# The design and implementation of a bespoke Enterprise Resource Planning system (ERP) for an acoustical engineering company.

Betrand I. Ugorji, Bernadette-Marie Byrne University of Hertfordshire, Hatfield UK & Richard Collman ACE/ ACC Bourn, Cambridgeshire. Email: b.ugorji2@herts.ac.uk

*This paper will describe the tasks completed so far as part of a Knowledge Transfer Partnership between the University of Hertfordshire and Acoustical Control Engineers (ACE) a 'small and medium sized enterprise' (SME) based in Cambridgeshire, UK.*

*ACE's 25 personnel design, manufacture and install noise and vibration control systems to solve a wide range of acoustic problems. The projects undertaken include acoustic enclosures for supermarket refrigeration plant and for generators used in many situations, together with other more diverse applications such as controlling noise in the workplace and even on a luxury boat.*

*Before the current KTP project the company used some partially computerised systems consisting of spreadsheets to perform acoustic analyses, pricing and project management functions supplemented with a paper based system to 'fill the gaps'.*

*Enterprise Resource Planning (ERP) systems provide an integrated database for all parts of the organisation allowing decisions to be based on a complete understanding of the organisation's information, avoiding the problems due to duplication of data and ensuring that the consequences of decisions in one part of the organisation are reflected in the planning and control systems of the rest of the organisation. ERP systems became popular from the 1990's mainly in relatively large organisations due to the complexity and cost of these systems. This project is unusual in that rather than adapting an off-the-shelf ERP solution to ACE's very specific and specialised requirements we are taking an ERP development approach in an SME whose legacy systems are made up of spreadsheet and paper based systems.*

*For the software development an Agile approach has been used. Agile involves software development methods based on iterative and incremental development. The initial attempt was to start developing the ERP from an Open Source ERP Source Code; however this effort was futile as a result of the bespoke nature of ACE's business and product lines. Mapping ACE's data model to the database which any existing ERP system could be adapted to, proved to be a very difficult problem. Therefore, developing the ERP from first principles was inevitable. Several of the ERP modules have been developed, user training has taken place and the core modules have been signed off. The project is due to complete in September 2014 and by this time we will have further information on how the ERP system has increased the competitiveness of the company, as well as experience of introducing an ERP into an SME. However, as would be expected the work undertaken developing the system so far has had several significant effects on ACE and acted as a catalyst for change in various parts of ACE's business.*

***Key words**: ERP, SME, Software development.*

## Background

### An Overview of ERP Systems in Business

ERP systems enable businesses to reduce cost, increase efficiency and output by increasing the speed and accuracy with which they achieve their strategic objectives. Computers have a young history with the first batch processing systems being used in the 1960s. These would usually be for a

single system within a department; for example payroll systems within an organisation were usually the first processes to be computerised. Systems have now progressed to organisations having large centralised databases which can support multiple-users. Figure 1 depicts an ERP system model.


Figure 1: ERP - A centralised database system

ERPs are business wide information systems that aim to integrate all the information from many business functions such as Materials Requirements Planning (MRP) which calculates materials requirements and production plans to complete known sales orders and to forecast sales orders. An ERP system provides an integrated database for all parts of the organisation allowing decisions to be based on a complete understanding of the organisation's information, avoiding the problems due to duplication of data and ensuring that the consequences of decisions in one part of the organisation are reflected in the planning and control systems of the rest of the organisation.

Prior to ERP systems, organisations data were typically spread across several separate information systems. For example, a firm could have separate systems for purchasing, order management, human resources, and accounting, each of which would maintain a separate data source. The aim of ERP would be to subsume these into a single seamless system. Research has shown that system fragmentation is the primary culprit for information delays and distortions along the supply chain (Repoussis *et al.*, 2009, Upton *et al.*, 1997).

## Advantages of ERP Systems

An ERP system seamlessly integrates and manages an organisations data from various departments, automates its processes and provides valuable information required for efficient running of the organisation's day to day activities. This results in better supply chain management, competitive advantage, reduced time-to-market, and effective reaction to change in demand, lower operating cost, improved strategic planning, higher productivity, increased sales, increased margin, increased market share, easier reporting and improved customer service. ERP systems that interface with the internet play a vital role in globalisation. Firms would expect ERP systems to result in reduced costs, enhanced decision support, more accurate and up-to-date information, increased customer satisfaction, help to enable e-business, and the flexibility to change quickly (Su *et al.*, 2010, Hakim *et al.*, 2010, Kwahk *etal*, 2010). The next section will highlight the problems faced with investing in ERP systems.

## Disadvantages of ERP Systems

Introducing an ERP system is a major task (O, Leary, 2000, Gefen et al. 2000). However, if implemented successfully an ERP can aid the integration of the processes which then frees up time

for the organisation to look at improving those processes (Slater 1999). Though early ERP systems focused on large enterprises, smaller enterprises increasingly use ERP systems (Christos 2012).

This KTP project is unusual in that, rather than adapting an off-the-shelf ERP solution to ACE's very specific and specialised requirements, a bespoke ERP is being developed for the company. The problem with buying an off-the-shelf product is that of compatibility with the company's current business processes and practices. There is inevitably, some modification of an organisation's working arrangements and systems to suit an off-the-shelf ERP system's structure. Whilst this may not be excessive for organisations that buy and sell widgets or assemble them into standard products, highly specialised uses require far greater modification both of the system and of the organisation's working practices to achieve a workable compromise. Therefore, many companies have found it difficult to buy an ERP product and customise it to their present practices or change existing processes to fit in with an off-the-shelf ERP. There would also be considerable exposure to substantial ongoing maintenance costs and dependency upon the system supplier. In addition to the very significant implementation costs, there is a significant risk that the final system may be far from ideal.

Obviously, ERP systems do have some limitations and this has been widely documented. ERP's can have a negative impact on the work practices and culture of an organisation *(Allen et al., 2001, Bayraktar et al., 2009, Chudoba et al., 2005).* Boiral (2007) claims that there is a need for extensive technical support prior to its actual use. Birnholtz et al (2007) and Schneberger (2004) claim that it takes an average of 8 months after the new system is installed to see any benefits.

## Company History

Acoustical Control Engineers (ACE) and Acoustical Control Consultants (ACC) are both 'small and medium sized enterprises' (SMEs) based in Cambridgeshire, UK. ACE provides engineered solutions to noise and vibration problems while ACC provides acoustic consultancy solutions. ACE and ACC's 25 personnel analyse and solve a wide range of acoustic problems and/ or design, manufacture and install noise and vibration control solutions to these acoustic problems. The projects undertaken include acoustic enclosures for supermarket refrigeration plant and for generators used in many situations, together with other more diverse applications such as controlling noise in the workplace, defending a kennels in Court and even controlling noise on a luxury boat. Although distinct companies they are a tightly integrated family run business and it is important that information can be shared efficiently between the two organisations particularly because many projects have both engineering and consultancy aspects to them. Figure 2 below shows some of ACE products.


Figure 2: Weather Louvres, Cooling Tower Attenuation & Acoustic Refrigeration Plant Enclosure.

At the moment the company's legacy systems are made up of spreadsheet and paper based systems. These spreadsheets have been developed over many years for a range of business management purposes such as basic handling of enquiries, some sales forecasting and contract management, although there are major gaps such as no CRM system. Some spreadsheets have been developed for standard acoustic models whereas other acoustic analyses are developed on a case by case basis. Most pricing for engineering products are undertaken using spreadsheets but these are not efficiently linked together causing significant duplication of effort and the other problems associated with 'islands of automation'. There is virtually no integration between pricing and

manufacturing information with little computerised manufacturing control. A Sage accounts package is used for invoicing, credit control etc. Clearly there is significant room for improvements that can make a major difference to both efficiency and productivity. Being acoustic organisations working with decibels, the obvious name for an ERP system for both companies was deciBase.

### Problems and Project Motivations

So many years ago an attempt was made to develop an ERP system within ACE but with day to day business demands there was insufficient time available to do so and the project stalled. In order to reduce the time commitment the development was sub-contracted but it was taking nearly as long to specify the system in sufficient detail as to develop it in house, so this was also abandoned. Subsequently a second attempt was made to develop the system in house, but this was futile. ACE and ACC then considered purchasing an off-the-shelf ERP system to 'bespoke' it where necessary to suit their requirements.

One of the key requirements of ACE is that their ERP be very flexible and provide a good model of reality. One example of this is that ACE and ACC have ongoing relationships with clients and other people lasting several decades, during which time these people may work for several different organisations. During ACE's pre-KTP research it became apparent that virtually all off-the-shelf ERP or CRM systems, could not properly model the relationship with individuals. Instead they created the equivalent of a contact card for an organisation's employee, but when the person left that company a new contact card had to be created for them as an employee of the next organisation. With some systems it was possible to provide a link between the different contact cards to link the information, but this is typical of some of the adjustments that have to be made to off-the-shelf systems.

Off-the-shelf ERP systems are designed to tackle some of ACE/ ACC requirements, but they are very generic products which have to be configured or customised for each application. The vast majority of ACE's products are unique for every project, greatly complicating a standard ERP systems implementation and restricting what it would be able to achieve in practice. However, whilst an ERP system represents a fairly large investment in itself, the implementation costs are likely to be at least as much as the initial system and frequently significantly more. Taking all of the above factors into account it became clear that a more appropriate solution would be for ACE to develop its own ERP system in house. A KTP was a perfect means to actualise the ERP development plan.

## ERP System Development

### System Requirements

The key requirement of ACE/ ACC is that their ERP provide a good model of reality. The ERP is to be able to undertake acoustic analyses and then seamlessly provide the resultant information to be used to select appropriate products, calculate prices, issue and follow up quotations then convert them to contracts where orders are obtained. This order/ contract information should then seamlessly flow through the manufacturing, delivery and installation system before triggering an invoice for the work.

deciBase is a major development and could not realistically be completed in a single KTP with a single associate due to the amount of time and work required for the design and implementation of a full ERP system. Given the above constraints, first, it was decided to undertake the development in stages, tackling the most critical areas first on a modular basis. Secondly, an incremental software development framework for a complex software project would be most appropriate for the project.

### Methodology

This section describes the approach that is undertaken towards the actualisation of the project requirements and presents the tools, the technologies, the design and architecture of deciBase. The section following this will present the project outcomes.

**Development Framework**

Given deciBase requirements, we adopted a software design and implementation approach which decouples all system components but at the same time allows for easy system integration. We are using Object Oriented Programming (OOP), Test Driven Development (TDD) approach and Domain Driven Design (DDD). The advantage of this is that we focus development efforts on the business requirements of a specific system module, carry out enough code tests before deploying the module to production server on completion. Then we test again, train users and quickly respond to changes.

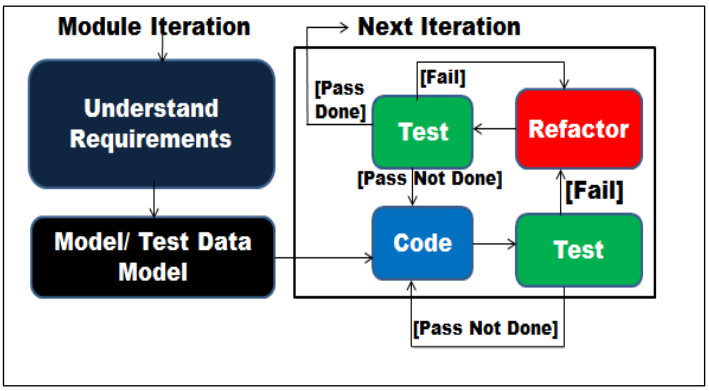


Figure 3: deciBase - Agile Test Driven Development

This development approach is Agile, involving use of the Model View Controller (MVC) design pattern. It has proved suitable for effective collaboration and has allowed us incrementally develop only what is required. Our approach is also similar to Scrum because we can identify the Scrum Roles, Events and Artefacts but is different because a Scrum team requires a minimum of 3 developers not one.

**Tools and Technologies**

The ERP software development platform is Windows 7 Enterprise 64-bit Operating System, Intel® Core™ i5-3360M CPU @ 2.80GHz OS Processor and 7.88GB of free RAM. A modelling tool (Visual Paradigm UML) is being used in capturing system requirements, developing the business process models, drawing the Use Case diagrams, modelling the database with Entity Relationship Diagrams (ERD) and compiling the systems Data dictionary. A combination of W3C web standards and Java Enterprise Edition 8 technologies (JavaEE 8) including - HTML5, Javascripts, CSS3, XHTML, JSON, Web sockets and JPA2.1, JPQL, EJB3.1, Servlet3.0, JSR 352, and JSF2.2 respectively are used in developing deciBase. Java EE is being used in programming the business components of deciBase while XHTML, HTML5, Javascripts, JQuery and CSS3 are used in developing deciBase user interfaces. SQL is used through Java Persistence API (JPA) for querying the database which runs on Oracle JavaDB database 10.9. deciBase is deployed onto Glassfish-4.0 open source enterprise application server. deciBase source code is being edited and compiled using the NetBeans 8.0 Integrated Development Environment (IDE) and Maven 4.0.0.

## System Design and Architecture

The system design identifies 5 component layers namely – The database, entity, service, presentation and user interface. It ensures a clean division of responsibility for code maintainability and scalability. The last 4 layers are non-distributed and are deployed together into the same application server container. However, each layer is isolated by well-defined interfaces. They belong to the Model-View-Controller of the MVC design pattern. The last 4 layers are distributed from the first layer, the database and are connected to the database via JDBC. Figure 5 shows the system design.

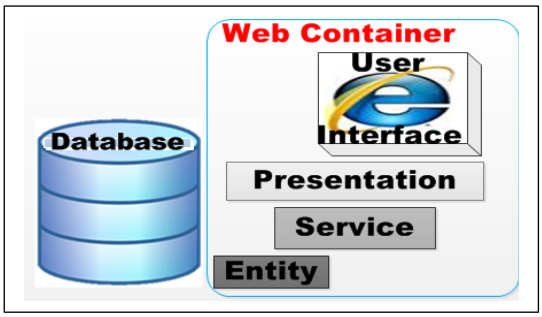

Figure 4: deciBase component layers

**Database Layer –** The database is the centralised data store that consists of the relational data model of deciBase. It is normalised up to 3rd normal form, therefore eliminating duplicates.

**Entity Layer –** deciBase entity layer maps Plain Old Java Objects (POJOs) to database entities. It adopts a design-by-contract principle which ensures that security validations, integrity constraints, patterns and precisions are not violated before data is written to the database. The entity layer is designed to use precompiled database queries popularly known as prepared statements or stored procedures which improves the performance, security and efficiency of deciBase.

**Service Layer –** The service layer handles deciBase's business logic, provides transaction, security, etc. It manages entities in the entity layer and the database layer.

**Presentation Layer –** The presentation layer handles deciBase's presentation logic, presents data to the user interface, collects user inputs from the user interface, delegates' user inputs to the entity and service layer, and controls user interface navigation.

**User Interface Layer –** Is the layer through which users can interact with deciBase.

Data validation may be performed across all layers. We are developing the business domain objects of deciBase strictly on JavaEE standard libraries. This ensures that deciBase stands the test of time as JavaEE standard libraries will always remain supported by Oracle.

The key design glue to deciBase that has enabled loosely coupled, highly extensible system architecture and seamless component integration is OOP using Inheritance, Interfaces and Context and Dependency Injection (CDI). CDI allows the injection of CDI Beans from any of the model layers wherever they are required. We have also avoided code duplication. The code snippet in Figure 6 shows how CDI is used in wiring the business domain model components from various modules.

```
@ViewScope @Named
public class ContractPresentation  extends ViewSession implements Serializable {
@Inject QuotationPresentation quotationPresentation; // QuotationPresentation  is from Quotation module
@Inject ProjectPresentation projectPresentation;       // ProjectPresentation  is from Project module
@Inject ContractService contractService;
@Inject ContractEntity contract;
                                                    // Empty constructor, getters & setters omitted
public void AddContract(){
 contractService.create(contract);    // CDI injects all Objects required to execute 'AddContract' logic
}}
```

## Academic and Project Outcomes

**Project Outcomes -** Presently, the Accounts, Activity, Project, Consultancy, Communications, Contact, Core, Security, Reporting, Legacy, Admin and Maintenance modules have been developed. User training has taken place. 7 of these modules are completely signed off while the rest are on incremental sign off usually after integration testing. The Quotation and Contract modules are currently being developed. deciBase is simple and user friendly. 2-Factor authentication, least privilege enforcement, access control and anti-password hacking are some of its security features.

deciBase is more advanced than most off-the-shelf ERP systems. One of the major advantages of deciBase is flexibility and close modelling of reality. For instance, deciBase easily copes with the situation which is becoming more common where one person has multiple employments at the same time. deciBase accurately models this situation by treating people as entities in their own right and establishing employment links to organisations as appropriate. deciBase provides the seamless integration between ACE & ACC whilst maintaining their individual identities and brands.

deciBase is yet to be commissioned. However, as would be expected the work undertaken developing the system so far has had several significant effects on ACE and ACC, and acted as a catalyst for change in various parts of these companies' businesses.

**Academic Outcomes -** There is an on-going PhD research on Intrusion Detection System in Cloud Environment being carried out by the project associate at the University of Hertfordshire (UH). This KTP has produced a seminar, 2 MSc. students supervision support and 2 academic papers before this one. The seminar on Database and Application security was attended by final year engineering students at UH on the 16th of April 2013. The first academic paper 'Towards Secure Web Service-based e-Businesses' was presented by the associate at The 14th Edition of the Postgraduate Networking Conference (PGNet) 2013 at Liverpool John Moores University, UK, accessible via http://www.cms.livjm.ac.uk/pgnet2013/Proceedings/papers/1569775519.pdf. The second academic paper 'Cloud Security: A Review of Recent Threats and Solution Models' was presented by the associate at The International Conference on Cloud Security and Management (ICCSM) 2013 at the Washington University, Seattle, USA on 17th October 2013. This paper is accessible through the ICCSM Conference proceedings and http://researchprofiles.herts.ac.uk/portal/files/2819772/Cloud_Security_A_Review_of_Recent_Threats_and_Solution_Models.pdf

## Conclusion

In as much as the benefits of ERP systems cannot be overemphasised, recent studies have indicated that nearly 30 to 50 percent of global ERP deployments worldwide are problematic ones (Umble et al., 2002, Mabert et al., 2003). This is attributed to firms failing to manage their organisational needs at the same time as the technical implementation of their ERP systems (Scott et al, 2000, Koch, 2002).

Research shows that it takes on average of 8 months after the new system is installed to see any benefits from an ERP system (Koch et al., 1999). An ERP is a long-term investment with benefits arising in the medium to long term not the short term (Alee, 1999). In the past 3 months the various modules for deciBase have come together and positive user testing has taken place. We are aware of the problems which have occurred in other ERP deployments. Many of these were due to the customisation of either the off-the-shelf software, or trying to change the existing processes to fit in with the software. As ACE has developed its own ERP from first principles this has not been a problem for us and we aim to see the successful deployment of all the modules of our ERP system, deciBase, before the project ends in late September 2014.

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