Development Strategies for Information Systems in Rapidly Changing Environments: a Novel Developmental Approach for a Council System

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Abstract

This paper discusses how the impact of factors of time and environmental change in Information Systems development led to the adoption of a development method that exploited the spatial aspects of Geographical Information Systems (GIS). It presents a case relating to a South Australian Council who identified a need for an Information System for their Asset Management function and reviews the problems caused by changes in the environment. The first development approach, based on the Deming Cycle, produced a system that met the specification but was unable to cope with the problems caused by the changes in the business and physical environments that occurred during the development period. Having recognised the significance of potentially continual environmental disturbance an innovative approach using Geographical Information Systems was developed to facilitate effective response to future change by minimising development time and also by producing a conceptually simple scheme for information representation within the system.

Keywords

IS Development Methodologies, Government, Project Management, Geographical Information Systems, Spatial Information Systems, Asset Management

INTRODUCTION

Much of the traditional project management literature identifies time as one of the 'pillars' of project management, along with cost and quality, or sometimes functionality. Kerzner (1998), for example, comments that "the time-cost-performance triangle is the 'magic combination' that is continuously pursued by the project manager throughout the lifecycle of the project … Unfortunately, most projects eventually find crises where this delicate balance necessary to maintain the desired performance within time and cost is no longer possible". This dynamic relationship between time, cost and quality has been extensively explored and considerable effort devoted to the estimation of project as well as to the 'crashing' of critical activities through the use of extra resources to ensure that a significant milestone is met. This paper recognises that time (or, perhaps more accurately, duration) has a significant impact on the development of information systems projects, but also argues that the greater the duration of the project implementation, the more chance there is that the surrounding rationale for the project will have changed. Thus it is possible for a project itself to be delivered in line with the required time, cost and quality requirements (and therefore be deemed to be a success) but still be considered as a failure due to changes that have occurred during the execution of the project. This is classed by Fortune and Peters (1995) as a Type 4 failure when ‘the objectives that were set were met without undesirable consequences or side effects, but by the time they were achieved there was no longer any merit or satisfaction in achieving them’.. In the case outlined in this paper a large Council database was developed successfully but significant changes in the organisational structure meant that the project would have required considerable expenditure to modify the records and structures developed to suit the new setting. Worse yet, the possibility of further changes to the organisations boundaries and the general uncertainty of the environment suggested that this could well become a continual, rolling, problem. The setting is thus in line with Quadrant I in Kliem & Ludins Project Management Application Typology (Kliem & Ludin, 1997) where risks lie in cost, schedule, quality, people or technical areas. In recognition of the environmental change issues ways were therefore sought to develop a novel strategy that would allow a system to be developed such that it would possible to accommodate changes in data content, structure etc in a timely and flexible manner.

IMPACT OF CHANGE ON COUNCIL INFORMATION SYSTEMS

Information systems have been impacted upon by computer and communications technology that is changing at a phenomenal rate. A Victorian State Government paper estimates the rate of technological change at ‘2x in 18 – 24 months and telecommunications being even greater’(Williamson, 1996), echoing Moore's 1965 law – named for Intel cofounder Gordon Moore –, which states that chips get twice as powerful every 18 to 24 months (Heid and Snyder, 2000). Developments in software also have to cope with high rates of change as developers try to respond to changes in business requirements and the environment as a result of the E Business driver. The1999 Software Engineering and Information System Network (SEISN) workshop of IT academics and industry specialists commented that:

> “The software development environment changes so rapidly it is difficult for business organisations to keep pace with these changes and to understand not only what is available, but also what software or system would meet their business requirements along a complex dimension of needs”

The problem is not new, in fact a 1968 conference coined the phrase ‘software crisis’ which referred to the fact that systems took too long to develop, cost too much, and didn’t work very well (Fitzgerald, 1999). It is clear that we still face problems of time, cost and quality and that the major areas of concern are the development and implementation times for information systems projects.

Rapid development approaches are recognition of this fact and are an attempt to address the problem. They are gaining popularity with examples such as Rapid Application Design (RAD), Rapid Prototyping, Prototyping, and Evolutionary Development (Eva, 1999 but many large organisations have not yet adopted these and still use more traditional project management approaches.

The remainder of this paper focuses upon a South Australian council that was faced the need for an information system to support their asset management function in a complex and changing business environment. The circumstances surrounding the development of a specific information system will be explored and the ways in which attention to the problem of development times in changing business environments and the impact of factors of time and how this understanding lead to an innovative approach that reduces systems complexity using the concept of space.

CASE: CITY OF ONKAPARINGA

Background

The city of Onkaparinga is considered to be the largest council in South Australia, having a geographical area greater than 520Km^{2}and a residential population base of 150,000.It was formed in 1997 from the amalgamation of the three former councils of the City of Noarlunga, the city of Happy Valley and the District Council of Willunga. Upon amalgamation the information systems were disparate, to say the least, with a combination of different software packages, databases and manual paper based systems. When Onkaparinga was formed a temporary organisation structure with a time horizon of two years was implemented. At the end of this period an asset management function was formed, which management claimed as unique to South Australian Local Government and possibly even National Local Government. The development of an asset management function was in response to a new accounting standard – AAS27 – that was imposed upon councils in 1994 and was to be gradually phased in over four years. The standard applied accrual accounting techniques to infrastructure assets like roads, reserves, buildings, etc and was aimed at encouraging councils to understand the consumption of their infrastructure assets and the resultant cost implications. It has led to a gradual shift in council operations service delivery from a reactive approach to a strategic management approach.

Toward problem definition

On amalgamation, the task of bringing the various asset systems of the former councils together was assigned to the civil engineering function. It was quickly realised that that there were a number of problems including a lack of metadata, particularly asset definitions, and on further investigation it was found that the likely definitions differed from one council to the next. For example, one council defined a road as the area of land existing within a road reserve, whereas another defined a road as pavement and asphalt surface. Because assets were defined differently they were also grouped differently. Asset hierarchies were developed on definition and reflected both organisational structure and work practices. Each council had their own structures and work practices and therefore the asset hierarchies were also unique.

Once this lack of common definitions was appreciated the decision was made to develop new hierarchies that reflected the new organisation's needs. The question was then asked 'what are the new needs'? This was difficult to answer for two reasons. The first was that asset management was not high on the political agenda as amalgamation issues took precedent. Amalgamation promised the community benefits like reduced rates and increased services (Stevens, 1996) and this, combined with issues surrounding the set up of a new organisation, consumed much of management's attention. The second difficulty was that asset management of infrastructure assets was a new field and not yet well understood

Project development

It was decided to form a cross-functional team who were commissioned to define needs, recommend an asset data structure to meet those needs and investigate 'best fit' software solutions that would accommodate those needs. The method of problem identification was one developed in house adapted from The Deming Cycle (Evans and Lindsay, p344, 1996) known as PTCI (Plan, Test, Check and Implement). It is a seven stage iterative approach primarily designed for process improvement, comprising four planning stages with testing, checking and implementing forming the remainder.

The stages are described as:

1. What is your problem or issue and what is your agreed objective.
2. What is the process as it occurs now.
3. What is the biggest problem? (Ask 'why' 5 times to identify the root cause)
4. What steps do you need to take to eliminate the root cause so this problem doesn't occur again?

5. Test/trial your new process in one of your teams (or with a sample of your customers) for a set time period.
6. Check your results (measure of success) of your test.
7. Implement your improved process.

This process took around 12 months and was completed during May of 1999. At this time a new organisation structure was announced in preparation for a July 1st 1999 implementation. It quickly became clear that the new structure invalidated a portion of the development work which largely reflected the now obsolete organisational structure. A corporate decision was also made to adopt a particular Geographical Information System (GIS) software package. Unfortunately the team's proposed software solution relied heavily on another GIS package and did not integrate with the chosen corporate package. The team members were assigned to new departments and responsibility for asset management was moved to the Economic Development department. This move was made because senior management felt that asset management was of strategic importance and the new structure should reflect and support this importance. The Economic Development department had previously experienced some success in the field of asset management and was well positioned to support further developments.

LESSONS LEARNED

There were a number of lessons that could be drawn from this experience and the ongoing development process. Simply put, the project took too long and was not flexible enough to accommodate the changes occurring in Onkaparinga's environment, even though the whole project took just over one year which, under normal circumstances, would have been considered to be a very acceptable duration. Successful systems development within a rapidly changing environment would only seem to be possible if the methodology or design recognise this feature and are such that changes can be accommodated..

Project complexity and Development time

Development time has been signalled here as a critical factor and the following is a brief description of identified project factors that had a likely effect on development time.

There were two aspects relating to project complexity, the first being a lack of general understanding of systems requirements for asset management. The whole concept was new and potentially impacted on all facets of council operations. When attempting to define specific needs of any one function, it was found that boundaries of responsibility were not clearly defined. Each department then tried to include responsibilities that were not necessarily their own and thus increased complexity. The process thus contained elements of politics, culture, technology and was a good example of an ill-defined problem situation that would possibly benefit from a ‘soft’ development methodology (Checkland, 1981, Checkland and Scholes, 1990). The possibility of the adoption of a ‘soft’ methodology is being considered for future projects.

The second complexity issue was that of the project’s scope, which took into account all aspects of asset management. The project took into account all facets of asset management and again, this was a product of ambiguity regarding responsibility. In this early stage the broad scope was necessary as the project was as much an education process about asset management as an IS development project. It was felt that once the whole is understood then the parts could be worked upon. In practice this concept did not eventuate and asset management as a whole remained the primary focus. This was probably because a substantial proportion of those involved did not have a clear understanding of the whole and it was difficult to distinguish between asset management and managing the asset. The difference is that asset management has a strategic context, where managing the asset is more of an operational issue. Future projects may be able to decrease development time by focusing on a sub – system, or taking a modularised approach, thus reducing each projects scope and size, although it is recognised that a holist view must still prevail.

Organisational Change

Building on the idea that there are potential benefits in limiting a project’s scope is the notion that the extent of change an organisation experiences will increase with the extent of project implementation. It is fair to assume that the implementation of any new system requires some degree of change. The change process has been described as unfreezing the status quo, moving to a new state, and refreezing the change to make it permanent. Unfreezing can be achieved by increasing the driving forces, reducing the restraining forces or a combination of both (Robbins and Barnwell, 1996). It was found that because the scope of the project was large it would have a large impact on many parts of the organisation. The changes often meant the various sections would have their workload substantially increased for little gain to their sections. These sections obviously resisted such change! It was felt that if the project’s scope was reduced, it may reduce the extent of change and thus, positively affect resistance to change.

Environment

While development was occurring a number of environmental changes occurred that impacted the project. State Government pressure lead to the amalgamation of some councils to achieve such benefits as economies of scale, increased services, etc. Onkaparinga was the result of one such amalgamation and implemented a temporary organisation structure, further guaranteeing future organisational changes. The implementation of the accounting standard AAS27 created a gradual, but fundamental shift in council operations. The Local Government act – the context within which a council operates – has only recently been through and substantial review. In fact the very reason the project was initiated was in response to such environmental pressures.

During the life of this project there were a number of fundamental changes that affected the project. For example, the State Government changed a number of suburb boundaries and although this did not affect systems design it did require the manual updating of many data records. Other changes did affect data structures, for example an increased interest in coastal management issues which led to the formation of a new work and to the definition of a new class of asset. These changes caused a significant re-think on how the system was to operate and caused a re-design of many parts of the system.

Flexibility

The initial asset hierarchies developed by the project team reflected previous work practices, organisation structures and other factors such as political and work boundaries. Once modelled, the organisation structure and work practices were changed, which had an impact on asset hierarchies. The conclusion was that the model was not flexible enough to accommodate such changes. This created a dilemma for the development team as the CEO had announced that similar structural changes would occur at some point in the future to accommodate the evolving organisation. In response, the team's aim was to incorporate flexibility through innovative use of the concept of space facilitated by recent changes in technology. The following discussion uses Entity Relationship Diagrams (ERD) as a vehicle to demonstrate the concept and its use.

ADDRESSING LESSONS LEARNED

After more than a year of systems design and implementation, Onkaparinga had a set of asset management systems that did not totally match their needs. A review of why the systems did not meet current needs identified that systems requirements were based on a particular point in time. The environment was typified by rapid change and therefore, requirement also changed rapidly. The result was to look for ways that either decreased development time or increased systems flexibility so that changes could be absorbed. Following is a discussion on why typical text based data structures were found to be inflexible in the case and how the problem was addressed using the concept of space. The discussion uses Entity Relationship Diagrams (ERD) to demonstrate concepts.

System inflexibility

Onkaparinga organises field operations based on geography and work type. For example, a team may consist of horticultural staff who maintain reserves in their particular area. The type of questions an asset management system may be required to answer would be 'how much does it cost to water a reserve and compare that cost with the average cost of watering all reserves in that work region'. To answer this question using a typical text based system, the resultant ERD may resemble Figure 1:

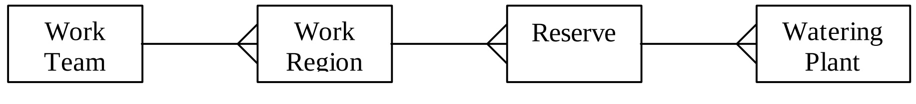

Figure 1: Simple asset hierarchy

In this case, both a reserve and watering plant are considered assets and form a simple hierarchy of reserve as parent and watering plant as child. This would also be a representation of the physical model. If we take a macro view of this the logical design model may be expressed as:

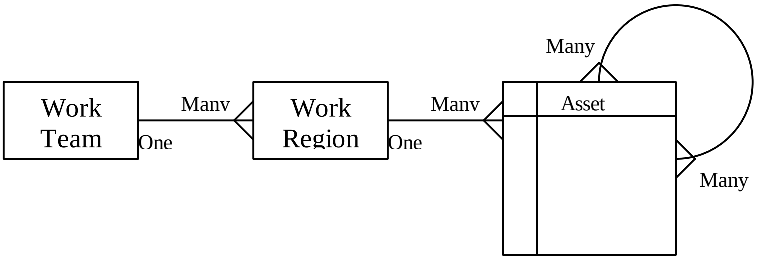

Figure 2: Logical design of simple asset

When we consider the environment that Onkaparinga has had to operate within, we have to consider the impact the environment has on these relationships. Consider an example where such pressures may require a team to expand their area of responsibility. The result may be that their work boundaries are redefined and they become responsible for an increased number of assets IE Play equipment and footpaths are added with reserves. There is no impact on the logical model but there may be an impact on the physical design model. For example:

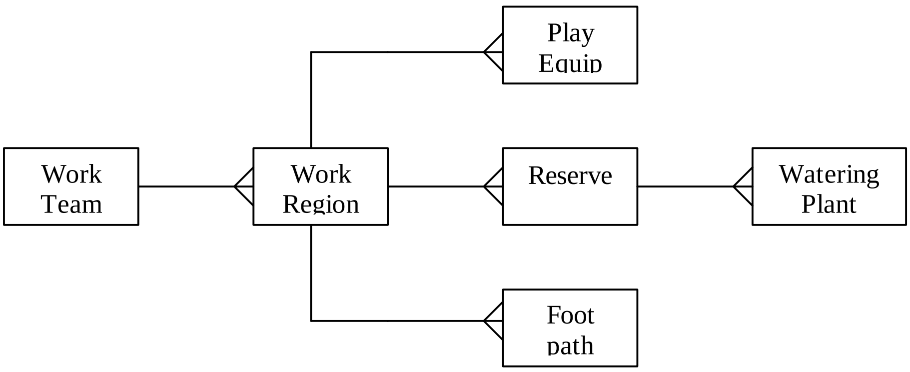

Figure 3: Physical design of expanded

This is where the problem lies. Each time there is a decision to change an operational process it has an impact on the information system. In this case a field is added to the Play Equipment and Footpath tables to create a relationship with the work area they each exist within. If a change is broad, it has the potential to impact on many entities requiring large amounts of data processing. This design is not flexible enough to cope with such changes on a regular basis due to the amount of data entry work it can generate.

Flexibility using space

It is the asset portion of the logical ERD that is affected by change. This then represents an opportunity for improvement. The area in question is represented by the following ERD:

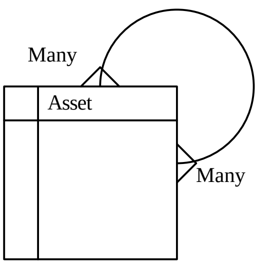

Figure 4: Logical design – recursive many

If we represent the logical design model this way, we can see that an intersecting table is needed to manage the many to many relationship in the physical design model. The usual way to handle this situation is to create a table that has a primary key comprised of the primary keys of each table. If we consider that the assets in question are static, or do not move, then they have a relationship with the space they occupy or exist within. This can be represented as:

Figure 5: An asset's relationship with

Database design theory teaches us to be wary of such relationships as one entity may actually be an attribute of the other but, in this situation, space can be used as an intersecting entity to manage the many to many relationship and can be represented as:

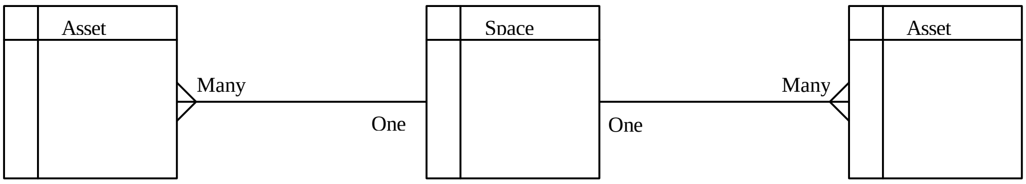

Figure 6: Space as an intersecting entity

PHYSICAL IMPLEMENTATION OF THE SPATIAL CONCEPT

Practical implementation of this concept is not necessarily easy, as it requires software that can handle spatial data and combine it with textual data so that they can be used together. However, there are GIS tools that are capable of doing this task (Pullar and Stock, 2000) and they are becoming more popular for managing data in a spatial context (Van Den Berg, et al, 1999, Howarth, 1999, University of Pittsburgh, 2000).

GIS are often seen as a tool for visualising spatial data (Van Den Berg, et al, 1999), but they also have the capacity to perform spatial analysis. Spatial queries such as the selection of an object that is within, adjacent to, or intersecting another spatial object can be used. It is this feature that makes physical implementation of the previously discussed use of space as an intersecting entity possible. Building on the scenario outlined previously, an example may be 'Select all the water areas of a reserve that exist within work area X'. The key to the power of this concept lies in its ability to adapt to change. For example, if a work area is redefined, the only thing in the database that needs modification is the spatial or graphical component of the entity, thus avoiding the need for numerous data fields to be updated or added.

CONCLUSION

This paper has outlined the events and lessons drawn from a particular information systems development that produced a product that did not fully meet the needs of its intended users even though the development process did produce a system that met the original requirement. A review of the process highlighted a number of possible reasons why. Requirement analysis was performed using a method designed for process improvement. Although it is not felt that this was not a cause of the outcome, the fact cannot be ignored that this may have been a contributing factor. Given the nature of the situation, the possible use of a 'soft' development methodology may have positively affected the outcome.

The review of the development in the case study also lead to the conclusion that the whole process took too long. Requirements analysis was, as is typical, performed for a given point in time. When this was being performed, the case organisation was experiencing a volatile environment during a period of rapid organisational change. Because the environment is difficult to influence, the only way to deal with it is to respond therefore, the review focused on areas that may reduce development times. Reducing a projects scope and complexity may be an effective means by which time is positively affected. The changes are then small and may also reduce employee's resistance to change, again reducing development time. The main difficulty with this argument is that if change does occur after the system is implemented then a redesign must still take place. A complimentary strategy would be to seek flexibility in a design process that recognises and 'absorbs' change.

It was found that, for this specific data set, the idea of spatial concepts using GIS produced a flexible outcome that would changes in the council environment. By maintaining an object's spatial context, the need to define relationships is reduced. More importantly, if relationships change or new ones are developed, the system can absorb these changes. Unfortunately, this concept only really applies to objects that do not move (or are modelled so that they theoretically do not move). The model relies on a relationship between the object and the space it occupies. The application of these concepts has only been applied in a specific field, but further work will be carried out to explore the applicability of the concept to other data sets given the increasing power and decreasing cost of GIS.

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