

**An Investigation into the Development of a Facilities Management
System for the University of Cape Town**

By

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University of Cape Town

Development of a Facilities Management System for the University of Cape Town

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Synopsis

The objective of this study is to create a Facilities Management System (FMS) for the University of Cape Town. Facilities are currently managed through a combination of autonomous software packages and “pen and paper” planning. The goal of this study is to establish software connectivity between all of the current data holdings.

The study focuses on the Universities Physical Planning Unit (PPU) as they are the central authority for planning and facilities data storage. The PPU has a need to upgrade their current work processes and this project served as a first phase of the systems upgrade. Through an investigation of the PPU’s data holdings and current software systems it was established, as a short- to mid-term solution, that an improvement in work efficiency and deliverables could be achieved through the implementation of smaller scale systems upgrades than a complete Facilities Management System. This is more concurrent with the resources available to the Unit.

The study concludes that the implementation of a full FMS is a project of far greater scale than is possible to achieve without enterprise wide support and that the implementation of a small scale Geographic Information System (GIS) in the form of a Spatial Information Catalogue (SIC) would allow individuals on campus to realise the benefits of a full scale FMS and so begin to garner enterprise wide support for such a system.

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1. INTRODUCTION

The underlying objective of this research was to create a Geographical Information System (GIS) for the management of the facilities and physical spaces of the University of Cape Town (UCT). GIS has been implemented by many institutions as a solution for facilities and asset management systems, these include universities, electricity boards, transport companies, cities, states and many others.

“Facility management is a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology”

(International Facility Management Association, IFMA)

The project of creating a facilities management system for UCT was initiated as a postgraduate study for the Physical Planning Unit (PPU) of the University. In the first year of the project the goal was to initiate the creation of a new system for the PPU to improve their function as a working Unit at UCT. As the PPU’s main objectives are the management and planning of space on UCT’s campuses it was deemed that such a system would indeed be a Facilities Management System (FM).

Although a basic understanding of the machinations required for implementing such a system were known at the projects inception, understanding of the required resource investment, regarding time, money, understanding, staff training and departmental change, that would be required was limited. Through the course of the study outlined in this thesis a more realistic understanding of the requirements for the implementation of a facilities management system has been gained. The project was also limited by having to work within the budget of the PPU and had no budgetary powers of its own. It also lacked a mandate to create any changes to the PPU’s current systems or policies. Due to the fact that the project was started in isolation by the PPU all potential stakeholders were not involved. If the project had had a greater support base further progress could have been made as the burdens associated with implementing such a project would not have fallen solely on the shoulders of the PPU staff. This would have allowed more time for staff training and project development.

The implementation of a GIS for facilities management (FM) at the University Of Cape Town would involve combining all spatial and attribute data that have inherently been collected in the universities various databases into a single Information System. Currently most of the Universities departments and units maintain their own databases for basic human resources and resource management. The most common data in various databases is the spatial dataset, e.g. room and building assignment. By creating a single integrated base spatial dataset with accessibility for all levels of UCT management a common denominator is found for communication between the Universities various databases. The structure and construction of a spatial database is discussed in chapter 4.

This common denominator, space, allows for the creation of a single database that can be used by all the Universities faculties, departments and units. By referring to a single data store data redundancy, inconsistencies and duplication of effort are avoided. Data sharing between the various managerial entities of a facilities management structure is also greatly increased allowing for more informed decision making.

“GIS (also) provides the opportunity to integrate infrastructure management with room-level detail..... The geometric access and organization methodologies in GIS provide a powerful and flexible means of organizing, analyzing, and presenting information at every level of a company's infrastructure.”

(Debra Gondeck-Becker, 1996)

The possibilities of data and information sharing across campus would allow for analysis at all levels of the managerial hierarchy. This leads to one of the greatest challenges for the design of such a system, which is managerial support at all levels. Without the support of all potential stakeholders and beneficiaries the system is doomed to failure from the outset. As Tor Bernhardsen (1990) states in “Strategies for GIS implementation” it is essential for working units inside an organisation to feel genuinely responsible for creating and maintaining the entire function or system. Without the above mentioned responsibility it is likely that stakeholders will shy away from the project and not commit the necessary resources to guarantee the projects success.

In order for UCT’s current spatial and non-spatial data to be integrated into a single system a large investment of time and money would be required to normalise or standardise the

Universities current data holdings in order to create uniformity. Most data holdings on campus are currently held in a variety of formats and/or systems and standardisation of these holdings would be essential for the success of an FM. Gross duplication of data is also evident at UCT, within single databases, as well as between them. The implementation of the SAPR3© central database system sought to alleviate much of this, however this system is still not fully operational in all expected areas and many departments still cross-reference with their own data holdings. The standardization of datasets would greatly alleviate this problem. Hence the need for support from all levels of UCT's management structure as the initial workload, namely data collection, verification, manipulation and standardisation would affect all stakeholders, from the bottom up.

The second challenge is to ensure that the development team responsible has sufficient resources and know-how to implement such a system. Systems of this nature are generally cross-platform or cross-program, integrating various software packages to create a single system. Full knowledge of the capabilities of each software package, as well as establishing connectivity between them, is required. The software packages would include:

- one or more database packages for attribute data storage
- a CAD package for spatial data creation and editing
- a GIS package for the integration of spatial and non-spatial data as well as an user interface
- a web form design package so as to make the system available on UCT's intranet.

Various systems exist which incorporate all of the above mentioned attributes and there are many programs which cover one or more of those attributes with the ability to connect to other programs. While a specific system was not chosen for this project the functionalities mentioned here are vital.

This thesis will start by giving a broad outline and background to GIS as a facilities management tool as well as a brief background and history of UCT. A discussion on implemented facilities management projects and their relevance to this particular project will follow. Thereafter the PPU's current spatial and non-spatial or attribute data will be investigated to determine the extent of current data holdings. Data formats will also be

explored in order to establish inter-system compatibility. Once the data holdings have been established the integration of the data into a spatial database can occur. With all data resident within a spatial database, or at least in the correct form to be incorporated into such, the development of a FM can start. Once the discussion on development is complete this thesis will end with its conclusions and recommendations.

University of Cape Town

2. A BACKGROUND

2.1 GIS

2.1.1 GIS Implementation for Facilities Management

Since the emergence of Geographic Information Systems (GIS), some forty years ago, their potential as a management tool has been realised. The implementation of GIS in a facilities management (FM) or asset management (AM) capacity has been exploited since the late sixties (Lynn & O'Laoide, 1990). Initially GIS was only used in a management capacity by large corporations, such as energy suppliers, due to the large costs involved with implementation and maintenance of such a system. Costs, though still high, have been significantly reduced with the advancement made in both hardware and software systems. Facilities management systems are now employed in a wide variety of industries and organisations such as airports, local government, universities, telecommunications and transport management to mention but a few.

The savings in time and money related to full integration inside a single company or organisation weigh up against the cost of implementation and maintenance of a facilities management system. Initial costs for such a system are high due to:

- hardware and software requirements,
- data conversion and collection needs and
- user and needs analysis
- staff training/retraining.
- description of business process

It is very important to invest in an in-depth needs analysis and cost to benefit ratio study before an organisation embarks on such a project (Bernhardsen, 1990). A cost/benefit study also allows for strategic planning for the implementation of an FM and the answering of key questions, such as:

- Begin now or later?

- Invest aggressively or stay within the normal budget?
- Use a tailor-made or a general system?
- Should geographical coverage be limited or comprehensive?
- Design and maintenance of the database?
- What changes in routines or business rules will be required?

(After Bernhardsen, 1990)

The answers to the above questions will have a significant effect on the cost, time-frame and effectiveness of implementing a FM. In order to answer the questions it becomes necessary to obtain input from all affected levels of an organisation, which, if the system is to be comprehensive, includes all levels of an organisation. Although some of these questions are investigated in this dissertation, comprehensive answers to the above questions require decisions from levels of management not approached during this study.

It has been noted by Bernhardsen (1990) that organisational problems generally present more of a challenge than technical ones and that a large range of questions will come to the fore, having different levels of importance to different levels or structural entities within an organisation. The introduction of a FM will lead to a change in work flow and routines within an organisation as well as between itself and others. Although it is important that the FM design be driven by the requirements of the organisation, to serve the organisation, a certain amount of change within an organisation is inherent with the implementation of a new system. It is important to have answers to the above questions and issues early on in the development of a facilities management system. All beneficiaries of the system must be made to feel that their input is important. A FM cannot succeed without the support of its potential end users.

2.1.2 Is GIS the Answer to Integrated Facilities Management?

In recent years GIS has emerged as a powerful tool for space management. It is a progression from traditional paper based mapping systems to the fully computerised approach. With this migration comes an entire array of new concepts and tools which could never be conceived using traditional map analysis. This virtual explosion of possibilities in the spatial

management and analysis arenas has led to the inception in many fields that GIS is the 'answer to our prayers'.

“GIS is a technical innovation as important to the spatial sciences as was the invention of the microscope to the biological sciences” (Albers, 1987 as quoted by Reeves & Petch, 1999)

Such sentiment has been in less evidence as GIS has made the migration from a 'specialist technology' to commercial use. As much as 60% of GIS projects fail after large investments of time and money. The reasons for these failures are becoming apparent as GIS begins to adopt the more refined and understood approach of traditional Information Systems (IS). GIS experienced a similar scenario to IS in that initially it fell in the realm of academics and computer scientists, and not everyday users.

It became apparent in IS that the requirements of the client should be the governing force behind the development of any system. This led to the inception of such positions in Information Technology (IT) as Systems and Business Analysts. The major role of these positions is to ensure that the product meets the requirements of the client, while perhaps not reaching its full potential in the eye's of its developers.

This difference in approach is described by Reeve and Petch (1999) as “technology push” versus “demand pull”. Many GIS systems were, and still are, commissioned as the result of “technology push”. This leads to systems which, whilst incredibly powerful, are too complex and technically challenging to be successfully implemented at an enterprise wide level, or are never signed off as their development continues to evolve with the technology itself. A shift to designing IS systems which respond to “demand pull” has proved to be far more successful in IT and a migration of GIS development to this approach is becoming more apparent, with the associated results.

2.2 The University of Cape Town

2.2.1 A brief history

The University of Cape Town is South Africa's oldest University. It was founded in 1829 as the South African College which provided secondary and tertiary education. An increase in funding from both government and private sources saw the College develop into a university in the twenty years between 1880 and 1900.

The emerging gold and diamond mining industries were a major driving force behind the development of the university at that time and led to the foundation of the Departments of Geology and Mineralogy. Science was also boosted with the foundation of the first dedicated laboratories. It was also during this period that women were first admitted and the College consolidated its tertiary status.

The founding of The Medical School, Department of Education and the introduction of engineering courses took place between 1902 and 1918. The establishment of UCT as a university occurred in 1918 at the bequest of Alfred Beit. The establishment was helped considerably by substantial gifts from the mining magnates Julius Wernher and Otto Beit. A large amount of support was also received from local residents as well as, for the first time, the state.

In 1928 the University moved to a portion of Rhode's Estate on the slopes of Devil's Peak. The move led to the establishment of the Groote Schuur Campus, more commonly known as Upper, Middle and Lower Campus. The Groote Schuur Campus today constitutes the largest percentage of UCT's holdings and constitutes the heart of modern UCT.



Figure 15. The view of Devil's Peak from the Plaza of UCT's Upper Campus

In the years that followed UCT established itself as a leading teaching and research university. During the Apartheid Era, from the 1960's to the 1990's, UCT maintained sustained opposition to the government, especially in the area of higher education.

The first black students were admitted to UCT in the 1920's, but black representation remained small until the 1980's and 90's when deliberate processes of internal transformation were put in place to meet South Africa's new higher education needs. The admission of black students rose by 35% in this period. The success of UCT's transformation can be measured by the diversity of its 2004 student body where just under half of the 20 000 strong student body is black and almost half are women. Today the University has six faculties supported by the Centre for Higher Education (CHED). These faculties are Law, Humanities, Health Sciences, Engineering and the Built Environment, Commerce and Science.

It is internationally recognised as one of Africa's leading research universities, with over 30% of its students enrolled in postgraduate studies who are supported by more than 60 specialist research units. Over a quarter of South Africa's "A-rated" researchers can be found at the University of Cape Town.

After the UCT website (UCT 2004, <http://www.uct.ac.za/history/?f=1>).

2.2.2 The Mission Statement of the University of Cape Town

In order for an Information system to gain acceptance within an organisation it is important to understand the motivation that drives the organisation. This motivation is usually defined by the vision or mission of the organisation, the ideals which define the goals of an organisation and its staff. Formulating a common mission for an academic institution becomes difficult as the nature of academia requires the individual to continuously question existing situations and the focus of academia is inherently on the individual. Given these factors it becomes difficult to formulate a common mission. For this reason tertiary institutions usually have a mission that is formulated around the goal of higher education.

“Our mission is to be an outstanding teaching and research university, educating for life and addressing the challenges facing our society.

Educating for life means that our educational process must provide:

- a foundation of skills, knowledge and versatility that will last a life-time, despite a changing environment;
- research-based teaching and learning;
- critical enquiry in the form of the search for new knowledge and better understanding; and
- an active developmental role in our cultural, economic, political, scientific and social environment.

Addressing the challenges facing our society means that we must come to terms with our past, be cognisant of the present, and plan for the future.

In this, it is central to our mission that we:

- recognise our location in Africa and our historical context;
- claim our place in the international community of scholars;
- strive to transcend the legacy of apartheid in South Africa and to overcome all forms of gender and other oppressive discrimination;
- be flexible on access, active in redress, and rigorous on success;
- promote equal opportunity and the full development of human potential;
- strive for inter-disciplinary and inter-institutional collaboration and synergy; and value and promote the contribution that all our members make to realising our mission.

To equip people with life-long skills we must and will:

- promote the love of learning, the skill of solving problems, and the spirit of critical enquiry and research; and
- take excellence as the bench-mark for all we do.

We are committed to academic freedom, critical scholarship, rational and creative thought, and free enquiry. It is part of our mission to ensure that these ideals live; this necessarily requires a dynamic process of finding the balance between freedom and responsibility, rights and obligations, autonomy and accountability, transparency and efficiency, and permanence and transience; and of doing this through consultation and debate.” (UCT, 1996)

In order to achieve the above mentioned goals and ideals, especially those in the last paragraph, it becomes necessary to implement systems in order to monitor such concepts both quantitatively and qualitatively. Such systems serve as both a management tool as well as a measurement one. In the case of a FM it is possible to monitor such things as freedom and responsibility, rights and obligations, transparency and efficiency, and permanence, among others, through the management of space and its allocation.

For example, should 300 students be assigned to a lecture it is neither responsible nor efficient to assign that lecture to a venue which cannot accommodate such student numbers. It would deny the student’s rights with respect to their quality of education as well as flout the Universities obligation to provide adequate learning conditions as stipulated in the above mission statement. It is, however, possible that such situations can, and do, arise through a lack of space, information or adequate space management.

This is not to say that the University would not be able to achieve its goals without a fully fledged FM, but such systems and others like it are necessary to provide the backbone managerial infrastructure from which higher ideals can be achieved.

2.2.3 The Geography of UCT

As mentioned above UCT was established in 1829. In the 175 years that have followed the University has developed alongside the city of Cape Town. The University today consists of six major campuses with numerous satellite locations throughout the city, the Western Cape Province and the country of South Africa as a whole. The six major campuses are Upper, Middle and Lower Campus (also referred to as the Groote Schuur Campus), Hiddingh Campus, Medical School and the Graduate School of Business (GSB).

The Upper, Middle and Lower Campus' are located adjacent to one another on the slopes of Devil's Peak above the suburbs of Rondebosch and Rosebank. Hiddingh Campus is located on the original site of the South African College in the centre of the city. Medical School is located adjacent the hospital Groote Schuur in the suburb of Observatory. The GSB is located inside Cape Town's lucrative Waterfront commercial district.

Upper Campus is by far the largest learning centre of all of UCT's campuses. It is also the second oldest campus, along with the Middle and Lower Campuses. Hiddingh Campus is the oldest of UCT's Campuses and now serves as the Arts campus. Due to the age of these campus an additional factor is brought into account as far as facilities management is concerned. Namely that a number of buildings on Hiddingh and Upper Campus are national monuments and so cannot be drastically altered or remodelled. This forces facility management and development to work around these sites when expansion or development takes place, as well as commit resources to maintaining these buildings in as original a state as possible.

Below is a map illustrating the layout of UCT's main campuses in relation to central and southern Cape Town.



Figure 16. An aerial view showing the layout of UCT's six major campuses with relation to the central Cape Town area

2.2.4 The Management of UCT

UCT is an academically managed university. In many countries universities are managed as businesses with profitability as a major goal. Not so at UCT. Academic management of the institution allows for greater academic freedom as the directions the University chooses to take are governed by research and academic goals rather than commercial ones. The University is still required to be economically viable, but is not required to sacrifice less mainstream research in order to maximize profitability.

Academic management, or a University managed by academics, tends to follow a democratic approach to management, with a council or committee based management structure. Whilst this has the obvious advantage of all voices being heard in the decision making process there are also disadvantages to such a system. One of the biggest disadvantages is time. Due to the nature of the decision making process and a need to consult with all interest groups it can take a considerable amount of time to reach consensus on various issues. Another major disadvantage is that many positions are filled by staff who, while specialists in their fields, are not necessarily well experienced or trained for a management role. These disadvantages can lead to development and change being delayed. A lack of specialized, experienced staff can also lead to a lack of sufficient control mechanisms for development processes. The academic staff are supported by administrative staff who handle the everyday management of the University in most non-academic areas as well as constitute a large portion of the organisational bodies residing at the top end of the Universities management hierarchy.

UCT staff are divided into two distinct groups, academic staff who constitute 48% of the Universities staff, and administrative and support staff (PASS) who constitute the remaining 52%.

The academic hierarchy at UCT is similar to other universities. Academic fields are grouped by faculty, each of which has a dean. Faculties are divided into departments, each with a head of department (HOD). Those activities which do not constitute a department are considered units. Units generally fall inside a department, but may be responsible directly to the faculty level.

The academic staff are supported by six administrative departments, each with an executive director. These departments are; Properties and Services, Communication and Development, Information and Communication Technology Services (ICTS), University Libraries, Finance, and Human Resource Management. These are the departments who would most directly benefit from the implementation of a FM for UCT. The PPU is a unit inside the Properties and Services department. Together the management of the administrative departments and the heads of departments of the academic ones make up the management structure of UCT.

Presiding above the faculty level is the Vice-Chancellor (VC) and the Deputy Vice-Chancellors (DVC's). The University does have a Chancellor, elected on a ten year cycle, but this position is titular and does not directly influence the governance of the University. Two bodies exist to ensure the correct governance of the University and to ensure the accountability of UCT. These two bodies are; The Council and The Senate.

The Council is responsible the ultimate governance of the University.

“The Council of an institution, its Senate and Vice-Chancellor through the Council, are accountable for their actions to the State through the Minister of Education.”

(UCT (2004), *www.uct.ac.za*)

The Council consists of the executive officers, including the VC and the DVC's, members of staff, students and members who are neither staff nor students. The Council's responsibilities are:

- Act in the best interest of the institution;
- Determine the mission, objectives, goals, strategies and policies for the progress of the institution;
- Ensure an environment conducive to efficient, effective, economical and ethical attainment of the institution's goals;
- Maintain and ensure a financially secure, healthy and viable environment; and
- Account for all decisions taken at the institution, including the submission of the required reports and documents to the Minister of Education (and others)

(UCT (2004), *www.uct.ac.za*)

The Senate is responsible for the academic governance of the University. The Senate consists of the VC, the DVC's, HOD's, deputy HOD's, elected members of the academic and administrative staff as well as elected students and members of the Council.

Two other important bodies within the management structure are the Registrar and the Institutional Forum (IF). The Institutional Forum is a legislative body who advise the Council on a wide range of issues. The IF's role is the implantation of national legislation and policy on education. The Registrar is responsible for academic administration and legal issues concerning the University as well as serving as the secretary to both the Council and the Senate.

It is crucial that the implementation of any new system within an organisation take the structures of that organisation into account. The system's main purpose should be to augment the function of the organisation. To this end it is important to review the organisational structure into which the system will be installed to ensure that its development and implementation can occur as seamlessly as possible to the maximum benefit of the organisation.

3. A Review of Existing FM Projects

For comparison purposes it is important to review the implementation of Facilities Management systems within other organisations or companies. UCT is a fairly unique case for facilities management. Although many universities use a GIS based FM system most of the published cases are examples of universities in the USA. While these institutions share an academic commonality with UCT they are run or managed very differently.

UCT is an academically run university while most US universities are run commercially, with the academic staff being employees of an executive management body. While the pros and cons of academic management have been discussed above it is important to note that the approval of a project of this scale at UCT would be a far more complex and contested decision. UCT also has considerably less resources available to it than most US institutions, not only in house, but in the public and private sectors as well.

These differences aside there would still be considerable similarities between a FM at a US University and UCT. Likewise, while in many respects different, commercial FM systems designed for installations such as airports and energy companies do still provide valuable knowledge and experience which can be applied to the development of a FM for a higher education institution in South Africa.

3.1 Facilities Management at the University of Minnesota

Various US universities, the University of Minnesota being a prime example, have implemented facilities wide management systems using GIS as the fulcrum around which the system operates. The University of Minnesota is considerably larger than UCT, comprising of five major campus and 80 000 students while UCT also has five major campuses but only approximately 20 000 students.

The implementation of their facilities management system has considerably improved data sharing and management as well as improved reporting and decision making processes by facilitating the flow of information between business functions and supporting dynamic

integration between departments (Debra Gondeck-Becker, Implementing an Enterprise-Wide Space Management System - A Case Study at the University of Minnesota, 1996).

The system has a multi-tiered function, with usefulness extending from individual building or facility managers to finance departments. By including functionalities such as inventory, asset management and costing, as well as the basic space management, a successful system was created (Debra Gondeck-Becker, 1996).

The success of a FM may be measured by the amount of functionality incorporated into its design. This does not mean that the more functions a FM has the better it is, but rather that a FM is far more likely to gain acceptance and appeal by being able to serve a greater “customer base” within an organisation or institution. In this example the FM was designed and implemented to serve a far greater portion of the Universities staff than those with direct involvement with the management of the physical facility. Below is a diagram representing the areas incorporated into the system.

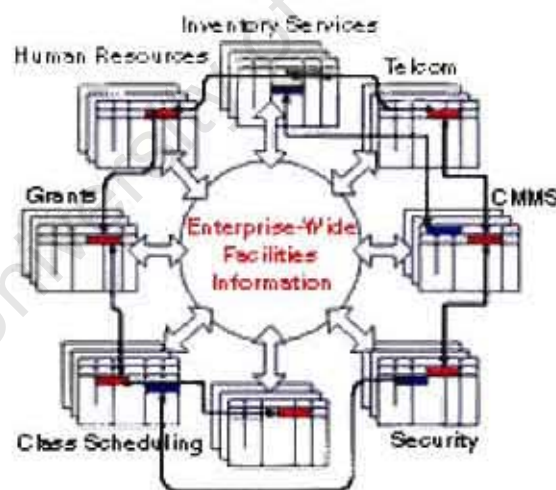


Figure 17. A schematic representation of the themes incorporated into the University of Minnesota's FM. (Debra Gondeck-Becker, 96)

While far more is incorporated into this design than would be originally planned for a system for UCT it shows the potential for development of a FM system to incorporate all the major data handling requirements of an academic institution. It is possible to add functionality and databases to a FM system post implementation but some foresight is required at

implementation to allow for such expansion. It is important to keep the system open ended in order to allow for growth. It is inherent that as a facility develops and grows its FM should be able to respond.

The scope of the facilities management project of the University of Minnesota is far larger than that at UCT. The project was a facility wide information system with involvement from all levels of the management structure of the university as well as an external consulting group. External consultants were hired to oversee specification and project management and major software manufacturers (e.g. ESRI, Oracle and AutoCAD) were invited to tender their products as system modules. This level of involvement by the software suppliers allowed for easy and reliable customization of the products used, as well as the availability of a vast store of development experience (Debra Gondeck-Becker, 1996). UCT has some experience of this type of external consulting and tendering process through the development of the SAP/R3 central database system.

Consultant involvement could be considered imperative simply for the expertise and experience which would be made available to the project. It is important that UCT remain “at the reigns” of the project though. The project has to be seen as being designed by UCT for UCT and not a generic system imposing methodology and process requirements upon the existing workings of the University. While it would be naïve to assume no change would occur to work process it is important that all changes fall inside an acceptable work framework.

The FM designed and developed for the University of Minnesota was a very large project with the full support of that universities management structure. The systems scope and functionality were specified to encompass more than mere space management. Through the designation of an “Application Owner” the FM is able to easily interface with other departments interested in using spatial data for query and reporting purposes. This position seems to have been very successful and vastly increased the systems usability and effectiveness. This system is a prime example of the successful implementation of an integrated GIS system for the management of university campuses.

3.2 Colorado State University

Taken from the properties management page of the website (<http://www.colostate.edu/Depts/Facilities/planning/index.html>) of Colorado State University (CSU) is the outline of a system very similar to that of UCT. This is a system that focuses mainly on property management for the purposes of development and reporting. The data structure links objects through the identification of a unique code. Objects, such as a room or building, are stored as spatial entities with a small amount of critical attribute data. This system very closely resembles the current system used by the PPU. Building plans are stored in CAD formatted drawings and attribute data is stored in a MSAccess database.

Drawings are uniquely coded to allow for easy identification when cross referenced with the database, likewise objects within a drawing (eg. Rooms) are similarly identifiable. These drawings are, when cross referenced with the database, used to create reports such as Room Assignment, Room Use, Functional Use, etc. This process is almost identical to UCT's current system in make up.

A critical procedure performed by the CSU is the regular re-survey of facilities to verify and update data concerning the facility. While such a process should be in state at UCT the rapid growth and development of the University coupled with its relative size to the PPU make it virtually impossible for such a procedure to be properly executed. This has led to the slow degradation of data held by the PPU. While it can be said with some confidence that the errors within the PPU's datasets are not great the identification of these data errors or omissions is a task of some magnitude, requiring extensive resurvey for comparative purposes.

Regardless of the type of system used facilities management is completely dependant on the data available to it. It is imperative that all data stored by a facilities management system or body is as accurate as possible in order for the most accurate and informed reporting and planning to be achieved.

3.3 Los Angeles World Airports (LAWA)

Facilities management technologies exist in a wide variety of contexts. While the facilities managed by the systems may be drastically different the basic aim of the management system is usually the same – to increase efficiency and effectiveness, to do more for less. The following section reviews how LAWA, along with the consulting group Carter & Burgess implemented a FM to do just that.

(<http://www.c-B.com/information%20center/aviation/ic.asp?tID=2&pID=185>)

LAWA is an aviation authority responsible for the management of four Southern California airports. It has over 2500 employees and an annual budget of US \$ 750 million. Mark Ricketson, FM-IT Manager at Carter & Burgess, says that airports have been given an unexpected opportunity to modernise and upgrade. This is due to a number of factors, the main ones being that airport revenues are down at the moment but are expected to resurge in the not too distant future.

LAWA has invested in a multi-billion dollar Capital Improvement Program. With over 100 000 drawings, maps and diagrams spanning over 75 years they saw it as common sense to invest in a FM-IT system. This system was implemented for management purposes, but also as a cost saver.

“Much of the savings is in cost avoidance - we have a system that serves all our divisions and departments as a shared digital file cabinet. By maintaining it, the data remains accurate and up-to-date. There's no question that having access to good information on the infrastructure saves us money.” says Micaela LeBlanc, Manager for LAWA's Information Technology Division.

3.4 Summary

Three important points are illustrated by the above examples. The first example is of the kind of FM that any facility would be proud of. The FM is comprehensive and covers a wide variety of data types and has a large blanket effect over many departments. This FM was a very large project, requiring a large amount of support, from the managerial hierarchy of the University of Minnesota as well as budgetary support. The project also took a long time to complete, the initial stages were complete by the end of 1998, two years after inception, but development continued for some time afterwards.

The second example illustrates that the complexity or functionality of a FM system becomes irrelevant if the data stored within the system is not accurate. Paramount to any FM system is the quality of the data stored within it.

The last example stresses the point that any FM's main objective, or purpose for existence, is to increase the efficiency and decrease the cost of running a facility. Even though such systems generally come with a high initial cost, or capital investment, the long term benefits from increased efficiency and effectiveness should easily out way those costs in the case of a successful Facilities Management System.

4. The Data Holdings of UCT

This project was initially a cooperative effort between the author and the Physical Planning Unit (PPU). The rapid expansion of UCT in recent years, combined with increased budgetary and staff constraints, has led to the PPU experiencing increasing difficulties in providing an effective service to the University. It was hoped that by implementing a new space management system some of these issues could be addressed. As part of the investigation a study of the current data holdings and business processes was conducted.

4.1 Non-Spatial Data Holdings

UCT has vast data holdings, most of it non-spatial. Unfortunately there is no central data storage or control centre at the University, and so a large number of differing data formats and various database structures have been encountered. The SAPR3 system is the only integrated system used by all departments (Academic or Professional and Support), but it currently only incorporates Purchasing and Human Resource Management.

All other data capture and storage is handled in department specific fashions, i.e. there is no uniform method. Due to this piecemeal approach, together with a lack of sufficiently trained staff, the data storage of most departments is less than ideal. In many cases paper based (or hardcopy) filing systems are all that is used. Databases which are run by departments tend to be individual achievements which, while storing relevant data, do not follow standard database practices and are dependant on individuals. These databases do not have the required editing and validations rules to ensure data integrity, nor are they well documented and so such systems do not suffer new users or hand-over. In other words, while sufficient in the short term, these databases are not sustainable in the long term. Table data is often viewed “spread-sheet” style with data entry, addition and query operations being performed directly to these tables. It should be noted that only one unit (the Physical Planning Unit or PPU) was studied in depth, but functioning as a Staff Member at the University has allowed for the *sotto voce* observation of various other departments and units and data management trends are obvious. This is reinforced by a survey conducted in 2001 (B.

Lauterbach, U.K Rivett: *A Methodology for the Design of a Property and Space Management System*. (2001). Below is a figure illustrating the relationships of the PPU's current database.

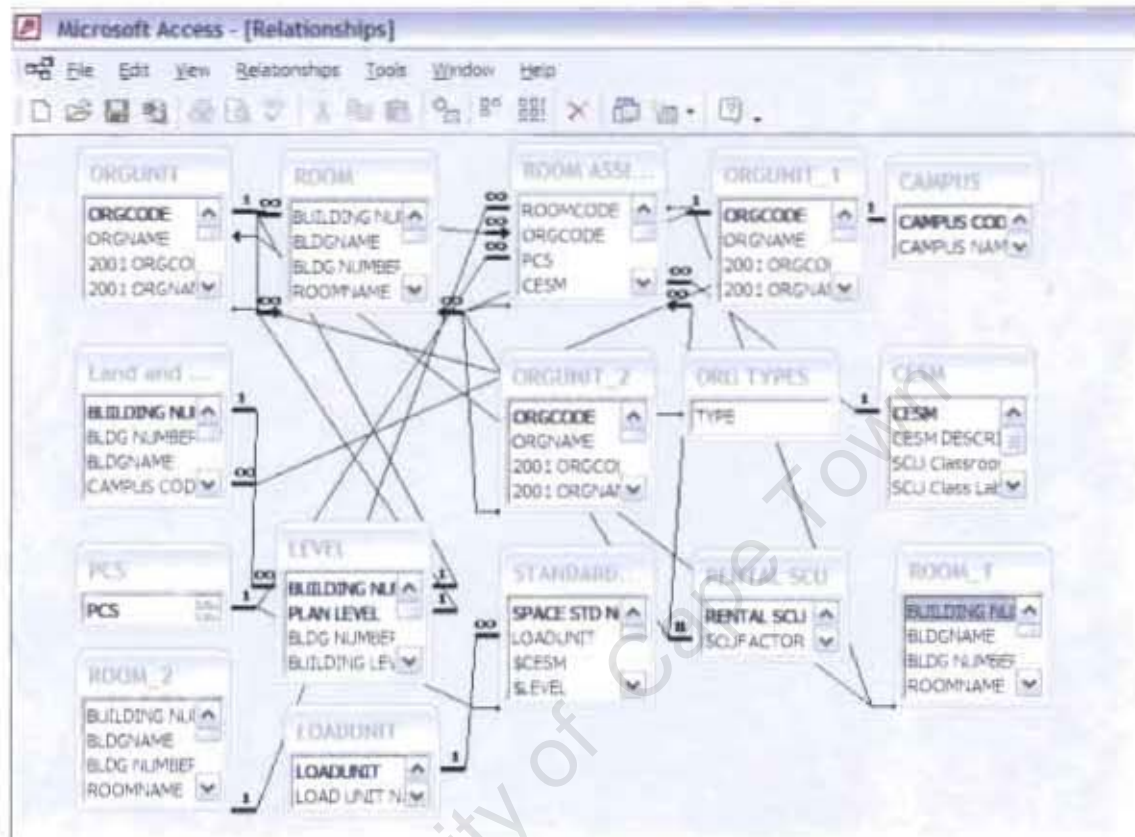


Figure 18. The Entity relationship diagram of the PPU's current database, SPACENOW

The above diagram shows an entity-relationship model of twelve tables, with a number of repetitions of the same table. An entity-relationship model defines how the tables of a database relate to one another. These relationships need to be as clear and logical as possible. The reason for this is the concept of cascading. Cascading implies that should a change occur to the data in one table this change will automatically be reflected in all tables related to that which was changed. Should the same table be a member of multiple, unrelated relationships then cascading is not possible or, potentially worse, cascading will only occur in some relationships and not others, thus creating disparities. The following figure shows that the database contains thirty-one tables.



Figure 19. The tables which make up the PPU's SPACENOW database

Whilst it is not necessary for all tables in a database to be included in the entity-relationship model, a large number of the above tables are redundant and unnecessary. Tables falling outside the entity-relationship model should only contain data with no logical link to the rest of the database. Such tables generally exist for the purposes of reporting where data without a direct relationship may need including in a report in order to make it comprehensive. Should the data in a table outside the model have a direct relationship to that inside the model it will not benefit from cascading. This leads to multiple updates being required and often to conflicting data, i.e. if a room name was updated in one table but not another storing the same data, there will no longer be a correlation between the two tables when that specific room is queried. This leads to data loss and corruption as well as requiring a duplication of effort in order to keep the database stable.

A revised entity-relationship model of the PPU's database was created, as part of this project, in an attempt to improve the database structure. The new database consisted of fourteen tables, thirteen of which formed the entity-relationship model. The fourteenth table lists a government categorisation listing which is required for reporting purposes. In the new structure every data type was stored once only with a relationship link to any directly related data. No repetition occurs in this database structure and cascading is possible. This database was, however, not populated as the required labour hours to perform such a task were not available. A more detailed description of the creation of this database follows in chapter 5.

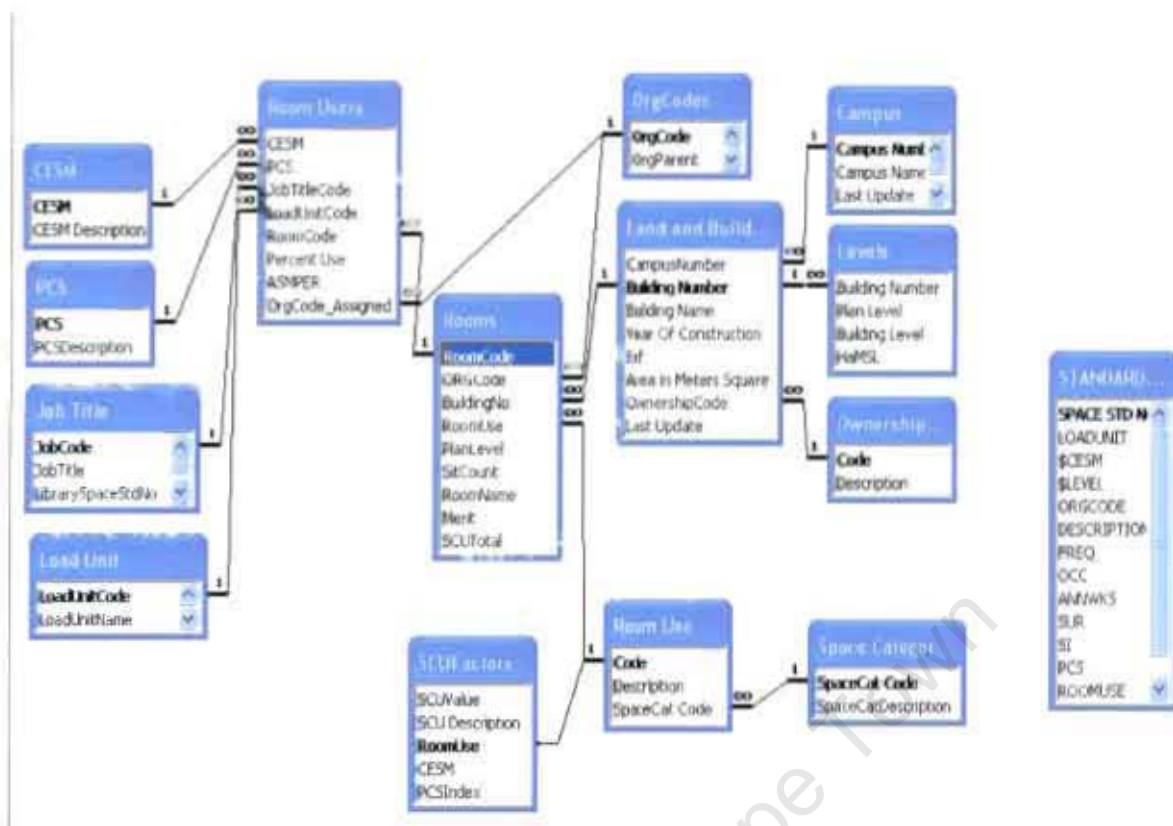


Figure 20. The entity relationship model for a new PPU database

The functionality of the PPU revolves around their central database and the recreation of all the queries and reports used with their current database proved to be a task requiring a considerable investment of time and technical knowledge. The process would require not only a competent knowledge of the database package and database practises, but also a complete understanding of the PPU's data types and reporting requirements. The need for a database change or upgrade is still paramount to the improved functionality of the unit, however without the support for such an upgrade it would be near impossible for them to create a product of the required quality. A certain amount of downtime must be expected as it is necessary for the current staff members to participate in the creation of a new database as well as undergo training in order to fully utilise a new system. Due to the limited man-power of the Unit and the need for it to continuously service the University such downtime is simply not viable at present. A discontinuation of the PPU's services for any length of time would also cause a backlog which would only aggravate the current condition of its data holdings.

Due to the state (or formatting) of most of the Universities non-spatial data it has become apparent that the implementation of a single data structure and formatting standard would be a long term task which is beyond the scope of this project. Central data storage with enforced data formats and/or structures is the task of a team of developers and would require considerable backing from the higher echelons of power at UCT. This process was meant to be completed with the implementation of the SAPR3 system, but this system has far overrun it's initial implementation date and as yet is still not operational in all originally planned areas.

4.2 Spatial Data Holdings

Spatial data capture, storage and manipulation at UCT is the task of the Properties and Services Department (P&S), or more specifically the PPU which falls under P&S. Currently all spatial data is stored either as hardcopy or as Bentley Microstation© .dgn CAD files. Unfortunately, due to the rapid expansion of UCT in recent years and a lack of manpower and technical knowledge, the spatial data sets are often incomplete or obsolete. This is also a by-product of the lack of central data storage and management strategy as well as a lack of communication between the various University departments, where spatial data is concerned. Changes in spatial data can only be captured if they are reported.

Formatting is a serious issue to be considered as well. While all CAD drawings are in .dgn format the data (or layer) structure of each drawing is not consistent. Drawing rules have been in use by the PPU for some time, but due to staff turnover and work load the standards are not always kept. This is the main reason for incomplete data sets within certain extents (such as a building). A further factor which aggravates the issue of incomplete datasets is the size and nature of the University. Often minor alterations will be made to a buildings floor plan without the PPU being informed and so drawings are not appropriately updated. Due to this and other factors, such as UCT's rapid expansion to cope with continually increasing student numbers, the Unit often finds itself playing "catch up" as apposed to being aware of all changes before they happen. A lack of drawing rules or standards for external contractors is another reason for incomplete or conflicting datasets. A drawing standards document has recently been compiled by the PPU. This standards document relates to basic concepts such as: colour standards, line

thickness and, most importantly, which features or data should be drawn on each layer as well as the exclusion of all hidden layers (hidden layers are only hidden in the original CAD package they were created in). In theory external contracts will not be signed off until all drawings have been supplied in the required formats and structures. While the PPU has been very helpful in the identification of problems with their current data capture and storage techniques they are only able to adopt a “From now on...” approach as they do not have the manpower or time to adopt a “Redo.....” approach.

To complicate the issue it has become apparent that various other departments store spatial data, usually use-specific, but due to poor communication and data handling procedures this data has not been compiled into a single dataset.

An effort has been made to standardise the PPU’s spatial data holdings into ESRI’s shapefile format. A spatial survey was also done of UCT’s Upper Campus in order to provide a baseline dataset for the GIS.

5. Spatial Data Conversion and Creation

In order to represent UCT using a GIS it is essential that spatial data covering the extents of the University exists at the right scale and in the right format. The process of spatial data collation can be divided into two separate requirements. The first requirement is to ensure that all existing data is in a usable, universal format. For the purposes of this project that format is ESRI's shapefile (.shp) format. The second requirement is that data be collected in order to "fill holes" in the existing datasets.

As the spatial datasets of UCT exist either as CAD files or paper maps it is necessary that this data be converted to shapefiles, via a CAD (.dxf) to shapefile (.shp) format conversion or digitising paper maps to shapefiles. Due to the piecemeal nature of many of the spatial datasets a baseline spatial dataset is also required in order to tie all existing data together. The processes for fulfilling the above requirements are outlined below.

5.1 CAD to GIS format conversion:

In order for the PPU's current spatial data holdings to be incorporated into a GIS system it is necessary to convert all CAD drawings into a format more compatible with the GIS package used. In this case it is necessary to convert all CAD drawings to ESRI's shapefile (.shp) format as most of the GIS packages used by UCT are ESRI products.

Those building plans of UCT buildings which are kept in electronic format are kept as Microstation (.dwg) files. Unfortunately this is a proprietary format and not generic to the ESRI line of GIS software packages. Hence a formatting conversion is required. Firstly the .dwg files need to be converted to the more universal .dxf CAD format. This should be done from Bentley's Microstation, but is possible to do from most CAD packages. ArcView is able to read .dxf files and so this conversion is necessary to get the baseline data into the GIS package.

A CAD file is usually constructed of various layers depicting different feature types, such as Text, Polygon, Line, etc., while in ArcView every feature type or layer is represented by a different file (.shp). This leads to multiple shapefiles being created

from an individual .dxf CAD file. All relevant CAD layers need to be converted to Shapefiles individually.

The GIS software does not read assigned layer names as a CAD package would, but only the layer number. It is therefore important that the various CAD files representing the Universities buildings have the same layer structure with like features falling on the same layer in all drawings. Although some attempt has been made to do this in the past there has been no strict formatting control and so it is only possible to say that, generally, most drawings conform to a fixed layer structure.

The need to convert from one format to the other is not only for application preference, but has a more practical reason. The CAD drawings are “flat files”, they store no attribute data concerning the content of the drawing and what you see is what you get. The closest these CAD drawing gets to attribute data storage is the text or label layer resident in the CAD file. There is no direct link between the text layer and the other drawing layers other than that association which the human eye makes when viewing the drawing. There is a spatial connection between the text layer and other layers in the drawing, but no software connection. For the purposes of GIS it is necessary to create this software connection. This is done via the Spatial Join operation inherent in most GIS packages.

The Spatial Join function simply merges the attributes of two data layers by assigning the attributes for features in one layer to the “closest” feature in a second layer. In the CAD drawings every room has a label. If the “room” layer and the “text” layer are converted to shapefiles then the labels or attributes in the “text” shapefile can be assigned as attributes to the “rooms” shapefile by performing a spatial join between the two. Firstly both CAD layers need to be converted to shapefiles. For the “room” layer this is simple, the layer containing the room polygons is selected and converted into a shapefile. For the text layer it is a little more complicated. Firstly a label may overlap more than one room, secondly the GIS package does not see a label as text, but as a line with a text attribute. If all the lines of the “text” layer fall completely inside a single polygon then a spatial join to transfer attributes from the “text” lines to the “room” polygons can be performed. However, as mentioned above, the “text” line may overlap more than one room polygon. This in turn would lead to one label attribute being joined

to more than one room, or the label attribute being joined to the wrong room. This problem is resolved by converting all “text” lines to centre-of-gravity points. This method is based on the assumption that the centre of the label falls over that polygon which it was designed to represent. This may, in fact, still not be the case, but has returned a much higher success rate than doing a spatial join between lines and polygons. A small amount of user editing may be required to ensure that there is a one-to-one relationship between labels and polygons. It is possible to conduct the spatial join between points and polygons before any editing is done as the process will report the number of un-joined features, or features which took part in more than one join.

Once the label attributes have been joined to the “room” polygons the “room” shapefile represents the room layout for a particular level of a building, with associated attribute data attached.

Once a complete “room” file has been created three other layers are converted to shapefile, these are: The line structure layer, the polygon structure layer and the building outline or footprint layer. Line structure is simply for representation and allows the user a more detailed view of a building level. The polygon structure layer is used to calculate areas. It is subtracted from the room polygons to calculate room areas (i.e. should a room have a pillar in it the area of the pillar must be subtracted from the area of the room to obtain an area representative of available floor space). The outline or footprint layer is used as an outline representing the external extents of the building as well as representing the building at an increased scale (i.e. when viewing a map of the whole of Upper Campus, for example, the user will only see this footprint file in order to simplify the view).

Although this process was not automated during this study it is possible to do so using ESRI’s ArcView or ArcGIS through the use of scripting or extensions. A script is a user written routine or function (similar to a macro) which can be run to perform certain predefined processes. An extension is the compilation of a script into a small program which can be “attached” to the original GIS package, hence the name “extension”. The drawback to automation of the conversion process is that it will assume the conditions of every conversion to be identical. This in turn requires that all CAD drawings are drawn exactly to a specific set of standards, eg. Ensuring that all features of a type

always fall on a specific layer and that all label centre-points fall within or over the feature that said labels represent.

Once all CAD drawings have been converted to the required shape-file format, and georeferenced, it becomes possible to enter them into a single GIS “view” allowing the user to see the real world spatial relationship between the drawings. In order to augment this overall view it is necessary to collect some baseline spatial data of the site in question.

5.2 Creating the Campus Map

Although this FM system focus’ on the interior space of the university it was deemed necessary to create a map of campus for overview purposes. This baseline dataset is required in order to relate all other spaces on campus to each other. Although the Upper Campus of the University Of Cape Town has been surveyed many times, these surveys were generally piecemeal, covering only the area of interest for a specific project, and the data stored in various formats including CAD and paper based maps. These surveys, while useful, were too piecemeal or outdated to fully serve the purposes required by the Facilities Management System and UCT’s Physical Planning Unit and so it was undertaken to resurvey the Upper Campus of UCT in order to create cohesion between existing survey records and to create a baseline reference map.

Due to the location of the University, namely on the side of a mountain, GPS proved to be unsuitable for 80% of the required site area. This was mainly due to mountain’s “shadow” which occluded a large portion of the available satellites. The Upper Campus of UCT is also built up, resulting in urban canyons and a great potential for multipathing. The lower slopes of the university were surveyed using GPS. The extent of the GPS survey was limited to the sports facilities and fields as sufficient satellites were available in these open areas to allow for accurate measurement. The top 80% of Upper Campus was surveyed using the traditional tacheometric approach.

The Department of Architecture, Planning and Geomatics has placed and maintains a network of control points and bench marks on Upper Campus for teaching purposes. This network was used as the ultimate control for the Upper Campus survey. The survey consisted of running traverses to extend control to required areas, followed by a

tacheometric survey to pick up relevant features. Only basic features were surveyed, namely road and parking lot outlines and building corners.

The road and parking lot outlines were surveyed in order to provide a baseline infrastructure dataset. The building corners were surveyed in order to georeference existing building plans. This was necessary as the current plans for the buildings being used are the “as planned” plans as apposed to the “as built” plans. This means that the original plans for the buildings were being used and that any changes that were made during the construction or at a later date were not represented on the plans, rarely will a buildings dimensions and absolute location match exactly with those of the original plans. Inconsistencies were identified between the “as planned” and “as built” plans, but these were considered to be sufficiently small not to warrant a large investment for corrective purposes.

All data was processed using Microsoft’s Excel spread sheeting software. While more specialised software is available Excel was considered sufficient for the task at hand. Once a point cloud was created it was imported into ESRI’s ArcMap. ArcMap was then used for all editing and visualisation purposes.

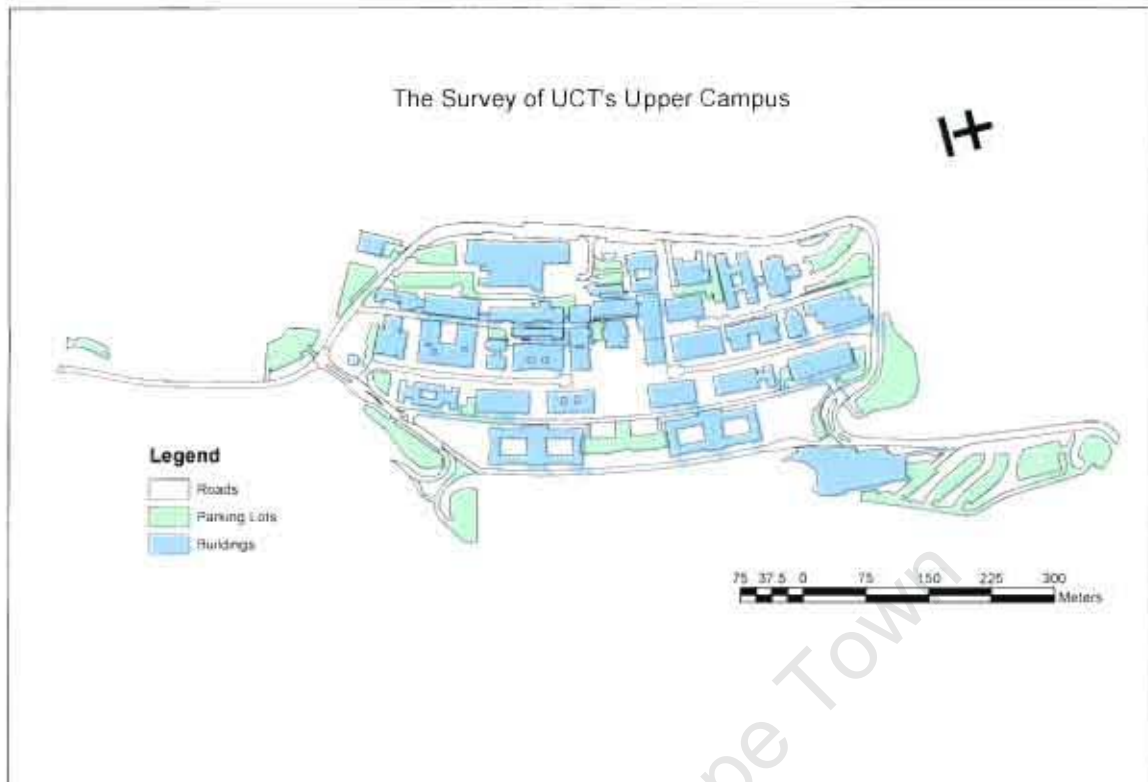


Figure 21. The roads, parking lots and buildings of Upper Campus, as surveyed for this project

A three dimensional triangular irregular network (TIN) was also created using the height data obtained during the survey. This TIN was then used to generate contours for the Upper Campus.

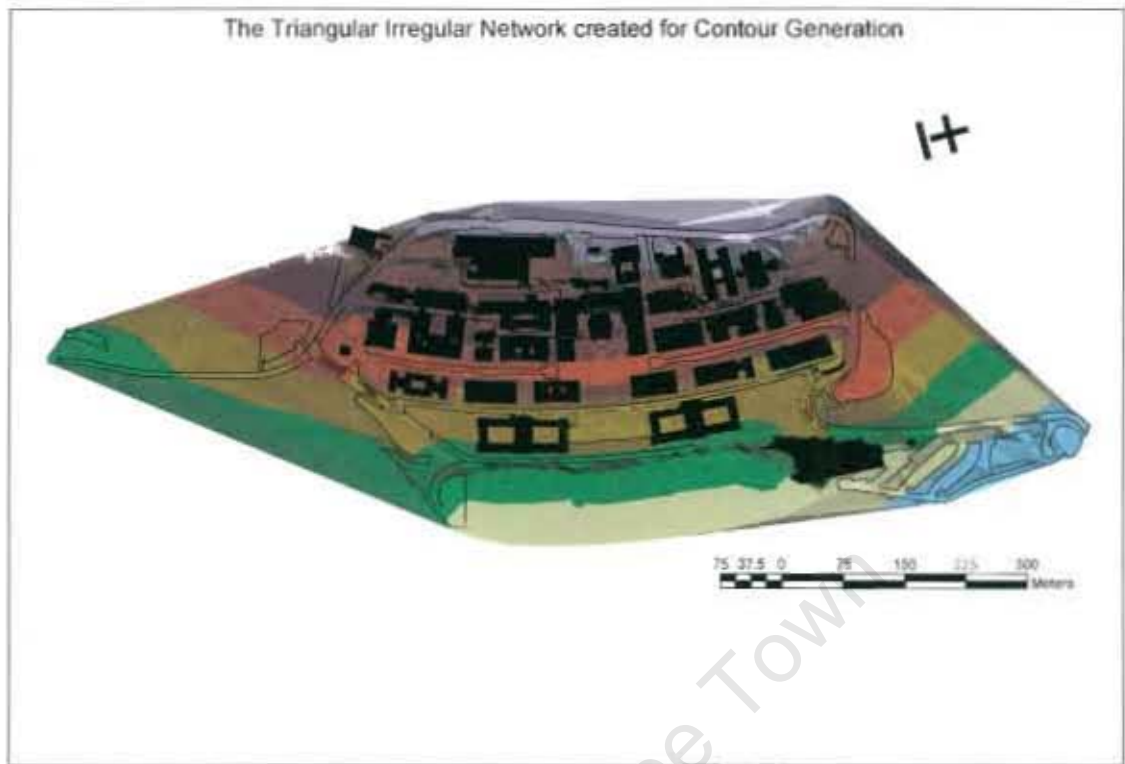


Figure 22. The TIN generated for height data on the Upper Campus

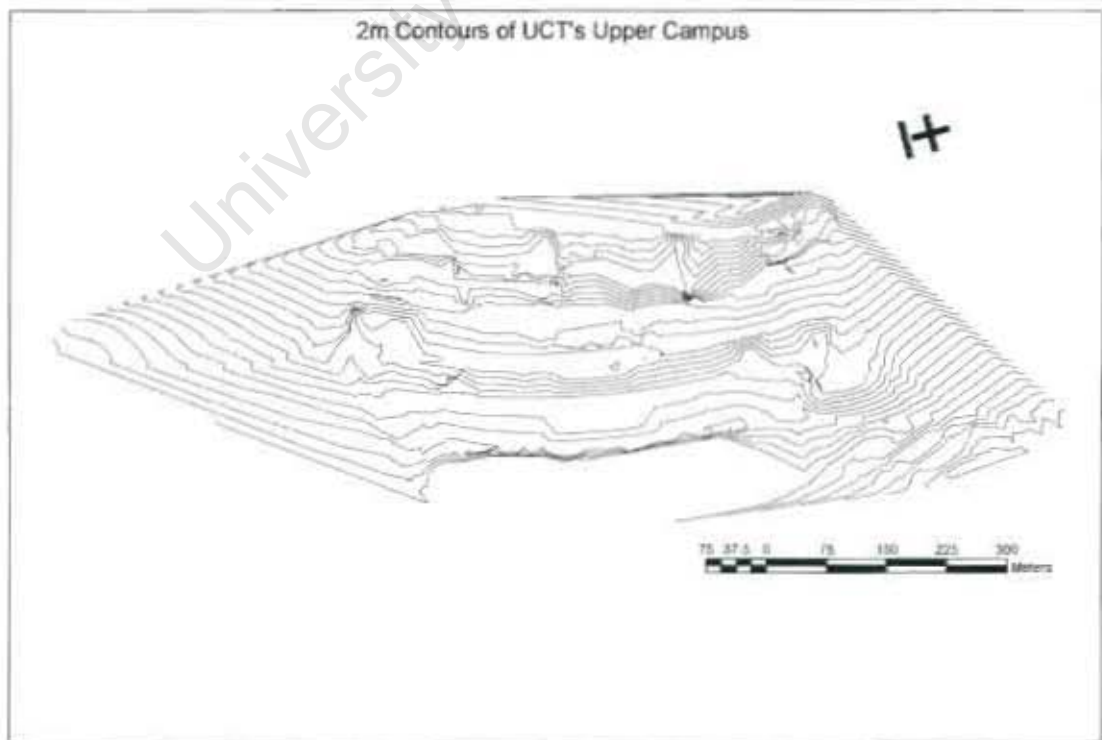


Figure 23. Contours of Upper Campus generated using the TIN

This map, while relatively sparse, was considered to be sufficient for the basic purposes of a general overview of Upper Campus. This data has already been used for both planning and academic purposes with regard to the alleviation of the parking issues which plague the Upper Campus. A more detailed survey, while required, was beyond the resources available for this project.

Once all the required data types have been identified, sufficient datasets have been created and formatting issues have been resolved the data is ready to be combined into a Facilities Management System.

University of Cape Town

6. The Spatial Database

6.1 Introduction

ESRI defines a spatial database as:

“A geographic (spatial) database that is hosted inside a relational database management system that provides services for managing geographic data. These services include validation rules, relationships, and topological associations.”

(Building a Geodatabase, GIS by ESRI, 1999)

Spatial or Geodatabases are essentially conventional databases with the added ability of being able to store spatial data. By combining all the data types into a single system it becomes possible to conduct complex analyses and queries across a wide range of themes easily and efficiently. It also allows for quick and easy representation by allowing users to create thematic maps and graphics without having to cross reference from various, dissociated data stores. An example of how a spatial database can improve workflow is given below. The following two figures were created using attribute data attached to the shapefile of a single floor of one of UCT's buildings.

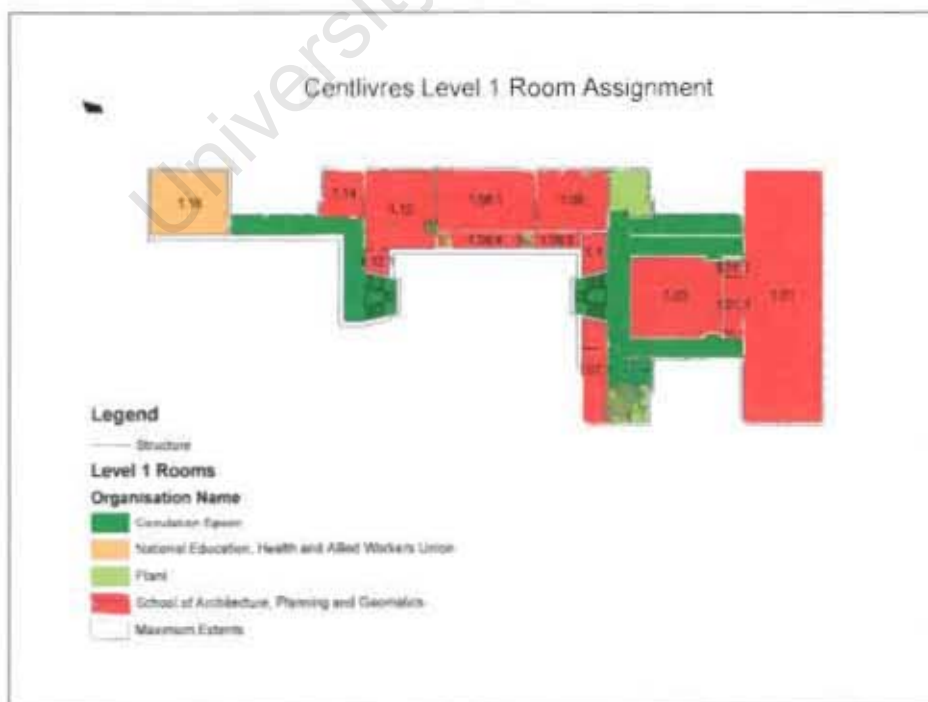


Figure 24. A Room Assignment plan generated using GIS

The above layout was created by choosing which attribute to symbolise by within a GIS package. Traditionally such an image would be created in CAD with the symbolisation being created manually by cross-referencing the existing CAD drawing of the building level with a database containing the room assignment data of that level. With this data stored inside a spatial database such manual cross-referencing is not required as all the data used to create the graphic is stored inside a single system. It is also possible to change the criteria of the display quickly and easily by symbolizing by a different attribute stored within the database. Another example is given below.

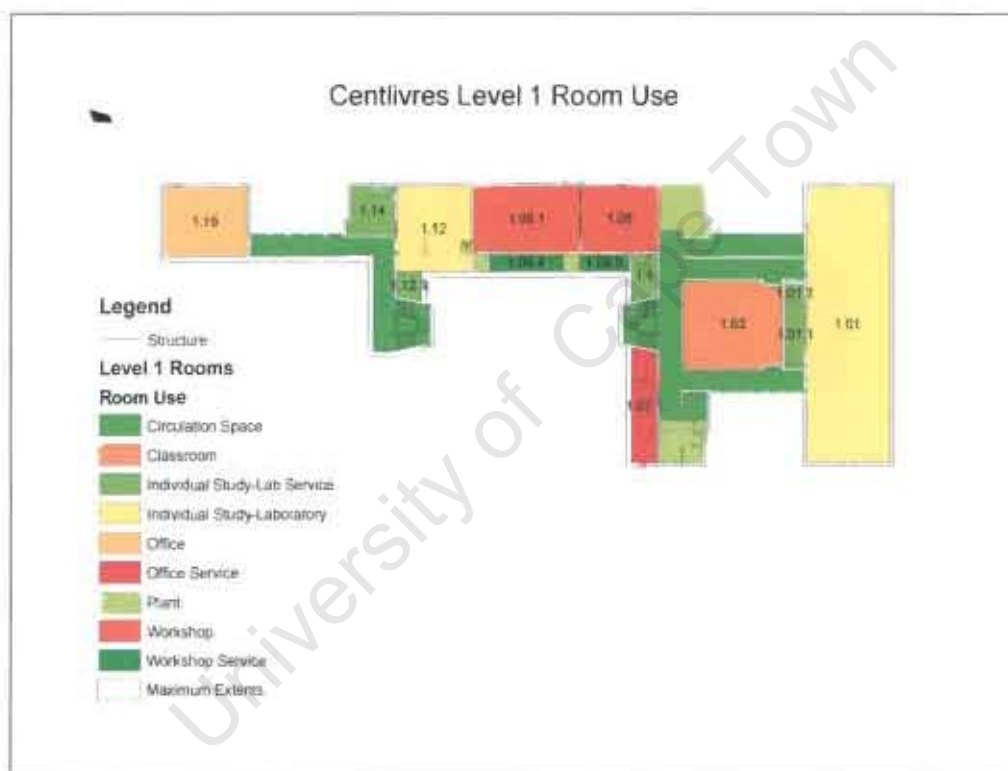


Figure 25. A Room Use plan generated using the same GIS as above

In order to combine spatial and non-spatial data together in a single system it is necessary to identify or create links between these data types. This is most easily done in the spatial context, i.e. the physical location of the non-spatial data is taken into account in the database. Should a particular entity or process be associated with a particular location then a link needs to be created between this entity/process and that location. This is done in using the standard database practise of keys.

Due to the vast amount of non-spatial information stored at UCT it quickly became apparent that trying to incorporate it all into a single system was well beyond the scope of this project. This would be a considerable task and would require considerable time and investment on the part of the University into various information technologies. It was decided, rather, to create a database or library of all spatial data on UCT with unique indices for each spatial entity. By publishing tables relating indices to buildings and rooms it would become possible to join non-spatial and spatial data.

6.2 Creating Unique Indices or Keys

In order to create keys between spatial and non-spatial data it is necessary to uniquely identify every spatial unit or entity in the database. For a facility such as the University Of Cape Town the most basic spatial unit was identified as the room, with rooms being grouped under a larger entity, the building. One can then take this structure to the campus level with buildings being grouped by campus. This leads to a hierarchical structure of one-to-many relationships. Data associated with a campus is applicable to all buildings on that campus and, likewise, data associated with a building is applicable to all rooms in that building.

All rooms in UCT are identified by a name. While this name is unique inside a building it is not unique inside a campus, i.e. two buildings on the same campus may contain rooms with the same name. This becomes apparent when one understands the naming convention. Room names are constructed by the room's position inside a building. A room on level five of any particular building will have a name which starts with a 5. Rooms are then numbered sequentially by floor, so the first room on level 5 would be room 5.01, etc. Further, should a room be sub-divided the sequencing starts again so if room 5.01 was divided into two offices they would be numbered 5.01.1 and 5.01.2. While this system uniquely identifies rooms inside a building the rooms on the same level of a different building would be named the same way.

Two methods for uniquely identifying the rooms were considered, the first was to assign a unique code to every room on campus. This field would uniquely identify every room, but would have to be a "hidden" field in the database as the numbers would be nonsensical to a

human user. This method held appeal as such unique identifiers already exist for most UCT rooms. The only room types not assigned such a unique code in the PPU database are Custodial and Mechanical space. This is due to these spaces not being directly administered by the PPU. Another advantage of this system is that there is no need for room's unique code to be sequentially numbered, if a room were to be sub-divided after having its unique code assigned that code would fall away and to new, unique codes would be generated.

The second method of unique identification is far more intuitive. That is to combine the unique building code with the room name. All UCT buildings are assigned a unique code, regardless of campus. A combination of this code with a rooms name would identify the building and then the room, thus uniquely identifying the room. This code would make far more sense to a user as they would be able to interpret the number. The disadvantage of this system is that should rooms in a building be changed it could lead to a large number of records being updated as new room numbering could have a cascading effect.

The first method of identification was chosen as handles for the spatial entities. The reason for this was more practical than the arguments laid out above. Quite simply there is no convention for a "room names" format and departments differ in how they record these names. Some use periods, e.g. 5.01.2, while others do not, e.g. 5012. While this seems a reasonably trivial issue it has great bearing on the "key" field for rooms in the database. Firstly the inclusion of periods limits the data-type of such a field to "text" and not "integer" and secondly it leads to ambiguity. A human may well see that 5.01.2 and 5012 are in fact the same rooms, but a database package would see these as two different rooms. The second reason for using a uniquely generated index was that, as mentioned above, these uniquely generated indices already exist for most UCT rooms. While this issue is not simply solved by the creation of a unique identifier the possibility for the creation of look-up tables is created. Should a department require the use of spatial data they would not need to significantly alter their database to comply with the codes convention, they would simply need to create a look-up table to act as an "interpreter" between their database and the spatial database.

6.3 Database Relationships

As mentioned above there are three basic spatial entities in the database, these are: Campus, Building and Room. These three entities have a one-to-many relationship, i.e. a campus can have many buildings, but all those buildings are on one campus, likewise a building may have many rooms, but all those rooms are in one building. This leads to a very simply database structure.

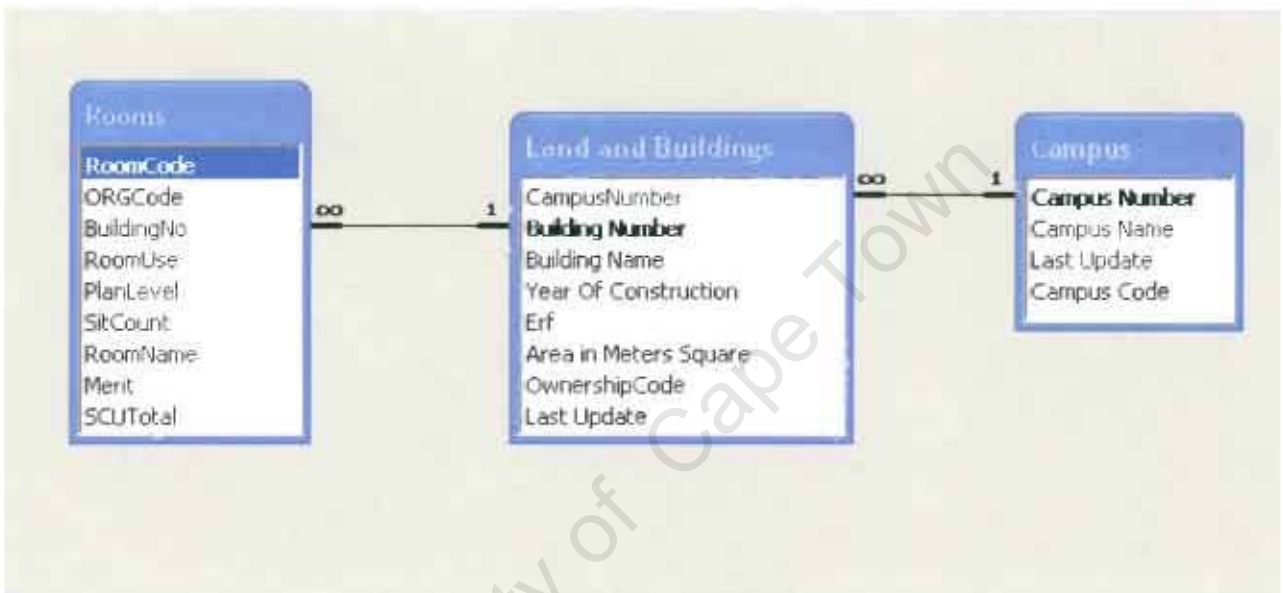


Figure 26. The core entity-relationship model for a spatial database for UCT

This structure is expanded somewhat by the inclusion of lookup tables to expand the amount of data stored about each entity. While most attribute data is stored by conventional databases some of this data is inherent and so is best stored with the spatial data. Two forms of attribute data were identified to be included in the spatial database, both relating to rooms. These data-types were: Orgcodes and Room Use. Orgcodes are codes used to identify the various administrative or managerial entities at UCT. These are codes representing such entities as faculty, department, unit, etc. By attaching orgcodes to rooms it is possible to identify who the room “belongs” to. The second attribute included in the database, Room Use, is included to identify exactly that. While a department should be well aware of the use made of the rooms it occupies the inclusion of room use allows for a higher level of analysis. It also allows a central standard for administrative entities to compare there records against, thus ensuring a single store for such data. Thus the database structure can be expanded.

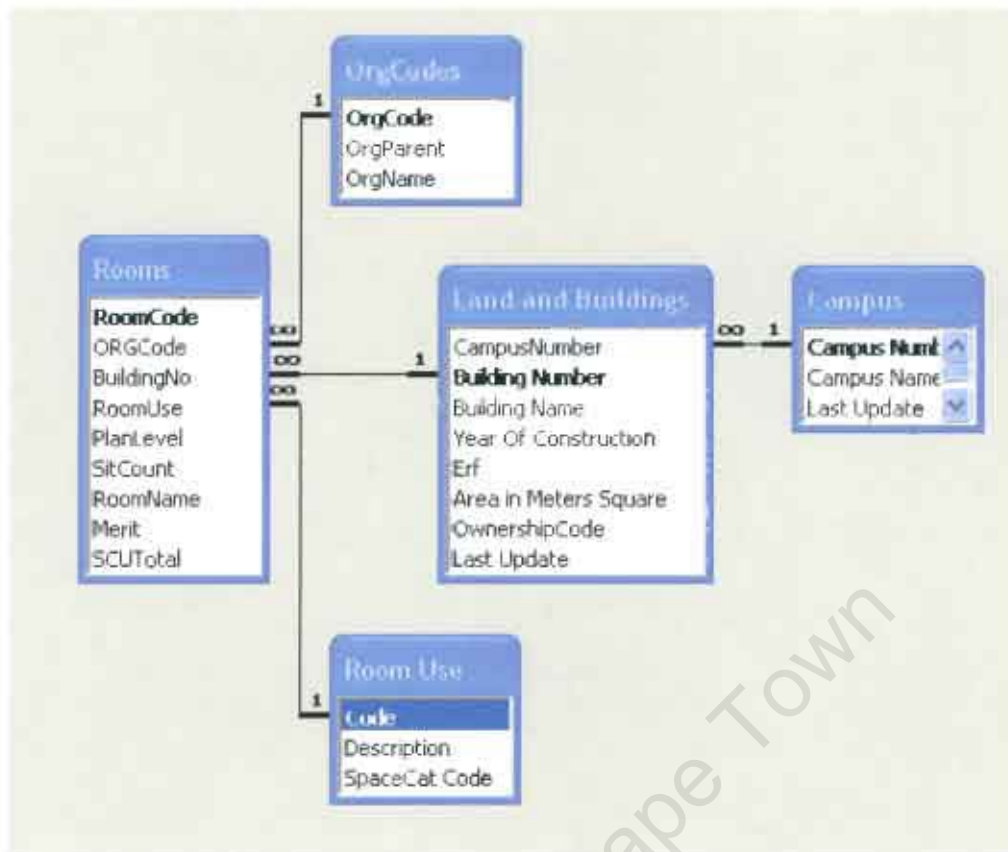


Figure 27. The core model expanded to include important attribute data

For the purposes of the PPU all other attribute data can be connected to the tables shown above through the use of unique keys. A full database structure, containing all spatial and attribute data, was constructed for the PPU.

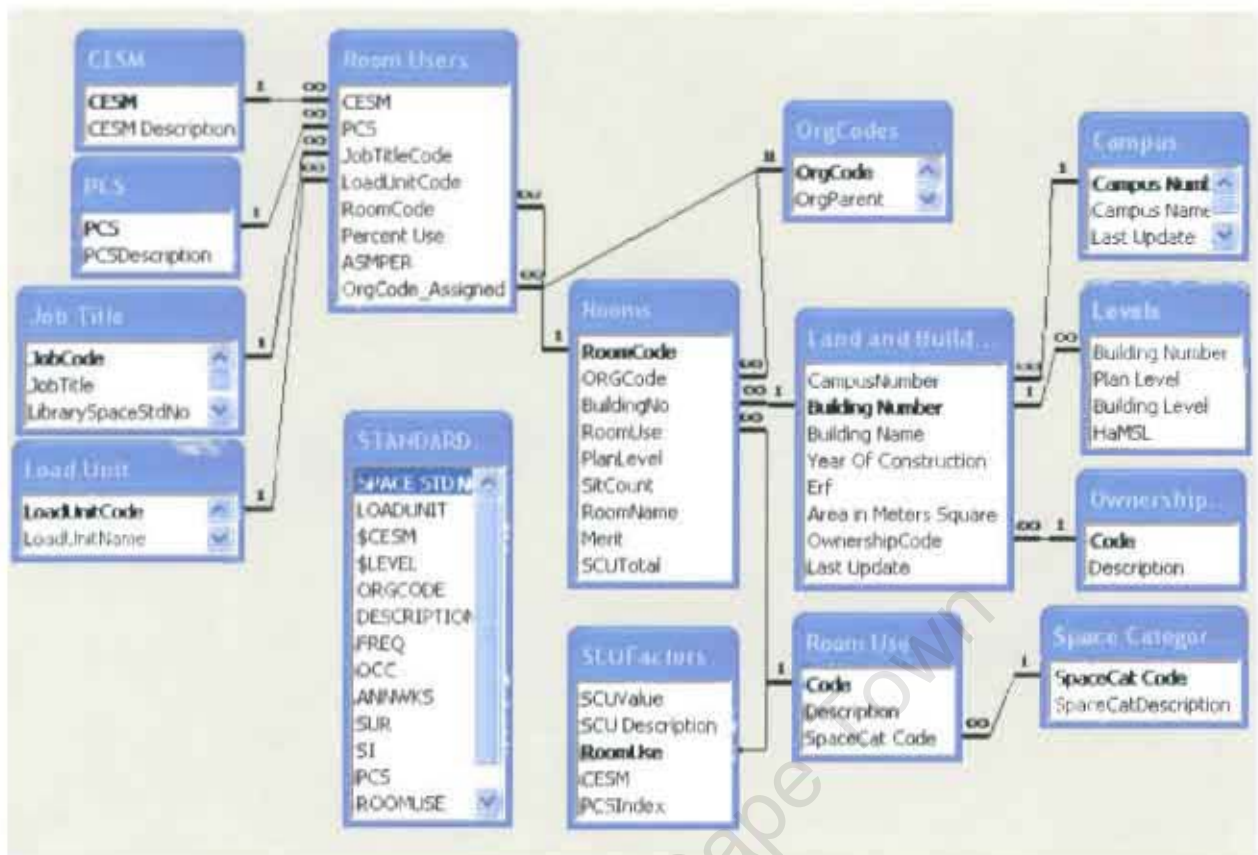


Figure 28. The core data model expanded to include all data types stored by the PPU

This entity-relationship model was created in Microsoft's MSAccess database package, which is not a geodatabase, however, the relationships would remain the same inside a geodatabase. It is also possible to connect MSAccess databases directly to ESRI's ArcView using the Structured Query Language (SQL).

As is seen above the connection of attribute data to the basic spatial database is simply a matter of finding a unique identifier or key between the two datasets. For the purposes of the PPU it is important to have both spatial and attribute data stored inside the same database permanently as the integration of the two data types is core to the functioning of the Unit. For UCT entities outside the PPU requiring the use of spatial data the core database, represented in figure 13 above, would be sufficient to provide connectivity between attribute data and the spatial data store.

7. System Development

The conducted investigations showed that the potential for the scope expansion of this project is enormous. It was decided that the main focus would be on the following three tasks: Data manipulation, System development, System motivation.

7.1 Data Manipulation

As discussed in the previous section, the relevant data holdings are, in many cases, incomplete, disparate, obsolete and in conflicting formats. In order to integrate these data sets into a single system the challenge is twofold: Create universal formatting rules which are then applied to all relevant datasets and, through considerable investment, the updating, correcting and verifying of these datasets.

7.1.1 Formatting: The implementation of universal formatting for data storage would considerably improve the potential for amalgamating UCT's data stores into a single system. It would also allow for easy data sharing between departments as well as increasing the ease of handover to new employees. Once an employee understood the workings of one department's data holdings migrating to another department would require only a familiarisation with the data itself and not with the management system.

7.1.2 Data Integrity: A common axiom for both mathematical formulae and computer programs is "*What you put in is what you get out*", i.e. no matter how impressive a computer program or system, its outputs are still entirely dependent on the data it has to work with. The lack of data integrity in the PPU's SPACENOW database is an example of a system which cannot give reliable outputs due to the unreliability of the data stored within it. The verification of current data, along with the capture of new data is, potentially, the most cost intensive process required in order to implement a successful Facilities Management System at UCT.

Addressing both of the above challenges would considerably improve the Universities ability to handle and analyse data regardless of whether or not a Facilities Management GIS is implemented.

7.2 System Development

Of all the tasks required for the development of a Facilities Management System this one falls mostly into the realm of the “techies”, i.e. software developers and systems analysts. This is the area where it is most important to respond to “demand pull” and not “technology push”. Although technical expertise is required to develop the necessary software, development should be governed by the academic needs and business procedures of UCT and not by the potential of the technology available. One of the big questions for system development is whether to use a single package specifically designed for facilities management or to create a union of software packages already in use. Both of these options are a means to the same end, the question is not which the better means is, but which is the most suitable?

Single system packages do exist for facilities management purposes. These include ESRI's ArcIMS facilities management package among others. The advantages of a single package system are obvious, namely the need for training in only one software package and a single, central data storage package. All spatial and non-spatial data is stored in the geodatabase and no cross-package linkages are required to perform queries and reports on the datasets. The symbolisation and production of maps or plans is also the function of this single system.

This type of system is ideal for a department whose sole function is the management of a facility, in this case a university. Such a system would require considerable re-education of current UCT staff as well as a dedicated server with full time administrators. The system would also require any external users to either undergo considerable training or operate through a trained technician.

Most UCT departmental requirements for spatial data are limited. Very few departments have a continuous need for GIS type operations and the maintenance of a conventional database is sufficient for most of their purposes. Occasionally a

department or faculty will need a graphical representation of their assigned space and utilisation. If a single facilities management package were maintained by a dedicated department then such a requirement would be a query of that department. All data to be visualised would be exported to the facilities management software and the required visualisations produced.

Using a multi-package system, i.e. a GIS package with linkages to a conventional database package or packages, it would be possible to link the data to be visualised directly to the spatial dataset. This operation is considerably less complex and could be performed “in-house” with a minimal amount of training.

When considering a FM system the following questions arise:

- Do we want to create a system which will then govern our data storage and manipulation methodologies?

or

- Do we want to provide a tool which can be used alongside current management tools at UCT?

and

- Do we wish to create a single facilities management system which would require a considerable investment of time, money, staff and hardware?

or

- Do we wish to create a tool which will be at the disposal of any interested parties within the universities management hierarchy?

Answering these questions is not a simple task and it is unlikely that decisions based on these questions will be black and white, however, it is important that these questions are well considered in the decision making process.

The creation of a baseline spatial dataset is of the utmost importance, regardless of how it is then implemented. The use of this dataset within a GIS package which would allow the import of or the connection to existing non-spatial datasets would allow for the visual representation of data, allowing for overlay operations and analysis quickly, easily and efficiently. These operations could just as easily be performed by a facilities management package, however, a facilities management package requires a far more

formalised operation procedure as well as a greater amount of support for the system. Current on campus GIS knowledge does not extend as far as facilities management programs and so external consultancy would be required in its conception and installation.

The question here is not which is the best system available? Instead the question should be what are the requirements of the University? Is it necessary to invest large amounts of time and money as well as set up a dedicated administrator for such a system, or would a lower end system, administered by the PPU or another existing department alongside their current systems be sufficient?

Another consideration is that with a complete spatial dataset of the universities property holdings it should be relatively easy to upgrade from the lower end system to a single, facilities management package.

The greatest issue of such a system for UCT at the moment is not which system to use, but what data to use. Once a baseline dataset is created, using ESRI's shapefile format, the type of system used is governed only by the fact that it should recognise this format, i.e. be an ESRI product. This is not as great a limitation as it would seem as all the universities current GIS software licence agreements are with ESRI.

The question of system is more a question of how is the data going to be used to service the organisation. A powerful system capable of performing extreme data analysis and manipulation, while impressive, is pointless if only 5% of its functionality is going to be used by university staff. A single package system would also place far more constraints on data management than using a GIS which integrates with current database packages. Though it has become apparent through observation that there is a need for data standardisation on campus a single facilities management system would create a far more inflexible set of standards than an integrated system.

The implementation of the SAPR3 system has suffered greatly by the fact that the system requires set data formats with specific workflow types. It is therefore apparent that the implementation of a system which sets "the way things should be done" is a less than ideal and that a system which allows one to "do things the way we want to" would meet with far greater success at UCT. Obviously it is not possible for any

system to meet all the requirements of every user, but an open ended approach is far more likely to receive acceptance than one which specifies work methodologies.

For this project it was decided that system development would entail the integration of various types of software packages, namely a database package, a CAD package, a GIS package and possibly a web design package.

7.2.1 A database package: Although this system centres on space it is often the attributes of space which analysts are most interested in. Many tasks can be performed without having to refer to the spatial component at all. It is therefore necessary to have a central database where all attribute or qualitative data is stored for the purposes of update, retrieval, query and reporting.

7.2.2 A CAD Package: A standard computer aided drawing package is required for the easy update and creation of spatial data. Although most modern GIS packages support the easy update and creation of spatial data the tools available in most CAD packages are more powerful, and more familiar, allowing for greater ease of use for the staff responsible.

7.2.3 A GIS Package: The GIS is to serve as the user interface. Users will be able to combine both attribute and spatial data in a single interface allowing for advanced query and analysis procedures. The GIS also allows for visual analysis by displaying query and analysis data in a view. This allows for an “on the ground” scenario creation.

7.2.4 A Web-Design Package: the creation of web-forms would allow the system to be used on the Universities intranet. This would allow for query, analysis and updates to be conducted by the relevant users without having to consult a centre. Access rights are an issue with this scenario, but if clearly defined the web based system has great potential for ensuring the use and success of the system.

7.3 Motivation for the System

This is potentially the most difficult phase of any software system development. Without the support of key role players and authorities, as well as enterprise wide understanding and support such systems are doomed to failure from inception (Derek Reeves, James Petch,1999). While official support for this project is forthcoming from the PPU they lack the resources to single-handedly implement an enterprise wide facilities management system. Through informal consultation it has become apparent that other departments support the concept and realise its potential, but once again lack the resources to contribute significantly. Most noticeable in their informal support is the Networks Unit of the Information Communication and Technology Services (ICTS) Department.

The above discussion reveals that the investment required for the development of a Facilities Management GIS is large. The resources, cooperation and understanding needed for the development of such a system require an enterprise wide commitment. From this it becomes apparent that without the commitment of all levels of the management structure such a project could well fail.

8 CONCLUSIONS AND RECOMMENDATIONS

The development of an integrated facilities management system for UCT could improve the Universities management of limited resources to gain optimal utilisation from the space and facilities currently available to UCT management. Such a system would also bring the PPU more in line with modern facilities management practises.

8.1 Data issues

A FM would dramatically improve data handling and storage. This is crucial to any facilities management as all decisions are based on the available data. The better the data, the more informed decisions will be. A FM would also facilitate data sharing, allowing other departments within the University greater access to spatial data and its associated attributes which could create the opportunity for them to participate in better informed decision making. All spatial data concerning UCT must conform to a rigorous set of standards. While an effort is being made to ensure that this occurs, it is necessary to revisit older datasets and manipulate them to reflect the standards in place. It is also necessary that any new data, whether collected “in-house” or by external contractors is not signed off or accepted until it complies with the spatial data standards of UCT.

These standards must not only be concerned with formatting but must also serve as a quality control in order to ensure the accuracy of the data.

In the case of a new feature or structures on campus it is important to ensure that the spatial data or plans of these structures reflect the features “as built” and not “as planned” as the management of new features will only be concerned with their true state and not their envisioned state. While it would seem that a feature or structure should be a reflection of the plans for it there are often discrepancies, some bigger than others, between the two.

All spatial data, with relevant attribute data or handles, must be compiled into a single spatial database in order to create a comprehensive spatial data set. While the structure of such a spatial database has been laid out in this thesis it has not undergone implementation. The structure laid out here should serve as a guideline for a spatial database for UCT, but some revision may be necessary at implementation to ensure the correct functioning of the database.

8.2 Management and Business process issues

In response to the questions laid out in paragraph 7.2 above it is vitally important that any FM system that may be considered be forced to operate according to the terms of the University. That is to say UCT must have a clear idea of what is required from the system and how it would serve the management of UCT and translate this into a clear definition for the development of the system. The implementation of an “out-of-the-box” system is not recommended for UCT. Rather, any system implemented by UCT should be developed in close consultation with both potential everyday users as well as casual users in order to increase its appeal as a management tool.

It is imperative to review the organisational structure to ensure that the implementation of a FM system will be to the maximum benefit of the organisation, to this end it is necessary to incorporate all levels of UCT management and potential stake-holders into the decision making process which would govern the development and implementation of an FM at UCT.

It is necessary to ensure that the technical expertise and know-how concerning the machinations of an FM system and its subsystems are available for system development.

While the staff at UCT do possess many of the technical skills required for the implementation of an FM system it is recommended that external consultants and software vendors be contracted to specify and oversee development of various subsystems to ensure their correct function and connectivity within the system as a whole.

Although the outsourcing of technical and business requirements is recommended it remains imperative that UCT remain firmly in control of the decision making process. The system must reflect the needs of UCT and not the perceived advantage of what is technically possible. The project must respond to “demand pull” and not “technology push”.

8.3 Software issues

Although it has been specified that all spatial data collected conform to a specified set of standards it is unlikely that all sources will be able to provide data in ESRI's shapefile format. It is therefore necessary to allow data to be handed over in a more universal format. The CAD standard .DXF format is recommended as the best format for such a purpose. All external sources should be able to provide data in this format and converting the current CAD drawings of UCT to the .DXF format is a trivial, though time consuming, process. A system should be put in place for the easy conversion from the .DXF format to ESRI's shapefile (.shp) format. It is possible to script such a conversion process and it is strongly recommended that such a conversion process be implemented.

A high level decision is required as to what type of FM system should be implemented. While it is recommended that a multi-package, inter-connected system be implemented to allow a piece-meal approach to FM implementation with minimum disruption to the day to day running of UCT the possibility of implementing a single package system should not be discounted. The implementation of a single package system would be a more disruptive, resource intensive process, but would probably show finished results in a shorter time frame. A final decision on which system to use should be the result of consultation with all stakeholders as well as an in-depth understanding of what exactly will be required of the finished product.

8.4 Further Study/Work

A comprehensive spatial dataset which covers all of the holdings of UCT is required. This is potentially the most cost intensive activity proposed in this study, however, informed decision making is only possible if all the relevant information is available. Whether to be implemented in the type of FM proposed in this thesis or not it is still strongly recommended that an effort is made to consolidate and ensure completeness of the spatial data of UCT. This may require the resurvey of large portions of UCT, both without and within the built environment.

The potential for implementing intranet access should a FM implemented by UCT requires further investigation. Such access through the use of web forms would greatly improve the

accessibility and appeal of the system. Using web forms with hierarchical levels of access or rights to spatial data sets would greatly improve the function should such a system be implemented.

8.5 The Physical Planning Unit

The PPU commissioned this project in order to improve efficiency and delivery. Through observation it became apparent that this would be possible even without the full implementation of a campus-wide FM system.

The required investment of time and resources for the implementation of a campus management system is more consistent with that of an enterprise wide project, which requires a larger investment of resources than is available for a Masters degree. It was decided that by analysing the PPU's current work flow and setting standards it would be possible to steer their data handling and management techniques in a direction which would be more compatible with an integrated system, as they would be a central role-player in the creation of such a system.

By enforcing drawing standards within the PPU it would be far easier to migrate between spatial data formats, as well as improve data sharing with interested and effected departments. These standards would be applied to data provided external sources, by writing them into tenders and contracts. By standardising data structures and types it becomes far easier to manipulate the data *en masse*, and to maintain data integrity.

A redesign of the SPACENOW database would also significantly improve the operation of the PPU. SPACENOW is an in-house project which has been administered by its users. The database was not created with clearly defined operating standards and is poorly documented. It has also grown far beyond the size conceived by its creator. This situation has resulted in the database having degraded through use. Clearly defined operating rules and data handling methods should be translated into a new database which better supports the functions of the PPU.

While the necessary planning/engineering skills are well represented in the PPU, computerized planning systems require knowledge of the underlying processes of such systems in order to be used to their full potential. Hence staff training or retraining is crucial to the improved operation of the PPU as the current computer skills of the Unit's staff are of a self-trained nature. Current database operation and use are considered a means to an end with little regard for database functionality and integrity. It is not necessary for all staff members to undergo such training, but a clearly defined database administrator should be appointed with hierarchical levels of database access and control assigned according to staff roles.

Furthermore, the use of GIS, its functionality and advantages, should be more actively embraced by the Unit. Only through exposure to the technology will the potential for a full GIS be realised.

8.6 A Spatial Information Catalogue (SIC)

A Spatial Information Catalogue (SIC) is a compilation of all spatial data into a single, central system or software package. Only attribute data which can be used as handles or keys should be stored in this system, i.e. only unique identifiers (ID's) will be stored in the attribute tables associated with the spatial data.

CAD packages, while sometimes allowing the storage of tabular data, are essentially drawing programs. The end result is a picture, or, if one took note of such things as scale, units and/or orientation, a map or plan. A GIS, which has a standard coordinate system, is a package which allows the storage of non-spatial or attribute data with the map or plan. This attribute data is stored in a table which is linked directly to features on the map or plan. It can be used in two fundamental ways: 1) Queries and subsequent symbolisation, e.g. show all buildings with more than three lecture theatres, and 2) As a link between the spatial data and other attribute data, e.g. a table recording the number of network points in every room on campus can be joined to the attribute table of a building plan provided that each has a common unique identifier for each room. This can then be used to symbolise a map of campus showing how many network points there are in each room.

Thus a Spatial Information Catalogue is, very simply, a GIS with the emphasis on location and display. As such it only requires the storage of linkage attributes. Providing departments

with the unique identifiers would allow them to export data from their own databases and attach it to the SIC, thus effectively allowing them to create their own GIS. This method ties in far better with the current UCT “Do it yourself.....” *modus operandi* and will allow those with an interest in GIS to move forward far faster than they would be able to if the entire University were expected to progress together. While such a system could in no way be considered an FM it would serve as an FM tool as well as introduce the basic concepts and advantages of a GIS based FM system to the community of UCT.

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