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A Virtual Research Management Enterprise Architecture Using Axiomatic Design

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Abstract—**Development of virtual research management enterprise architecture (EA) can provide solutions to the current challenges of research management in academic institutions and create necessary capabilities to manage and control the flow of research process among individuals, groups, and institutes. As a new approach to organizational operation, virtual enterprises (VE) introduce new business models and management techniques. The aim of this study is to provide architecture for designing and developing virtual research management based on axiomatic design method. For this purpose, first the design framework has been developed by investigating theoretical principles and using content analysis method. In the next step, the components of research management architecture have been extracted based on proposed framework and using axiomatic design method. Finally by surveying experts, the proposed architecture is validated and its application in an Iranian academic institute has been studied as a case. Proposed architecture in this paper can be used in distributed and dynamic academic research environment. Proposing new methodology for research management enterprise architecture, integrating virtual organization concepts in enterprise architecture design, introducing a methodology for identifying research management system requirements, introducing key components in designing and developing research management based on virtual enterprise are innovation aspects of this research.**

Keywords- Enterprise Architecture, research management, virtual enterprise, axiomatic design method, GERAM

I. INTRODUCTION

Research management systems help in creating innovative environment for leading the research in universities and other research institutes. In a broad sense, research management means management of science and technology flow among individuals and organizations for facilitating innovation process [1].

Quality is the main concern of research management and new approaches in this filed try to offer effective output and desire to mix different methods to achieve the research result. From the technology-oriented perspective, enterprise

architecture (EA) is a set of processes, tools, and structures necessary to implement an enterprise-wide coherent and consistent IT architecture for supporting the enterprise business operations [2][3]. EA is fundamentally concerned with identifying common or shared assets–whether they are strategies, business processes, investments, data, systems, or technologies [4] [5] and refers to a comprehensive description of all of the key elements and relationships that make up an organization [6]. Two key elements in any enterprise architecture framework are: 1) A definition of the deliverables that the architecting activity should produce, and 2) A description of the method by which this should be done. Enterprise Architecture's inputs are business and technology drivers, and architecture output include organizational models, transition plan, orchestration and accommodation, tools, etc… [7].

There are many reference models for enterprise architecture in organizations that each introduces different structures and principles for designing and implementing enterprise architecture [8][9]. Information technology enterprise architecture has been developed with the aim of increasing IT manageability and removing inconsistencies and resource wasting from the fact that business environments are changing and information systems are growing inevitably [10]. Service-oriented enterprise architecture is a new research field including business, service and information systems as three main layers. Virtual enterprise architecture is another form of enterprise architectures that can benefit from service oriented views. Virtual enterprise is a group of organizations which collaborate with each other in order to achieve a specific goal. Thus, the main specifications of the virtual enterprises are a temporary network of organizations, in a limited life time, where the partners collaborate with each other from the geographically distributed locations. The virtual enterprise is modeled in a form of entities and relationships among them [11]. Virtual enterprise research management is a goal oriented set of independent distributed agents of research that each one tries for maximizing its benefits and cooperates to achieve total goals [12]. An agent can be defined as an entity in a system where different entities exist and each has one or multi special tasks. Any agent is the entity which has goal, program, behavior and commitment to its behavior [13]. The agents can be categorized by specifications such as independence, flexibility, passivity, purpose, social participation and interaction [14]. Principally, the agent-oriented system can be conceptualized on the basis of agents but can be implemented without any related software structure [15].

There are many solutions for providing general services of academic research management. For example SAP's research solution introduces a reference framework for providing general services of academic research [16]. This solution is based on industry value chain and includes research faculty/institute, research portfolio, discovery, investment and evaluation, research project, organizational management, publications, result, and support areas to initiate, perform, manage and support research in universities and research institutes. This study provides an architecture for virtual research management enterprise in a dynamic and service-oriented environment. This architecture can be used by innovative research centers for designing, creating and supporting research management structures in order to increases efficiency and effectiveness of research. Following issues shows main concerns of this paper:

1- What are Conceptual components of dynamic, distributed and cooperative research management model?
2- What is the appropriate method for designing academic research management architecture?

This paper is organized as follows: section 2 will describe limitation of current frameworks and advantages of the approach that will be introduced in this paper. In section 3, steps of developing virtual research management enterprise architecture will be explained and in section 4, the proposed architecture will be verified through a case study in a research institute.

II. CURRENT EA FRAMEWORKS AND ADVANTAGES OF THE COMPOUND DESIGN APPROACH

Investigating enterprise architectures illustrates important principles in design and development of enterprise architectures. Some of them have been proposed generally and can be used in various fields. But others have focused on specific areas and cannot be applied to the other fields without major changes [17]. Another important point in the context of enterprise architecture is identifying the main components of the architecture. These components map different stakeholders' requirements to the major components of the reference architecture [18]. Most architectures lack a clear methodology for design. A methodology can be described as a combination of symbols and high level design processes [19].

Architecture frameworks are designed in response to environmental needs. The environment includes variety of aspects such as partnership, competitors and stakeholders, governance and regulation, market and economy, industry and technology, cultural characteristics and clients and users. Most of enterprise architecture frameworks don't have any methodology and designing tools. In fact, there isn't much information (but some general data) for creating and developing enterprise architecture and frameworks and particularly for reference architecture. Providing a design methodology for enterprise architecture based on the analysis of reference enterprise architectures and frameworks and issues related to design, is one of the most important targets of the research management enterprise architecture. The proposed design methodology includes following characteristics:

- It is general and flexible so that it can be applied for various needs of research management.
- It includes all components and procedures needed to provide a reference design model and clarifies component's relationship.

- It facilitates the use of reference models and best practices.
- It is comprehensive and considers all aspects related to the virtual research management environment.
- It provides better analysis of the complexity of the information and communication technology.

Determining the essential components of the system is important in design of enterprise architecture. These components are driven by mapping different requirements to the elements of reference architecture. These components can include: layers of reference architecture, rules and principles of implementing reference architecture, governance structure, role of stakeholders and how the architecture interacts with them, standards and current best practices.

The proposed design architecture integrates features and concepts related to human, technology and process. Human concepts can be applied for defining the role of human recourses and their interaction in design and organization of research management. Technology concepts clarify supportive infrastructure and technologies of business processes and finally, process concepts describe the functions and main processes of research management.

The design limitations are caused by environmental factors and should be considered in the design process. By using axiomatic design, the proposed architecture can be customized for the features appropriate for the purpose of research management.

Identifying requirements of research management and Enterprise Architecture design processes requires the precise definition of related concepts. An optimization approach for the design of research management enterprise architecture must integrate the right solution for the challenges of the current research environments including research management business and innovation, ontology and capabilities of virtual organization, risk management, structure of virtual organization and design of management services.

The goal of the proposed architecture is determining specifications and key components of service-oriented enterprise architecture and providing a method for designing agent-based research management architecture based on virtual enterprise approaches. The advantages of the design approach used for the proposed architecture rather than others include:

1. GERAM (Generalized Enterprise Reference Architecture and Methodology) has been used as a reference development process for the design of the academic research management architecture due to its comprehensiveness [20]. GERAM deals with methods, models and tools needed to build and maintain the integrated enterprise [21]. The scope of GERAM encompasses all knowledge needed for enterprise engineering/integration. Thus, GERAM is defined by a pragmatic approach providing a generalized framework for describing the components required for all types of enterprise engineering/enterprise integration processes. The GERAM framework identifies the basic concepts to be used in enterprise engineering and integration by its most important component named GERA (Generalized Enterprise Reference Architecture). GERA provides a framework for modeling and analyzing based on lifecycle [20].

2. Axiomatic Design method has been used for designing components of the proposed architecture. The primary goal of axiomatic design is to establish a systematic foundation for design activity by two fundamental axioms and a set of implementation methods. There are two axioms as follows:

- The Independence Axiom: Maintain the independence of functional requirements.
- The Information Axiom: Minimize the information content in design.

Axiomatic design provides a framework for describing design components. The goal of designing is to create a design knowledge base to improve the activities and provides principles of design based on thinking processes and reasoning tools. Elements that distinguish axiomatic design from other design theories include design domains, design hierarchical, round-trip processes between design domains, and two axioms of independency and information [22]. The axiomatic design consists of four domains. Customer attributes (CAs) describe customer needs regarding a product, system, or process. Functional requirements (FRs) are minimum requirements that meet customer needs and describe functionality of system. Design Parameters (DPs) in physical domain explain plan specifications that satisfy functional requirements. Finally, process variables (PVs) define procedures that create and develop designed product. System or organizational design begins with understanding customer needs and expectations. Likewise, axiomatic design is initiated with understanding customer needs and expectations. Design process starts from a high level abstraction and develops to more detailed levels of the system. The output is displayed in a design hierarchy of the functional requirements correlated with specific design parameters [23].

III. Developing Virtual Research Management Enterprise Architecture

This section explains the necessary steps to construct Virtual Research Management Enterprise Architecture. The steps are shown in figure 1.

Figure1: The steps of developing Virtual Research Management Enterprise Architecture

In following, each step has been described in details.

Step1: Research Management EA Design Framework

In order to design research management enterprise architecture, first the framework of the design should be defined. Design Framework is developed based on steps of Axiomatic Design method and by content analysis of reviewed literature regarding concepts of Grounded theory. Grounded theory is a systematic and qualitative method to extract theories from data to describe concepts and interactions of a phenomenon [24]. Data sampling, coding and integration are the

main steps of creating new theory [22]. For this purpose, main issues related to research management and enterprise architecture are inducted based on derived concepts:

Enterprise Architecture Reference Frameworks [25]

- Main goals: design requirements, principles, rules and standards, EA Analysis/modeling, Designing the concept model and the enterprise structure
- Architecture system model: input (Business motivators, ...), process (mapping of principles and rules of environment)
- Architecture design process: Perspectives, scopes, non-functional (NF) requirements, enterprise architecture abstraction levels
- Architecture ontology: enterprise architecture, content, organization and methodology

Service Oriented Architectures [26]

- Main goals: Key technology assets, Service components evaluation, Conformance, mobility and interoperability, Design principles
- Service-oriented View: Strategic framework for technology development, design and implementation of enterprise application, Architecture style and integration framework

Virtual Enterprise Modeling [11]

- Main goals: Communication, collaboration, coordination, Structure, behavior and information integration, Cost and benefit sharing
- Multi-agent system design: Addressing multiple aspects, Concurrent and distributed problem solving advantage, Negotiation, information sharing and coordination
- VE implementation: Describing entities and relationships, Defining goals, roles and activities and establishing the VE, Supporting to choose best partners

Agent based Modeling Methodologies [1][15]

- Main goals: Multi-agent conceptualization, agent--oriented Engineering (object-oriented techniques and knowledge engineering)
- Agent-based modeling: Description of concepts, design processes, symbols, techniques and recommendations, Conceptualization of system, Rules, tasks and interactions model
- Design considerations: Development view and approach, Scope of applications, Support approval and validation

GERAM [20]

- Main goals: Identifying/describing the concepts of organization, Designing architecture components, Architecture Integration knowledge
- EA concepts: Business processes, organizational construction, description of roles, support processes description
- Process-oriented modeling: determining modeling scope, describe processes, determining entities life cycle

Research Management Business and stakeholders [16]

- Main goals: identifying environmental, operation and NF requirements (goals, plans, stakeholders interest, IT governance
- Business considerations: Business architecture, structural dynamics, resource allocation, decision-making
- Organizational Structure: Coordination mechanisms, resource allocation and decision making model, agent modeling

The design framework of research management enterprise architecture shown in Figure 2 is synthesized by integration of investigated concepts about architecture design process (AD method).

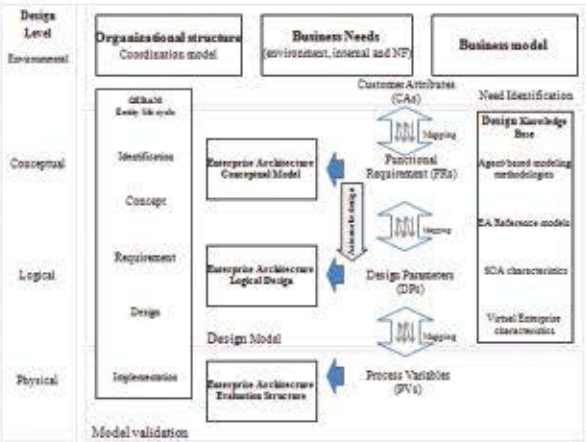

Figure2: Research management enterprise architecture design framework

Regarding the comprehensiveness of GERAM, it is selected as a base structure to identify and describe EA components. On the other hand, axiomatic design provides appropriate method for determining EA requirements and mapping them to related components and to the concept of the architecture. According to the proposed framework, architecture design process consists of four levels including environmental, conceptual, logical and physical design. In the environmental level, requirements of the system are identified based on investigating organizational structure and business value chain. In conceptual and logical level, components of research management architecture are defined and described using axiomatic design mappings process and by considering the GERAM's entities lifecycle. And finally the metrics and structure for evaluation of the model are identified by mapping the design parameters to process variables in physical design level.

Step 2: Research management EA needs

The research management EA needs can be identified through content analysis of the research management solutions (collected cases). Although there are many types of research center and thus many solutions can be found for managing them but as this paper focuses on academic research management, solutions like SAP (as mentioned before) and Innovation Systems are better suited .Innovation system concept is focused on information and technology flow between people, organizations and research institutes in order to provide innovation process. In this system, university provides scientific knowledge. Research institutes, government and economy are responsible to support and encourage research. Financial institutes and consult corporations

are critical to commercialize research and development [27].

For identifying research management enterprise architecture needs, more than 20 related research management solutions such as research and development standard [28], the process of higher education (HDG) [29], the research support systems [30], requirements of research development process [28], mission, goals and strategies of research [31], a model of research management- Australia's innovation system [32], innovation conceptualization [33], collaboration management process, [34], systematic approach of innovative studies - the Economic Development Cooperation [35] have been studied.

Research management needs are extracted, organized and verified by means of content analysis, Shannon's entropy and expert surveys. Shannon's entropy is a method which quantifies the expected value of the information contained in a message [36]. Requirements engineering is the process of discovering objectives and implicit needs of a software system to develop and build explicit and complete specifications of the system. Environmental needs are related to internal and external environment of the system. Functional requirements define the behavioral capabilities of the system. Non-functional requirements are extracted to define supplementary specifications about the system behaviors and functions [37]. Shannon's entropy result is shown in table 2:

TABLE2: RANKING RESEARCH MANAGEMENT REQUIREMENTS USING SHANNON'S ENTROPY

	research management needs	frequency	uncertainty	efficiency	rank
Business (Environmental)	Customer relationship	2	0.2017	0.0107	4
	interaction with industry	4	0.4034	0.0213	3
	knowledge and technology transfer	5	0.4683	0.0248	3
	research legislations	4	0.4034	0.0213	3
	management of stakeholders conflict	5	0.4683	0.0248	3
	research support	6	0.5214	0.0276	2
	research culture	8	0.6051	0.032	2
	intellectual property	6	0.5214	0.0276	2
	research portfolio	15	0.788	0.0417	1
	Research investments	10	0.6701	0.0354	1
	communication management	12	0.7231	0.0382	1
	research technical collaboration	16	0.8068	0.0427	1
Organization (Functional)	Research evaluation	5	0.4683	0.0248	3
	Education	3	0.3197	0.0169	3
	research services	3	0.3197	0.0169	3
	risk management	4	0.4034	0.0213	3
	research resources	5	0.4683	0.0248	3
	Legal support	7	0.5663	0.0299	2
	Financial support	7	0.5663	0.0299	2
	knowledge and technology management	6	0.5214	0.0276	2
	research infrastructure	9	0.6394	0.0338	2
	research institution	6	0.5214	0.0276	2
	Result publishing	13	0.7464	0.0395	1
	research profiles	16	0.8068	0.0427	1
	research configuration	10	0.6701	0.0354	1
	research project management	12	0.7231	0.0382	1
	Research skills	13	0.7464	0.0395	1
Attributes (Non- functional)	interoperability	2	0.2017	0.0107	4
	service publishing	2	0.2017	0.0107	4
	learning	2	0.2017	0.0168	3
	research quality	4	0.4034	0.0213	3
	research performance	5	0.4683	0.0248	3
	resource availability	4	0.4034	0.0213	3
	System distribution	3	0.3197	0.0169	3
	components composition	4	0.4034	0.0213	3
	dynamics of structure	3	0.3197	0.0169	3
	design openness and independency	3	0.3197	0.0169	3
	research innovation	8	0.6051	0.032	2

Step 3: Research Management Functional Requirements

Components of the research management EA and also measures of validation are extracted using the axiomatic design process. Axiomatic design begins with understanding customer needs and expectations. Output of design process is a hierarchical tree of functions and components that satisfy these needs and compose enterprise architecture of the research management.

In the first step, the customers' attributes were mapped to functional requirements of the research management EA. Functional requirements constitute a minimum set of independent characteristics that completely describe features and functionality of the system. In this step, the process of breaking down the entities and Round-trip mapping between domains result in the decomposition and further details of needs and requirements of the research management EA.

To reduce the complexity of the design, only a limited number of important needs were considered at the beginning of the design process. After confirmation of the experts' opinions about the needs priorities with result of the Shannon entropy needs classification, final research management EA needs were defined as follows: CA-1) Research leading, CA-2) Research investment, CA-3) Research collaboration, CA-4)Research participation, CA-5) Research platform, CA-6) Research human resources, CA-7) Research ethics, CA-8) Research administration, CA-9) Research effectiveness, and CA-10) Research publication.

Process of mapping customers' attributes (CAs) to functional requirements (FRs) is shown in figures 3, 4 and 5. The conceptual design of research management EA are carried out by analyzing and integrating results of mapping functional requirements and considering related reference models and design knowledge. Details of conceptual model components are directly derived from functional requirement mapping data.

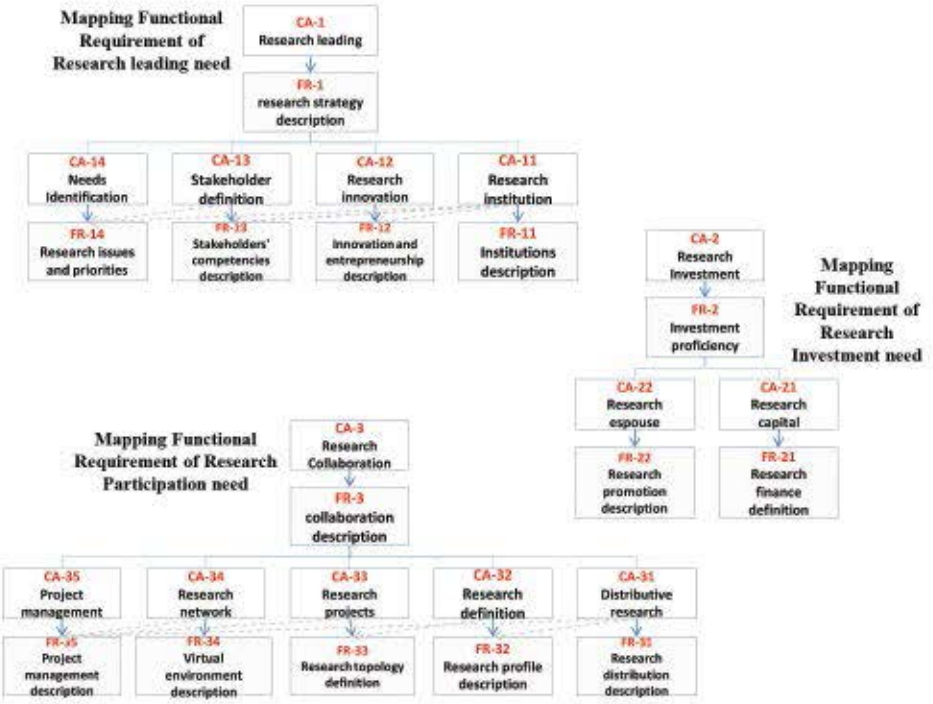

FIG.3: MAPPING RESEARCH LEADING, INVESTMENT AND COLLABORATION NEEDS

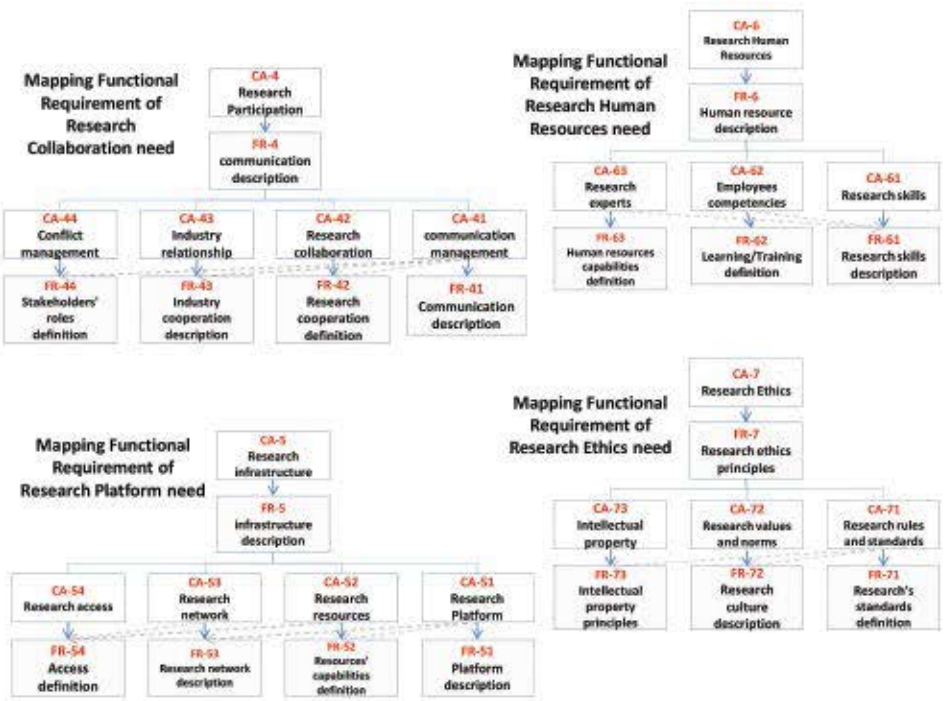

FIG.4: MAPPING RESEARCH COLLABORATION, PLATFORM, HUMAN RESOURCES AND ETHICS NEEDS

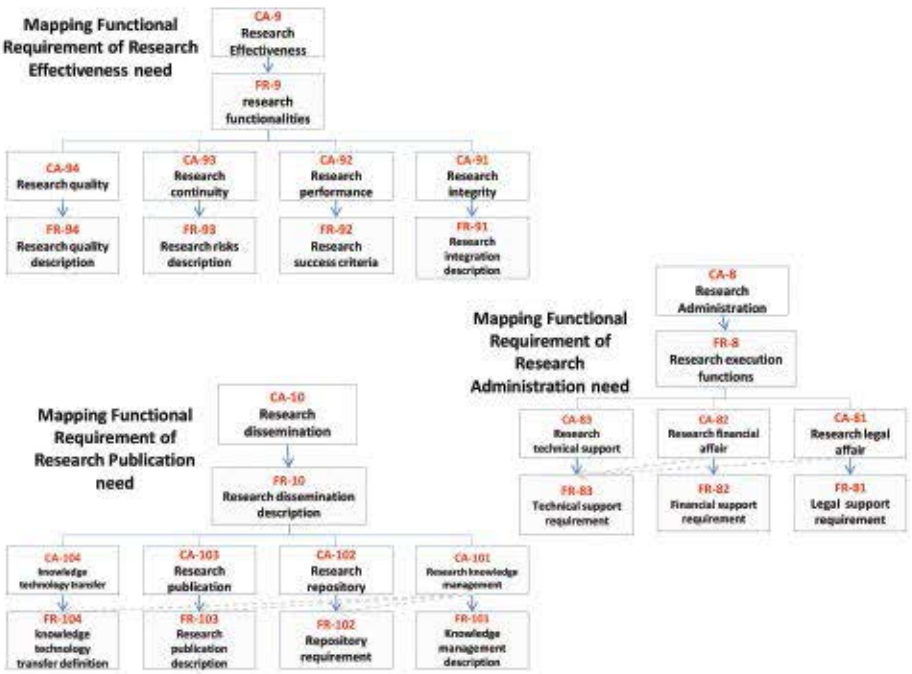

Fig. 5: Mapping research administration, effectiveness and dissemination needs

Step 4: Proposing Research Management Architecture

After identifying functional requirements and conceptual structure of research management EA, in the next step, components of research management EA are extracted through mapping the functional requirements (FRs) to design parameters (DPs). At this level, more details about enterprise architecture were obtained by further decomposing functional requirement and design parameters. The result of mapping process represents the essential components satisfying functional requirements of research management. These components are used to integrate and form the model of research management enterprise architecture.

The cube model of research management enterprise architecture shown in figure 5 is developed by integration of design parameters based on derived conceptual model and considering related reference models that mentioned in the design framework. The first and second levels of design parameters are shown in figure 6.

Components of the proposed architecture are brought together by introducing three EA domains including research management, environment support and implementation areas. Component on research management domain axis is organized based on layers of conceptual model adopted from service-oriented architecture Research strategy and business layer in the proposed architecture provide a business-centric structure for research management architecture. Defining research management implementation areas can make it possible to select right solution for different stakeholder's interests. In this regards, it is important to consider different environment support such as standards, governance, performance and virtual environment management aspects.

Fig. 6: Proposed research management enterprise architecture

IV. Evaluating Proposed Research Management Enterprise Architecture

The validity of the proposed architecture is verified by study a research institute case and designating application of the model for satisfying needs of research management in the academic research environment.

The method for validation of model is designed based on decision making theorem [38]. It states that to gain effective innovation and production process in the system (research management functionalities) a decision making process (based on architectural design) should address quality and performance aspects. The model is a projection of the real world and the data collected in the model should carries the information needed for the decision-making in a given context. The decisions will, when carried out, give an effect in the real world (goals, Strategies and activities). To build validation components, the derived design parameters (DP's) in the previous step are mapped to process variables (PV's). In the next step extracted PV's were orientated with research management needs to identify abilities of the proposed architecture for designing and decision making of a research management enterprise architecture.

Academic Center for Education, Culture and Research (ACECR) is an Iranian public non-governmental institution, established in 1980, with the mission of promoting science and technology, culture, education and entrepreneurship. The institution provides necessary procedures and structures to build research foundations needed by universities and research institutes. Validation criteria are determined by performing the final step of axiomatic design method. In the first step, research management needs of ACECR (Khaje Nasir Toosi University of Technology branch) were identified by studying goals and missions of the institute. The research management's needs can be classified in two main groups as follows:

- Environmental needs relate to national knowledge and technology development goals and priorities (10 items) and research responsibilities and priorities of ACECR in regards to theme (13 items)
- Internal needs relate specifically to Khaje Nasir Toosi University of Technology branch internal research objectives and priorities (27 items), organizational structure (13 items), activities (8 items) and challenges/success factors (11 items)

The extracted PV's include Research strategy and business structure (PV-1), Research institution structure (PV-11), Research innovation ontology (PV-12), Research investment components (PV-2), Research virtual environment structure (PV-3), Research distribution structure (PV-31), Project management structure (PV-35), Research communication plan (PV-4), Research infrastructure components (PV-5), Research human resources Plan (PV-6), Research skills and learning plan (PV-62), Research rules and principles (PV-7), Research technical and operation services implementation plan (PV-83), Research evaluation system (PV-9), Research publishing structure (PV-10), Research publication system (PV-103), and Research Knowledge/Technology Transfer plan (PV-104). The assessment results only indicated how the architecture's components were related to ACECR research management needs. Summary of mapping Results (needs and process variables) are shown in table 4.

Table 4 – Compliance of proposed architecture's components with ACECR research management needs

		Institute Development Needs	Proposed Model's Solutions
Environmental Needs	Country's Research and Technology Sector (Goals and Priorities)	a) Knowledge centric development, b) Institution of research policing and conducting, c) Increasing capacity of research and technology units, d) Providing financial and human resources and fascinating research innovation, e) Creating systems of commercializing research outcomes, f) Building capacities for promotion of leading technologies	PV-12, PV-4, PV-10, PV-1, PV-3, PV-5, PV-6, PV-2, PV-103, PV-104
	Academic Center for Education, Culture and Research (ACECR)	**Research goals and priorities including** a) Promoting research and research abilities in society, b) Proposition and supporting research issues, c) Providing national proficiencies hubs	PV-1, PV-4, PV-5, PV-10, PV-3, PV-103, PV-104
		ACECR common responsibilities including a) Creating organizations for research publishing, b) Sponsorship academic and cultural research papers, c) Providing research activities environment for young researchers	PV-3, PV-103, PV-1, PV-62
Internal Needs	Groups Goals and Priorities	**Resources, human capital and communication development policies and strategies including** a) Universities and research institutes relationship, b) Qualitative development of academic/expert capabilities, c) Acquire and preserve of academic human resources, d) Relationship with administrative institutes, e) International relationships	PV-4,PV-62, PV-6, PV-1, PV-103, PV-3, PV-5
		Research services development and transforming innovation to economic value including a) Promoting Information Technology and utilizing research outcome, b) Development of technology transfer and acceptance, c) Creating knowledge and training expert resources, d) Development of research groups and provision of human resources space and facilities , e) Developing collaboration and corporation with research institutes, f) Supporting research commercialization process and activities, g) Conducting and providing information support for knowledge intensive businesses	PV-11, PV-5,PV-31, PV-103, PV-104, PV-1, PV-3, PV-6, PV-10, PV-12, PV-2, PV-4
		Research activities including a) Preparing research plans, b) Providing expert and consultancy services, c) Holding conferences and workshops, d) Reparation of education courses, e) Publishing journals and books, e) Utilizing research results, f) Insuring financial and intellectual benefits of researchers	PV-1, PV-83, PV-10, PV-62, PV-7
	Organization structure	a) Documentation quality and control Supervision/auditing systems, b) Projects and documents Management, c) Resources, planning and research development, d) ICT professional services center, e) learning and education services, f) Project management, g) Coordination and support	PV-9, PV-35, PV-3, PV-83, PV-31, PV-62, PV-103, PV-10, PV-1, PV-5, PV-6
	Challenges and critical success factors	a) Attainment of required human resources, b) Providing independent research spaces (humans and infrastructures), c) Fulfillment of HR educations requirements, d) Policing technologies and professions, e) Communicating and interoperation with universities and research institutes	PV-6, PV-4, PV-1, PV-5, PV-34, PV-62, PV-11, PV-12, PV-3

In table 3, for each need of the research management in ACECR, a number of possible solutions are listed among process variables of the proposed model. Based on the results of evaluation (coincidence of the model usage variables), the needs related to research objectives and priorities, organizational structure and challenges/success factors of the research groups were entirely covered. For all needs specified in the above section, there is at least one associated component in research management enterprise architecture model. For the environment section, almost 70% of the needs are covered (some of the major remaining needs in this area are outside of research management enterprise EA design scope).

In addition, by reviewing the results, the attained validity of the components of the proposed model for designing the ACECR research management enterprise architecture is shown in figure 7.

According to the results obtained from mapping specifications and capabilities of the proposed architecture to research management needs of ACECR, the content of the proposed architecture has an adequate validity.

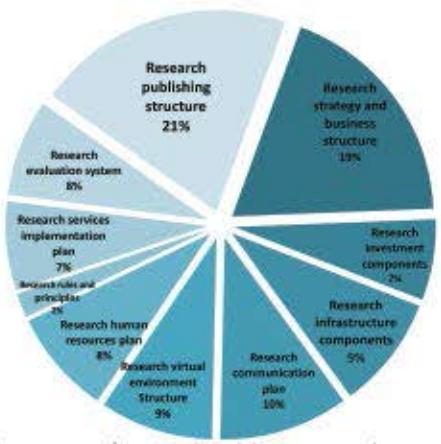

Fig. 7: usage of proposed model components in ACECR

Providing enough information and support for addressing quality and performance aspects in enterprise architecture decision making and design process is realized by maintaining independence between FRs and connections between FRs and DPs and also simplifying selection of DPs and PVs meeting the research management functional requirement of ACECR.

V. Conclusion & Further Discussion

The main goal of this study is introducing architecture for designing virtual research management enterprise. From organizational structure point of view, process of developing a virtual enterprise is not only a technology-based matter but a combination of organizational structure and associated technologies are required. Designing enterprise architecture based on virtual enterprise environment is a new research area emphasizes on using agent-oriented modeling methodologies to identify and implement interactive attributes of service agents/components in the enterprise architecture. Proposed architecture in this paper can be used in distributed and dynamic academic

research environment. By using GERAM and axiomatic design method, it is guaranteed that all aspects regarding to enterprise architecture design has been covered. Identifying functional requirements of research management simplified design process and made structured and systematic design possible. Identifying and categorizing research management requirement is done based on benchmarking and requirements engineering, and then prioritized based on expert survey and Shannon's entropy results. Also selecting limited important needs led to selecting optimized design solutions. Result validation is done based on content analysis and experts surveys in identifying research management needs, using valid design methods and references and studying a real research management case for evaluating proposed architecture components.

Innovation aspects of this research are proposing new methodology for research management enterprise architecture, integrating virtual organization concepts in enterprise architecture design, introducing a methodology for identifying research management system requirements, introducing key components in designing and developing research management based on virtual enterprise.

Regarding to the novelty of the agent-based modeling research area associated with virtual and research management enterprise, the issues of developing models and mechanisms for subcomponents of research management enterprise architecture is suggested as future research. In particular, the following research topics are proposed: a) investigating challenges, opportunities and obstacles of implementing proposed enterprise architecture model in a research institute, b) developing a model and methodology for designing non-functional aspects in virtual enterprise architecture of research management, c) developing service interoperability model for academic research management based on virtual enterprise.

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