Parkamax: Parking Management Solution

by

Eloise Swart
26075042

Submitted in partial fulfilment of the requirements
for the degree of

BACHELORS OF INDUSTRIAL ENGINEERING

in the

FACULTY OF ENGINEERING, BUILT ENVIRONMENT
AND INFORMATION TECHNOLOGY

UNIVERSITY OF PRETORIA

October 2009

Executive Summary

With the increase of private car usage, the demand for parking is also becoming greater. Many office buildings have parking areas available to employees and visitors, but is often in short supply. One option is to expand by building additional parking areas; this option requires high capital expenditure. The other option is to manage the available parking space better.

Many solutions to parking problems are available, but each solution only tends to a part of the problem. No complete solution is available. The need exists for a parking management system that encompasses all the elements that contribute to the effectiveness and efficiency of a parking area.

The objective of this document is to give background about the project and parking problems, discuss available solutions and present the development phases and methods used to obtain a complete parking management solution. This solutions will result in a company with management tools, data reports, a payment processing system, security access control, improved parking bay usage, and implemented business intelligence rules. Additionally, it will change parking, previously known as an expense, into an income generating asset.

The Parkamax system will be implementable at any parking area; taking it from its current level of capability maturity to the desired level of competency by building on the existing infrastructure and adding new technologies and system capabilities. This system will be beneficial to any organization with a need for parking.

Contents

List of Figures

List of Tables

List of Acronyms

ERD Entity Relationship Diagram

ORTIA O.R Tambo International Airport

SATT Sport and Traffic Technologies

LPR License Plate Recognition

CCTV Closed Circuit Television

CBD Central Business District

RFID Radio Frequency Identification

iNP Intelligent Number Plate

ILD Inductive Loop Detector

MM Maturity Model

SPII Support Program for Industrial Innovation

DFD Data Flow Diagram

TFMC Total Facilities Management Company

ITS Information Technology Services

NNOC National Network Operation Centre

NBSC National Business Solutions Centre

TARPS TCel Assets and Revenue Protection Services

Chapter 1

Introduction and Background

Futurists are predicting that the world will not end with a bang, but will end when enough people can't find parking place (Buchwald, 1983).

Parking is a problem that creates unnecessary conflict between employees, visitors and the human resource departments of organizations. Parking has even been used as an incentive for jobs applications. South Africa, being a middle-income country, is fast growing and has high levels of car ownership (Shaw, 2006). Parking is therefore a very significant problem for many people. When looking at solutions to the problem in large metropolitan areas abroad, the use of public transport modes is encouraged and the access to these modes are increasingly being developed (Bregman, 1999). The public transport system of South Africa does not fulfil the needs of commuters in all areas of travel.

Better parking facilities have been a hot topic for the properties of ABSA, Telkom, Ellispark Stadium, the Innovation Hub and many office buildings across the country.

The availability of parking spaces depends greatly on the management of the parking area. Below-capacity usage often occurs and results in unoccupied reserved parking bays and a parking shortage for users. Parking is an increasingly valuable asset to any company and the management thereof has become cardinal.

Fourier E, a division of Fourier Approach, was contacted by Total Facilities Management Company (TFMC) to help them optimise the parking areas for TCels three main campuses in Pretoria and Johannesburg.

The initial project included the following aspects:

- Mapping the As-Is processes, including the processes used to allocate and book parking at the Campus (TCel Towers buildings), Centurion and Roseville parking lots

- Investigating problems encountered and opportunities for improvement, taking into consideration other successful installations and a literature review
- Recommended solutions and processes to best optimise TCels parking space

The project was completed and a document was presented to the TCel representatives with recommendations for the revised parking system. The development of this process probed the further development of a comprehensive parking management system that captures all the related components. Fourier E and Venture Solutions collaborated in a joint venture to develop this system.

To capture all the elements of a parking system, parking itself was broken down into its simplest form and divided into four categories. The first category is short-stay parking. This intensive usage parking has high turnaround rates and is found at retails centres. Medium stay parking is seen in urban-type car parks with mixed users; parking is used for business, by visitors or by town-centre shoppers. Parking areas located at the main transport terminals of a city with light and irregular usage times, are known as long-stay parking areas. Tidal parking occurs in staff parks with predicted inflows of cars in the mornings and the opposite at the end of the day.

Parking areas at the TCel facilities are categorized as tidal.

1.1 Problem Description

There is a high demand for additional parking spaces at office buildings. Many available parking spaces are under-utilized; many parking bays are open, but users are told that the parking is full. This creates the need to build or buy parking space, but this capital expenditure rarely generates the required income for the new infrastructure.

To design and implement a complete parking management solution would increase usage and income, without causing major expenses. Many solutions for payment and access control at parking areas are available, but no complete solution is available that provides a payment and access control system, facility management, and business intelligence development. The development of a solution like this would prove valuable to any company that has problems with parking. To catalogue and categorize the problem statement, the PIECES framework was used. (Lonnie D. Bentley, 2007)

1.1.1 P: Improve or correct the performance

- Low utilization of the available parking bays available on the site.

- Manual paperwork.

1.1.2 I: Improve or correct the information (data)

- Inaccurate data.
- Low level of accessibility.
- Low level of reliability.
- Information that is not useful.
- Data is not available in time.
- Data is captured redundantly.
- Data is not well organized.

1.1.3 E: Improve or correct economics (costs)

- Low to no revenue from users (New markets can be explored).
- Unnecessary administrative costs.
- Cost-effectiveness for both the customer and client.
- Costs can be unknown or untraceable.

1.1.4 C: Improve or correct control (security)

- No anti-pass back enforcement.
- No zone movement information.
- Minimum user identification.
- Decision-making errors occur.

1.1.5 E: Improve or correct efficiency

- Complex processes.
- Efficiency and optimality of parking allocation is low.
- No reservation system.
- No add-on modules.

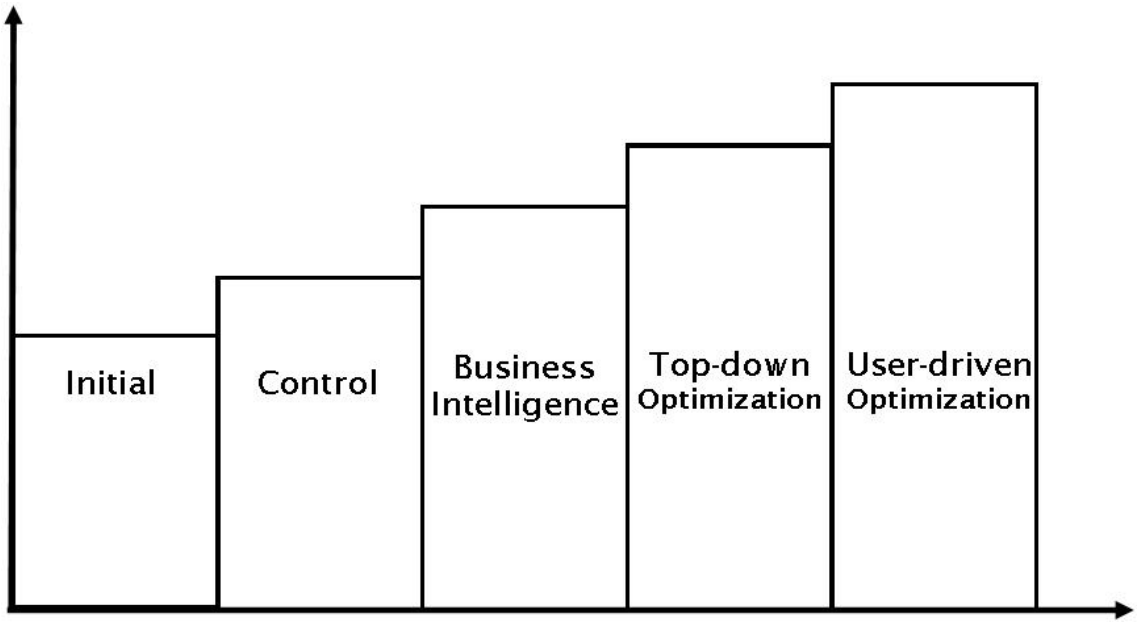


Figure 1.1: Parking Management MM

1.1.6 S: Improve or correct service

- Usability of the system.
- Response to faults and damages.
- Innovation and improvement cycle.
- Change management.
- Compatibility with current system.

These problems are common ones found at parking structures. To identify which of these problem occur at the TCel parking areas, process flow diagrams were created. These will be discussed in Chapter 3.

1.2 Scope

The development of a solution will ultimately increase the utilization of a parking area. It can be divided into the 5 phases illustrated in the Parking Management Maturity Model (MM) in figure 1.1. This model is a static MM of the system as a whole.

The typical constraints for the system include budget limits, the current level of maturity of the parking area being surveyed, a lack of technological skills, the

diversity of the needs of the parking users and parking owners, business policies, and the demand for parking. The scope creep can influence both the budget and the level of maturity required for a parking area. After some implementations have been made, adjustments, improvements or down-scaling could cause scope creep. Before any parking solution will be developed, the statement of work needs to be agreed to. This will foremost include the level of maturity required for the specific project, the costs involved and the schedule of the project.

1.2.1 The role of TCel within Parkamax

The initial TCel project required a basic system analysis and suggestions of changes that can be made that will influence the management drastically.

This part of the project includes the following developments:

1. Gathering of information of the current system.
2. Creation of a status quo document that will be presented to the managers at TCel. This document will give them an indication of the current system. The document will also include possible solutions: information regarding standard systems that can be implemented, as well as business intelligence methods and processes that have been developed.
3. After approval from the client, these solutions will be implemented.
4. An audit of the new system will be performed.

1.2.2 Parkamax Innovation

Together with the development of parking management solutions for the TCel parking facilities, a generic maturity model and system architecture will be developed. This model will be based on the findings from the TCel project and then be used for future projects.

The further development of this project as a generic model that will be marketed and sold to clients, will not be included in this project. Any further developments in the form of web interface reservation and optimization algorithms for the higher maturity levels, will also be excluded.

1.3 Aim

The aim of this project is to analyse the current parking management systems at the mentioned facilities and then redesign and develop a system that would use the

available parking space optimally. The solution will consist of a structure to manage and use the parking spaces that are available at the facility, without adding more parking bays. Parking should be seen as an asset that has the potential to generate income and with the optimized system, an increase in profits will be brought about. The solution comprises hardware and software program recommendations, parking management strategies, and a system design to deliver a complete parking solution.

1.4 Document Structure

This document consists of a literature review about possible solutions, case studies, and different methods that will be used to develop the solution. It then goes on to describe the parking structure used for the initial analysis for TCel and how the Parkamax system idea developed. The complete Parkamax system is then classified according to the different maturity levels and the system design. Future research is then also discussed in the last chapter. Further research topics and development opportunities also follow.

Chapter 2

Literature Review

After further investigation of the parking management systems currently in place, obvious problems in the system were unauthorized access and use of parking bays, unauthorized use of visitors parking bays, lift clubs, collecting payment, over- allocation, skew or incorrect data, and safety risks.

To define these problems according to more specific requirements, the necessary abilities of the system were identified. To further differentiate between abilities, the level of capability should be weighted. The system requires the ability to count the number of cars entering a specific zone, identify open parking bays, indicate open parking bays to new employees or visitors, identify the owner of a vehicle parked on an already allocated parking bay or zone, facilitate payment management for parking area users, supply real-time information regarding parking usage, utilization, and availability, and handle parking bay allocations fairly and freely according to the organization's hierarchy.

There are typical measurables that will be looked at in the parking area itself. The dynamic capacity is the rate at which traffic passes a given point within the parking area, given in units of vehicles per hour. The static capacity within a designated or complete car park, is the total number of stalls. The area of the parking area divided by its capacity is the static efficiency, given as area per stall. The number of vehicles within the car park in an hour, is also a measurable.

2.1 Case Studies

2.1.1 O.R Tambo International Airport (ORTIA)

At ORTIA, Sport and Traffic Technologies (SATT) recently installed their Intelligent Parking system at each of the parking areas on the premises. This consists of

Figure 2.1: LED indicators showing the availability of parking bays

a bay detection system and variable message signs. This guidance systems main objective is to advise motorists of available parking in multiple parking zones and allowing the motorist to decide where they would like to park well in advance of their arrival at critical intersections. The system then directs the motorist to this parking bay along the shortest, fastest route. The system also gives the operator of the parking area complete control over the system by allowing them to monitor and operate the system effectively and efficiently. Benefits of the system are a reduction in congestion, time and fuel spent by users searching for parking, less queues as motorists will go to parking areas with the most available bays, and better flow of traffic through the area. Intelligent parking results in higher revenues and profitability for parking facilities. The software is Windows-based and can operate as a stand-alone system or as part of a client/server architecture. Instant real-time information is available of the operational status of the parking bays with regards to the number of open bays, number of reserved, occupied, and disabled bays, reserved bays occupied past their reserved times, vehicles parked for longer than a determined amount of days, and any damaged sensors.

Many different system and parking reports can be requested for complete control of the system.

The sensors used by this system are SATT BEC 106A sensors. They are mounted above the parking bay in a clear polycarbonate box and use ultrasonic technology to detect if the parking bay is occupied or not. The detection range of each unit can be set from 1 to 8 meters. The unit has the ability to show a green, red, yellow or blue light to indicate the status of the bay, as can be seen in figure 2.1. It uses LED indicators to show the status through a static or flashing mode configuration.

With the SATT technology installed as guidance system, ORTIA still needed a system for parking management, including a fully automated parking and revenue control system that provides a tamper-proof solution, quick response and a centralized control room, amongst other features. Customized reports and VIP access cards at all South African airports, interfacing with License Plate Recognition (LPR)systems and variable message signs, and increased security through Loop and

T theft prevention are future development considerations (Sport and Technologies, 2009).

The ZEAG Group installed the ZEAG-Orion system; a control and management system for parking areas that boasts with contemporary design, clever software, and a highly user-friendly interface. The system offers: contract parker management, Closed Circuit Television (CCTV), credit card clearing, stored-value card (memory capability), park and ride facility, card management, lost ticket function, validations against business rules, and remote control of peripherals.

When all the parking developments at ORTIA is completed, a total number of 16 000 parking bays will need management (ZEAG, 2008).

2.1.2 Downtown Victoria, Canada

A specific area experiences that unpriced core parking is 90 percent occupied during peak hours, whereas many unoccupied parking spaces are available a few blocks away. Local businesses requested that the government build a parking structure of about USD 5 million that would require annual subsidies of USD 500 000 or would require the users to pay for parking usage. From experience in similar down town parking areas, it is known that unpriced parking does not incur enough revenue, is generally underutilized, and does little to alleviate parking problems. Local government then decided to rather implement a new management system instead of a new parking structure. With regular tracking of parking usage and turnover rates, the objective of encouraging efficient use of parking facilities managed to reach usage figures of up to 85 %. These strategies were used:

- Increase the enforcement of regulations, particularly during peak hours. Enforcements should be friendly and fair.
- Reduce on-street time limits for increased profits.
- Expand the core area boundaries to increase the number of parking bays for short-term use.
- Encourage businesses to share parking areas by using business parking for a restaurant at night, for example.
- Encourage the use of alternative transport modes (Commute trip reduction and down town shuttle services).
- Develop special regulations for disabled access, delivery vehicles, loading zones, etc..

- Provide ample signage to indicate to motorists where to park.
- Implement a residential parking permit program if it becomes necessary to address spill-over problems in nearby residential areas. Try to accommodate non-residential users as much as possible.
- Have an overflow parking plan in place for special events with a greater need for parking.
- Maintain or establish high standards for parking facilities (design, aesthetics, the environment, and safety need to be considered).
- Apply the following principles when pricing the parking:
  - Adjust the rates as needed to maintain optimal utilization.
  - Structure rates to favour short-term usage in core areas and encourage longer-term parkers to use areas that may be further away.
  - Provide special rates for different uses (evenings or weekend differ from weekdays).
  - Use the revenue acquired to improve enforcement, security, facility maintenance and marketing programs to encourage the use of alternative transport modes.

(Litman, 2008)

2.1.3 Parking areas managed by EASIPARK

EASYPARK is a South African company that specializes in parking management services. They have been managing parking areas at malls across the country, as well as some parking garages at office buildings.

Johannesburg Property Company

Easipark was contracted to manage and operate all the parking garages owned by the Greater Johannesburg Metropolitan Council in down town Johannesburg. Together with Jo'burg Propco, upgrades, new equipment, re-wiring of electricity, painting, and resurfacing of about R 23 million was done to the 7 parking garages. The utilization of the 1920 parking bays increased to 85 %.

Harry Hofmeyr parking garage

This multi-storey car park in the Johannesburg Central Business District (CBD), owned by Gauteng Legislature, consists of 640 bays. Easipark installed a magnetic strip central-cashiering system with 4 entries and 4 exits. It now handles approximately 23 000 cars per month.

Brooklyn Mall shopping centre

This mall is managed by Investec Properties on behalf of Growthpoint Properties and is a very busy regional shopping centre in Pretoria East. It has over 1800 undercover parking bays and now makes use of a pay-on-foot system with 13 automatic payment stations, 12 entries, and 12 exits. The system also allows shoppers at key anchor tenants to purchase voucher tickets that are pre-encoded and offer discount to parkers who shop at these stores. About 250 000 casual parkers per month and 350 tenants use the parking facilities.

2.2 Hardware Solutions

To create a system that eliminates manual administration, hardware solutions need to be considered. The following possible hardware solutions were found.

2.2.1 Radio Frequency Identification (RFID) Technology

RFID is incorporated into basic devices and used for identification and tracking without contact or a line of sight. The reader sends electromagnetic signals to the transponder (in the form of an electronic tag). The tag then transmits its code to the reader. With this technology, the presence and location of an object can be tracked within an organization or given space. RFID uses a combination of radio broadcasts and digital coding technology; thus contact-less data transfers can take place. The tags can be found in many shapes and sizes. The hardware part of the tag can be built into items or added to specific access-cards designed for this purpose. Some countries have implemented this technology into their passports, whereas other uses include race timing, transportation payments, asset management, and product tracking. RFID technology has been implemented at the Bakwena Platinum Highway toll gates for easy access and payment through the gates. The Gauteng Department of Public Transport, Roads and Works has introduced the new Intelligent Number Plate (iNP) project . The purpose of the project is to reduce criminal activities like car theft. The new plates will be made of aluminium

(having a life span of 5 years) and have an electronic security feature that uses RFID technology for embedding information on the plate (Department Public Transport Roads and Works, 2009).

2.2.2 RFID Radar Technology

A company called Trolley Scan developed a technology in 2005 that would enable an RFID system to not only measure the identity of the transponder, but also the distance of the transponder from the reader. The technology has the ability to measure the distance travelled by the radio signal accurately. It also has the ability to measure the location of multiple transponders simultaneously and makes use of the same low-cost passive, battery assisted transponders used in standard RFID readers. By using RFID-Radar, a tag in a specific vehicle can be identified and located in the parking area. Newer developments of this technology guarantees ranges of up to 40 meters. Some of the benefits of using RFID are:

- Storage capacity between 128 bytes and 8 kilobytes.
- No line of sight or contact required.
- Enhanced data security (authentication and encrypted data transfer).
- Can operate in harsh, dirty and humid environments.
- Several tags can be read simultaneously.
- Read / write functionality (reprogrammable).
- Serialization (unique identification).
- Reduced human interference.
- Improved time management.
- Real-time information.

The flow of information is illustrated in Figure 2.2. (Scan, 2008)

2.2.3 Vehicle detection units

Over a period of 6 years, the parking management company, Intellipark, have been developing vehicle detection units that can indicate whether a specific parking space is occupied or not. This Intellimeter, as it is known, is connected to a parking meter

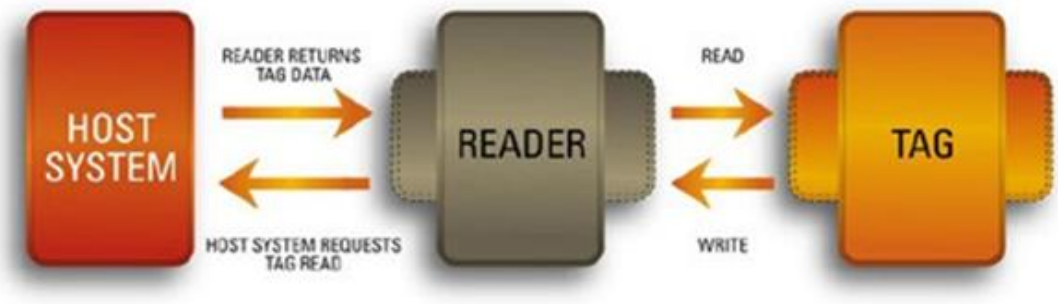


Figure 2.2: RFID information flow

and is mainly used for curb-side parking control. This technology is a combination of 10 patents covering vehicle detection and wireless communication (LAN/data collection), (Intellipark, 2007). A further development of this technology is the ability of the sensor to monitor its temperature. Due to the long periods of no status change, the infra-red light becomes warmer and affects the accuracy of the reader. Provision has now been made for this and the detection units interact with the system to flag these heated sensors. The system also has the capability of flagging sensors that are occupied for longer than a specified time.

Inductive Loop Detection

An Inductive Loop Detector (ILD) consist of one or many loops of wire that are embedded in the pavement or flooring over which the vehicle moves. The loop is connected to a control box that is triggered by a frequency between 10 KHz and 200 KHz. When a vehicle moves over or rests in the loop, the induction is reduced and the presence of a vehicle is detected. The control box can supply data about the passage and presence of a vehicle, the count, and the occupancy of a specific loop. The system can also detect the direction of movement and the sensitivity of the sensors can be adjusted.

Video Image Processors

This computer has character recognition software for license plates that identifies plates at a speed of up to 2 images per second. The computer matches the images with a database at 288 match comparisons per second. It has been designed to specifically meet the demand of large-scale intelligent transportation system applications. It can also be implemented for electronic toll violation enforcement, video tolling, ticket less parking, controlled access monitoring, segment speed analysis,

and travelled time analysis.

Microwave Radar

These sensors are installed above or next to the vehicle route and depending on the electromagnetic wave used, can measure the vehicle's presence, and in some cases, its speed as well. This is done by using the echo of microwave radiation to detect and locate distant objects. These sensors are ideal for all weather conditions, (Mashrur A. Chowdhury, 2003).

Infra red

This technology makes use of two components: an emitter and detector. There are 5 types of sensor response detectors: near, short-wave, mid-wave, long-wave and very long-wave. Infra red does not have a long range and therefore will be used like a remote control.

Magnetometers

This technology uses and instrument that measures the strength of the magnetic field around the instrument. It can be implemented by measuring the magnetic field of an ferromagnetic object like a vehicle. The meter itself will need to be improvised to meet the requirements of the parking system, (Klein, 1899).

2.3 Parking Management Principles

To implement new hardware to a parking area can increase utilization, but by applying simple principles to the management system, utilization can be increased without unnecessary expenditure. These principles are guidelines for planning decisions for a car park.

Consumer choice This principle ensures that the users of the parking area has more than one viable parking and travel option to choose from.

User Information Motorists should have information of the parking options available to them in terms of parking availability, regulations, pricing, and alternative travels options (walking and ride sharing). User information can be improved with signs, maps, brochures, websites, and electric guidance systems.

Table 2.1: Typical peak parking periods for various land uses

Weekday	**Evening**	**Weekend**
Banks and Public services	Auditoriums	Religious institutions
Offices and other employment centres	Bars and dance halls	Parks
Park and ride facilities	Meeting halls	Shops and malls
Schools, day care centres and colleges	Restaurants	
Factories and distribution centres	Theatres	
Medical clinics	Hotels	
Professional services		

This table indicates peak parking demand for different land use types. Parking can be shared efficiently by land uses with different peaks.

Sharing Parking facilities should serve multiple users and destinations. This works well if peak hours differ for each destination or if motorists park at one facility and then walk to many destinations.

Parking and ride sharing The following ways of sharing parking are available:

- Shared parking rather than reserved spaces. Motorists share the parking space by occupying it alternatively.
- Share parking among destinations. The parking can be shared by destinations that use the parking facilities at different times (Office building shares with a theatre that only operates at night). See Table 2.1 for the peak demand periods.
- Public parking facilities. Public parking (on-street, municipal off-street, and commercial facilities) generally serve multiple destinations and by converting these facilities from free, single use to paid, public parking areas, will lead to more efficient shared use of parking bays.
- In Lieu fees. The developers of the parking area will help fund the public parking facilities instead of providing private facilities for one destination only. Generally, this is very cost efficient and can be mandated or optional.

Efficient utilization. In practice, this means that parking spaces are frequently occupied and that the floor space available is used optimally. There are many ways to better utilize the space available:

- Start making use of previously wasted areas like corners, edges, and undeveloped land. Spaces that are too small for cars, can be used for motorcycle and bicycle parking.

- If the street width permits is, change from parallel parking to angled on-street parking for more spaces.
- Provide special smaller spaces for motorcycles and bicycles and if not possible, request these users to share a normal parking space.
- Reduce the size of the parking space. A portion of the spaces can be sized for compact vehicles; this can save up to 20 % off each space. Short-term parking requires a larger space than long-term parking. It is therefore wise to discern between different types of parking needs.
- Valet parking can increase capacity by 20-40 %, especially when used during busy periods.
- Remove of consolidate equipment, material, and any junk stored in the parking area. This space can be better utilized as more parking bays.

Flexibility. Parking plans should accommodate situations where uncertainty and change have an influence. The following adjustment factors should be considered: geographic location, residential density, employment density, land-use mix, transit accessibility, car sharing, walking environment quality, demographics, income, housing tenure (Are houses owned or rented?), pricing, unbundled parking (Is the parking sold or rented separately from the building?), parking and mobility management, design hour (Amount of allowable annual hours a parking facility may fill), and unforeseen event planning.

Prioritization. Spaces that are of higher user-value should be allocated for specific higher-priority users.

Pricing. If possible, users should pay directly for parking. The highest cost that users would still be willing to pay, should be calculated. More convenient, accurate, flexible, and increasingly cost effective electronic systems are available. They accommodate various payment methods and keep data records that can be used as a management tool .

Peak management. Peak-demand should be dealt with, with special efforts from the management team. In future, required parking needs to be reduced with committed employee ride sharing programs, (Smith, 1983). This will reduce peak hour traffic at major business and office centres; office hours binding employees to specific ride times.

Quality vs. quantity. The quality of the parking facility should be considered as important as the amount of parking available. Aesthetics, security, and user information should also be important factors.

Comprehensive analysis. All possible costs and benefits of the parking facility should be considered when planning the parking. (Litman, 2008)

2.4 Parking Management Policy

According to Smith (1983), parking requirements at a specific location or for a larger metropolitan area, should be reviewed on a regular basis. By carrying out a review, parking problems, new literature about parking, and changes in local land-use and transportation plans, can be considered. The increased use of alternatives to private car usage, expansion of existing and additional transport systems, a shift to smaller cars, recognition of special parking areas (disabled, bicycles, etc.), and increased mixed-use land developments have had an effect on local parking requirements. The following procedures should be followed to review local parking standards.

Determine generic development characteristics: The usage type, size, intensity, and other characteristics should be determined for residential, commercial, office, industrial, and institutional developments.

Review case studies: The policies of similar cities or parking structures should be reviewed and compared. This should only give indications and not be used as a standard. Review the following standards: parking literature, municipal parking studies, experience reports of other planning jurisdictions, and local zoning ordinances.

Survey parking demand and problems at the existing development: Many times this survey will result in a parking demand with no perfect answer. Follow these process steps: identify parking problems, relate traffic and user characteristics to the type of development, determine the daily and seasonal demand variations, relate these to peak demand periods (field studies and parking counts), and investigate opportunities for alternative parking arrangements.

Establish parking policy: Develop the parking policy according to the level of service that needs to be provided. The policy should comprise of minimum

requirements for off-street and on-street parking, opportunities for smaller stalls and shared parking (peak demand,) and the design and layout policies.

Determine zoning requirements: The number of parking spaces required, the parking lot design, and the exceptions and modifications required, should be considered.

Monitor parking standards: The efficiency of the policy should be monitored and updated regularly with field checks and surveys.

A complete parking policy would give the user all the necessary information as suggested in the parking management principles.

2.5 Capability Maturity Model

A Maturity Model (MM) describes the different levels of process improvement by providing an order in which the improvements should be managed. A capability MM is divided into 5 representative stages and any process can be categorized according to one of them. Level 1 is the initial phase and describes processes that are chaotic and unstable. The success of this organization depends on the individuals of the firm and not the processes. Level 2 is when a process is managed; it is planned, performed, measured, and controlled. Level 3 is a defined process using standards, procedures, tools, and methods. Level 4 is the maturity of a process that is quantitatively managed. Processes are subdivided and controlled with statistical and other quantitative tools. Level 5 maturity requires optimization; processes are continuously improved, (CMMI Product Team, 2002).

2.6 Development Techniques

The parking systems at TCel and the Innovation Hub will be analysed and redesigned. The following techniques will be used for the development process:

2.6.1 Entity Relationship Diagram

Data modelling is a technique used for defining business requirements for a database. A simple data model is called an Entity Relationship Diagram (ERD). It represents data in terms of entities and relationships. An entity is a class of persons, places, objects, events, or concepts that has to be captured. Each entity consists of different attributes; these are the descriptive properties or characteristics of an entity. The

relationships show the interaction between the entities. By using this technique, a diagram showing the system results and can be used as the architecture for further developments, (Lonnie D. Bentley, 2007).

2.6.2 Process Modelling

This technique is used for organizing and documenting the flow and structure of a system. A system consists of many processes and each process needs to be set apart. A Data Flow Diagram (DFD) is used to show the flow of data and the processing performed by the system. With a process model, processes are grouped according to the object, person, or department that activates the process flow (swim lanes). Processes are also divided into different levels to make better visual illustrations. The CaseWise program package will be used to model processes.

2.6.3 Linear Programming

Linear programming is used to solve optimization problems. By defining a maximum or minimum objective function and all the contributing constraints, the optimal solution can be found. This tool will be used in the higher maturity levels when the mix of parking types needs to be determined and to find the algorithms required for an optimized parking allocation system.

2.7 Additional Findings

At the commencement of this project, it was expected that complete parking solutions were available on the market. After extensive research it was found that hardware or management solutions were available, but never to the extent where a total solution was available to a client. It was therefore decided by Fourier that this project would serve as an investment and innovation project that they would be able to market once the development has been completed. An funding organization introduced by the Department of Trade and Industry , (SPII, 2007), known as the Support Program for Industrial Innovation (SPII) agreed to a 50 % matching scheme for all resources needed for this project.

Evidence of the need for a complete parking management solution can be deduced from the information. The chapters following this, will include the data analyses done to gain control over the parking area, the conceptual development phases of a solution and any relevant design strategies for the completion of the project.

Chapter 3

TCel

3.1 As-Is Analysis

3.1.1 Current Facilities

The three TCel locations each consist of one or many parking areas. Data for each in terms of the location, size, and capacity were gathered from a TCel investigation report and interviews with the different stakeholders.

TCel Pretoria

This TCel location consists of Building D and other leased buildings in the close vicinity. The investigation report indicates that there is a discrepancy between the allocated amount of bays and the available bays. The status of some of the parking areas is shown below:

Building A

- 198 bays

Building D South

- P1 Parking Level: 187 bays, 187 discs issued, dedicated parking with a mixture of various job levels Under Control
- P2 Parking Level: 250 bays, 411 discs issued. First Come First Served and lift clubs Over-allocated
- P3 Parking Level: 300 bays, 453 discs issued. First Come, First Served and lift clubs Over-allocated

- P4 Parking Level: 326 bays, 612 discs issued. First Come, First Served and lift club Over-allocated
- Podium: 142 bays for visitors parking

Building D North

- P1 Parking Level: 264 bays on record of which 50 bays are out of use because of various reasons - 214 bays are available
- P2 Parking Level: 232 bays on record with some additional bays marked as A/B/C added to a number. Dedicated parking with mixture of various job levels - Under control

Building E

- 10 underground parking bays

The following reasons were given for parking bays that were not usable:

- VIP parking that is demarcated and not in use unless they are needed for VIPs.
- New power correction influence the structure.
- Schindler Lift construction camp's allocated parking.
- Leaking cement slime and other salts from the badly waterproofed podium. The salts and slimes damage the cars' paintwork and the cost to install drip trays is increasing.

TCel Centurion

The bays at this location are as follows:

- Building A 776 bays available.
- Building B 731 bays available.
- Building C 364 bays available.

This location does not have a parking capacity problem. The management has allocated bays according to the parking policy. The users get a specific number and is only permitted to park there. The rest of the staff parks in a first come first served approach area.

The temporary discs are allocated to permanent TCel staff that needs parking for a short period of time. They receive a temporary parking disc that has an expiry date.

TCel Roseville

This parking area does not have a parking capacity problem. The majority of vehicles that enter this area are fleet vehicle that are easier to allocate because they only need parking for short periods of time.

3.1.2 Current system and technology

Babylon

TCel uses an access control system called Babylon, developed by Siemens. This system provides access to authorized users by allowing access to a user with a specific identification card at a certain location.

A profile is created for a new employee by gathering information like personal details, the specific devices (card reading devices) permitted to allow access to the employee, the time windows of allowed access (days and hours of the week) and a badge number. A generic profile can be cloned to apply to groups of users.

Each entrance and exit of the TCel parking areas has a boom and card reader. Employees swipe their identification cards against the card reader and are then allowed access according to the access system criteria.

Each card reader has an access log that TCel uses to determine which users (according to their badge numbers) are logged into the system and their times and dates of access. Entrance and exit card readers are separate devices and can therefore identify in and outward movements of the users.

The Babylon system has an anti-pass back functionality, but it cannot be used at the TCel parking areas, because the gates and buildings of the TCel facilities use the same system. The anti-pass back functionality requires users to swipe in at a gate, swipe in again at a building and then swipe again at the building and gate when leaving the facility. If one of the swipes was not logged, the user will not be able to leave.

By not making use of the anti-pass back functionality, users abused the card system by swiping colleagues in or out. The system data then shows that one person in logged in more times than being logged out or vice versa.

The technical manual of the Siemens Building Technologies Babylon system was reviewed and it was found that the system has more functionality than TCel used. Functions like pin-code identification, temporary access denial, X-ray scanning, and video capturing were not implemented. Access, alarm, system, visitor, and video logs are also retrievable.

Even though the Babylon system functionalities are not fully used, the system

lacks parking management tools. It might be possible to still use this system for building access control and then integrate it with the parking management system, but it would be better to use a complete new system as this system is hard to configure and maintain.

CCTV Cameras

There are CCTV cameras at the gates that are maintained by TFMC and can be used for audits. There are date and time labels on the footage. No vehicle- or employee identification or recognition intelligence is implemented.

3.1.3 Current Processes

The following processes were identified for TCel from their parking policy and interviews with the various stakeholders.

TCel Parking Hierarchy

The TCel Parking Hierarchy (see Figure 3.1) shows the different locations where parking can be allocated:

- Visitors Parking
- Designated Parking
- Motorcycle Parking
- Disabled Parking

It also shows the roles and the order in which access to parking is allocated for each location.

Parking Management Processes

The process flow diagrams illustrate the parking system at TCel before any suggestions were made or implemented. These diagrams show the flow of information between the different stakeholders of the system. From these diagrams, the problems in the system could be identified.

The process shows how an employee applies for access to parking, how the application for access to parking is approved, how the employee is allocated parking and ultimately how he/ she utilises the parking. It also shows how allocated parking is cancelled, how visitors parking is arranged and other administrative processes.

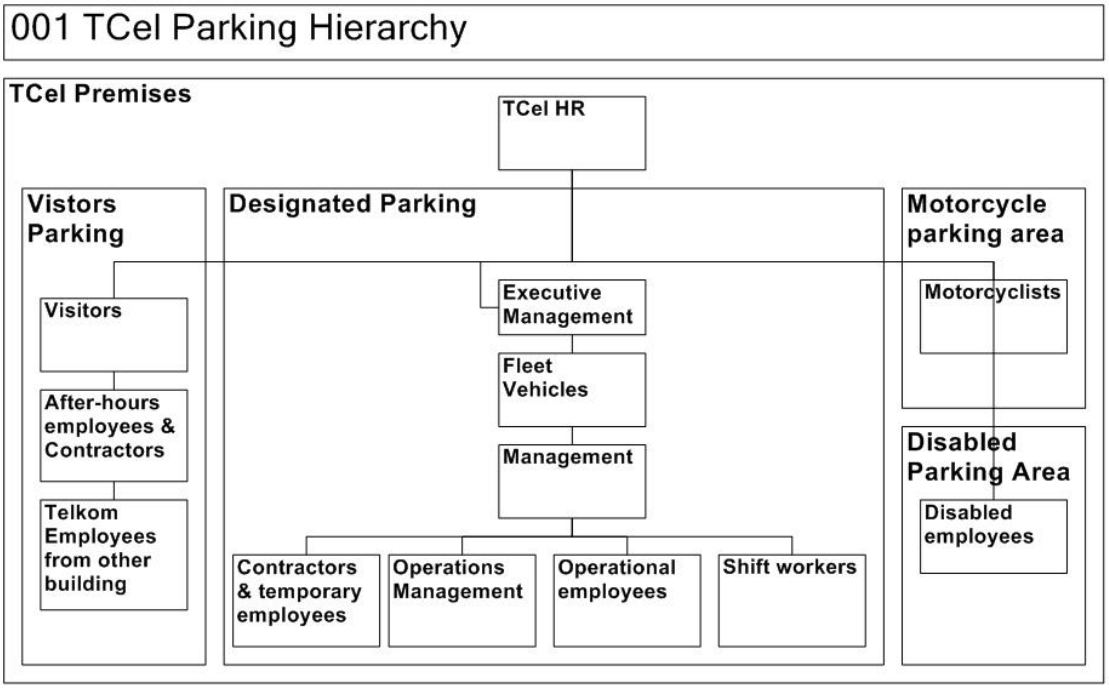


Figure 3.1: TCel Parking Hierarchy

If an employee received a parking disc from the Parking Administrator (TFMC) his access card can be programmed to allow access to the parking area.

Parking is allocated to an employee, firstly if there is parking available and secondly according to the level of the employee. There are parking rules, to which an employee has to adhere to while making use of TCel parking. These rules and the allocation governance is documented in the TCel Parking Policy.

Figure 3.2 shows the high level diagram. The processes in Figure 3.3 to Figure 3.16 , show each of the sub processes as well as the process for visitors and fleet vehicles that require parking.

3.1.4 Current Problems

The following problems were identified from interviews with the role players and observation on site visits to the different facilities. It was clear to see that the management and control of the parking areas have room for improvement.

Unauthorized access and use of parking bays

- Illegal parking in allocated parking bays.
- Illegal parking in VIP parking bays.

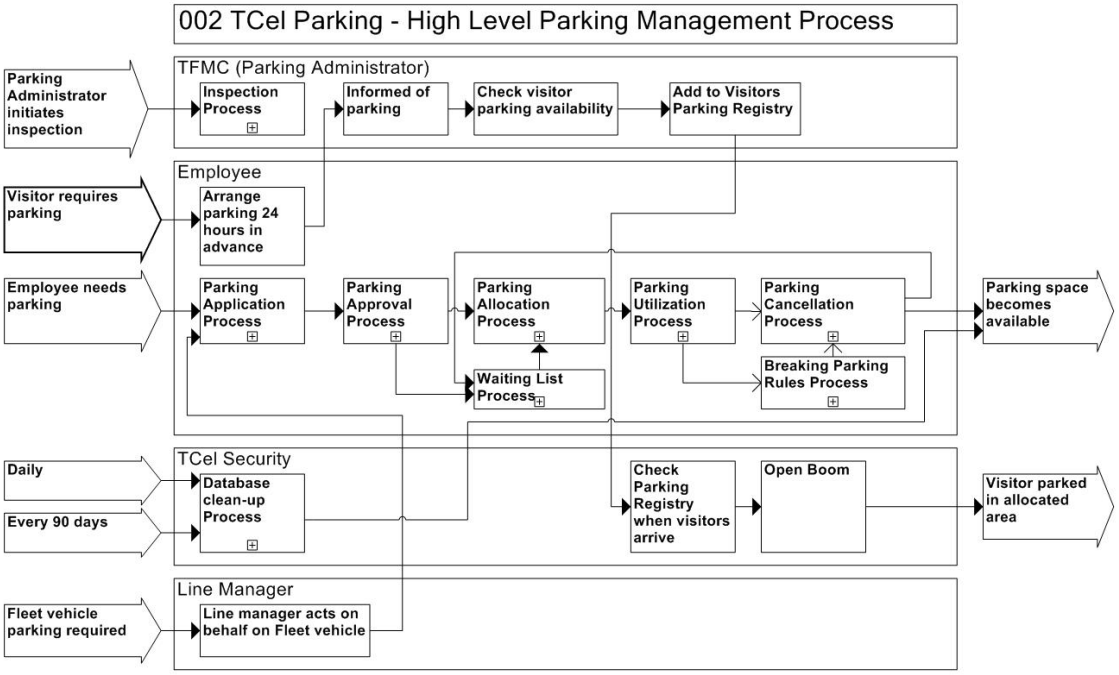


Figure 3.2: TCel Parking - High Level Parking Management Process

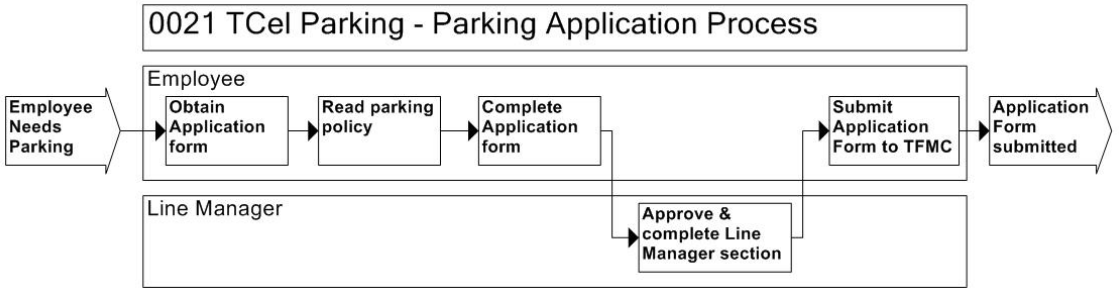


Figure 3.3: TCel Parking - Parking Application Process

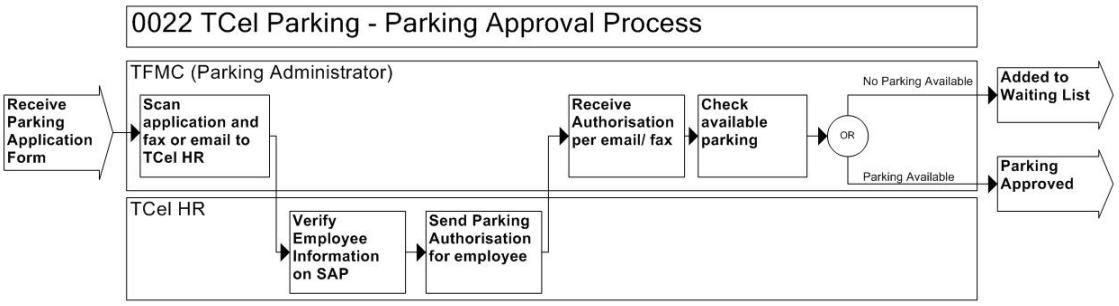


Figure 3.4: TCel Parking - Parking Approval Process

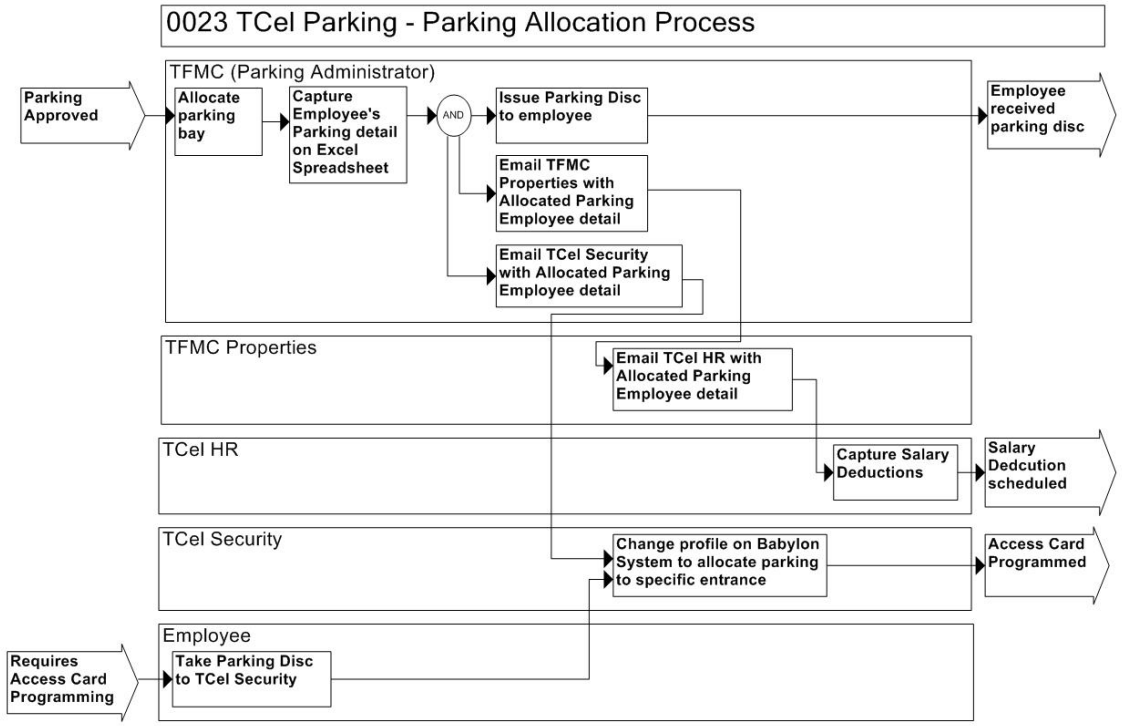


Figure 3.5: TCel Parking - Parking Allocation Process

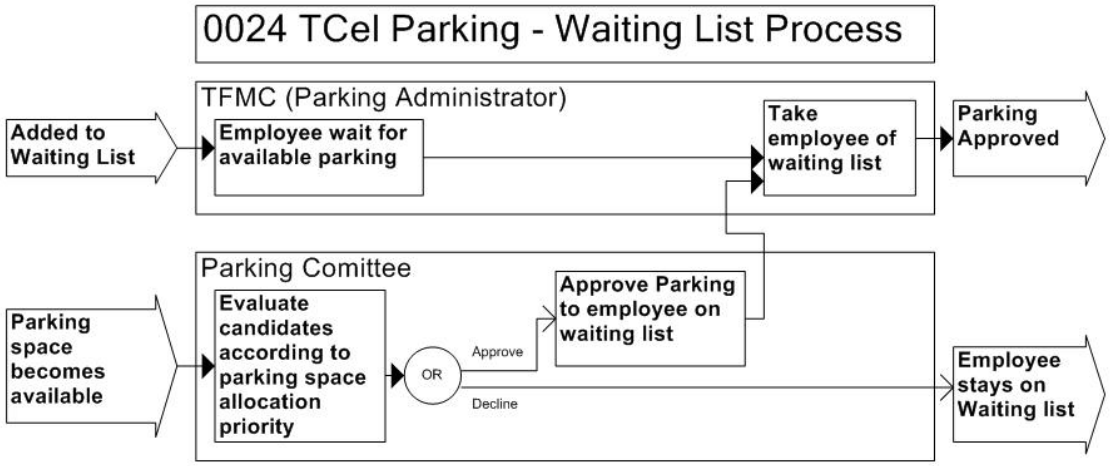


Figure 3.6: TCel Parking - Waiting List Process

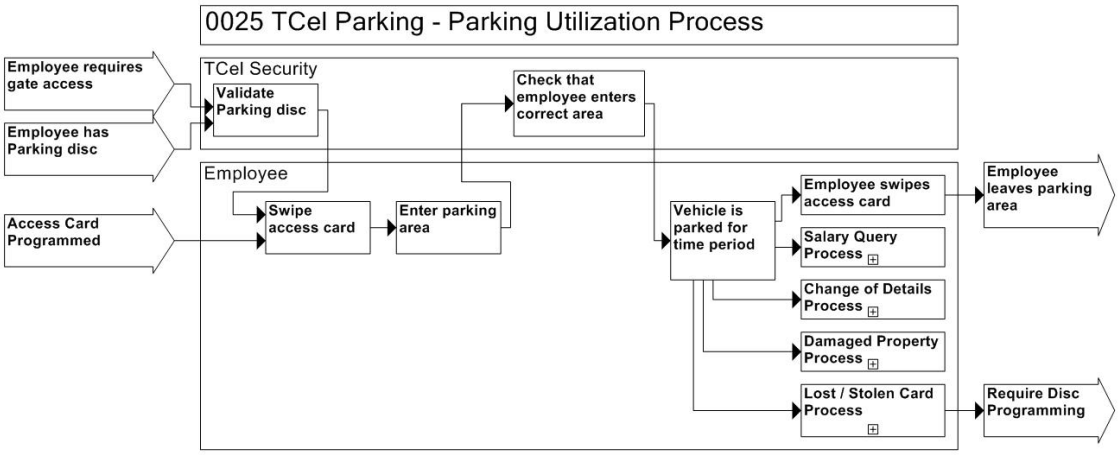


Figure 3.7: TCel Parking - Utilization Process

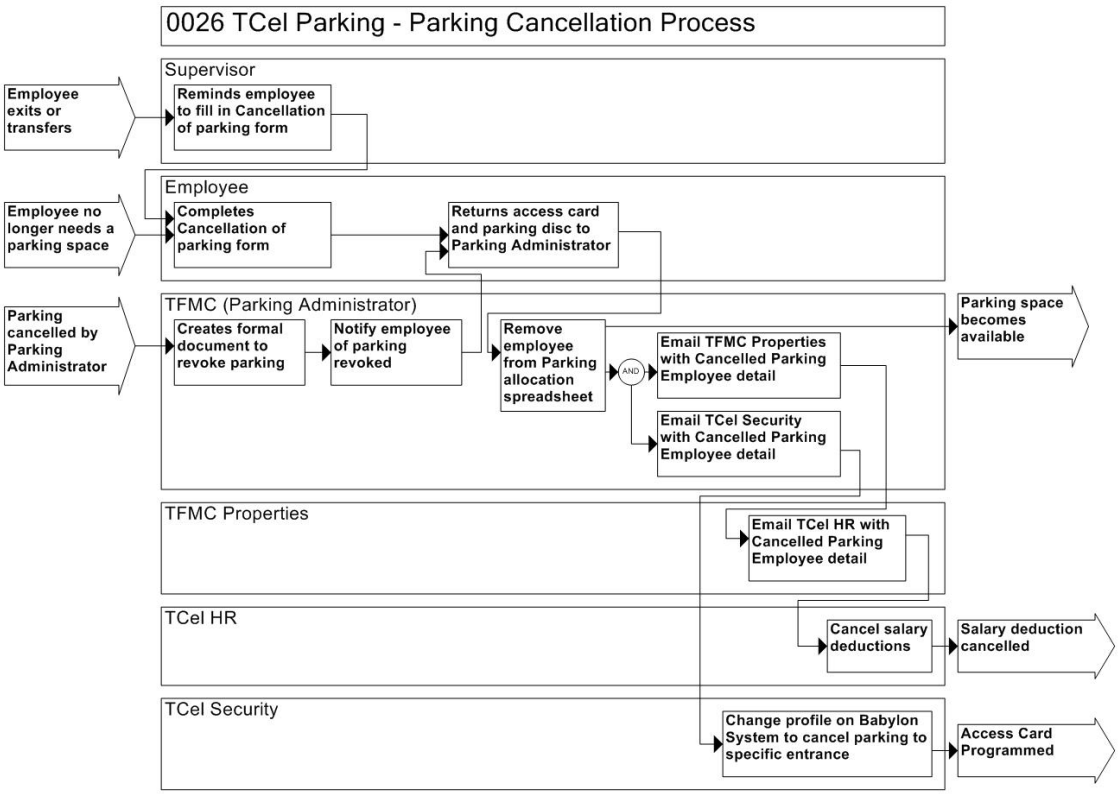


Figure 3.8: TCel Parking - Cancellation Process

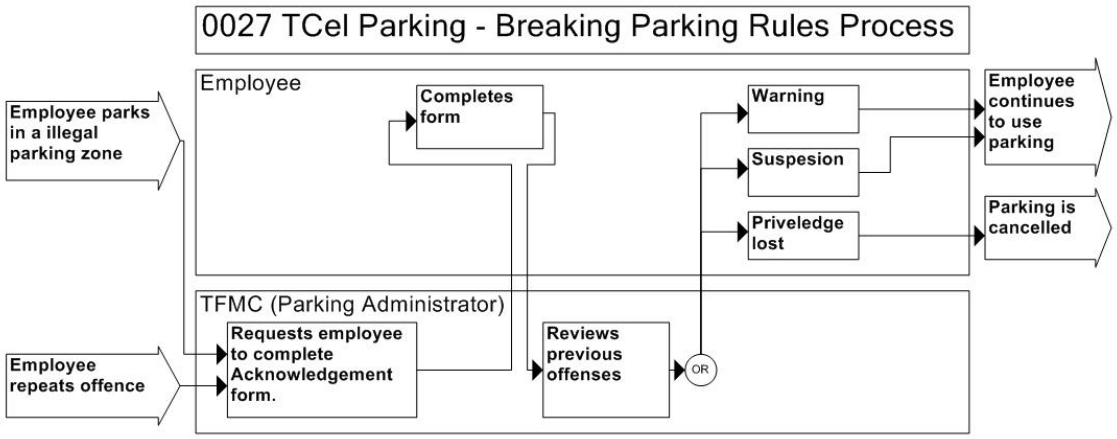


Figure 3.9: TCel Parking - Breaking Parking Rules Process

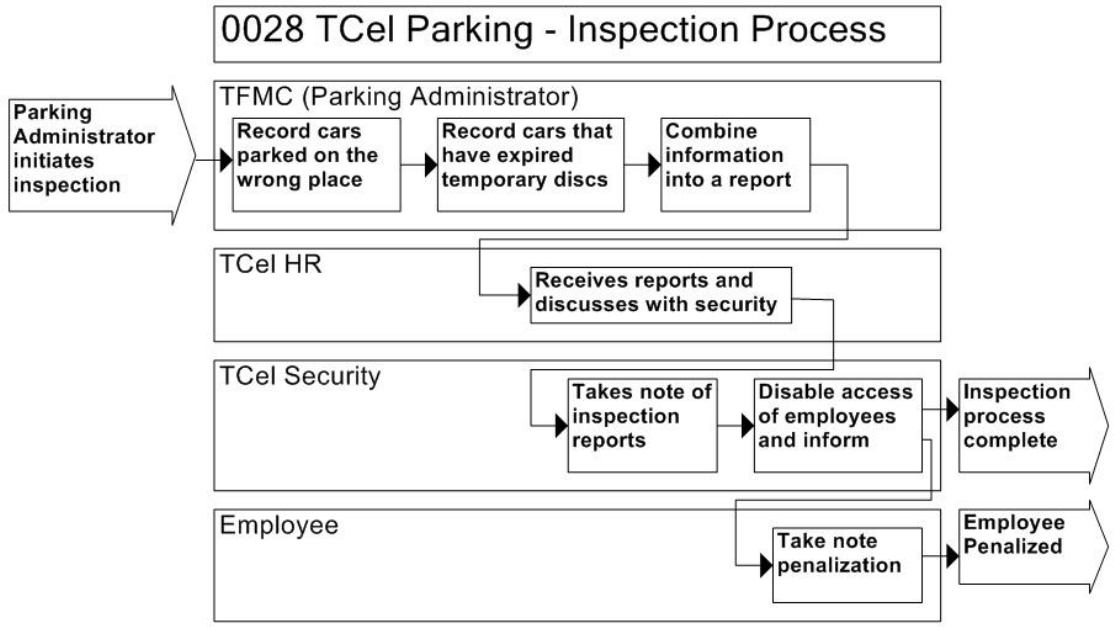


Figure 3.10: TCel Parking - Inspection Process

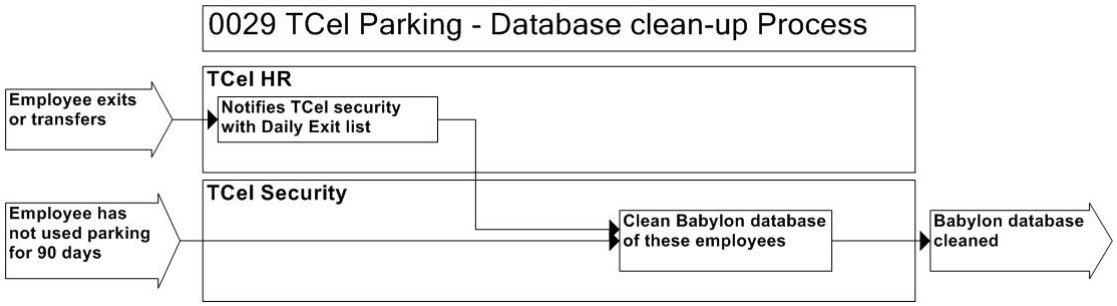


Figure 3.11: TCel Parking - Database Clean-up Process

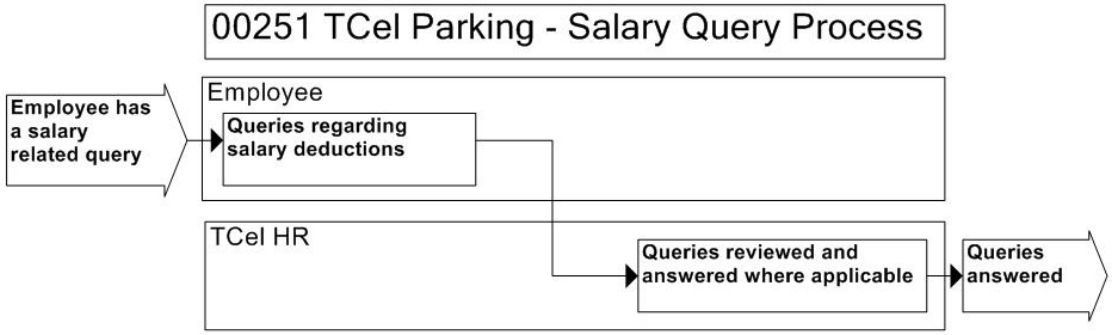


Figure 3.12: TCel Parking - Salary Query Process

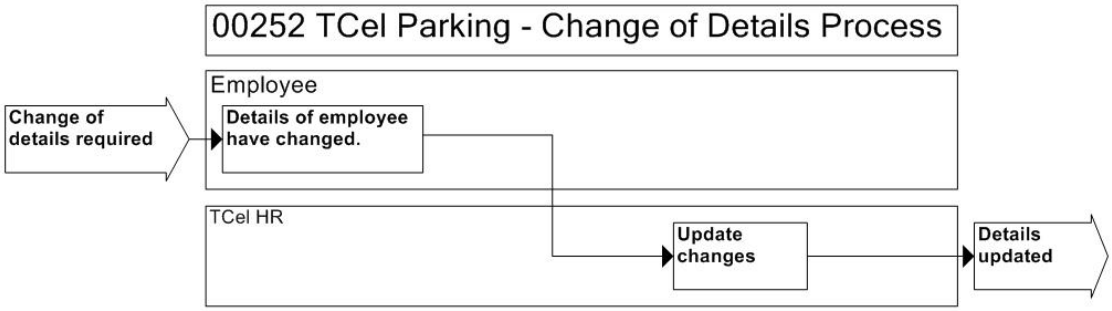


Figure 3.13: TCel Parking - Change of Details Process

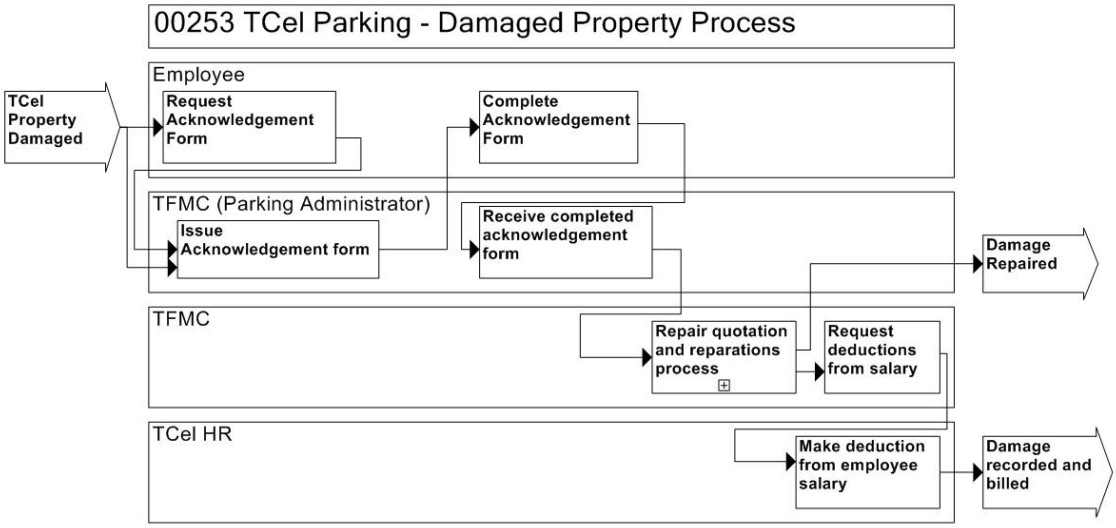


Figure 3.14: TCel Parking - Damaged Property Process

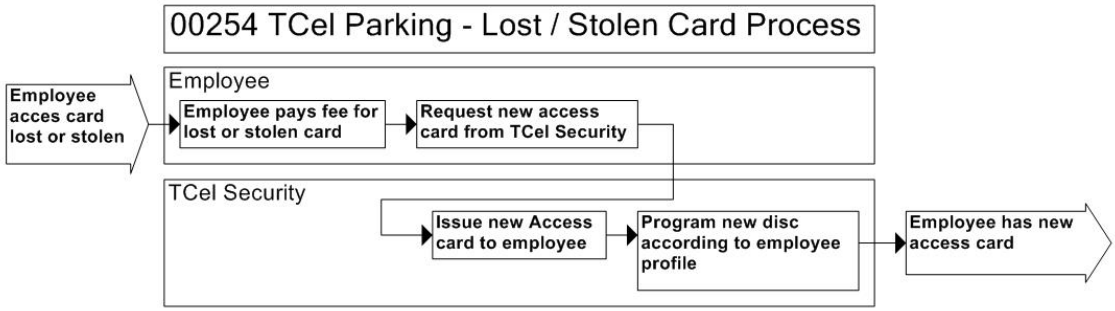


Figure 3.15: TCel Parking - Lost / Stolen Card Process

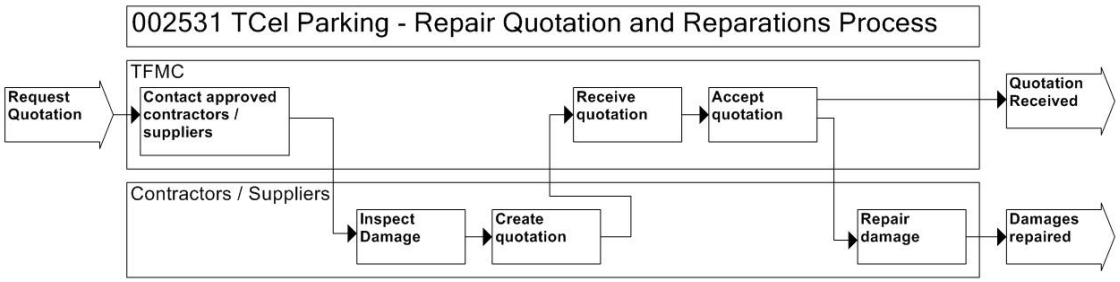


Figure 3.16: TCel Parking - Repair Quotation and Reparations Process

- Parking over two parking bays.
- Illegal parking in entrances.
- Tedious manual inspection processes.
- Failure to display parking discs on the right hand side of the windscreen.
- Manual monitoring of parking discs by TFMC; sometimes assisted by TCel Assets and Revenue Protection Services (TARPS).

Unauthorised use of visitors parking

- Illegal use by staff; the podium parking area is accessed before the security staff arrives (6:00 am).
- The visitors' parking area is full during the day and no parking is available for the visitors.

Lift Clubs

Lift clubs are encouraged by the management to reduce the number of cars used. Each of the cars are given an access disc for when that car is used during the rotation.

One parking bay is allocated to the lift club. Employees later decide to drive alone with their own car and more than one car then gains access to the parking area. The employees then park on any parking bay and this causes a problem for whoever was allocated to that parking bay. Five parking bays, for example, are then used instead of the one that was allocated and paid for.

Collection of payment

Regular tenants' payment is deducted from their salaries. TCel has difficulty in collecting payments from contractors and agencies. Payments are made for the first month and then neglected onwards. TCel has contractors from seven agencies.

Over allocation

Figures show that an estimated 5600 workers from 11 buildings require parking. TCel only has about 2000 parking bays.

Skew or incorrect data

- The data is kept in a Excel spreadsheet, maintained by TFMC and is only adjusted when new employees apply for access or when an employee cancels their parking.
- TCel security receives a daily list of exit-employees with which they clean-up the database. This list is not available to TFMC. The list should be used to update TFMC's spreadsheets.
- TCel security cleans up the database by removing dead cards (cards that were not used in three months). This data is also not available to TFMC, which means that their spreadsheet do not indicate the correct number of parking bays allocated.
- The skew and incorrect data gives TFMC and TCel the false impression that the parking bays are 100 % allocated or even over-allocated.

Safety risk

From inspection it was seen that employees park in front of emergency exits and lift operator access doors. This poses as a great safety risk in the case of an emergency. It is proposed that TFMC performs a health and safety audit of the current parking layout.

Table 3.1: TCel Pretoria Allocation - Data Analysis

Pretoria Building	**Description**	**Total Parking Bays**	**Allocated Parking Bays**	**Allocation %**
Building A		192	180	93.75
Building B		47	45	95.74
Building C		50	27	54.00
Building D	P1	26	253	
(North and East)	P2	252	252	
		514	505	98.25
Building D	LG	21	17	
(South)	Ramp	12	12	
	Curb	10	9	
	P1	226	225	
	P2	384	384	
	P3	448	446	
	P4	598	595	
	Motorcycles(P2)	36	34	
	Total	1735	1722	99.25
Building E		28	15	53.57
Total		2566	2494	97.19

3.2 Data Analysis

3.2.1 TFMC Allocation Spreadsheets

The data analysis was done on the TFMC spreadsheets of the TCel Pretoria and Centurion facilities. The sheets are used for allocating parking bays to employees. No data was received for the Roseville campus.

The data received is assumed to be reliable, but not guaranteed to be 100 % accurate- some irregularities were discovered. A probable cause of the discrepancies could be that the booms were left open during peak times or were not fully functional.

Table 3.1 and Table 3.2 shows information for each buildings at the Pretoria and Centurion facilities. The building name, floor level (where applicable), total amount of available parking bays, and amount of allocated parking bays with the allocation percentage (allocated bays/ total parking bays) are given.

Note that there is a difference between the total parking bays between the TCel investigation report and Table 3.1 and Table 3.2 . This is because the totals in the two tables include all the parking bays. The investigation report did not take parking bays that are subdivided into A/B/C, etc. into consideration. The actual total number of parking bays was determined from the spreadsheet data.

Table 3.2: TCel Centurion Allocation - Data Analysis

Centurion Building	Description	Total Parking Bays	Allocated Parking Bays	Allocation %
Building A	Executive Bays	24	1	4.17
	Visitors Parking	75		
	Disabled Parking	10	6	60.00
	Senior Managers Parking	60	54	90.00
	Staff Parking	604	1562	258.61
	Total	773	1623	209.96
Building B	Executive Bays	30	23	76.67
	Visitors Parking	40		
	Disabled Parking	5	2	40.00
	Managers Parking	75	71	94.67
	Staff Parking	571	908	159.02
	Motorcycle Parking	10		
	Total	731	1004	137.35
Building C	Executive Parking	9	11	122.22
	Visitors Parking	31		
	Disabled Parking	2	4	200.00
	Staff Parking	316	393	124.37
	Motorcycle Parking	6		
	Total	364	408	112.09

The perception that the TCel Pretoria buildings D North and South are over-allocated was proved incorrect. According to the allocation spreadsheets, they are 97.19 % allocated.

The perception of the TCel Centurion facility is that it has sufficient parking available for the daily demand. According to the TFMC allocation spreadsheets, they are over-allocated. This could mean that the TFMC spreadsheet at this facility is not cleaned-up when employees leave or don't need parking any longer. The over-allocation is concentrated in the staff parking area.

3.2.2 Babylon Access Control Logs

The access logs of the Babylon system was received for the 5 months between 1 January and 31 May 2009. The data was acquired from TCel's log files that are housed on a computer network. This log file captures the date and time stamp, information about the specific device, and the location of the entrance/exit. Microsoft Excel 2007 was used to manipulate the data by using pivot tables. This enabled the sorting of the data into time segments of each day of these five months. It was thus possible to find the exact amount of vehicles that entered and exited each of

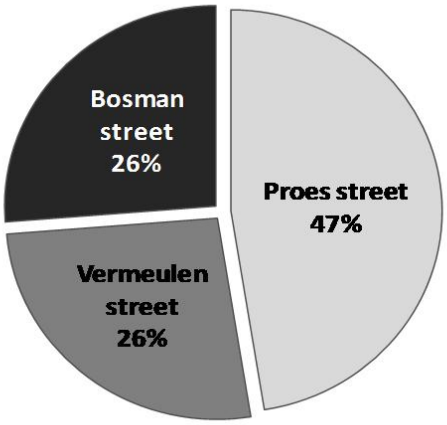


Figure 3.17: Street entrance and exit traffic levels

the buildings within time limits.

The following was done to analyse the data:

1. The number of exits and entrances per month, per gate for the two buildings (Building D South and North) was determined. From this the gates and months with the most traffic and highest activity were identified.

2. The number of exits and entrances for the highest activity month, per day for the two buildings (Building D South and North) were determined. The utilisation per day was then compared to the capacity of each building and the day with the highest activity was identified.

3. The number of exits and entrances for the highest activity day, per hour, was determined. The cumulative utilisation per hour was then compared to the capacity of the building.

Exits and entrances per gate per month

Building D South has three entrance and exit locations: in Vermeulen street, Bosman street, and Proes street. Building D North has two in Bosman street and one in Proes street. The entrance and exit data of the two buildings and the difference between the entrance and exit data are shown in Table 3.3 and Table 3.4.

In terms of the traffic flow around these locations, it could be of value to TCel to investigate a method of spreading the traffic more evenly between the three locations. Figure 3.17 shows the traffic at each of the locations from the two buildings. This can be achieved by allocating access to a specific gate. Currently, if employees have

Table 3.3: Building D South: Number of entrances and exits per month per gate

		Entrance	**Exit**	**Total**
Bosman	Total	26660	28234	54894
	January	4955	5378	10333
	February	5568	6139	11707
	March	6227	6294	12521
	April	4543	4738	9281
	May	5367	5685	11052
Proes	Total	47535	58229	105764
	January	8692	10603	19295
	February	9857	11887	21744
	March	10583	13338	24191
	April	8426	10426	18852
	May	9707	11975	21682
Vermeulen	Total	44416	43296	87712
	January		8279	8279
	February	10982	8875	19857
	March	12493	9990	22483
	April	9775	7443	17218
	May	11166	8709	19875
Total		118611	129759	248370

Table 3.4: Building D North: Number of entrances and exits per month per gate

		Entrance	**Exit**	**Total**
Bosman	Total	17755	17906	35661
	January	3377	3944	7321
	February	3568	3630	7198
	March	4211	4773	8984
	April	3377	3016	6393
	May	3222	2543	5765
Proes	Total	30352	29650	60002
	January	5785	5527	11312
	February	6244	6520	12764
	March	6814	6404	13218
	April	5237	4734	9971
	May	6272	6465	12737
Total		48107	47556	95663

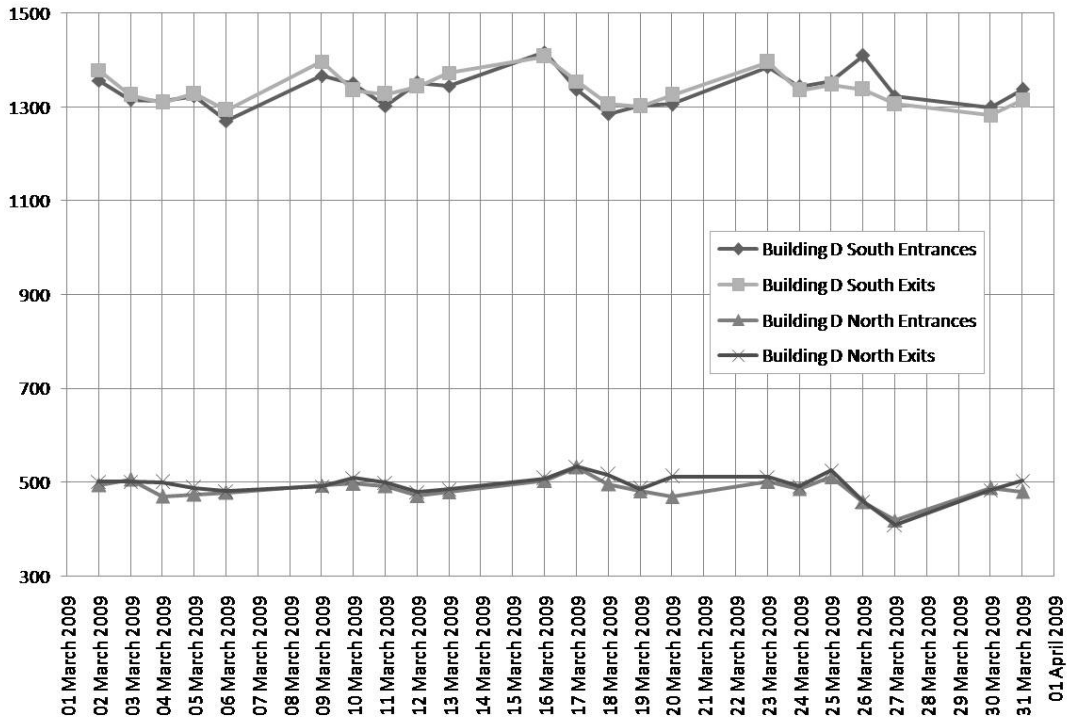


Figure 3.18: Entrances and exits per weekday (March) for Building D South and North

access, they can enter at any gate. The building that the employee works in and the direction of entrance and exit should be considered with this allocation.

Exits and entrances per day for the highest activity month

From Table 3.3 and Table 3.4, the month with the highest activity in terms of entrances and exits can be deduced; this month is March for both the North and South buildings. A possible reason for this month being the highest could be that March is the last month of TCel's financial year, causing financial personnel to visit the buildings more often. Figure 3.18 illustrates the entrance and exit volumes during weekdays in March for the two buildings.

The South building's maximum number of entrances per day in the given month is 1417 and the maximum number of exits is 1408. When compared to the total number of parking bays of the South building (1735), the number of parking bays was sufficient over the five month period. Figure 3.19 shows the cumulative usage for each day of the month of January and the average cumulative value of the month. This proves that the number of parking bays in this building was sufficient for the demand, as the maximum value never exceeded 600 (below the capacity of 1735). The North Building's maximum number of entrances (532) and the maximum

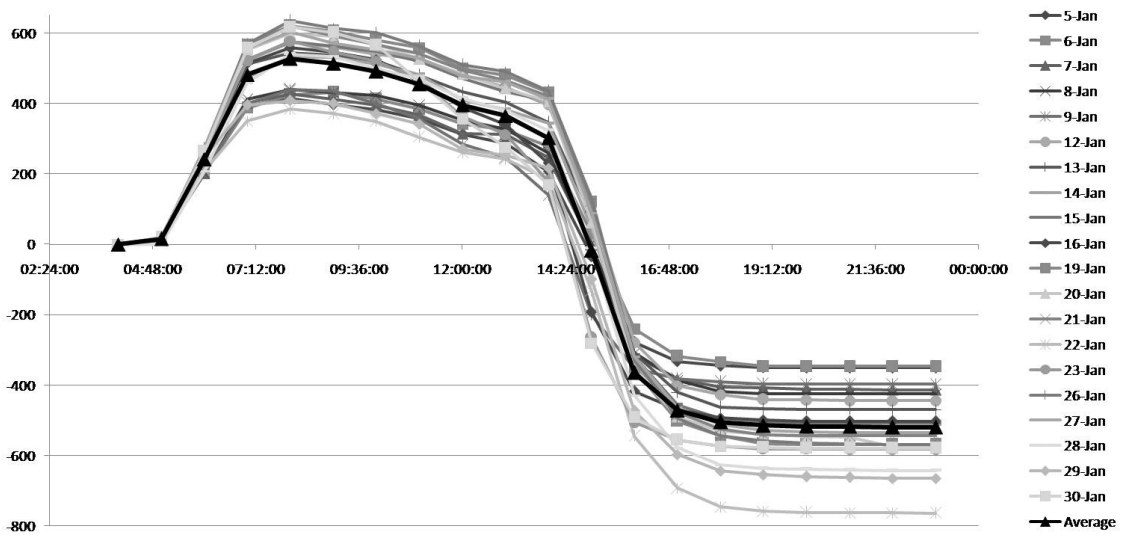


Figure 3.19: Daily Cumulative and Average Utilization for January in Building D South

number of exits (533) both exceed the total number of parking bays available at the North building (514). The day with the highest activity (See Table 3.5, never had more than 376 cars parked inside the building.

It was found that the parking areas in the TCel Pretoria buildings are not really over allocated as thought and that the actual utilisation is lower than the physical capacity. Even during the highest activity month's (March) highest activity day, the capacity was sufficient for the demand. This can imply that the actual demand for parking is not as high as the allocation figures indicated and that there is more parking allocated than what is needed. It could also imply that the employees resort to parking elsewhere, because they are under the impression that the parking areas at TCel are 100 % utilised. Table 3.6 and Table 3.7 show the percentages for the the 5 month period.

Daily Entrance and Exit Patterns

From the number of entrances and exits in a day, a clear pattern is evident (See Figure 3.20). Most arrivals (entrances) are between 6:00 and 8:00 in the morning and most departures (exits) are between 15:00 and 17:00 in the afternoon. This concurs with a tidal parking pattern.

Entrances and exits per badge

As mentioned earlier, some discrepancies were found in terms of the entrance and exit levels per badge number (employee). This means that there are either more

Table 3.5: Building D North: Entrances and exits per hour

Hour	Entrance	Exit	Cumulatively Parked*
5	10	1	9
6	130	4	135
7	179	5	309
8	67	11	365
9	25	14	376
10	16	16	376
11	12	17	371
12	10	28	353
13	27	12	368
14	14	36	346
15	13	85	274
16	16	179	111
17	6	65	52
18	3	35	20
19	3	12	11
20	1	11	1
21		1	0
22		1	-1
Total	532	533	

Cumulatively Parked = Entrance - Exit

Table 3.6: Actual Utilization

Building	Month	Utilization
Building D South	January	13.35%
	February	43.88%
	March	44.59%
	April	36.14%
	May	42.21%
	Average	**41.71%**
Building D North	January	42.46%
	February	49.24%
	March	51.12%
	April	46.27%
	May	49.00%
	Average	**47.62%**

Table 3.7: Maximum Utilization

Building	Month	Utilization
Building D South	January	36.60%
	February	62.42%
	March	63.05%
	April	62.59%
	May	62.48%
	Average	**63.05%**
Building D North	January	69.26%
	February	70.04%
	March	74.32%
	April	72.37%
	May	73.93%
	Average	**74.32%**

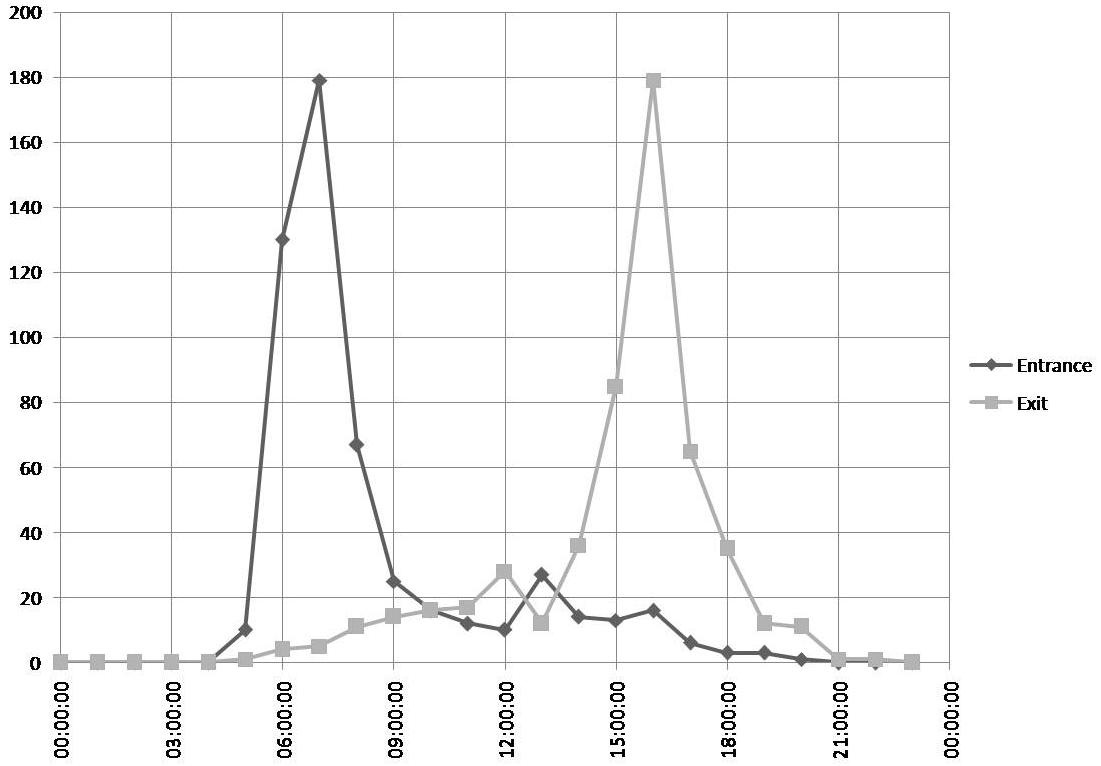


Figure 3.20: Building D North Highest Activity Day: Entrance and Exit patterns per hour

Table 3.8: Badges per building with uneven swipe in and out totals

Building	Uneven	Total Badges	Uneven %
Building D South	727	1205	60.33
Building D North	243	401	60.60

Table 3.9: High volume activity per badge

Badge Number	Entrance	Exit	Total
Building D South			
4519	8	7	15
4961	8	9	17
7292	21		21
407458	40	21	61
Building D North			
202272	7	3	10
207505	60	93	153

entrances than exits or vice versa. This might mean that the employees enter or exit without swiping, or that they are swiping for other cars to enter the parking areas.

The same sample dates were used as earlier. Table 3.8 illustrates the total amount of badges that were swiped per day and the number of badges that had uneven totals (One entrance and two exits results in an uneven total of three).

For both buildings the number of badges with different amounts of in-and-out swipes is 60 %.

Table 3.9 shows the badge numbers with unusually high entrance and exit figures. These could be security guards that open the gates on behalf of employees or visitors.

3.3 Relevance of TCel project

The TCel project analysis aided the identification of problems in a typical under-managed parking facility and to define the user requirements. These requirements were used for the development of the Parkamax system.

Chapter 4

The Development of the Parkamax System

The TCel parking project led to the discovery of many problems that organizations with a parking area might face. Through the data analysis and literature study, the need for a complete parking solution was strengthened. The development of a generic parking model became more necessary and piloted the Parkamax system.

To develop a parking system that could be applied to many different situations, it required a system that could be broken up according to the specific need of the user.

4.1 Maturity Model

The Parkamax system had to be able to take any parking system from its current level of parking capability to the level of maturity desired by the client. Then a solution would be proposed to progress the client from the status quo to the desired level. To achieve this, capability levels had to be defined for specified classifications. The maturity model shown earlier (Figure 1.1), illustrates a standard capability maturity model. The model shown in Table 4.1 , was further detailed to have the ability to classify any parking system according to five different criteria. Each of these can be at a different level of development and cannot be measured together if accurate maturity levels are required.

- Management information
- Financial management
- Hardware and technology

- Physical infrastructure
- Access and allocation

A specific parking module can be defined according to a combination of these criteria.

Table 4.1: Parkamax Maturity Model

Level	**Management Information**	**Financial Management**	**Hardware and Technology**	**Physical Infrastructure**	**Access and Allocation**
Description	Measure the capability of the manager at the top to know what's going on, on the ground. Know exact capacity, allocation and utilization	Measure the capability of the financial/payment process in terms of automation and differentiation between different users	Measure the sophistication of the implemented hardware and technology to get the desired information management and financial management data	Measure the capability to determine exact location with demarcated bays, zones, levels and buildings; and other characteristics of the parking area	Measure the capability to control the access to the parking area

Table 4.1: Parkamax Maturity Model

Level	**Management Information**	**Financial Management**	**Hardware and Technology**	**Physical Infrastructure**	**Access and Allocation**
Optimized Level 5	Parking spaces are optimized based on actual utilization and patterns. Based on rules. Parking allocation is dynamic. Advance warning and notification of bays. Reservation system.	Pay for actual usage.	Automatic payment system with variety of payment methods. Optimization algorithms, Notification signs. Web-interface. Additional identification devices. Visibility to parkers.	Bays are completely defined by descriptive information, location, and utilized type (scheduled, available, allocated, utilized)	Access and allocation for visitors as well.
Allocated Level 4	Exact number and location of available bays. Vehicle movement tracking data. Exact allocation.	Financial process for regular users/tenant and visitors.	Automatic or manual payment system. Information Gathering device display to management.	Bays are classified according to location and descriptive information (Surface type, size, restrictions, etc.).	Vehicles and persons are allocated to specific parking bays and are monitored. Automatic process for identification of known and unknown persons and visitors.

Table 4.1: Parkamax Maturity Model

Level	**Management Information**	**Financial Management**	**Hardware and Technology**	**Physical Infrastructure**	**Access and Allocation**
Identified Level 3	Exact number of available bays.	Financial system for regulars and tenants.	Access information system. Identification device and reader.	Parking bays are classified according to their location (building, levels, zones, bay number).	Specific vehicles and persons (or lift clubs) are automatically identified and granted access and allocation to specific building, level or zone based on pre-approval. Manual process for unknown/ unexpected visitors.
Controlled Level 2	Limited information on total number of available bays.	Pay on entry and exit.	Access Control.	Known capacity of demarcated parking bays.	Access to parking area granted on pre-approval. Manual identification of vehicles and persons.
Initial Level 1	No information.	No financial management.	No hardware or technology.	Parking area has unknown capacity of demarcated parking bays.	Open to anybody.

When a parking system is at level 3 for each of the five criteria, it is classified as a module 1 parking system. Each of these criteria grouped in a specific arrangement, can be seen as the building blocks that are used to put a system together. The degree of capability is determined by the selection and combination of building blocks. The capability of the system is determined by the client's user requirements.

From the As-Is analysis of TCel's parking system, TCels maturity levels were determined:

- Management Information: Level 2
- Financial Management: Level 3
- Hardware and Technology: Level 3
- Physical Infrastructure: Level 3
- Access and Allocation: Level 3

After these finding, it was decided to make recommendations to TCel on becoming a module 1 parking facility.

4.2 Parkamax System Development

For the Parkamax system to function as a complete solution, the requirements were used to bring the concept into context and then break down the system into its functional areas.

4.2.1 Context Diagram

The context diagram defines the scope and boundary for the system. Only the system, external entities, and the organization are shown (see Figure 4.1).

4.2.2 Functional Decomposition

The processes that will be performed by the system administrators and users were translated into seven basic functionalities:

- System Administration
- System Environment Configuration
- Parking User Configuration

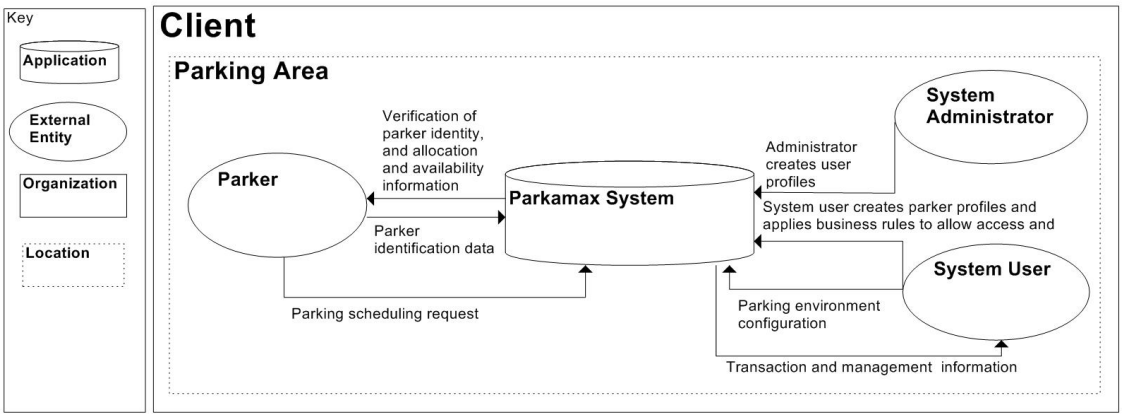


Figure 4.1: Business Process Context Diagram

- Transactions
- Allocations
- Reporting
- Audit Trail

All system activities will operate within these functionalities. These functionalities were used for the design of the system database and can be seen in Figure 4.2

4.2.3 Data Model

The data model consists of the ERD, the list of entities and other information like the rules and considerations for the system.

List of Entities

The list of entities shows each of the entities and its attributes, if it is a primary or foreign key, and examples of these attributes. This list can be viewed in Section A.1.

Entity Relationship Diagram (ERD)

The ERD (see Figure 4.3) is an illustration of the system arrange according to each of the entities and its specific attributes. It also shows the type of relationship between the attributes. The ERD forms the foundation of the database as all tables are created from. From the tables, all queries, forms, and reports are developed.

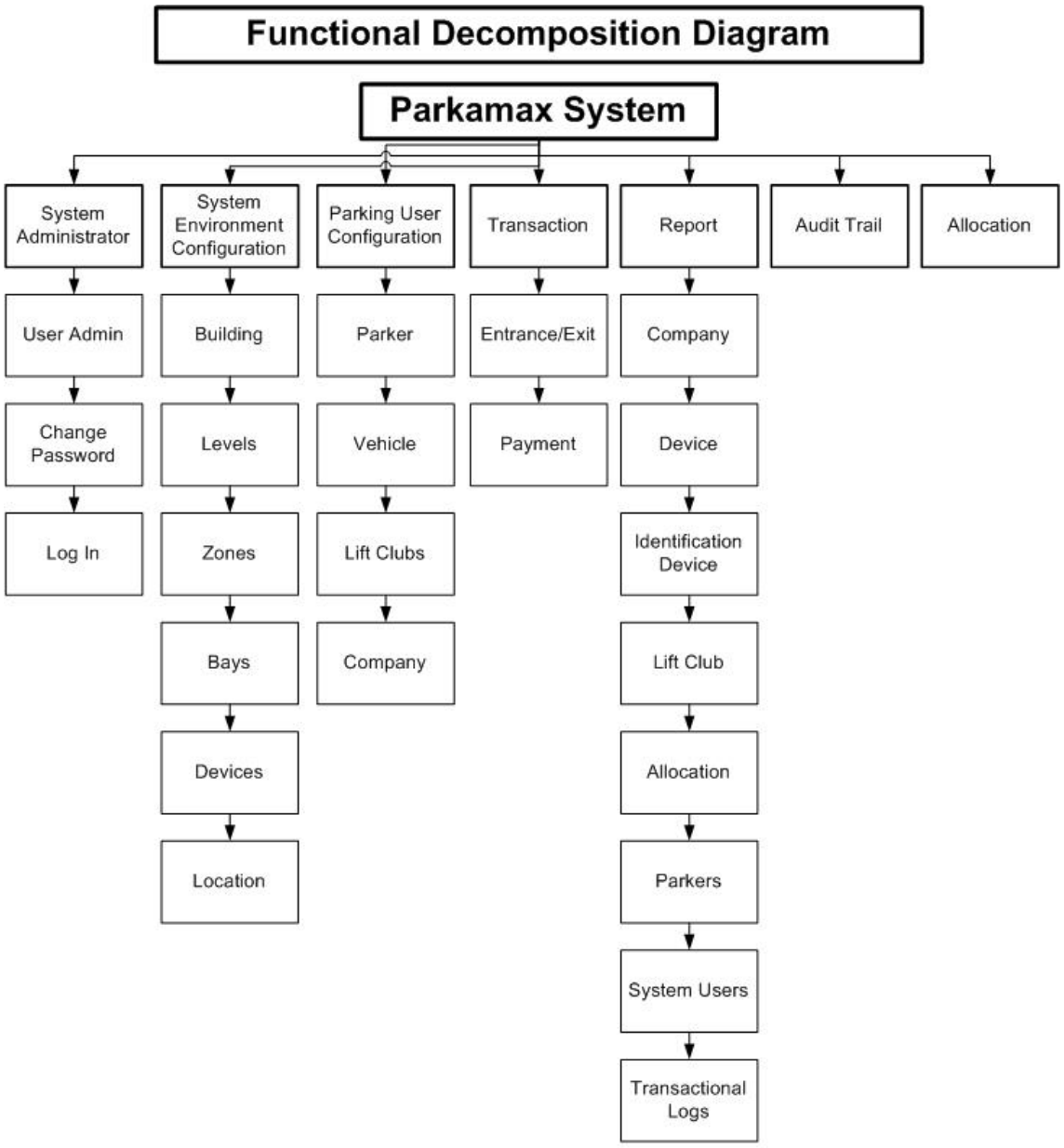


Figure 4.2: Functional Decomposition Diagram

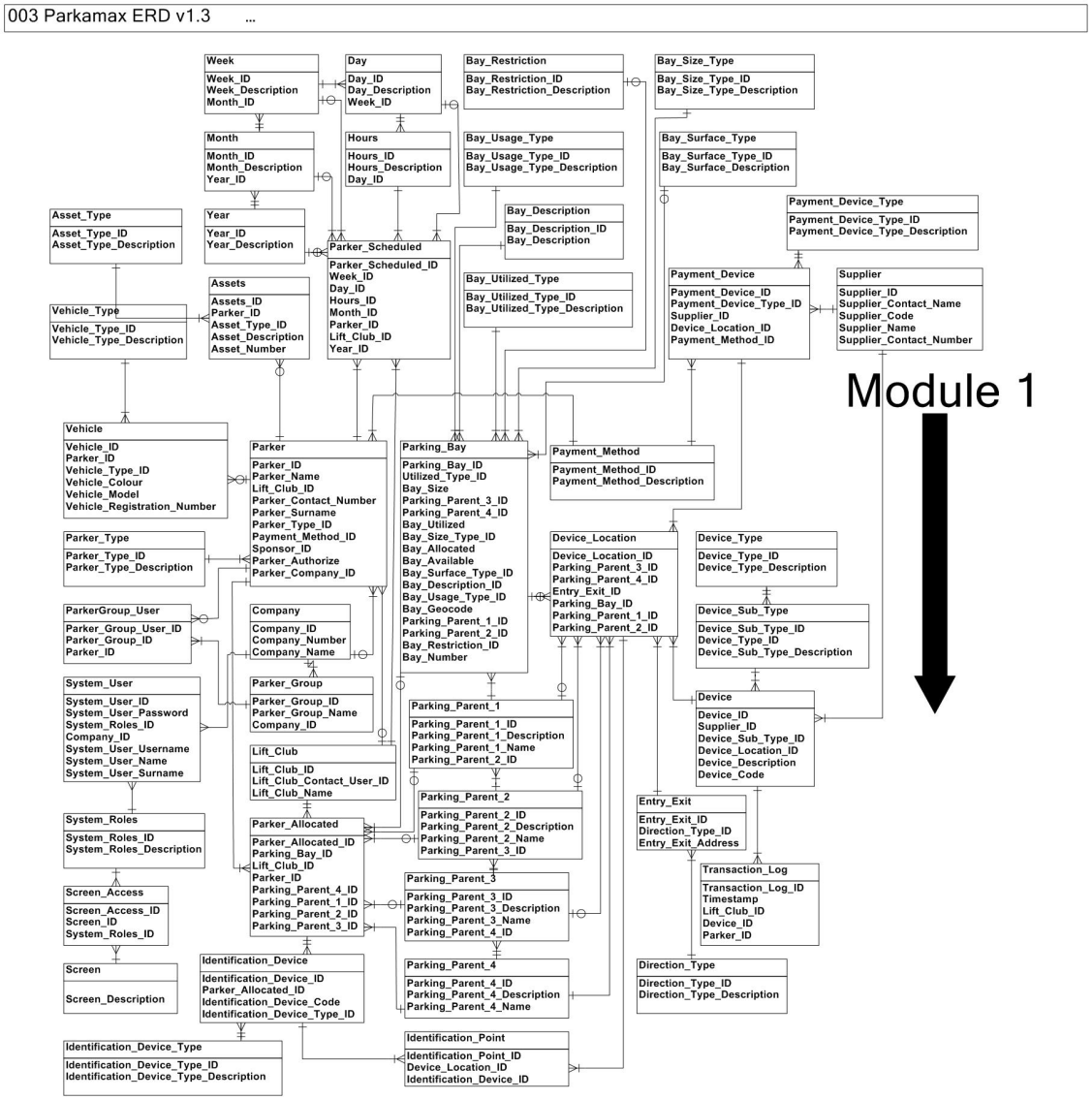


Figure 4.3: Entity Relationship Diagram (ERD)

Table 4.2: Access Rules of the System

Rule	Criteria
Authorization Rules	Are you allowed to get parking?
	Parker group
	Company
	Vehicle
	Asset
	Parker Type
	Lift Club
Allocation Rules	Where are you allowed to park?
	Parker group
	Company
	Vehicle
	Asset
	Parker Type
	Lift Club
Access Rules	Are you allowed to gain access?
	Authorized
	Allocated
	Scheduled
	Time
	Vehicle
	Asset
	Parker Type
	Bay Available
	Bay Allocated
	Bay Utilised
	Payment Made
	Payment Outstanding
	Payment Method

Table 4.3: Types of Devices

Device Types	
Identification Reader	Camera
	RFID Antenna
	Biometric Reader
	Pin Pad
	Card Reader
	Mobile Vehicle Identifier
	Automatic Number Plate Recognition
Access Control	Boom
	Gate
	Security Checkpoint
	Magnetic Lock
Display	Sign Board
	LED
	PC Monitor
Information Gathering	Vehicle Detector Unit
	Magnetic Loop Inductor
	RFID
	Mobile Vehicle Identifier

Table 4.4: Payment Methods

Payment Methods	
Monthly Salary Deduction	
Invoice	
Debit Order	
Sponsor	
Prepaid	Cash
	Pre-loaded Card
	Mobile
	Pay-on-Entry
	Parking Meter
	Electronic Bank Payment
Pay-on-Exit	
Pay-on-Foot	Cash
	Credit
None	

System Rules and Consideration

For any person to gain access to a parking area, the person must meet three conditions. If the person then meets the criteria, access is approved. These conditions are set out in Table 4.2 . The criteria for access are validated by using different devices. These devices are located within the parking environment and serve specific purposes (See Table 4.3). To associate a person with access rules, the person must be uniquely identifiable. An identification device is used for this purpose; examples of these are: parking discs, cards, RFID tags, biometric enrolments, entry codes, and facial recognition software.

The Parkamax system also facilitates payment for the use of parking by tenants and once-off users. For the payment process, automatic pay stations or operator pay stations are used (referred to as payment devices). These devices can accommodate many methods of payment as seen in Table 4.4, depending on the level of maturity of the parking system.

The screen layouts and descriptions of a module 1 database as defined in the Parkamax MM (see Table 4.1), can be seen in Section B. This database was developed in Microsoft Access 2007.

4.2.4 Implementation

The Access model was built to illustrate how the system would work and fit into the complete parking solution. The complete system will be developed in the Microsoft SQL program and the additional levels will also be included. This system will be packaged and able to integrate with the add-on models that will be developed in the next phase. These will be discussed in Chapter 5.1.

Chapter 5

Future Research and Conclusion

5.1 Future Research

The Parkamax system has the potential to be developed even further. The module one database with the additional functions that can be added according to the desired maturity level is complete, but there are add-ons that will be integrated into the system if any of the higher maturity level capabilities are required.

5.1.1 Optimization model

The Parkamax system will later be expanded by adding an algorithm to the system that can use the data from all the different devices and then compute different outputs. A user requesting parking space will arrive at the parking area entrance and identify themselves. The algorithm will take the current status of the parking area (regarding available and allocated parking bay information) and compute whether parking spaces are available. This real-time data will be fed into a model with an objective function of minimizing the distance between the parker's target destination and the available parking spaces. This model will be constrained by authorization, allocation, and access rules, as well as business rules and built-in intelligence of the system. Once the specified parking area is computed, the system will make use of display devices and indicators to direct the parker to that specific space.

Airlines make use of yield, pricing, and revenue management strategies to maximize air plane capacity. The concept of yield management lies within the fact that seats that are not filled before the plane take off, can be seen as perished goods, because no revenue can be incurred once the plane has departed. Market segmentation also occurs as the prices of the seats differ according to the time of purchase and seating classification (economy or business). This concept should be combined

with the logic of the optimization model to develop the system further.

5.1.2 Web-interface Reservation System

Because of the demand for better managed visitors parking and the lack of available space, a reservation system on the internet will be developed. This interface will allow visitors to apply for parking. The system will then allocate parking, facilitate payment, and issue a pin code that the parker can enter at the access control device at the parking facility. The parking space will be assigned to a specific person for a limited time frame. This web interface will integrate with the Parkamax system.

5.1.3 Marketing and Sales Strategy

The strategy will consist of a cost benefit analysis that shows that the initial capital investment will be paid back within a short period of time by comparing this value to the cost of additional parking and office space at other locations. The savings incurred from not renting additional space for employees while enough office space is available in the TCel buildings, financed the implementation of a module 1 parking system for TCel within less than two years. This structure proves that the capital expenditure is an investment with a good return.

5.2 Conclusion

A paradigm shift has occurred within the parking management environment. According to (Litman, 2008), the old paradigm assumed a parking environment with plentiful supply at a low, or to no cost to the parker. With this as objective, parking areas that were never filled to capacity, parking expenses that were added to the cost of the building, and parking areas that only fulfilled in that specific area's need, existed. This paradigm was governed by prediction and providing.

Litman (2008) states that the new paradigm promotes optimal supply and pricing to the parkers. It specifies that over-satisfying the demand for parking is risky and it emphasizes the efficient use of parking facilities. This new paradigm encourages careful analysis of the type of problem, as well as the location, timing, and involved parties. The easiest and most obvious method to solve parking problems like spill overs and congestion is to increase the supply of parking, but this method still causes other problems to surface. The better method to consider, is the management. The Parkamax system is the embodiment of this new paradigm.

When looking a the Parkamax system in terms of the different building blocks mentioned throughout the chapters, it has the capability of transforming any parking area. This system can integrate with any level of parking management and ensures that the system is developed to reach the desired level of capability. The system still has many opportunities for further expansion and the development of more building blocks will lead to a capability maturity level that leaves no room for inefficiency.

Appendix A

List of Entities

Table A.1: List of Entities

Entity	**Attribute**	**Key**	**Values**
Asset Type	Asset Type ID Asset Type Description	PK	Unique Laptop/ Desktop/ Projector
Assets	Assets ID Asset Description Asset Number Asset Type ID Parker ID	PK FK FK	Unique
Bay Description	Bay Description ID Bay Description	PK	Unique Covered/ Open/ Light
Bay Restriction	Bay Restriction ID Bay Restriction Description	PK	Unique
Bay Size Type	Bay Size Type ID Bay Size Type Description	PK	Unique Motorcycle/ Handicap/ Loading/ Standard

Table A.1: List of Entities

Entity	**Attribute**	**Key**	**Values**
Bay Surface Type	Bay Surface Type ID	PK	Unique
	Bay Surface Type Description		Gravel/ Tar/ Paved
Bay Usage Type	Bay Usage Type ID	PK	Unique
	Bay Usage Type Description		Normal/ Visitor/ VIP/ Emergency/ Conference
Company	Company ID	PK	Unique
	Company Name		
	Company Number		
Device	Device ID	PK	Unique
	Device Description		
	Device Code		
	Device Location ID	FK	
	Device Sub Location ID	FK	
	Supplier ID		
Device Location	Device Location ID	PK	Unique
	Entry Exit ID	FK	
	Parking Bay ID	FK	
	Parking Parent 1	FK	
	Parking Parent 2	FK	
	Parking Parent 3	FK	
	Parking Parent 4	FK	
Device Sub Type	Device Sub Type ID	PK	Unique
	Device Type ID	FK	
	Device Sub Type Description		
Device Type	Device Type ID	PK	Unique
	Device Type Description		

Table A.1: List of Entities

Entity	**Attribute**	**Key**	**Values**
Direction Type	Direction Type ID	PK	Unique
	Direction Type Description		
Entry Exit	Entry Exit ID	PK	Unique
	Direction Type ID	FK	
	Entry Exit Address		
Identification Device	Identification Device ID	PK	Unique
	Identification Device Code		
	Identification Device Type ID	FK	
Identification Device Type	Identification Device Type ID	PK	Unique
	Identification Device Type Description		
Identification Point	Identification Point ID	PK	Unique
	Device Location ID	FK	
	Identification Device ID	FK	
Lift Club	Lift Club ID	PK	Unique
	Lift Club Contact User ID	FK	
	Lift Club Name		
Parker	Parker ID	PK	Unique
	Company ID	FK	
	Lift Club ID	FK	
	Parker Authorized		Yes/No
	Parker Contact Number		
	Parker Name		
	Parker Surname		
	Parker Type ID	FK	
	Payment Method ID	FK	

Table A.1: List of Entities

Entity	**Attribute**	**Key**	**Values**
	Sponsor ID	FK	
Parker Allocated	Parker Allocated ID	PK	Unique
	Parking Bay ID	FK	
	Lift Club ID	FK	
	Parker ID	FK	
	Parking Parent 1 ID	FK	
	Parking Parent 2 ID	FK	
	Parking Parent 3 ID	FK	
	Parking Parent 4 ID	FK	
Parker Group	Parker Group ID	PK	Unique
	Company ID	FK	
	Parker Group Name		
Parker Group Parker	Parker Group Parker ID	PK	Unique
	Parker Group ID	FK	
	Parker ID	FK	
Parker Type	Parker Type ID	PK	Unique
	Parker Type Description		Temp/ Employee/ Contractor/ Visitor
Parking Bay	Parking Bay ID	PK	Unique
	Bay Allocated		Yes/No
	Bay Available		Yes/No
	Bay description ID	FK	
	Bay Geocode		
	Bay Number		
	Bay Restriction ID	FK	
	Bay Size		
	Bay Surface Type ID	FK	
	Bay Usage Type ID	FK	
	Parking Parent 1 ID	FK	
	Parking Parent 2 ID	FK	
	Parking Parent 3 ID	FK	
	Parking Parent 4 ID	FK	

Table A.1: List of Entities

Entity	**Attribute**	**Key**	**Values**
	Utilized Type ID	FK	
Parking Parent 1	Parking Parent 1 ID	PK	Unique
	Parking Parent 1 Description		
	Parking Parent 1 Name		
	Parking Parent 2 ID	FK	
Parking Parent 2	Parking Parent 2 ID	PK	Unique
	Parking Parent 2 Description		
	Parking Parent 2 Name		
	Parking Parent 3 ID	FK	
Parking Parent 3	Parking Parent 3 ID	PK	Unique
	Parking Parent 3 Description		
	Parking Parent 3 Name		
	Parking Parent 4 ID	FK	
Parking Parent 4	Parking Parent 4 ID	PK	Unique
	Paring Parent 4 Description		
	Parking Parent 4 Name		
Payment Device	Payment Device ID	PK	Unique
	Device Location ID	FK	
	Payment Device Type ID	FK	
	Payment Method ID	FK	
	Supplier ID	FK	
Payment Device Type	Payment Device Type ID	PK	Unique
	Payment Device Type Description		

Table A.1: List of Entities

Entity	**Attribute**	**Key**	**Values**
Payment Method	Payment Method ID	PK	Unique
	Payment Method Description		
Supplier	Supplier ID	PK	Unique
	Supplier Contact Name		
	Supplier Code		
	Supplier Name		
	Supplier Contact Number		
Transactional Log	Transactional Log ID	PK	Unique
	Parker ID	FK	
	Time stamp		
	Device ID	FK	
	Lift Club ID	FK	
Utilised Type	Utilised Type ID	PK	Unique
	Utilised Type Description		Occupied/ Unoccupied/ Unknown
Vehicle	Vehicle ID	PK	Unique
	Parker ID	FK	
	Vehicle Model		
	Vehicle Registration Number		
	Vehicle Colour		
	Vehicle Type ID	FK	
Vehicle Type	Vehicle Type ID	PK	Unique
	Vehicle Type Description		Motorcycle/ 4x4/ Sedan

Appendix B

Database Screen Layouts and Descriptions

An Access Database was built of a module 1 system.

B.1 Forms

Figure B.1 shows the screen that opens when the database is first opened. The user needs to fill in the text boxes and according to the user's role, one of two screens will open. If the user is a system administrator, figure B.2 will appear. The system administrator has the choice of configuring the system users (Figure B.3) or configuring access (Figure B.4). The system user configuration allows the administrator to add, change or delete system users, their roles, associated companies, and their access details. The screen access configuration allows the system administrator to add, change or delete system roles and screens, and then link a role and screen

Figure B.1: Main Screen

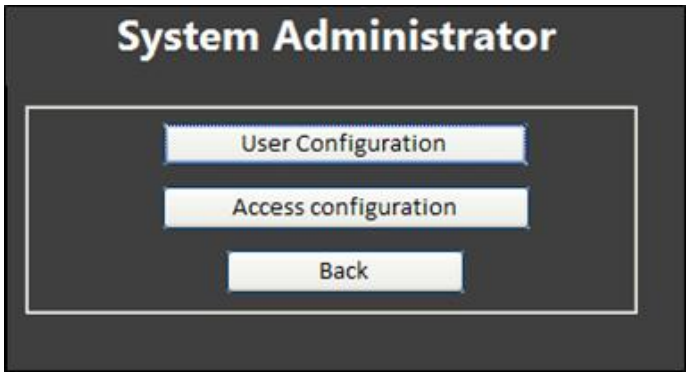


Figure B.2: System Administrator Screen

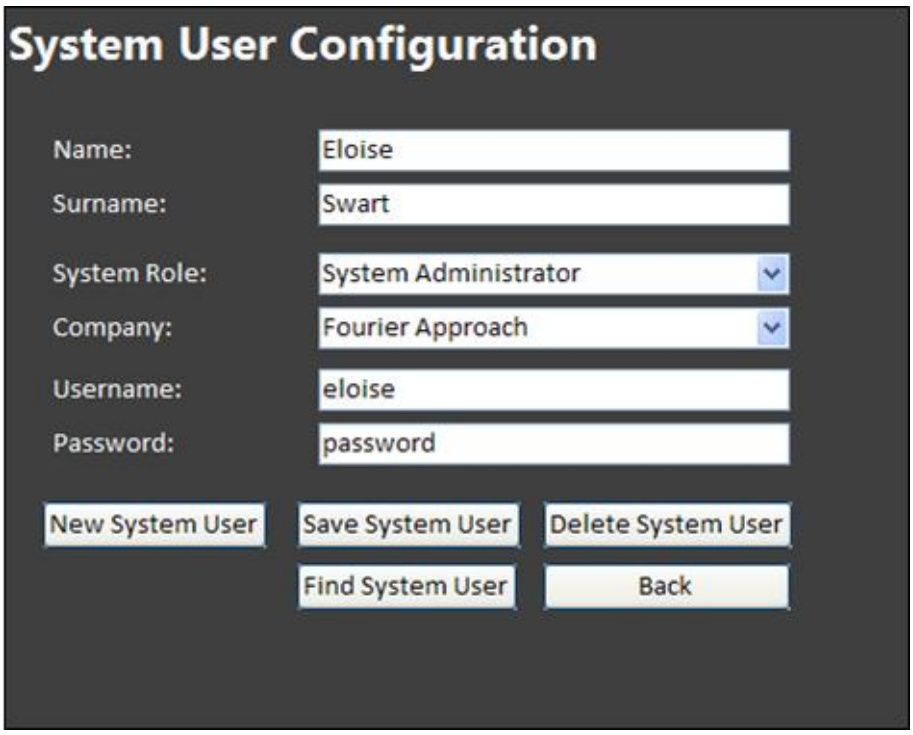


Figure B.3: System User Configuration Screen

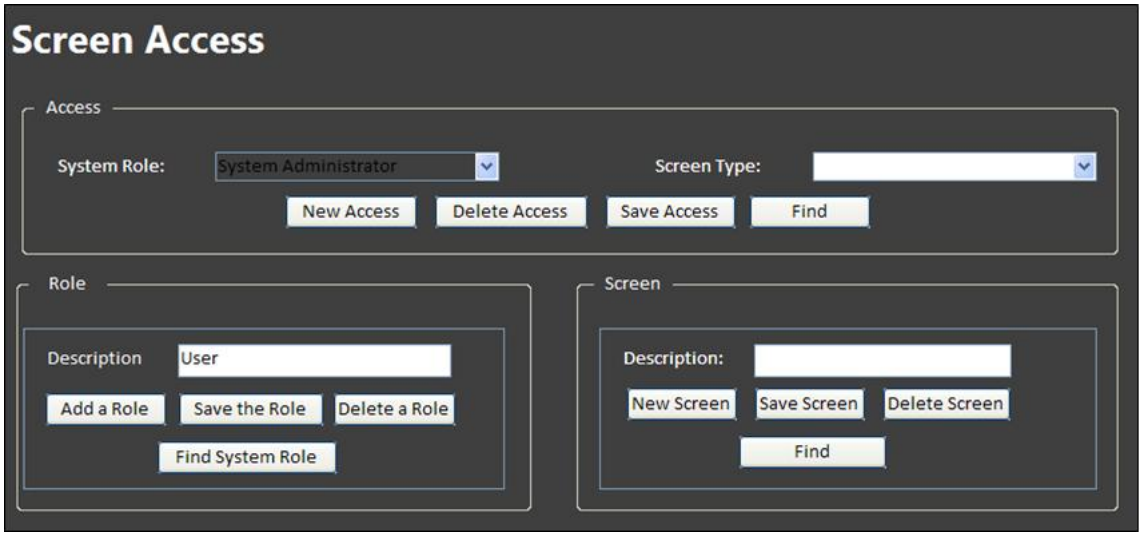


Figure B.4: Screen Access Configuration Screen

together as one type.

If a person signed in as a user, the screen as seen in figure B.5 appears. Here,the user has the following options:

- Configuring the devices according to their location, type and sub type (Figure B.6).
- Configuration of the parking environment by adding attributes to each sorting level and then creating relationships between them (Figure B.7).
- Configuration of companies that are involved in the parking system (Figure B.8).
- Configuration of parkers; this includes their personal details and vehicles (Figure B.9).
- Configuration of lift clubs (Figure B.10).
- Configuration of parking groups as well as assigning parkers to these groups (Figure B.11).
- Allocation of parkers to specific parking areas (Figure B.12).

B.2 System Reports

The user also has the option of viewing different reports:

- List of companies (Figure B.13).

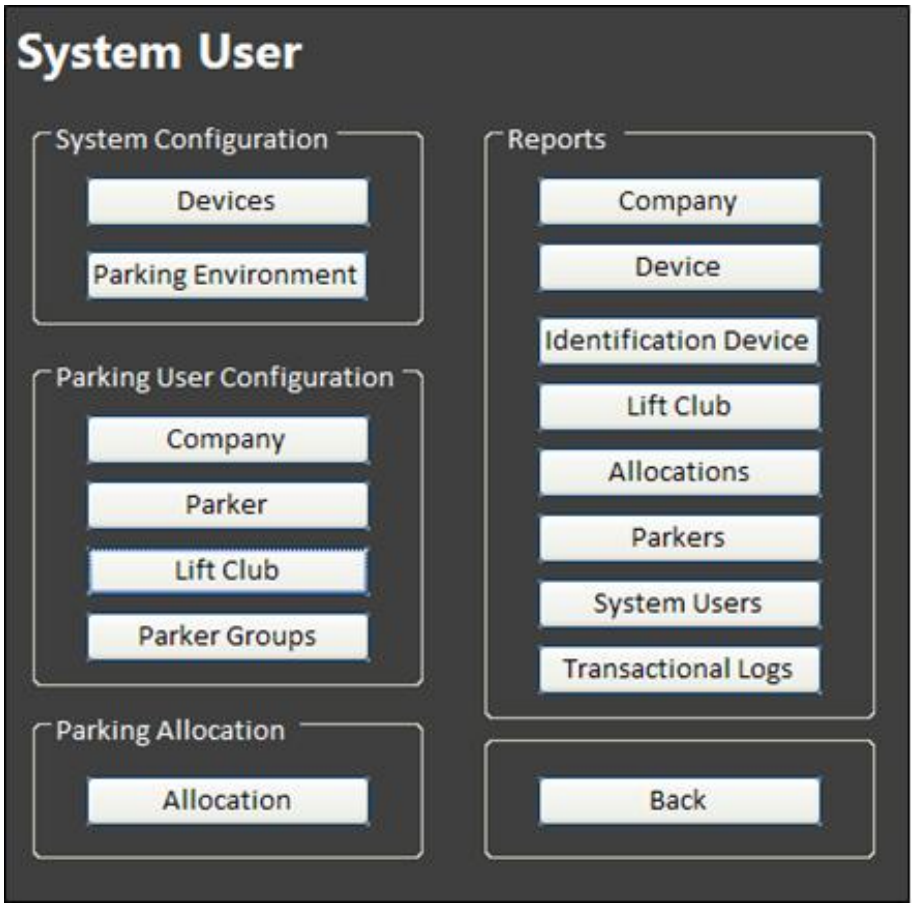


Figure B.5: System User Screen

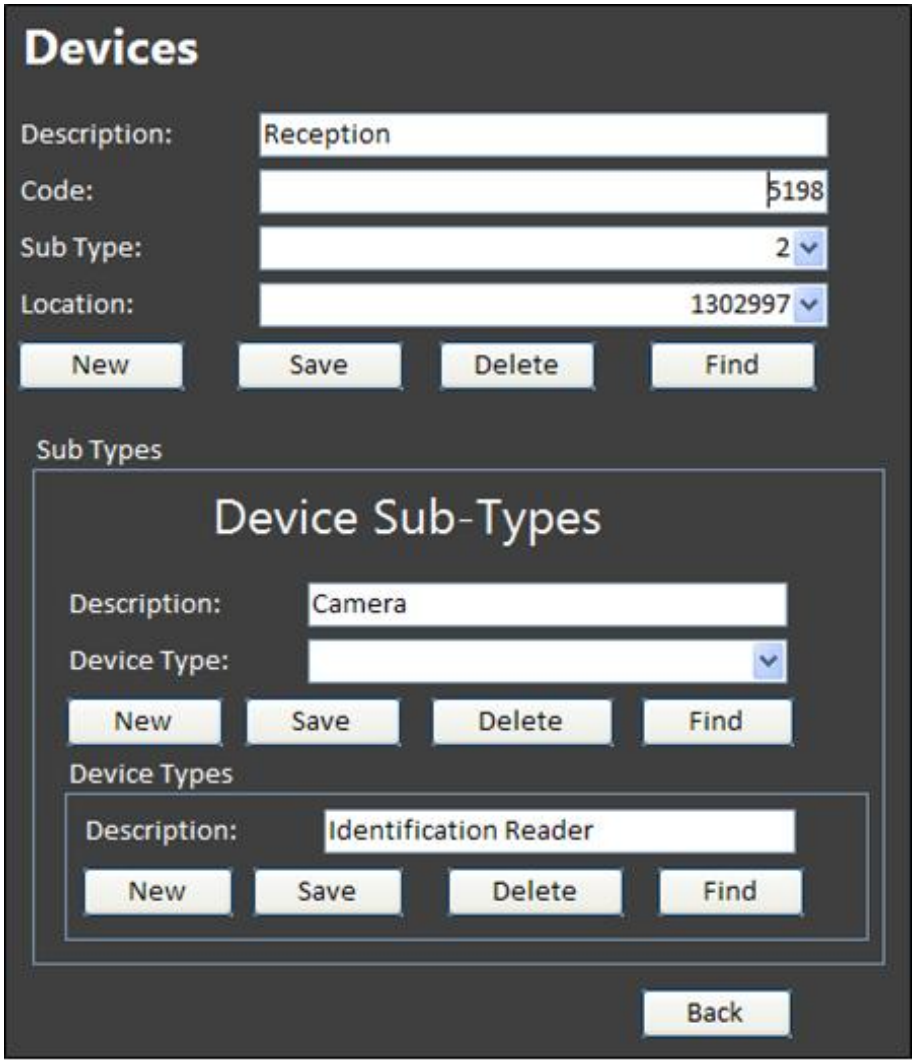


Figure B.6: Device Configuration Screen

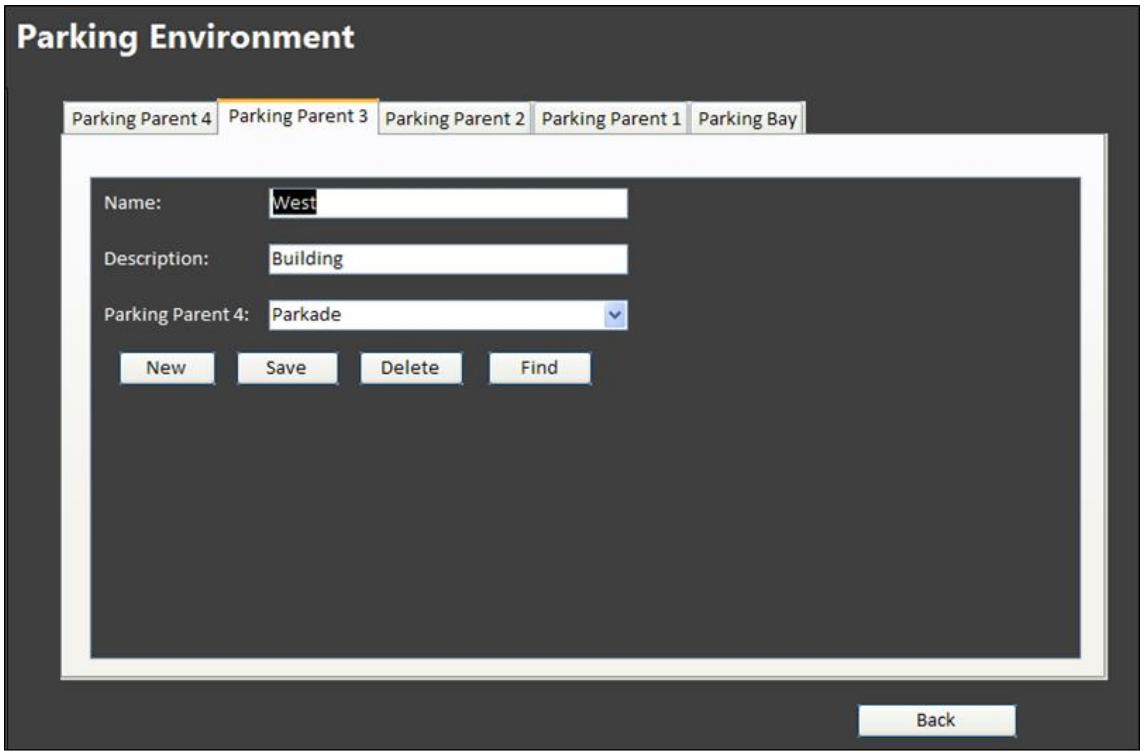


Figure B.7: Environment Configuration Screen

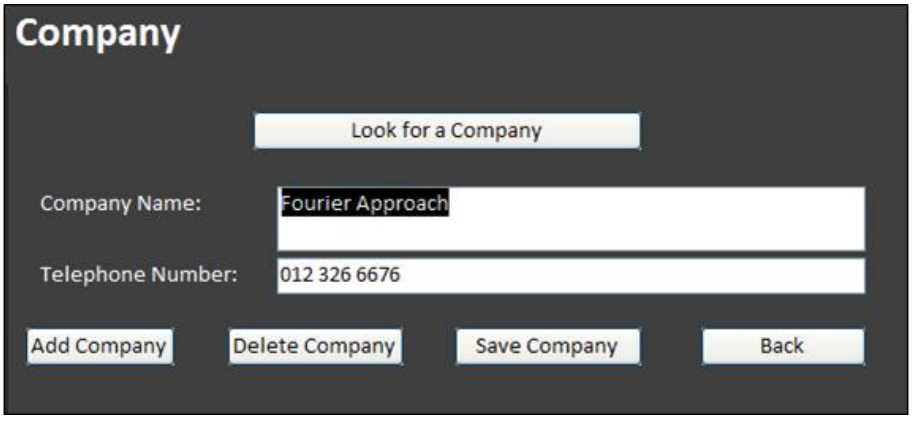


Figure B.8: Company Configuration Screen

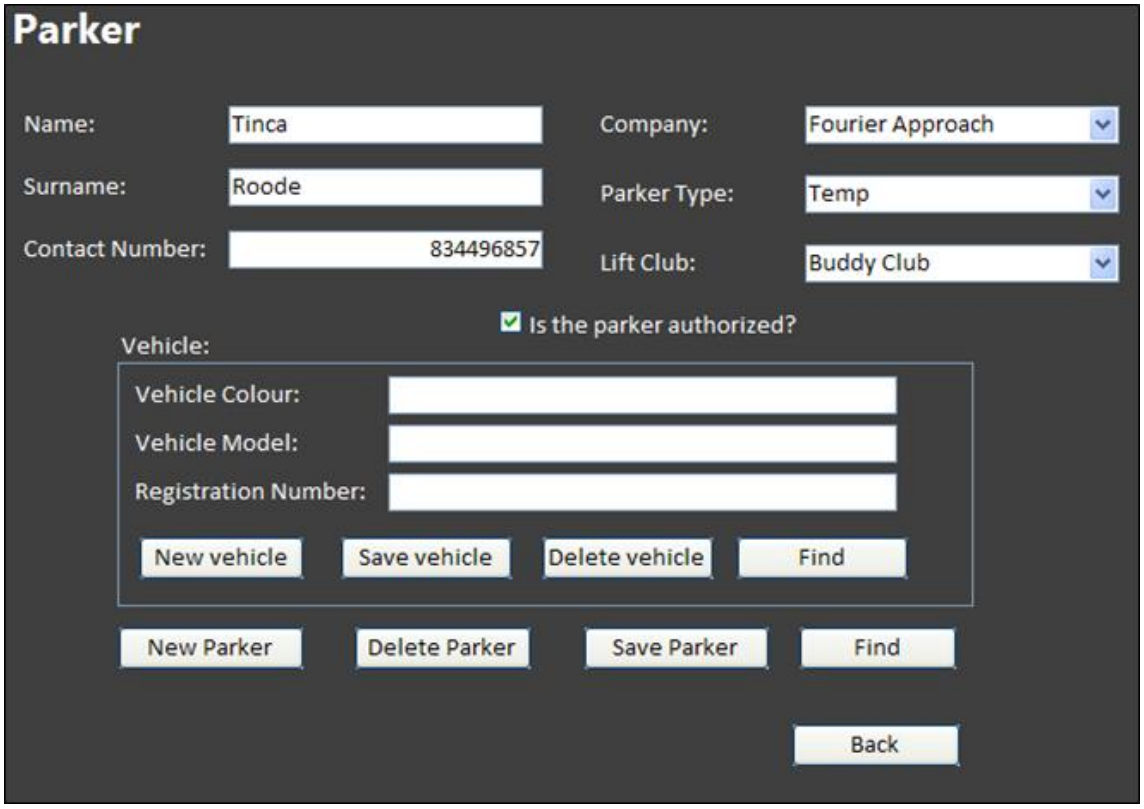


Figure B.9: Parker Configuration Screen

Figure B.10: Lift Club Configuration Screen

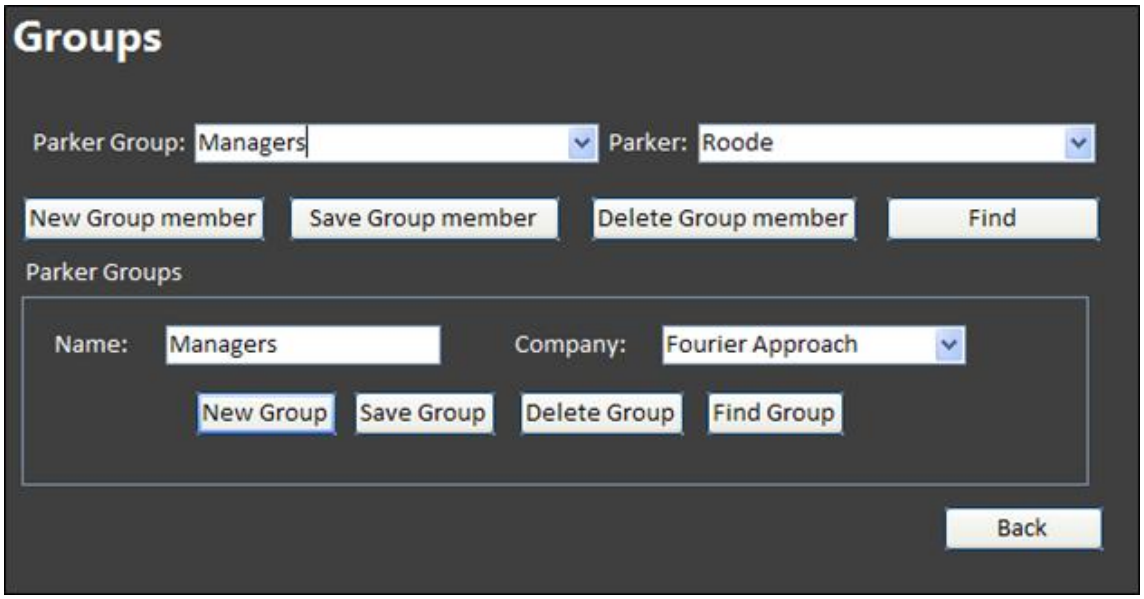


Figure B.11: Groups Configuration Screen

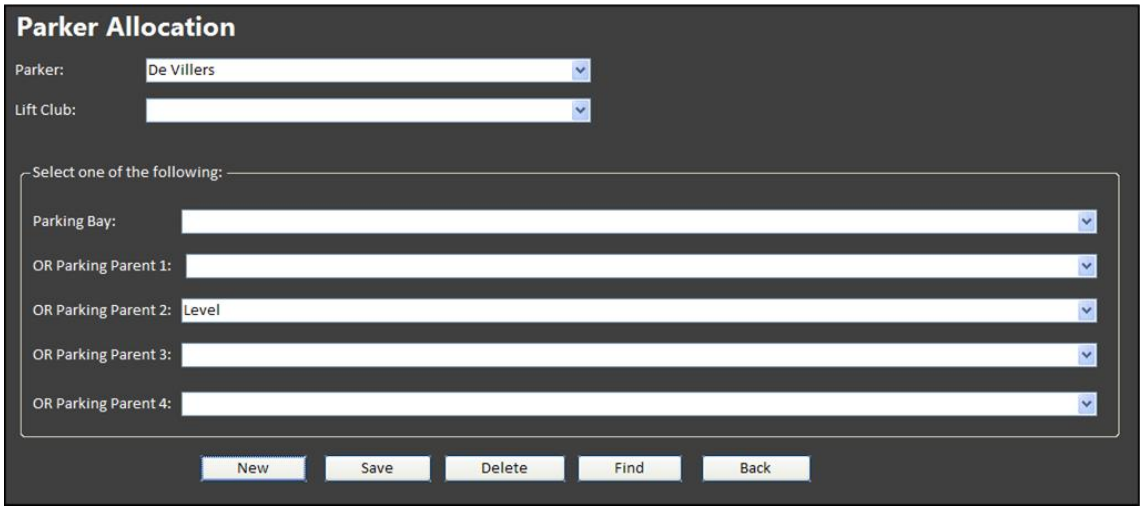
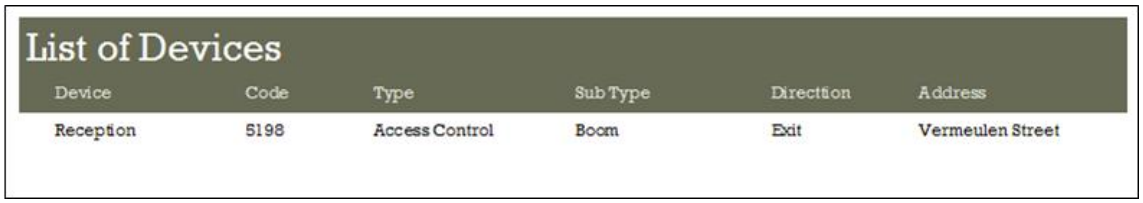


Figure B.12: Parker Allocation Screen

Figure B.13: List of companies report



List of Devices

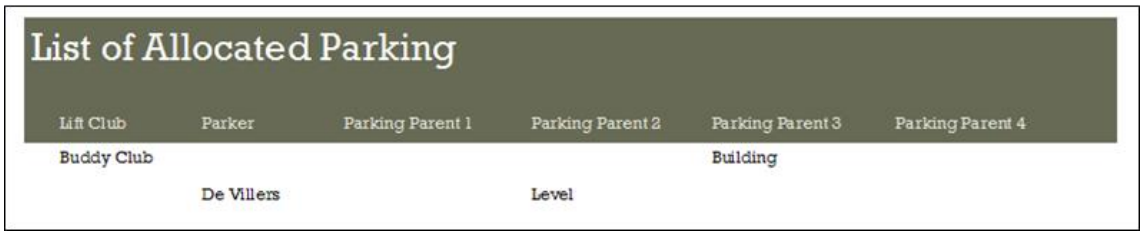
Device	Code	Type	Sub Type	Direction	Address
Reception	5198	Access Control	Boom	Exit	Vermeulen Street

Figure B.14: List of devices report

List of Lift Clubs

Lift Club and Contact Person	Surname	Name
Buddy Club: Juanita De Villers		
	De Villers	Juanita
	Roode	Tinca
	Swart	Renier
	Venter	Michelle

Figure B.15: List of lift clubs report



List of Allocated Parking

Lift Club	Parker	Parking Parent 1	Parking Parent 2	Parking Parent 3	Parking Parent 4
Buddy Club				Building	
	De Villers		Level		

Figure B.16: List of allocated parking report

List of Parkers

Name	Surname	Telephone	Type	Company	Authorized	Paymet Method	Lift Club
Christo	Jansen	267789987	Temp	Fourier Approach	☐		
Eloise	Swart	721417217	Employee	Fourier Approach	☑		
Juanita	De Villers	865598897	Contractor	Bigen Africa	☑		Buddy Club
Lana	Steyn	816659989	Temp	Fourier Approach	☐		
Michelle	Venter	987756588	Contractor	Bigen Africa	☐		Buddy Club
Renier	Swart	848879565	Employee	Discom Specialists	☐		Buddy Club
Tinca	Roode	834496857	Temp	Fourier Approach	☑		Buddy Club

Figure B.17: List of parkers report

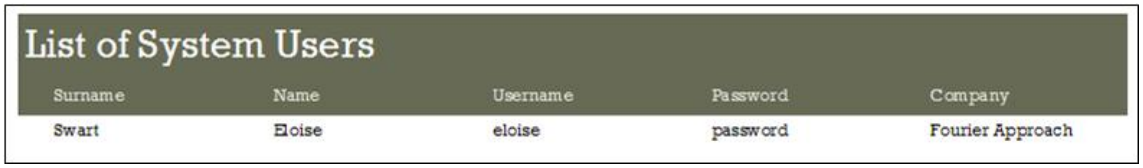


Figure B.18: List of system users report

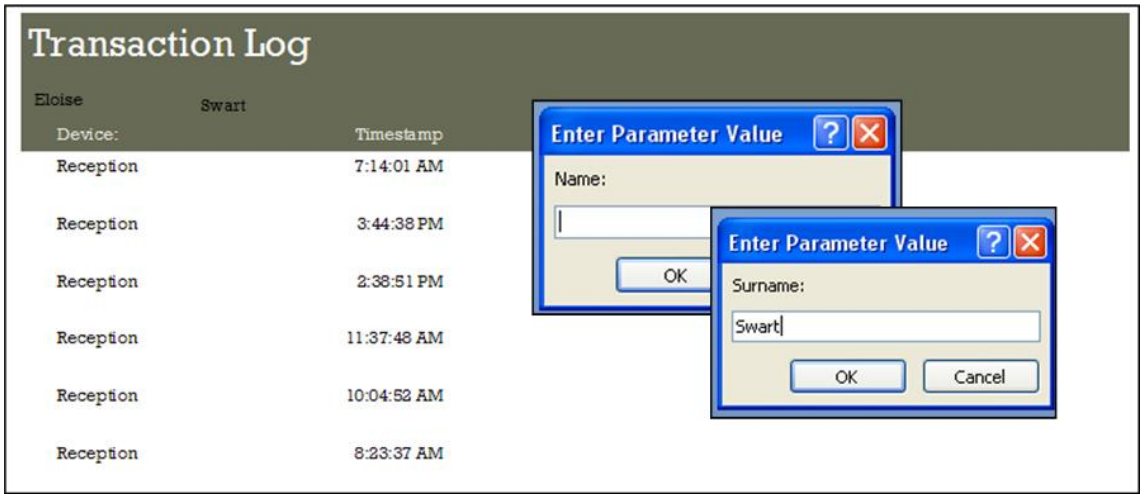


Figure B.19: Transaction log report

- List of devices (Figure B.14).
- List of identification devices.
- List of lift clubs (Figure B.15).
- List of parking allocations (Figure B.16).
- List of parkers (Figure B.17).
- List of system users (Figure B.18).
- Transactional logs for a user defined parker (Figure B.19).

Bibliography

Bregman, J. I. (1999). *Environmental Impact Statements*. CRC Press.

Buchwald, A. (1983). *Planning Advisory Service Report Number: Flexible Parking Requirements*, volume 377, chapter The Parking Proviso (Appendix A), page 25. American Planning Association.

CMMI Product Team (2002). CMMISM for systems engineering/software engineering/ integrated product and process development/supplier sourcing, version 1.1. Final Report Version 1, Software Engineering Institute Carnegie Mellon University, Pittsburgh, PA 15213, USA.

Department Public Transport Roads and Works (2009). Intelligent number plate registration system. www.transportandpublicworks.gpg.gov.za/numberplates.index.html. Accessed: 15 May 2009.

Intellipark (2007). Vehicle detection unit. www.intellipark.com/vdu.asp. Acessed: 15 May 2009.

Klein, L. A. (1899). *Sensor Technologies and Data Requirements for ITS*. Artech House.

Litman, T. (2008). Parking mananagement strategies, evaluation and planning. Transport, Victoria Transport Policy Institute, 1250 Rudlin Street, Victoria, BC, V8V 3R7, Canada.

Lonnie D. Bentley, J. L. W. (2007). *Systems Analysis & Design for the Global Enterprise*. McGraw-Hill/ Irwin, 7th edition.

Mashrur A. Chowdhury, A. W. S. (2003). *Fundamentals of intelligent transportation systems planning*. Artech House.

Scan, T. (2008). Rfid-radar gives precision long range measurement. www.rfid-radar.com/relaccuracy.pdf. Accessed: 15 May 2009.

Shaw, A. (2006). Achieving a pro-public transport agenda in South Africa The challenge for middle income countries. Technical report, Wessex Institute.

Smith, T. P. (1983). *Planning Advisory Service Report: Flexible Parking Requirements*, volume 377, chapter 2,3, pages 5,23. American Planning Association.

SPII (2007). Home page- support program for industrial innovation. www.spii.co.za. Accessed: 15 May 2009.

Sport and Technologies, T. (2009). Intelligent parking- parking guidence system. www.satt.co.za/parking.html. Accessed: 15 May 2009.

ZEAG (2008). Aiport case study O.R. tambo. www.zeag.com/en/solutions/airports/casestudyortambo/airportcasestudyortambo.aspx. Accessed: 29 April 2009.