

Business' New Requirement: Information Systems Integration – Methods and Technologies

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Abstract— Today, the integration of information systems has become a necessity due to the fact that the big companies have developed over time, mostly, separate information systems (which do not communicate between them) for the automation of different activities. If in the beginning the “situation” seemed to be under control, the boost in the number of customers, products, suppliers, etc. brought about an acutely increasing need for the companies' information systems to communicate with each other. Also, in its turn, the current economic crisis has increased the necessity to integrate the information systems within a company, thus simplifying any means of controlling the business. That is why in this paper we submit to your attention some types of information systems used by companies (Enterprise Resource Planning - ERP, Customer Relationship Management - CRM, Supply Chain Management - SCM) as well as possible ways of integrating these systems (integration through business processes and services). On the other hand, systems integration also implies integration of the data handled by these systems, so we will consider also some ways of data integration (databases, data warehouses) by means of technologies such as Oracle GoldenGate. Finally, we will describe a technique for testing, the integrated operation of a software product, more precisely, an integrated type of testing: Pairwise, a powerful testing technique.

Keywords—Customer Relationship Management, data integration, Enterprise Application Integration, Enterprise Resource Planning, Geographical Information Systems, Information Systems Integration, Supply Chain Management, Pairwise.

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I. INTRODUCTION

WITH the global economic problems generated by the current economic crisis, companies have had and still have, perhaps now more than ever before, the need for advanced information systems. “Many enterprises have implemented novel information technology and developed innovative e-business applications systems”[1]...but performance at this level is basically about integrated computer systems.

The real challenges arise when a company's information systems need integration. The advantages are, no doubt, numerous: from the reduction in the costs of maintenance of several information systems to simplification of work flow. “Information integration is a key benefit of Enterprise systems (ES). This integration can replace functionally oriented and often poorly connected legacy software, resulting in savings in infrastructure support costs.”[2]

In this paper, we analyze and present some *types of information systems* used by companies (*Enterprise Resource Planning - ERP, Customer Relationship Management - CRM, Supply Chain Management - SCM*) as well as possible ways of integrating these systems (*integration through business processes and services*). On the other hand, systems integration also implies integration of the data handled by these systems, so we will consider also some ways of *data integration* (databases, data warehouses) by means of technologies such as Oracle GoldenGate. Finally, we will describe a technique for testing the integrated operation of a software product, more precisely, an integrated type of testing: *Pairwise, a powerful testing technique*.

II. INTEGRATION THROUGH BUSINESS SERVICES AND PROCESSES

“By definition, Enterprise Application Integration (EAI) refers to *the process of integrating multiple applications that were independently developed, may use incompatible technology, and remain independently managed*”[3]. Within its two basic components, Business Process Integration (BPI) and Enterprise Information Integration (EII), EAI it's the most commonly and efficient approach in complex software development.

A. Integration through Business Services and Processes - Overview

Starting from software development patterns and three tier applications development, there are three layers of software integration: data integration, service integration and process integration. The level of complexity rises from data to process integration, and the level of abstraction as well.

Service and process integration lead to the completeness and coherence of integrated systems. Services comprise unassociated, loosely coupled units of functionality that implement actions. Rather than services embedding calls to each other in their source code, services use defined protocols that describe how they pass and parse messages using description metadata.

The most commonly used approaches in service integration are SOA (Service Oriented Architecture) and ESB (Enterprise Service Bus).

SOA implementations are designed using a wide range of technologies like XML web services, SOAP, RPC, CORBA and provide information systems capabilities as composite services that interact and exchange information in order to support all business processes and their functionalities.

ESB generally provides an abstraction layer on top of an implementation of an enterprise messaging system, which allows developers to exploit the value of messaging without writing code. Unlike the classical enterprise application integration approaches, ESB cuts the number of interfaces for interconnection between different systems, being capable of translating interfaces.

Starting from SOA concepts and design, services are associated and combined to work as a whole by using orchestration. The process of services orchestration in order to communicate, interact and exchange data between disparate functionalities, creates the context of business processes.

The most commonly used approaches in process integration are BPM (Business Process Management) and BPEL (Business Process Execution Language).

The scope of business process integration is to automate processes in order to achieve accurately and completely the same outcome as the separate business execution on disparate information systems, with increased efficiency.

Both services and processes, in the context of software integration, adhere to the following principles: abstraction, autonomy, composability, discoverability, formal contract, loose coupling, reusability, statelessness. A system based on a service/process integration mechanism will package functionalities as a suite of interoperable services/processes that can be used within multiple separate systems from several business domains.

Services and processes are reusable and can be discovered and consumed easily as they're developed using guidelines, documentation and designed as services through standardized process management tools. These approaches are cost effective and provide extreme flexibility in software integration processes.

B. Integration through Business Services and Processes – a Way to Increasing Information Systems Efficiency

When talking about efficiency it is very important to notice the costs and expenditures over the benefits. Information systems integration approaches are based on the principles of efficiency, while the complexity of integration projects raises as business grow and disparate software applications develop to feed the business needs.

The easiest approach to increase efficiency inside the software integration process is to interfere at the high level of business functionalities, that is services and business processes that map over the business requirements, validations and user actions.

Services encapsulate small business functionalities and sum up atomic business functions and operations. When services compose themselves into large functionalities and functional business modules, they form a business process. Once the level of complexity grows from services to processes, the level of abstraction also grows and creates an appropriate context for easier integration of heterogeneous software applications and information systems.

The process of reducing costs and increasing information systems efficiency is called business process automation. Business process automation consists of enterprise applications integration and using software applications throughout the organization.

In order to assure business process automation, there are several steps that should be made:

- Extend business functionalities of existing systems in order to achieve a certain abstraction level so as linkage between system components could be made; in this case, abstraction could be considered as a system specialization, because only customized functionalities can be instantiated and can give results in a production environment;
- Use special tools for business process automation – those tools are designed in order to simplify the automation of business processes, they can be used by unqualified IT users through an intuitive interface;
- Use a business process management implementation to provide architecture for all processes of the business to be mapped; this approach must take into account equilibrium between the delay caused by methodology usage and the benefits of a procedural work.

The liaison between business processes automation and service oriented architecture is made through standard interfaces implemented using web services. In this manner, business functionalities exposure is achieved by standard connectors and interfaces implemented in all customized environments.

SOA refers to a set of flexible design principles used in software development and integration, a set of interoperable services that intercommunicate within heterogeneous and disparate information systems from several business domains.

SOA also provides customers of services with access and availability to SOA based services, by exposing services and

contracts, XML interfaces and service access through service end points.

A commonly used approach in SOA is orchestration; it refers to the association of software functionalities in a non-hierarchical arrangement using a special tool that organizes all services, their metadata and characteristics and which can build an application using all these sources.

SOA architectures are efficient if they meet at least two conditions:

- Interoperability – services must provide the basis for integration among different platforms, business domains and business functionalities;
- Federation of resources – services should be published and easy to access, in order to enrich functionalities and business processes.

“Evolution of the semantic web raised new possibilities also in EAI. Although the typical SOA technologies rely only on syntactical approach for process based integration, adopting the fundamentals of the semantic web into the world of EAI is reasonable. For example it is also important to know about the capabilities of participating services while designing a collaborative business process. Classification of available services due to a common, global schema describing the concerned business area may also be necessary.”[4]

The conclusion of this issue is that meta-information is very useful for designers of business processes from collaborative services.

EAI solutions are efficient no matter which development integration solution is chosen: web services, SOA, WOA, process integration. The main advantages of integrating applications instead of using them independently, given the variety of integration technologies, lead to efficient and complete software solutions. Other EAI benefits would be the abilities to access real-time information and to sustain data integrity across multiple systems, automation and composition of business processes from different information systems that need to interact and communicate on both level of input and output.

III. SOME TYPES OF INFORMATION SYSTEMS AND POSSIBLE WAYS OF INTEGRATION

“The challenge is that companies implement multiple applications for a reason; each is designed to support the needs of a particular user group in performing their specific tasks.”[7] Owing to their benefits, these systems, ERP, CRM, SCM, are gaining their place slowly but surely, even in Romanian companies. This trend is backed up by companies that manufacture and sell such types of systems

A. Geographical Information Systems (GIS) and ERP Integration

Geographical information systems (GIS) have the ability of storing, manipulating, analyzing and visualizing the geospatial information through maps. Sometimes, visualizing the data on maps is more relevant than looking at the tabular data, which is why GIS has began to be integrated in key business

applications also. The synergy between GIS and ERP information systems, offers competitive advantages to any enterprise in both supply chain management and marketing areas.

Logistic firms require shorter order cycle, more reliable deliveries, better warehouse management and they must keep their transportation costs under control. In order to achieve these goals, the integration of GIS, GPS and ERP technologies was proposed by scholars [8] and by commercial software vendors. In the marketing area, ERP/GIS integration would be useful in all marketing mix components: product (segment customers by lifestyle and product category), price (implementation of pricing policy depending on location), place (site selection and delivery routing) and promotion (develop target promotions and campaigns, geocode customers, understand customer spending) [9].

Companies have several options for integrating GIS and ERP: build or purchase software connectors that directly connect a given ERP and GIS package, use passive middleware, or deploy frameworks for comprehensive integration with a given GIS package from an ERP vendor [10]. The most successful integration GIS – ERP was done by ESRI (the world’s GIS leader) and SAP (one of the ERP vendor’s leader). There are five main technical interfaces available for integrating SAP’s ERP and ESRI’s GIS software. The integration technical interfaces [11] include:

- SAP RFC connectors - RFCs (Remote Function Calls) allow for remote calls between SAP ERP and ESRI’s GIS software. The remotely callable functions are named RFMs or RFC-enabled function modules;
- Third-party connectors - Third-party connectors include the Way Control Broker (CB) from Information Builders which is component-based and allows director connection to packaged and legacy back-end systems. Control brokers provide an application level approach for greater control, performance and scalability;
- SAP generic GIS connector - The SAP GBC (GIS Business Connector) is a passive middleware that mediates between SAP solutions (designed for use with SAP ERP 4.5 and higher) and ESRI’s GIS software. The method is best used when there is flexible processing modeling with existing methods in both applications;
- Third-party EAI - EAI (Enterprise Application Integration) is generally defined as the combination of platforms, business processes, standards and applications that result in the seamless integration of two or more enterprise systems. The EAI platform integration interface for SAP ERP and ESRI’s GIS can be utilized when there are non-standard processes that require custom development;
- SAP EAI - SAP Exchange Infrastructure (XI) is SAP’s enterprise application integration (EAI) software used to facilitate the exchange of information between SAP ERP and ESRI’s GIS. SAP XI is considered an integration broker since it mediates between entities with varying requirements in terms of protocols, connectivity and format;

- ESRI's partner solutions - The SICAD-APX (application exchange) is an EAI (Enterprise Application Integration) solution from AED-SICAD (an ESRI partner) that integrates ESRI's GIS with SAP's ERP modules.

Sivan Design is another software developer which provides customized GIS solutions combined with ERP capabilities. Using its proprietary technology Geo-ERP™, Sivan Design is able to provide turnkey solutions for establishing lands, roads, or any other infrastructures management platform. The GeoERP platform consists of three independent solutions (LAPS - Land and Properties System, IGIS - Infrastructure Geographic Information System, CMMS - Contracts Management and Maintenance Sys) that use a mutual core and can share the same spatial database.

The integration of GIS and ERP is done by Oracle through its database Oracle Spatial 10g. This database is able to store and manipulate geo-spatial information because of its special data type SDO_GEOMETRY and spatial functions and operators. The Spatial functions can determine the relationship between two spatial layers, the geocoding engine geocodes addresses and the spatial data mining functions allow the searching of spatial data. Oracle's ERP: E-Business Suite can connect to the same database, in this way it will be assured an integrated data architecture (Fig. 1).

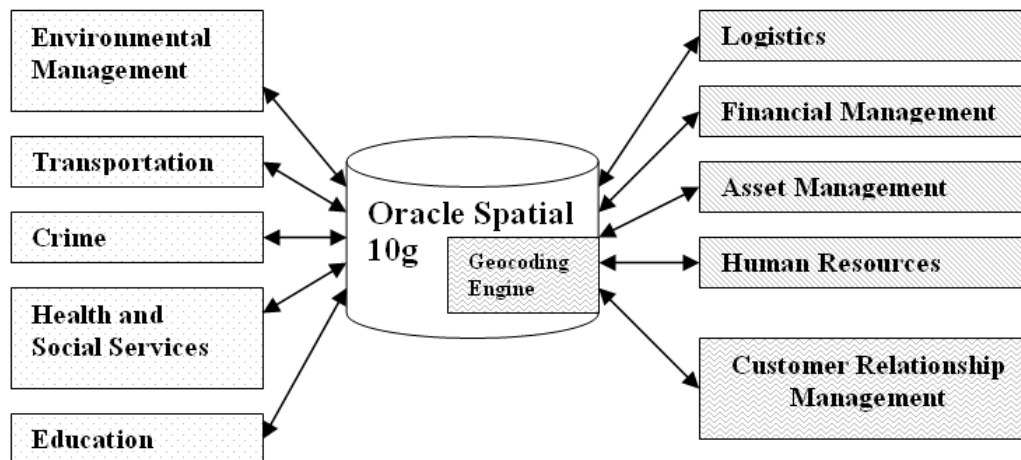


Fig. 1 - Oracle Spatial 10g Integrated Data Architecture (modified after [12])

With this integrated framework, Oracle offers the possibility of using GIS Specialist Systems (Environmental Management, Transportation, Crime, Health and Social Services, Education) together with the modules of its ERP System (Logistics, Financial Management, Asset Management and Human Resources) and CRM System. One of the most interesting features which Oracle Spatial has is the geocoding engine, which can use the customer addresses stored in CRM's specific tables and convert them to longitude / latitude entries so that maps could be drawn.

Einmax Corporation, which distributes natural gas and electricity in Canada, uses this integrated data architecture from Oracle, locating corporate data in a centralized database, reducing redundancies and encouraging cross flows of

information [12].

There are already many other companies which have chosen to integrate their ERP system with a modern GIS system in order to add the spatial dimension to the business processes. For example, a company in Germany-ivl GmbH— had successfully integrated Smallworld GIS with SAP R/3, using a product they had developed called GISConnect™ [13], GPU Energy has also integrated Smallworld with SAP R/3 using two main integration pieces (virtual database integration allows the GIS and SAP R/3 data models to be treated logically as a single model, and business process integration, offering a complex business processes freely spread over GIS and SAP R/3), San Diego's Street Services Division has successfully integrated a GIS with ERP [14].

Scholars have also analyzed the possibility of integrating GIS with other ERP modules: it was developed a system which “integrated database technology, expert system technology and spatial decision support system technology” [15] for land-use structure optimization applied in Beijing Pinggu area. GIS was proposed to be integrated also with other disaster management information systems, such as disaster resource planning (DRP), disaster impact assessment (DIA), investigation of disaster and hazardous risk assessment (IDHRA), onsite and offsite emergency planning, disaster management plans (DMPs), being adopted “during the disaster response time and preparedness stages” [16].

B. CRM Information Systems Integration

If advertising increases the prestige of a company, customers are those who add real value to the business (by continuing purchase of products and services sold by the company). Therefore customers make up an

overwhelming asset of a business.

“CRM is a widely-implemented strategy”[17] that focuses on initiating, maintaining, and retaining long-term customer relationships”[18] This strategy implies “using technology to organize, automate, and synchronize business processes— principally sales activities, but also those for marketing, customer service and technical support.”[17] Given the importance of the CRM product, many departments in the company participate to the defining of the business requirements and to implementation of such product (see Fig. 2): from IT (Information Technology) department to Marketing, Sales, Customer Service and even Human Resources departments.

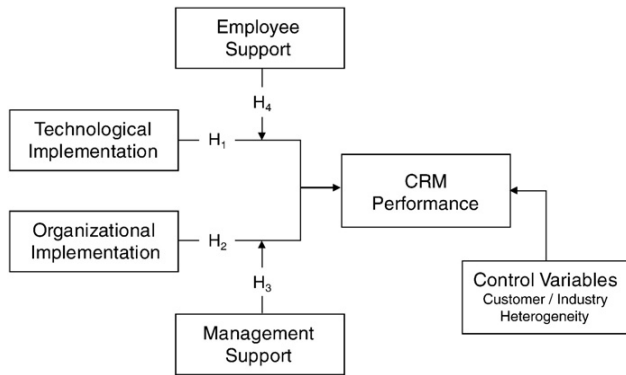


Fig. 2 - Performance model of CRM implementations; source: [18]

As it can be seen in Fig. 2, the success of implementing a CRM system largely depends on the degree of involvement in the process of company departments.

That CRM-type of systems have been and continue to be a success, contributing significantly to the increasing performance of a business, is a well known fact, but what is less known and publicized is the effort behind integration of these systems with other systems of a company.

In order to integrate CRM systems with other systems, a range of products are now available on the market, designed to help simplify this process. However, it is not an easy process at all. Tables 1 and 2 show the proposal of the company Scribe Software Corporation [17] regarding the analysis of the integration of CRM systems with ERP, Call Center, Marketing and other system, both in terms of data and of processes.

Step	From	To	Data	Description
1	ERP	CRM	Product Catalog	Provide CRM with latest available products and pricing
2	CRM	ERP	Quote	Provide ERP with quote for demand planning and calculate "available to promise"
3	ERP	CRM	Quote	Provide CRM with product availability for quote
4	CRM	ERP	Order	Place order with ERP
5	ERP	CRM	Order	Provide order confirmation
6	ERP	CRM	Invoice	Provide ongoing order deliver status and final calculated invoice including shipping and taxes

Table I – CRM Process Integration; source: [7]

Integrating information systems in general and, in particular, CRM systems with other systems, besides the many advantages, results also into a system that is very complex and sometimes even difficult to administer or upgrade. However, it seems that the balance benefits vs. disadvantages of integrating these systems tends to lean more towards the benefits. We do not say this for any reason. The main

argument is that an increasing number of companies are contemplating integration of CRM systems with other systems and even integration with Business Intelligence products, according to Market Watch magazine [19]. The first reason is that a large part of the CRM systems have not or have only partially implemented the data analysis component, and Business Intelligence could come to fix this "shortcoming".

And while the benefits of using CRM systems are well known, and we are referring here, primarily to: quality and efficiency, decreased costs, decision support, enterprise agility [17], their integration with the rest of the information systems of a company (in spite of complaints about the high complexity of the final system) comes to increase company's performance and its competitive edge.

Source	Data	Description	Value
Web site, marketing lists	Leads	Load leads on real-time or ad-hoc basis into CRM	Increase lead conversion rate and reduce administrative costs
ERP	Orders/Invoices Product line items	Copy and update invoice data along with product details into CRM	Increase revenue through product-based sales targeting & improve customer service
Call Center	Support incidents	Provide real-time support call history and status to CRM	Improve customer service
Field Service	Service tickets	Provide real-time service ticket history and status to CRM	Improve customer service
Call Center, ERP	Support contracts	Copy and update customer support agreements in CRM	Increase contract renewal rates
ERP, Data Providers	Credit history	Provide company credit history in CRM	Increase revenue by targeting credit-worthy customers and reduce collection costs

Table II – CRM Data Integration; source: [7]

C. SCM Information Systems Integration

About as important as the CRM and ERP systems are the Supply Chain Management systems or SCM. "Having as their key principle the production of those goods and services needed, where needed and when needed, this new management paradigm brings new opportunities to increase business effectiveness, along with a better satisfaction of market needs." [20]

According to the Council of Supply Chain Management Professionals (CSCMP), and as we can see in Fig. 3 "SCM encompasses the planning and management of all activities involved in sourcing, procurement, conversion, and logistics management. It also includes the crucial components of coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies" [17].

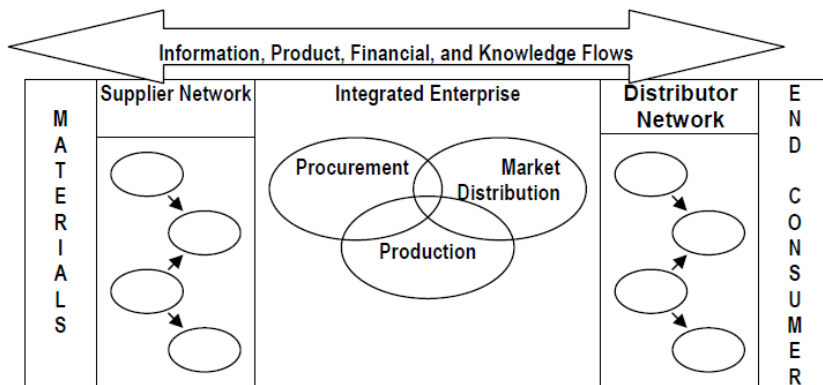


Fig. 3 - The structure of a SCM; source: [21]

SCM concept is little known and implemented in Romania, at information system level. Firstly, because “information systems integration” has a rather short “history” and, secondly, because “many SCM applications are based on information available largely within an ERP software that centralizes information to date across all departments” [20] of the company, and because system integration involves high cost that are difficult to sustain by companies, especially in the current national and global economic climate. Also, it is probably obvious that a SCM system would need to be integrated in the online environment, too, considering that the system will be accessed not only by company employees, but also by persons from the outside, such as suppliers, for example. So even if security of the use of these systems (SCM) should be high, *trust* in business partners is nevertheless another “parameter” worth considering. Therefore, all these disadvantages have determined companies, at least in Romania, to not “venture” too much in implementing this type of system.

However, implementation and integration of SCM type of systems with the other system of a company brings a number of advantages. “The primary benefit of SCM systems is better operational and business planning [...] and the real-time planning capabilities allow firms to react quickly to supply and demand changes.”[2] Other advantages are:

- “Greater control over supplier sand their quality standards due to strong relationships, better coordination, and collaboration among supply chain members;
- Better streamlined processes, shorter lead times and replenishment, and enhanced equipment readiness and utilization;
- Enhanced communication and cooperation among members of the supply chain, leading to enhanced product/ process designs;
- Faster customer response and improved delivery performance;
- Improved forecasting accuracy, and planning and scheduling capabilities;
- Higher productivity and better responsiveness to demand fluctuations;
- Lower levels of inventory through out the chain and

substantial cost reduction.”[22]

Owing to their benefits, these systems are gaining their place among the ERP and CRM systems slowly but surely, even in Romanian companies. This trend is backed up by companies that manufacture and sell SCM type of systems.

D. Integration through ERP, CRM and SCM Information Systems - Proposal to Use, in a “Special” Field: Public Administrations

We have already mentioned, in a series of previous articles, what might be taken over from the development of the ERP systems (especially in the “field” of methodologies and information technologies) in order to build up performing and reliable e-government systems: [23], [24]. But in terms of CRM and SCM systems, as far as the novelty they could bring to e-government systems is concerned, things are totally different from our point of view. Why do we say this? Firstly, because we believe that these CRM and SCM information systems can be successfully used in the public institutions without prior adaptation, besides their *integration* with other existing systems within the public institution. Undoubtedly, the examples will highlight exactly what we have stated above:

a) The CRM computer systems used within the public administrations

The e-government type information systems, no matter how performing they may be, can replace but cannot entirely substitute the human factor (represented by the employee of the public institution). First of all, because ambiguous situations can occur, in which the citizen, for example, does not know exactly which option to tick, what category to select for the ticket he needs to open (if we're talking about an e-government type information system operating with ticket type requests), and so on. In such a situation the human factor intervenes, that is the civil servant who will be able to counsel the citizen by telephone. In fact, that is the current way of acting in Romania: in order to solve their problems, the citizens either come personally to present their problem at the front desk office, or call the institution to request information by phone. Therefore, the Town Hall employee can counsel the citizen even in the event of an ambiguous situation concerning the use of an e-government type information system. Here comes the role of CRM information systems; when the citizen calls, it would be ideal for the call to be picked by the civil servant by means of a CRM system that will automatically record in the database the identification information of the call (phone number, call time, etc..), while the rest of the information will be entered by the employee that will answer the call (citizen's name and surname, city, etc..). Such an implementation can be extremely useful, especially because such an information system could be *integrated* with other systems of the institution. With the help of such a CRM type information system, reports can be retrieved and decisions can

be made as to the improvement of the public administration services, concerning the problems one might have with the e-government systems available for the citizens, and the list can go on.

b) The SCM type information systems used within the public administrations

In their turn, the SCM type information systems used in a public administration can be a solution to a series of problems such as: corruption, bureaucracy and their utilization can also remove some suspicions that now hang over the supplying contracts of various services coming from private firms to public administration in Romania.

The SCM type information systems, besides the advantages mentioned above, can also simplify the process of auditing the way in which a series of public funds were spent, increasing the citizens' degree of confidence in the state institution.

IV. TECHNOLOGIES OF DATA INTEGRATION: ORACLE GOLDENGATE (GG)

Oracle GG uses a low-overhead architecture to capture transactions nonintrusively from a source database by reading online transaction logs, transforming the data when needed, and applying those transactions with guaranteed integrity to a target database in real time. Oracle GG's processes run continuously-even bidirectionally-and support high-volume, rapidly changing environments, moving thousands of transactions per second with very low impact. The target database is a transactional replica at a logical level, which can be leveraged for multiple applications, including a rolling database upgrade.

A. Oracle GG Solutions - Overview

Oracle GG provides the following data replication solutions:

a) High Availability:

- Live Standby for an immediate fail-over solution that can later re-synchronize with your primary source.
- Active-Active solutions for continuous availability and transaction load distribution between two or more active systems.

b) Zero-Downtime Upgrades and Migrations: Eliminate downtime for upgrades and migrations.

c) Live Reporting: Feeding a reporting database so that you don't burden your source production systems.

d) Operational Business Intelligence (BI): Real-time data feeds to operational data stores or data warehouses, directly or via ETL (Extract, Transform, Load) tools.

e) Transactional data integration:

- Real-time data feeds to messaging systems for business activity monitoring, business process monitoring and complex event processing.
- Uses event-driven architecture and service-oriented architecture.

B. Operational Business Intelligence - Overview

"Modern Business Intelligence (BI) technologies are tightly integrated, easily, and widely deployed and usable for they are based on prepackaged application solutions. For these reasons, Business Intelligence has become so much easy to justify relevant investments and the cost for developing and maintaining a data warehouse has significantly decreased." [25]

For Real-Time Data Warehousing - The Oracle GG Real-Time Data Warehousing solution enables continuous, real-time data feeds for data warehouses or operational data stores, to improve business intelligence. Our log-based changed data capture has very minimal impact on the source, no batch windows and moves the data in sub-seconds. Each transaction's commit boundaries are maintained for data integrity.

Oracle GG's architecture also improves data recoverability in case there is an outage during the data movement. This is an important requirement as data latency decreases in feeding the analytical environment. Oracle GG's trail files that store the changed data are persisted, so if needed they can be reapplied to the target and also source system without having to capture the data again.

Transformations or co-existing with ETL:

Oracle GG out-of-the box can support a number of common data transformations often required for data integration.

However, where complex transformations are needed Oracle GG can be used to augment an existing ETL solution in several ways:

1. First, Oracle GG can deliver transactional data to staging tables in real time, which then would be used by the ETL to extract from and perform transformations and then load user tables. This method works best when the ETL product is optimized to perform the transformations within the target database. This is an "ELT" model.
2. Second method: Oracle GG provides the data to the ETL engine as flat files and in micro-batches. The latency depends on the ETL product and business requirements but we typically deliver every few minutes to an hour.
3. Third method: Oracle GG publishes changed data to a messaging system and the ETL solution (that can subscribes to the queue or topic) receives it in real-time.

In each of these architectures combining real-time change data capture with ETL decreases data latency to real time or near real-time and eliminates the batch window dependency.

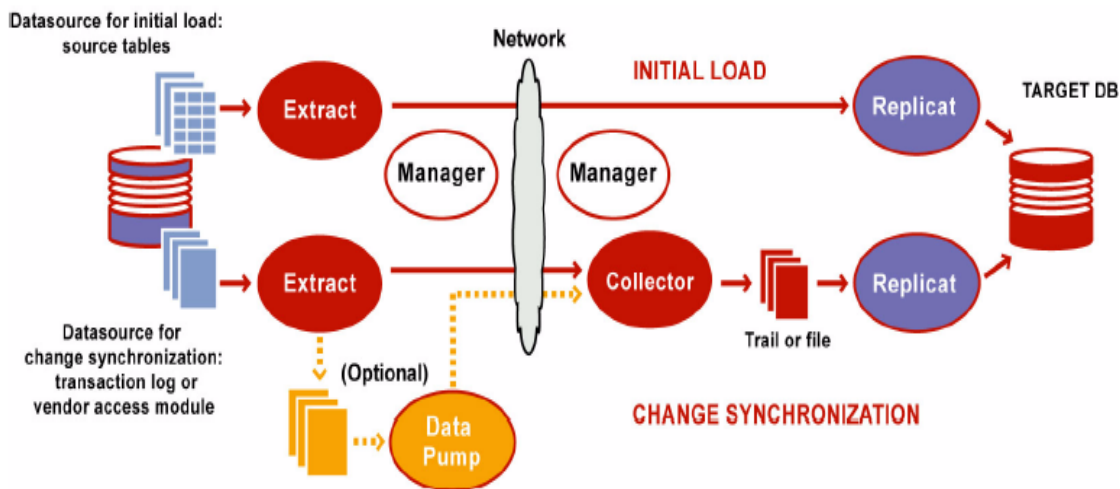
C. Oracle GG Software Architecture

The Oracle GG software architecture is comprised of three primary components: Capture, Trail Files, and Delivery. This modular approach allows each component to perform its tasks independently of the others, accelerating data replication and ensuring data integrity.

a) Capture

Oracle GG's Capture module resides on the source database

and looks for new transactional activity. The Capture module reads the result of insert, update, and delete operations by directly accessing the database transaction (redo) logs, and then immediately captures new and changed data for distribution.



changes. This is the basic configuration. Variations of this model are recommended depending on business needs.

The Capture module only moves committed transactions—filtering out intermediate activities and rolled-back operations—which not only reduces infrastructure load but also eliminates potential data inconsistencies.

b) Trail Files

Oracle GG's Trail Files contain the database operations for the changed data in a transportable, platform-independent data format. Trail Files are a critical component within Oracle GG's optimized queuing mechanism. They reside on the source and/or target server but exist outside of the database to ensure heterogeneity, improved reliability, and minimal data loss. This architecture minimizes impact to the source system because no additional tables or queries to the database are required to support the data capture process. The Capture module reads once, and then immediately moves the captured data to the external Trail File for delivery to the target(s).

In the event of an outage at the source and/or target, the Trail Files contain the most-recent data up to the point of the outage, and the data is applied once the systems are online again.

c) Delivery

Oracle GG's Delivery module takes the changed data from the latest Trail File and applies it to the target database using native SQL for the appropriate relational database management system. Delivery can be made to any open database connectivity-compliant database. The Delivery module applies each transaction in the same order as it was committed and within the same transactional context as at the source, enabling consistency and referential integrity at the target.

Please see below the logical architecture of Oracle GG for initial data loads and for the replication of ongoing database

Fig. 4 – Logical architecture of Oracle GG; source: [26]

The *Extract* process runs on the source system and is the extraction (capture) mechanism of Oracle GG.

A *data pump* is a secondary Extract group within the source Oracle GG configuration.

The *Replicat* process runs on the target system. Replicat reads extracted data changes that are specified in the Replicat configuration, and then it replicates them to the target database.

To support the continuous extraction and replication of database changes, Oracle GG stores the captured changes temporarily on disk in a series of files called a *trail*. A trail can exist on the source or target system, or on an intermediary system, depending on how you configure Oracle GG.

Manager is the control process of Oracle GG. Manager must be running on each system in the Oracle GG configuration before Extract or Replicat can be started, and Manager must remain running while those processes are running so that resource management functions are performed.

Collector is a process that runs in the background on the target system. Collector receives extracted database changes that are sent across the TCP/IP network, and it writes them to a trail or extract file.

Oracle GG helps organizations eliminate the downtime caused by both unplanned and planned outages, and improve system performance and scalability. The software can be configured to support Zero-downtime operations. Enable uninterrupted business operations during system upgrade, migration, and maintenance activities.

In-place upgrades require application downtime, which is not feasible in mission-critical, high-availability environments. Therefore, we will focus only on *rolling upgrades*.

Using Oracle GG in conjunction with Oracle Database

features, a rolling upgrade or a rolling migration can be performed without any application downtime—other than the very minimal time required for application switchover, typically less than one minute and in most cases, only seconds. Using its real-time, heterogeneous data movement technology, Oracle GG imposes negligible database downtime for upgrades or migrations from Oracle Database 8i, Oracle Database 9i, or Oracle Database 10g to Oracle Database 11g Release 2.

If Oracle GG is set up for bidirectional replication between old and new environments and both systems support the application in transaction processing, end users have the option to implement phased migration to the new environment and eliminates application switchover related downtime. The transition to the new database environment can be completely transparent to the end users.

Upgrading to a newer release of database using Oracle GG consists of the following high-level steps:

1. Set up a standby database running the previous database software version using an existing database backup.
2. Upgrade the standby database to a newer release.
3. Synchronize the standby database with the production database.
4. Test in active/live mode.
5. Switch over the application to the standby database. The primary database will be any time available for failback.
6. Upgrade the primary database to Oracle Database 11g Release 2 after comprehensive application testing at standby.

Oracle GG Veridata

Oracle GG Veridata is a standalone, high-speed data comparison solution that identifies and reports data discrepancies between two databases, without interrupting ongoing business processes. It allows data discrepancies to be isolated for testing and troubleshooting. Oracle GG Veridata is ideal for conducting data validation after the rolling upgrade, once the source and target are fully operational and running different versions of Oracle Database. It can also help to determine if a failback is needed, in case of any risky data anomalies.

D. Configuring Oracle GG for Real-Time Data Warehousing

A data warehousing configuration is a many-to-one configuration. Multiple source databases send data to one target warehouse database. Oracle GG supports like-to-like or heterogeneous transfer of data, with capabilities for filtering and conversion on any system in the configuration. Please see below the process to configure a data warehouse using Oracle Golden Gate:

a) Actions on source systems:

1. On each source, configure the Manager process;
2. Create a primary Extract group on each source:
ADD EXTRACT <ext_1>, TRANLOG,

BEGIN <time> [, THREADS <n>];

3. Create a local trail on each source:

ADD EXTTRAIL <local_trail_1>,
EXTRACT <ext_1>;

4. Create a parameter file for the primary Extract on each source with the following information:

EXTRACT <ext_1> [SOURCEDB <dsn_1>],
[USERID <user>[, PASSWORD <pw>]]
EXTTRAIL <local_trail_1>
TABLE <owner>.<table>;

5. Create a data pump Extract group on each source:

ADD EXTRACT <pump_1>,
EXTTRAILSOURCE <local_trail_1>,
BEGIN <time>;

6. Create a remote trail on the target and use the following command of each source:

ADD RMTTRAIL <remote_trail_1>,
EXTRACT <pump_1>;

7. Create a parameter file for the data pump group on each source with the following information:

EXTRACT <pump_1> [SOURCEDB <dsn_1>],
[USERID <user> [, PASSWORD <pw>]]
RMTHOST <target>, MGRPORT <portnumber>
RMTTRAIL <remote_trail_1> [PASSTHRU |
NOPASSTHRU] TABLE <owner>.<table>;

b) Actions on target system:

1. Configure the Manager process;
2. Create a Replicat group for each remote trail that you created:

ADD REPLICAT <rep_1>,
EXTTRAIL <remote_trail_1>, BEGIN <time>;

3. Create a parameter file for each Replicat group with the following information:

REPLICAT <rep_1>
SOURCEDEFS <full_pathname> |
ASSUMETARGETDEFS [TARGETDB <dsn_3>],
[USERID <user id>[, PASSWORD <pw>]]
REPERROR (<error>, <response>)
MAP <owner>.<table>, TARGET <owner>.<table>
[, DEF <template name>];

E. Deploying Oracle GG to Achieve Operational Reporting for Oracle E-Business Suite

Oracle GG's flexible architecture supports operational reporting for Oracle E-Business Suite by replicating business data from the Oracle E-Business Suite database to a secondary system dedicated to running read-intensive operations such as reporting.

Using Oracle GG to achieve operational reporting for Oracle E-Business Suite provides the ability to create seamless, near real-time copies of key Oracle E-Business Suite database tables for off-loading reporting functions to a replica (reporting) database. Reports can be created to run locally against the target reporting Instance using either Oracle reporting tools such as Oracle BI Publisher, or third

party tools.

A key point is that Oracle GG reads changed data from the database transaction logs rather than the database tables themselves. Its deployment consequently requires minimal

Examples of a few commonly managed targets are: databases, data warehouses, hosts, weblog server, SOA applications, Oracle Identity Manager, Oracle Siebel, Oracle People Soft, other applications and third-party products.

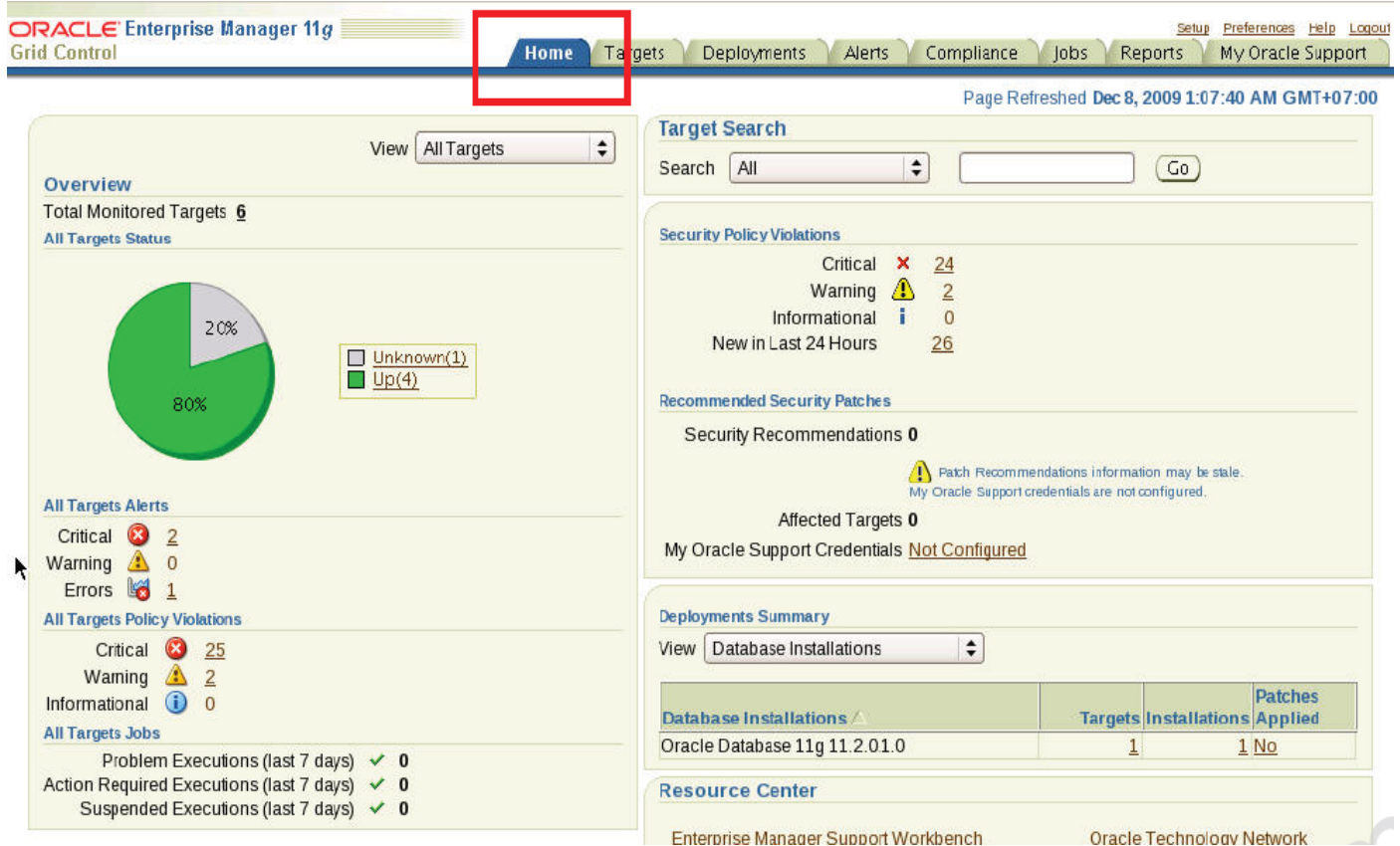


Fig. 5 – Oracle Enterprise Manager 11g interface

modifications to the Oracle E-Business Suite database, enabling it to provide organizations with a compact, non-intrusive, and easily-configured way of providing near real-time access to data for reporting purposes.

F. Grid Control and Data Warehouses

Enterprise Manager Grid Control is a management tool that provides monitoring and management capabilities for Oracle and non-Oracle components. Using Enterprise Manager Grid Control, you can:

- Monitor the health of all application components, the hosts that they run on, and the key business processes that they support;
- Identify the root cause of any problem in your application to fix it quickly.

Grid Control can be used to manage the Oracle footprint in any IT organization.

At any time while using Grid Control, you can view a list of all the targets currently being managed by Grid Control, regardless of the target type. This can be useful if you want to scan a list of all the targets that you are responsible for managing in your environment. From the list of managed targets, you can quickly assess the availability of the targets and then drill down for more information.

V. PAIRWISE, AN INTEGRATED POWERFUL TESTING TECHNIQUE

It is very important to ensure the usability and interoperability of an application, therefore the tests are invented in response to risks.

An integration test is the last step in the validation phase, and an efficient and powerful testing method is very useful.

Let's consider the next example: supposing that a web site company must operate correctly with the eight most popular browsers: Firefox, Google Chrome, Internet Explorer, Opera, Safari, Maxthon, Flock and Avant Browser (according to Topenreviews [29]), using plug-ins like RealPlayer, MediaPlayer, or none, running on different client operating systems (Windows 98, ME, NT, 2000, XP and Win7), receiving pages from different servers (IIS, Apache, and WebLogic) and running on different server operating systems like (Windows NT, 2000, and Linux). For a complete integration test, if we intend to execute all possible situations, we could end up with 1296 combinations. Considering that it is absurd to suggest so many test cases, we can analyze it using Pairwise testing technique based, in this situation (or similar), on Orthogonal arrays method [30]. "An orthogonal

array is a two-dimensional array of numbers that has this interesting property—choose any two columns in the array. All the pairwise combinations of its values will occur in every column pair. [...] Not only will all the pair combinations occur in the array, but if any pair occurs multiple times, all pairs will occur that same number of times.” [31].

A representative formula is Fig. 6. Applying it, we can determine the array size: it will be five columns, one for each variable in this example.

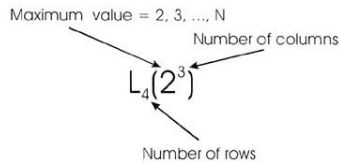


Fig. 6

The first column must support eight different levels (1 through 8). The second column must support three levels (1 through 3), etc. The required array size obtained is 816133. Unfortunately, an array with this exact size does not exist. In this case, we choose the next larger array [31]. We obtain orthogonal array $L_{64}(8243)$ which meets our requirements. This means that, using this orthogonal array, all pairs of all the values of all the variables can be covered in only 64 tests, i.e. 95% reduction in the number of test cases.

All is mainly based on the next rule: if all of the pairs in a given combination exist in other combinations, we can drop that combination.

Considering that in computer systems, defects usually involve a single condition, independent of any other condition in the system, Pairwise is a powerful technique for reducing the number of tests to be run. Based on the statistics, the use of this method prevents the occurrence of almost all critical and major incidents. But despite this, we have to admit that some disadvantages are presented. One problem appears when there are dependences between two or more variables, or certain options are required. Another problem is that an “all-pairs” table takes a significant time to construct and if we want to test more than pairs-triples, or n-tuples, the problem quickly becomes intractable for a human test planner. Fortunately, to solve these complex situations, special software applications were developed.

VI. CONCLUSION

The integration of the information systems for a company, “today”, it is necessary more than ever before, because in the companies, there are tens or hundreds of separate applications, which involves high costs and long time to matching the information. Therefore, the integrated information systems must inter-connect and inter-communicate as a complex, complete and coherent system and all systems parameters should interfere in order to assure compatibility and combined inter-operability. “[...] Improvements in operational integration enabled by Enterprise Systems can affect the entire

organization and therefore can positively impact firm performance” [2], irrespective of the method or technology used for integration.

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 - "XML Authoring Tool", *Proc. of the 4th European Computing Conference (ECC'10, University Politehnica of Bucharest)*, April 20-22, 2010, Bucharest, Romania;
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- "Information Systems Integration, a New Trend in Business", *Proc. of the 10th WSEAS International Conference on Applications of Computer Engineering (ACE '11)*, March 24-26, 2011, Meloneras, Gran Canaria, Canary Islands, Spain;
- „Information Technology Standards – a Viable Solution to Reach the Performance", *Proc. of the 12th WSEAS International Conference on Automation & Information (ICAI '11)*, Apr. 11-13, 2011, Brasov, Romania.

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