etc.)	√			√	√			√
	Student self-service functions (access to course catalogs, schedules, grades, transcripts, etc.)	√			√	√			
Internship & Mobility Management Systems							√		
Customer Relationship Management Systems (CRM)		√		√			√	√	
	Student/ Alumni Relations (Communication) Management	√				√		√	
	Staff Relations (Communication) Management	√							
	Marketing & Applications Management					√			
Fundraising & Development Management Systems		√							
Supply Chain Management Systems (SCM)				√		√			
	Contract & Tendering Management System						√		
	Purchasing (Acquisition) Management System						√		
	Procurement Management System *(can also be part of ERP)*	√	√	√					
Exam Management System						√			
Evaluation Management System *(can also be part of LMS)*						√			
	Plagiarism Detection System						√		
Course Management System		√				√			
e-Learning Systems				√		√		√	√
	Learning Management Systems (LMS)	√					√		
	Educative Social Software (Blogs, Wikis, e-portfolios, etc.)	√			√		√		
	Customized Educative Application						√		
	Video/Audio Streaming Management System						√		
Research Management System							√	√	√
	Research (Performance) Management System						√		
	Research Data Management System						√		
	Research Data Analysis & Visualization System						√		
Resource Administration / Rostering Systems						√	√		
	Room (Space) Information Management	√				√			
	Teaching Staff Planning Schedule System					√	√		
Facilities & Work Order Management Systems		√	√				√		√
Content Management Systems (CMS)						√	√		
Document Management Systems (DMS)						√	√		√
Web Content (Management) Systems (WCMS)		√					√		
(Digital) Library Information System (LIS)		√			√	√	√		√
	Scientific (Bibliographic, Catalog) Search Engines				√	√	√		
	Document Acquisition System				√				
	Complaint & Suggestion Forms				√				
	Research Publication Repository						√		
Business Intelligence & Data Warehouse (BI /DW)		√							
	Business Intelligence Reporting and Dashboards	√	√						√
	Learning Analytics Systems		√						
	Business Performance Analytics		√						
	Data Warehouse & Data Mining	√							
E-Mail Systems		√	√				√		
Communication & Collaboration Systems							√		
Office Automation System /Suite							√		
Service Management System							√		
	IT Service / Help-Desk Management	√					√		

Suggested Information Systems and Application Modules	**Educause Core IS Catalog** [81]	**Educause IS Snapshot** [13]	**e-education Framework** [79]	**Campus Wide IS** [78]	**IS Evaluation Model** [83]	**HORA Ref. Archit.** [41,71]	**TIER Ref. Archit.** [74]	**Cloud HE Ref. Archit.** [75,76]
Software Development Environments						√		
Social (Student Government & Club Community) Information System (forums, news, etc.)			√	√				
Sustainability Management System						√		
Quality Management System						√		
Project & Program Portfolio Management Systems						√		
Business Process Management System (BPMS)						√		
(Master) Information & Data Management System (Security, Reliability, Maintenance)					√	√	√	
Identity Management System		√			√	√	√	
Information & Document Exchange / Inter-Organizational Systems			√			√		
Integration Systems (EAI, Gateways, ESB,etc.)					√	√	√	√
Institution Specific Systems					√	√	√	
Other Systems					√	√	√	
Multi-language Systems					√			
(Enterprise) Architecture Management System						√		
Card Access Management Systems						√		
Author Identification Management System						√		

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