From Hospital Management Information Systems (HMIS) to Hospital Operational Platforms (HOP)

Tomi Thomo
Universiteti Europian i Tiranes, Blv. "Gjergj Fishta", Nd 70, H1, Tirana, Albania

Abstract

The typical Hospital Management Information System (HMIS) is consisted of a set of software modules. The software modules implement the IT operations of preset functionalities representing HMIS business areas. However, the recent advancements of technology, biology, and biomedical engineering reveal demanding needs for the inclusion of additional functionalities which are hard to embed into the existing software modules due to the introduction of additional processes within the Hospital's organization. The Hospital's administration is left without adequate tools to manage the development, implementation, introduction, and maintenance of processes. Managing processes provides flexibility in embedding, administering, and integrating additional functionalities in the Hospital's operations. Hence, a higher management level is required to administer the Hospital's HMIS functionalities which can be provided through the employment of an operational platform. The operational platform is capable of handling the HMIS processes and provides the managerial means to the Hospital's administration to govern with objective and measurable evidence. This paper describes the operation platform for a typical HMIS satisfying the requirements for the administration of a Hospital's organization with focus on patients.

1.Introduction

The complexity of the organizational structure and the operational intensity of Hospitals lead to the employment of systemic approaches. The operational effectiveness of hospital organizations can be assessed applying indicators [1] regarding the functional efficiency, the obtained quality, and the attained performance. The availability of data can be ensured by the operation of properly installed Hospital Management Information System (HMIS) capable of providing adequate data to develop the required indicators. However, the required data must be received from specialized Information Systems (IS), such as the Laboratory Information System, the Radiology Information System, the Clinical Information System, the Administrative Information System, the Blood Bank Information System, the Contracts Management, the Personnel's Management and so forth. Hence, HMIS is the consolidation of a number of specialized IS that must be interoperable within the Hospital's organization.

Hospitals need interoperable IS exchanging data seamlessly over reliable platforms. The platform are called to link a plurality of dispersed IS within the Hospital handling electronic health related data including the electronic health records (EHR). Thus, the platform is required to collect, store, process, and report real-time medical data from multiple sources. Also, the platform is needed to enable the semantic normalization of health related data by converting them in standardized formats performing the appropriate mappings and conversions using predetermined terminologies and standards. Hence, the platform provides the means and the tools for processing and

integrating health data within the Hospital that considers EHR to be major information focal point.

HMIS contextual operations involve three distinctive and determinant parameters [2] that affect the data fusion within the Hospital's organization and the participant's perceptions. The data fusion has two additional implications, first, the integration of information and second, the social interactions. Thus, the HMIS operations develop and integrate the exchanged information and intensify the social interactions independently from the employment of a systematized platform. Therefore, there is need for a platform that systematically integrates information and provides the means for social interactions.

The rest of the paper is organized as follows: it proceeds with references to the related literature, it continues with the objectives, it goes on with the operational functionality, and it proceeds further with the internal structure of an operational platform, and it ends with concluding remarks and future work.

2. Related literature

In the related literature, the term and the concept of the operational platform is approached with different business origins and aspects.

Cloud Computing [3] has been approached with the platform meaning presenting three basic components: a front-end interface, a set of specific users, and a stored content. The front-end is provided for communication purposes among the selected users and the contents stored in the platform. The internally running processes allow the communication among the users and the management of the storage content. The front-end interfaces can be web clients or standalone applications [4] bringing together users and facilitating the interaction among users and processes. The carrying internal processes are responsible for the operational platform's integrity, maintenance, and preservation of the presented functionality.

In [5], an operational platform is presented as a system with an internal infrastructure based on three major components: people, computer technology, and protocols supporting the decision making process. The purpose of the infrastructure is the cooperative interaction of the participants and the achievement of their desired functionality within an active framework of interactions. The platform supports the communication among the participating roles delivering the adequate service functions. The added value of the operational platform is achieved by the integration of the major constituting components by allowing their active interaction. The interaction among the participating roles over the operational platform achieves to affect the participants' behavior obliging them to perform with the terms of the operational platform.

The operational platform can be approached as a framework which can be analyzed into three levels of discrete programs [6]. The framework of the operational platform can be visualized as consisted of the infrastructure and the related performing operations, the access and the provided services, and the obtained results by the platform as a whole. Thus, in [6], the platform is evaluated according to the intended use, the extent of its usage, the completeness of the offered services, the security, and the offering confidentiality. Also, the platform is evaluated according to the platform's effects on the expected results. However, the results obtained with the

employed platform are examined for the achieved completeness, timeliness, accuracy, matching, and security [6]. Therefore, the operational platform can be viewed as a framework for achieving the desired outcomes.

The operational platform integrates, develops, and functions healthcare applications following the Service-Oriented Architecture (SOA) [7]. SOA provides a normalized integration of services to support the operating processing and facilitating the carried workflows in the operational platform. The employment of SOA provides standardization of the desired interoperation among the cooperating applications. Also, the adoption of SOA allows the inclusion of rules-based systems, data repositories, and the necessary preconditions for data normalization [7]. Hence, SOA is considered to be adequate architectural constituent for healthcare information integration and shared platform [7]. Moreover, SOA provides the advantage to support distributed computing applications in a universal computing environment integrating mobile devices extending existing platforms [8].

The operational platform must be present holistic characteristics. The main challenges and goals of the operational platform is the provision of support for [9] (i) the entire business aspects of the organization where it applies, (ii) the heterogeneous contexts and dimensions of the applying organization, and (iii) the modularity of the adopted architecture to provide the necessary flexibility according to the business requirements. Moreover, in [9] it is employed an architecture that adopts: (i) the user engagement of heterogeneous stakeholders, (ii) the integration by interfacing and linking of various components, (iii) the validation of the provided services, (iv) the availability of training for the participating users. Thus, the architecture in [9] provides the following services: data management, process management, transaction management, planning, and reporting. Hence, the operational platform is aligned with the business aims of the organization applying it.

The holistic attribute of operational platforms must be analytically specified in order to determine data origins. In [10], the authors describe the operational platform with three distinct levels of attributes: the national, the area, and the community level. Moreover, the operational platform must be equipped with modules to perform data mining since the data is increasing drastically due to the increase of the number of data sources developing big data schemes [10]. At each of the encountered levels of the operational platform the corresponding set of operations must be performed such as the front-end interfaces, the diseases packages, the employed standards, the used classification systems, and the patients' medical records. Hence, the organizational needs can be prioritized into layers of the operational platform.

Among the practical purposes of the operational platform is the support of the decision making process. The operational platform provides a framework to separate the associated business and healthcare related decision into strategic, tactical, and operational levels of decisions [11]. The operational platform introduces the capability to apply (i) mathematical models for the resource planning using the decision making levels, and (ii) the optimization of business operations and the healthcare analytics [11]. Thus, the operational platform must facilitate the application of mathematical models allowing the provision of mathematical evidence to base the decision making process.

The architectural structure of the operational platform includes a set of software agents satisfying specific needs. Those needs refer to the medical professionals' peculiar business requirements and the patients' specific disease related demands and social calls. The operational platform must be equipped with a multi-agent system (MAS) [12] satisfying the socio-technical requirements. The operation of a multi-agent system provides the capability to optimize the operating processes achieving the set goals of the operational platform. Thus, a business intelligence module must be present in order to support the decision making procedures at the appropriate level of the operational platform heading towards the organization's strategy and governance principles.

The operational platform is collecting information from various and different sources such as genomic data, clinical data, and behavior data [13]. In [13], it is claimed that the introduction of artificial intelligence can assist in reducing readmissions, preventing hospital infections, reducing the length of stay, predicting chronic diseases, and predicting patients' no-shows. In other words, the operational platform must be patient-centric and data-driven independently of the patients' and the physicians' locations [13]. The operational platform must be prepared to face large volumes of non-unified sets of data with real-time processing requirements demanding high level of integration and sharing among the medical stakeholders. Also, the operational platform must facilitate the knowledge discovery from the available excessive data sets forming big-data patterns capable of generating additional knowledge. Moreover, the operational platform must be equipped with a data collection module, a data pre-processing and a data processing module, an electronic medical records module, a patients' data correlation module, a patients' monitoring dashboard, and an alerts and notifications module [13]. The authors in [13], suggest the employment of a pipeline structure that it receives data from all available sources, it proceeds with data preparation, it continues with data processing, it goes on with appropriate data storage in order to provide the necessary facilities for artificial intelligent processing with natural language processing, knowledge representation, automated reasoning, and machine learning tools [13]. Hence, the operational platform must present an architectural form allowing the patients' management by the advantages of remote monitoring, cloud computing, big data and reactive machine learning [13]. Thus, the operational platform needs require an adequate internal architectural structure satisfying the data integration and data sharing among the different participating stakeholders.

From the medical applications point of view, the operational platform is required to ensure and amplify the clinical safety and effectiveness in the healthcare delivery. The operational platform must be approached by a systemic perspective [14] since it faces challenges related with the lack of interoperability standards, the lack of appropriate platform architectures, the absence of related regulations, and a suitable business environment. The operational platform must be capable to provide means to display properly medical data, to store medical data from various sources, to derive medical alarms, to support the medical decision making, to exclude the cooperation with unsafe sources of data, to support the workflow automation, and to provide continuously feedback on the encountered activity [14]. Hence, the operational platform must promote the safe authorized interoperability in a unified computing environment the functioning of the participating medical roles with the systemic traceability capabilities.

The internal structure of a typical operational platform is distinguished into functional layers. Each layer is assigned a functionality related to the user interface, the business services, and the storage [15]. These layers are escorted by additional modules to support the users' roles with the corresponding processes' instances on the platform and discrete modules to provide the aimed platform's functionalities [15]. Those discrete modules provide the capability to enrich the operational platform's functionalities with additional functions increasing the operational platform's flexibility and integration. For instance, the operational platform can be further equipped with Clinical Decision Support Systems (CDSS) that operate independently from the employed operational platform [16]. Thus, the architectural characteristic of modularity increases the operational platform's functionality with additional modules provided that there is the available the proper information infrastructure. For instance, the HL7 standard suggests a platform independent module (PIM) for implementing CDSS provided the availability of a knowledge module (KM) [16]. In this direction, there open source communities developing platform independent modules such as the Open CDS project [17] using the HL7 standards. Therefore, the architectural structure of the operational platform determines the capability of increasing the performed functionality provided the availability of a properly defined modular structural pattern. Indeed, the authors in [15] employed such architectural directions including a Clinical Decision Support Service which includes a user interface, a knowledge database, knowledge authoring, alert/reminders, and guideline modules to enrich the functionality of the proposed operational platform.

The operational platform is considered to be more than just a set of processes and the management of resources [18]. Besides the operational platform's architectural design, there must be considered the network of the acting roles on the platform which provide the value-platform concept [18]. The value-platform concept provides the managerial means to handle the network formed by participating roles which is different than the value-creating-system and the value-system platforms. The value-creating-system and the value-system approaches examine the platform considering just a set of activities [18]. However, the value-platform approach extends that model by examining the management and configuration of tangible and intangible resources [18]. Thus, an operational platform is more than a "manageable object" and the value co-developed by the carried activities of the platform [18]. The operational platform as value-platform is promoting the aspect of organizing the resources in network topologies. Therefore, the value-platform requires the consideration of the created value which is related with quality and performance, the knowledge and innovation, the legal aspects of the platform's functionality, and the capability of the platform to be parameterized and be adjustable to the organizational needs.

The operational platform is typically implemented abstractly on the cloud. Thus, there are provided various accessibility methods and there are offered many different software applications for data access and communication purposes. The use of social media assist in developing e-health and m-health software application which provide the means for healthcare service delivery [19]. The operational platform is used for transferring, processing, and disseminating the healthcare data for patients and clinicians while it is developing a clinical decision support system (CDSS) since it takes advantage of the personal health characteristics collected to be compared against knowledge based systems in order to raise medical recommendations to the medical professionals [19]. Therefore, the operational platform supports the dissemination,

interaction, and data sharing [19] among the participating roles with the requirements to control the validity of the exchanged information.

The operational platform can be seen from the point of view that facilitates the functioning of medical applications that written once and run without modifications in other computing systems. Hence, the operational platform must be capable of facilitating application programming interfaces (APIs) which can collaborate with the platform's computing infrastructure. Such considerations presuppose the application of standards followed by the operational platform and the third-party software developers concerning the development programming technologies, the terminology, and the standardization of the data [20]. The authors in [20] developed their project following HL7 FHIR in order to achieve the necessary data standardization. In other words, the operational platforms computing infrastructure declares the technical requirements and the complying APIs can operate within the operational platform respecting the set operational terms. Hence, the operational terms of the platform place the rules for the use of the resources, the semantic continuity, and the validation of the data [20].

The operational platform is required to have an appropriate storage base. The storage of data must facilitate the development of information and thus, the operational platform must be considered as an information hub [21]. The information hub must be escorted by knowledge base module supporting ontological structures to form useful information. Also, the operational platform must have the capability to perform references to external resources to support the knowledge processors [21]. The involved information provides the capability to develop APIs driven by the available information creating info-driven APIs [21]. Therefore, the operational platform must be capable of taking advantage of the developed and represented knowledge.

The operational platform experiences failures that must be encountered in the design phase. The failure analysis focuses on the performing workflows considering the events of the data collection, the applying filtering, and the occurring events [22]. Also, the failure analysis is concerned with the values obtained for data variables, structures, pointers, and records [22]. Moreover, the failure analysis is concerned with the assignment of software exception handling mechanisms that are incapable of facing all sorts of occasions and situations [22]. Thus, the operational platform must be capable of recovering from failures guiding its operation in a safe and acceptable functionality.

3. The HMIS evolution

The HMIS is consisted of a set of interacting and cooperating software modules. Over the years, there are HMIS software modules with separate and distinguished identify as they perform specific operations. For instance, the Laboratory Information System (LIS) is part of the Hospitals' IS. Similarly, the Radiology Information System (RIS) or the Picture Archiving and Communication System (PACS) have been considered as independent software entities within the nosocomial IT organization. Hence, HMIS is considered as a set of interoperating and inter-coordinated software modules.

The technological evolvement introduced additional communication means within the typical Hospital through the use of internet, wired and wireless networks, mobile devices, software provisions as services, adequate architectures, and the use of pictures, voice, and video in the everyday exchange of information. Thus, the

provided IT services within the Hospital have the capability to be integrated providing additional services satisfying the operational needs. Moreover, the Hospital's IT ecosystem is evolving presenting IT capabilities that could be matched with Hospital's needs provided there is a proper operational platform to accommodate and facilitate their interactions. Therefore, the current level of technological maturity presents the capacity to turn the Hospital from a closed to an open system exchanging and disseminating information.

3.1 Characteristic properties

The operational platform is a business model that creates value by bringing close producers and consumers. The business model in a typical Hospital seems to be remaining the same; however, the introduction of technological means has changed the behavior, the habits, and influences the cultural evolvement of medical professionals. The operational platform is creating value which is translated into quality and performance. Quality has always been the purpose for the employment of IT systems which directly affects aspects such as safety, satisfaction, and performance. The information producers and consumers find their loci in the operation of the IT system by making available data which is necessary for other employees' classes. Therefore, the operational platform is considered to be the intangible place where the functioning organizational rules, terms, and conditions provide the proper situational status to perform their intended tasks.

3.2 Design Objectives

The operational platform is expected to present specific characteristics that have to be considered at design-time. The design of the operational platform must achieve the following characteristics: (a) responsiveness, (b) process oriented, (c) flexibility, (d) scalability, and (e) integration capability. The operational platform is expected to respond and react to events. The responsiveness characteristic refers to the ability to dynamically adapt responses. The operational platform is more than a typical module-based system with preset functionality. Process-orientation of the operational platform refers to the capability of handling massive volumes of information. The bulk of information is administered by the internally running workflows and the availability of dashboards through which monitoring and adjusting is made possible. Flexibility is the characteristic that allows the adaption to changes in business and/or process requirements. The necessary flexibility is achieved by the capability to change operational parameters through reconfiguration of the applying functional rules of the system. Such flexibility attributes provide the capability to the operational platform to meet and satisfy the business requirements. Also, scalability provides the means to keep the performance requirements as the organization and its needs grow. The operational platform can accommodate and facilitate those changes in the functional processes that require more information and decreased lead time. Integration capability refers to the ability to be connected to every known business entity that is relevant to the running processes. The integration presupposes the predetermined resilient interfaces with other systems performing stable interconnections and secure transactions. Therefore, desired characteristics of the operational platform form a framework of attributes which must be satisfied by the performed design.

3.3 Structural requirements

The operational platform's building blocks are loosely coupled in order to satisfy the design requirements. The building blocks are: (i) administrator, (ii) transaction, (iii) data management, (iv) business management, (v) information management, (vi) process management, (vii) continuous quality improvement, and (viii) decision support. The administrator's processes are related with the users' and the services access. The transaction processes refer to the development of communication channels for the interaction between users and services. The data management addresses the maintenance of the obtained and used data including the platform's reference data such as classifications and standard values. The business management refers to the administration and performance of the business processes required to meet the business objectives. The information management handles the higher level processes as defined by the business management supporting the intelligent aspects of the operational platform. The process management provides housekeeping services for maintaining the active processes and the related services. The operational platform is equipped with the necessary set of processes monitoring and evaluating the processes performance. The decision support applies on the performing processes assisting the assigned roles with evidence to make decisions. Therefore, the operational platform is consisted of sets of interacting processes that create value for the participating data producers and the corresponding data consumers.

4. Operational functionality

The operational platform documents the performing processes, it applies data collection services, it generates reports of process, and it provides systematically the measured outcomes. Thus, the platform monitors the supervised subsystems and it feeds back the operational results to the functioning process in order to (a) improve processes performance and (b) contribute in the decisions' making procedures. The decision making activity is placed at the highest level of the operational platform since the decisions provide operational maintenance, growth, and further development by allocating properly the available resources. The decision support process is supported by continuous quality improvement activity taking place within in the operational platform managing the available sets of tangible and intangible resources.

4.1 Operational administration

The administration of the operational platform is performed by a dedicated software module that manages: (a) roles, (b) processes and services, and (c) data. The roles participating in the operation of the platform are assigned access rights to the available processes and their services, as well as, access rights to sets of data. Thus, the operational platform, for presentational purposes only, can be viewed as a closed system of processes and their services on which certain roles can have access. Similarly, the considered roles can have access to the data sets belonging to processes and their services. Hence, there is a one-to-many relationship between the encountered roles and the processes along with the included services and the corresponding data sets. The roles can be internal or external to the Hospital and they are treated according to the applying operational rules of the business processes.

4.2 Transactions and Resources interaction

The operational platform manages the interactions among the managing resources, controls, and monitors the occurring transactions. Thus, the operational platform is controlling all existing interfaces of the available services, keeps tracks of the performed activity, monitors the acceptable performance, and intervenes when the applying rules have been overruled. The validity of the applying rules on the formed situations are followed by Rule-Based Systems (RBS) [23] and Case-Based Reasoning (CBR) [24] systems which develop very powerful logical frameworks. Hence, controlling the interactions among the platform's resources, the circulating data becomes completely controllable too, supporting with confidence the end-users choices using the user interfaces. Therefore, the control of the resources relationships and the performed transactions provides the necessary cleansing of the input data.

4.3 Data Management

The data available in the operational platform belong to specifically determined services. Sets of services form processes that circulate within the operational platform and need data for their functionality. The processes need two classes of data: (a) standard data sets, and (b) transactional data sets. The standard data sets reflect the need for standardized values such as the code for a disease or the locally holding values for the biochemistry laboratory. The transactional data sets reflect the users responses interacting with the platform and additional control must be applied for data cleansing. The data management must be capable of examining the syntactic and semantic validity of the received data. Filtering the users' provided data requires additional control activity to minimize mistakes, reduce errors, and obtain semantically complying data. Therefore, the data management applies policies, processes, procedures, and services on the obtained data from the platform's interfaces in order to provide clean data for further processing.

4.4 Storage policies

The operational platform follows discrete policies according to the origins and the operational nature of the data. There are four policies applying: the administrative data, the process data, the transactional data, and the business data. The administrative data are stored in the physical media in separate sql-based database system. The process data are stored in sql database tables following the mater and slave patterns. The transactional data are stored in sql database tables and classified according to their resources' origins. The business data follow the database structures dictated by the specific business applications. The followed storage policy divides the large volumes of data in smaller sets in order to increase the processing responsiveness. Therefore, the separation and discrimination of the data according to its operational nature supports the principles of flexibility, scalability, responsiveness, and process oriented visibility.

4.5 Process administration

The operational platform is managing the operation of processes. The processes are well-defined and their contents are publicized. The processes are consisted of other processes and/or services. The services are software applications' packages and the relationships and interactions with the performing processes are documented. The running processes can consult the registry of processes and the vocabulary about their

semantics. Thus, the processes can interact with each other provided that they have been enlisted in the related platform's repositories. Running processes can behave in the predetermined manner; however, the combinatorial interaction of the increasing number of running processes can provide the adequate outcomes provided that the operation remains within the logical framework of the existing rules. The operational platform applies controllability by monitoring the running processes outcomes from their interactions, and at the same time, the platform applies observability by monitoring the operating status of each running process. Hence, a complete control mechanism is in place by monitoring the external environment of each running processes along with the internally holding conditions of each running process.

4.6 Business Process Management

The business processes are implemented with the operation of the HIS modules. However, the processes of the HIS must be examined, analyzed, parameterized, and documented along with the rest of the platform's processes. Analyzing the HIS processes with the same methods as the rest of the platform's processes, a homogenization is achieved and allowing to handle all processes with a unified and well-defined approach. Thus, the set of all running processes can be handled uniformly allowing the virtual interaction of the running processes. The HIS modules analyzed into discrete processes provide the capability to control the operation of those modules within the platform's framework. The interaction among the processes can be easily achieved either at the service level or at the database level but it requires access to the HIS modules database tables. Therefore, the business processes must be included along with the rest of the platform's processes providing a uniform operational field.

4.7 Information Management

The operational platform must be capable of managing the processes and developing complete information. The information is formed by the processes' interaction and it is monitored by the operational platform. However, the information is another type of the platform's resource and it is treated in accordance to the platform's resources requirements. In other words, information is related to processes, services, roles, and data forming a very thick network of relationships that allow making reduction, induction, and deduction inferences. Therefore, the operational platform is managing information as part of the performed resources management.

4.8 Continuous Quality Improvement

The operational platform adopts the strategy of continuously improving the provided quality. The obtained quality, as expressed by the processes' functioning, is continuously examined and evaluated. The evaluation of the quality is performed on quantitative and qualitative data. Moreover, the operation of the platform is under continuous monitoring controlling the associated risks. The associated risks and the evaluation outcomes are fed into the decision support system. Thus, the operation platform provides the quality characteristics of the operating processes and keeps logs about their performance. In addition, risks and evaluations are intelligently processed by analytic tools of the operational platform's services that provide additional materials for the support of the decision making. Therefore, continuous quality improvement is an intrinsic characteristic of the operational platform.

4.9 Decision Support System

The decision support services offered by the operational platform are provided into two distinct layers. The first layer concerns the users support while the second layers refers to the operational platform's automated decision making procedures. In other words, the decision making is discriminated into high and low level operations. The high level operations refer to the users support while the low level decision making reflects the decisions made by the operational platform to keep its intended integrity. The decision making procedure is consisted of a series of steps followed by the users or the platform itself. The procedure initiates with the development of a case or a scenario for which a number of options are available. The operational platform searches for the optimal decision among the available options. If the decision concerns a housekeeping mater, the operational platform performs and applies the selected optimal solution. For the users support cases, the operational platform provides to the user the available options notifying the optimality and the related consequences assisting the user to make the most appropriate selection. Therefore, the operational platform supports decision making consulting the users or applying optimal choices for the platform's operational stability and integrity.

4.10 Reporting

The performance of the running processes, the offered services, and their interactions can be presented as evidence of the achieved platform's productivity and efficiency. The operational platform provides the capability to issue reports containing data about the performance of its constituting materials and their interrelations. The issued reports provide a clear picture of the platform's efficiency while the use of analytic tools provides the capability of performing inferences from the obtained data. Thus, the operational platform users can configure the issued reports with the processes' specific characteristics obtaining insights from the platform's operation. The platform can provide predetermined reports as well as reports based on the users' specific desires. Reporting consists the major tool for monitoring the operational platform's performance and it provides the evidence upon which high level decision making is performed. Therefore, reporting is an intrinsic characteristic of the operational platform supporting the principles of process oriented visibility and transparency.

4.11 Maintenance and Housekeeping

The stability and the expected performance of the operational platform depend on the required and necessary maintenance and housekeeping activities. The maintenance activities focus on keeping up to date the platform's standard set of data. In this set of data is included the active processes specifications, the running services definitions and capabilities, the management parameters of the platform, and the standard data sets required for the operation of the processes and services. The housekeeping activities concern the satisfaction of the technical requirements of the operational platform such as disk storage space or tables' indexing maintenance. Thus, the operational platform provides the means to perform maintenance and housekeeping activities which are performed by the platform's authorized administrators. Therefore, the operational platform presents the required and necessary intrinsic characteristics to maintain the intended stability and performance.

4.12 Interoperation

The operational platform is required to function as open-system which is capable of cooperating with external applications. The cooperation of the operational platform is performed at the process level. The running processes of the operational platform provide an interface of services capable to embed the external applications results within the platform. The interoperation requires the necessary authorization in order to allow external processes to interact with the operational platform's processes. Thus, the interoperation of the operational platform is based on process interaction. Hence, the provided services by the platform's processes are publicized along with the authorization requirements to the external platform's IT ecosystem. The operational platform is open for interoperation to the set of publically available services' interfaces. Therefore, the operational platform is capable of cooperating with any external IT system that meets the constituting processes' requirements.

5. Design implementation

The implementation of the operational platform contains the description of the relations of the involved concepts, the architectural implementation, the platform's interface, the hosting of the platform, and the sustainable operation.

5.1 Relationships of Conceptual Components

The operational platform includes independent but cooperating and interacting management components. The cooperation among the management components depends on the operational characteristics of the running processes. The running processes are formed out of services which present specific interfaces. The matching of the interfaces characteristics allows the interaction and interoperability among the running processes. The operation of the services is supported by the appropriate processing and storage support. The figure below presents the developed interactions among the participating management components of the operational platform.

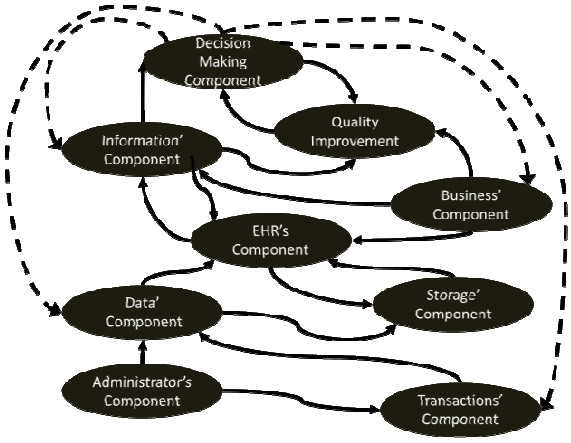

Figure-1. Interactions of the Operational Platform's components.

5.2 Architecture implementation

The technical implementation of the concepts presented in the previous section addresses the software development of the shown components with the corresponding software packages. The main components are the Administrator's, the Transactions, the Data Management, the Storage, the EHR component, the Business Management,

the Information Management, the Quality Improvement or Continuous Quality Improvement Systems (CQIS) [25], and the Decision Making component. The following figure presents the architectural structure of the operational platform.

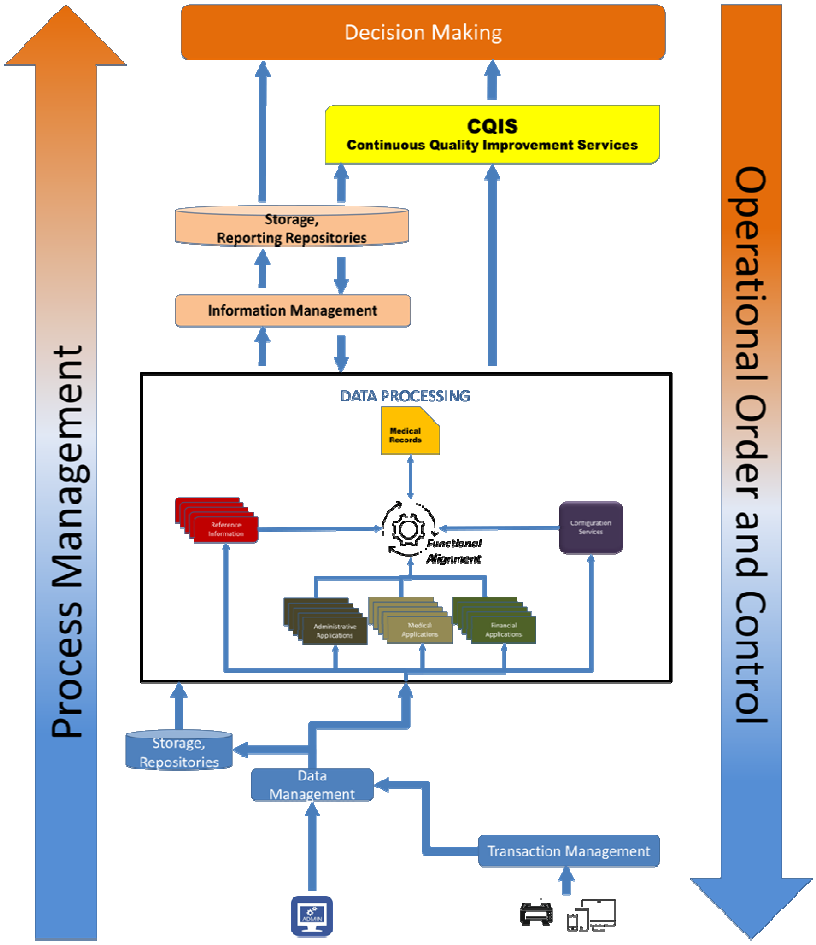

Figure-2. Operational Platform's architectural structure.

5.3 Administration

The administrator is provided with the necessary tools to set the functional framework for the operational platform. The available software applications handle the users, their roles, and their accessibility rights. The users' accessibility rights expand on selected processes and their associated services. The users, depending upon their assigned roles, are assigned privileges on the running processes and their services. The administrator determines the description of the available processes along with their demands for information specifications and storage. Also, the administrator specifies each process' contents determining the constituting services defining the (a) algorithmic model, (b) interfacing specifications, and (c) algorithmic control model. Thus, the operational platform's administrator can enlist the acceptable processes and services into registries. The registries can be used as selection lists by the co-operating processes increasing the flexibility of the operational platform. The running processes can take advantage of the available dictionaries that provide specifications for the services' interfaces. Moreover, the services can find additional details from the available vocabularies that support the services' interactions. The administrator can define the applying rules that are defined as (a) operational and (b) business rules supported by a typical Rules-Based System (RBS). Furthermore, the administrator can

define advanced rule constructs supported by a typical Case-Based Reasoning system (CBR). The rules and the cases noticed by the administrator apply on running processes and their services rectifying the operational platform's functionality. Therefore, the administrator defines and handles users, roles, processes, services, rules, and cases.

5.4 Interoperation

The running processes of the operational platform publicize the functionality of software services that provide the complete description of the available interfaces. The interfaces are typical APIs or applications' forms. The interfaces description is available in registries, dictionaries, and vocabularies. The registries provide a quick access while the dictionaries provide more details about the interface supporting its semantic status. Furthermore, the operational platform is supported by vocabularies that provide support to the involved ontologies. The ontologies support the operation of the information management component which is restricted in its operation by the employing RBS and CBS modules. Thus, an external application API or a typical application's form can participate in the operation of the platform provided the authentication prerequisites along with the functional requirements. Therefore, the operational platform provides a stable operating system for any external process that meets the platform's requirements.

5.5 Sustainability

The operational platform is characterized by its openness setting available the terms and the conditions required to get processes running on it. The administrator's activity can be performed by selected processes' services running on the operational platform. Usually, the administrator's role is assigned to technically trained personnel that perform the platform's maintenance and housekeeping. However, the operational platform's reporting system provides adequate and sufficient information to maintain its functionality and ensure the operational efficiency. The included decision support system is properly coupled with the major components of the operational platform in order to perform the necessary business and technical adjustments required to keep the platform functioning according to the stated intentions. Therefore, the operational platform facilitates the functionality of the necessary components to ensure its continuous technical and business improvements required for sustainable operation.

6. Technical Development

The software development of the typical hospital operational platform (HOP) involves the creation of sets of software classes. The figure below presents the classes of software entities which are required for the development of HOP. Each block in the following figure represents a class of a software entity. Further, the figure provides the interrelationships among the depicted blocks which provide the desired HOP functionality.

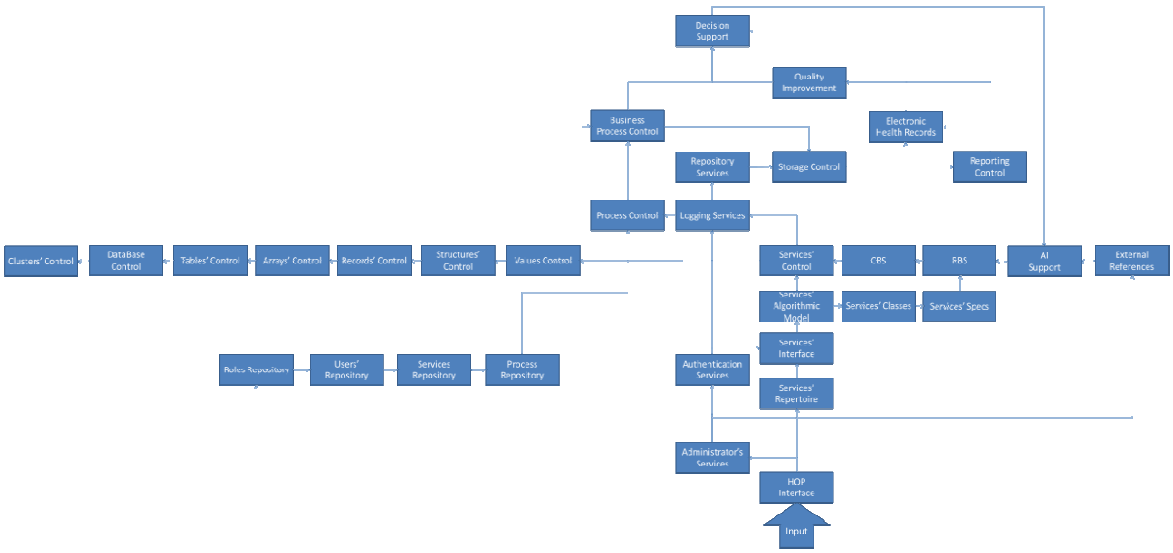

Figure-3. Implementation of HOP software entities.

The HOP interface relies on the web programming capabilities. In other words, a web page must be prepared to facilitate the interaction of users and other external services. Thus, the users' roles can be discriminated according to the assigned privileges while the accessing external services must be known to HOP authentication system. The following figure depicts the accessibility rights of the users depending upon the provided role in HOP.

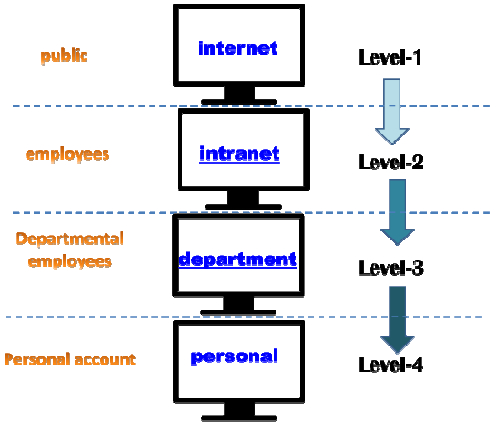

Figure-4. Accessing the HOP infrastructure.

7. Concluding remarks

Over the years, the typical HMIS structure covers specific areas from the Hospital's operations. However, technology and science provide additional means to support the clinical, laboratory, and administrative practice. Thus, typical HMIS requires additional supportive modules to cover the continuously increasing diagnostic information from various biomedical modules as well as the increasing volume of administrative information spawned from Hospital's operation. Therefore, the Hospitals require expanding their modular structure adopting additional specialized modules with the revealed need for orchestration of operations.

The presented operational platform model meets the set requirements of responsiveness, process-orients, flexibility, scalability, and integration. The Hospital operational platform (HOP) reacts to events presenting a dynamic behavior instead of the usual preset functionality of the typical HIS. HOP is process-oriented which makes it capable of handling the running processes providing the capability to administer massive volumes of information, and at the same time, to be considered as an open system interacting with externally process-driven systems. Thus, HOP is designed to respond to changes accordingly following the governing decisions making component and the underlying supporting ruling system. HOP can be expanded according to holding needs and be adjusted to maintain its operational effectiveness and efficiency. HOP is a stable, transactional, and highly resilient co-operating with external systems which can be adopted and integrated into a uniformly functioning operational platform

HOP requires further development and standardization. Evolving and standardizing the HOP components can facilitate the inclusion of advanced technologies and methods which are still very hard to be included in HMIS solutions. For instance, the Internet of Things or the ubiquitous computing cannot meet the necessary standardization to be introduced and adopted productively in HMIS installations. The HOP components require the development of additional components that allow taking advantage of high level conceptual managerial constructs such as that of strategy and policy. The inclusion of such concepts in HOP provides the capability to apply them at various levels of the Hospital's operation from the patients' treatment to the organization's management.

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