A Systems engineering approach to database development for the recording and analysis of work sampling studies

BPJ 420

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Executive summary

Work sampling is an effective and economically viable way to analyze the productivity of operators and machines alike. The design of a work sampling project is often tedious and repetitive. The University of Pretoria is frequently involved in productivity investigations that make use of Work sampling studies and methods of streamlining the process have become necessary.

A fully functional database capable of generating work sampling sheets; generating randomised timeslots; assimilating data and providing relevant statistical information; have been created. The work sampling sheets that can be generated is customisable for any given work sampling study that is conducted, and have been designed with user-friendliness as an important end goal,

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Introduction

The University of Pretoria often conduct work sampling studies for different firms in order to increase the respective business productivity. Many of these work sampling studies are conducted at several different companies which lead to an arduous process of going through the same long procedure several times.

Designing these forms involves going through the whole procedure several times if more than one time study is to be conducted. Once the data is collected it is often processed in a spread sheet, such as Microsoft Excel. If more than one work sampling study is to be conducted, these analyses often go through the same process as well.

When these two facts are combined the value of a process that can automate the generation of these forms, as well as analysing the statistics of the study in a logical way becomes apparent. Since time has a monetary value, and the proposed time that can be saved will be significant, streamlining the entire process represents a saving in monetary input.

Problem statement

The main problem that is identified is the lack of standardised process with which to generate charts for doing time studies. A functional database that is able to generate forms necessary for work sampling studies is either not available, or it is not relevant enough to the needs that the University of Pretoria currently experience.

Project aim

The aim of this project is to develop a software package that will streamline the University of Pretoria's process of conducting and analysing work sampling studies. This project aims to accomplish this process of streamlining by conducting a literature study on work sampling and by using the knowledge acquired to construct a database that can aid with the generation of work sampling forms, generate random time slots and that is capable of doing basic statistical analyses.

Project scope

The first part of the project will involve an extensive literature study that will serve as the research component. Gaining an understanding of the work sampling process will help with the later phases of the project.

The second part of the project involves developing the software for the creation of work sampling charts and the analysis of the work sampling data and ensuring that it the software functions as a single comprehensive package.

Three situations that a work sampling study can be applied in will be studied

- The application of the work sampling study n which one person or machine will be studied at a time in a fixed location
- The application of the work sampling study where several persons or machines are being studied.
- The application of the work sampling study where persons or mobile machines are not limited to an environment, but are free to move about.

Deliverables

After the project is completed, a fully functional database that is capable of

- generating work sampling charts;
- generating randomised timeslots;
- assimilating data and providing relevant statistical information;

will be created. The work sampling charts that will be generated should be customisable for any given work sampling study that is conducted.

This will be based on data supplied by Eric Brett, lecturer at the University of Pretoria.

Literature Review

Work sampling

General

Work study is defined by Van Niekerk as "The application of techniques, designed to establish the time taken by a qualified worker to carry out a specified job in a particular situation in a particular space." Work sampling is a subset of work study techniques that has long been used as a reliable investigative technique to help analyse what proportion of time workers spend in various predefined categories of activities in the work place (Niebel, 2009). Work sampling was pioneered in the British textile industry, and then later the technique was exported to the USA.

A broad description of the technique can be stated as a reasonably large sample of observations that are obtained at random time intervals. The percentage of observations acquired reflects the ratios of time that an activity occupies in a normal working day.

The technique is flexible and can be used in several instances, the most notable of which includes:

- Monitoring individuals or groups of operators to discover where man hours are lost due to unproductive practices
- Monitoring an individual machine or groups of machines to determine how much productive time is lost during breakdowns, reparations and the operation of the machinery.
- Monitoring and categorising the use of a resource or group of resources.
- The technique can be invaluable in showing where time is wasted in bottle necks. (Van Niekerk)

Even though the disrupting effect of observations made on workers is minimised with work sampling, especially when it is compared to techniques such as time studies, it should still be taken in to account during the duration of the study. Communicating with all parties involved

in the project is critical as it ultimately determines the success and relevancy of the study. A basic guideline on how to approach each party involved will be discussed.

Management

The attitude of management towards the work sampling study has a large affect on the attitude that middle management and ultimately the workers will have towards the study. Management should thus be informed of the purpose of the technique. A thorough explanation should also be provided (International Labour Organisation, 1979)

Supervisors and foremen

The attitude of foremen and supervisors is the most important challenge to overcome. Workers assimilate their attitude from middle management. This is because middle management is affected the most by the study. Several factors contribute to this. Some of which include:

- It is the foreman that is responsible for the effective management of the activity under investigation. It may feel like the person's job security is under threat.
- The foreman might feel that if the process is improved, that the value of the work he has done in the past is lessened. The first person to be contacted when a dispute arises is the foreman. He needs a thorough understanding of the study to solve these disputes (International Labour Organisation, 1979).

Middle management should thus get a very detailed description of the work sampling study and its purpose. The following rules should also be adhered to:

- A direct order should never be given to a worker; the authority of the foreman should be respected.
- Refer all questions outside the scope of study to the foreman. At no times should the work sampler contradict an order from a supervisor.
- Never express a critical opinion of the foreman to a worker.
- Never start a study without the supervision of the foreman,

- Give space for foremen and worker relationships to evolve (International Labour Organisation, 1979)

Worker

Worker may feel threatened by the study as his basic need of security is under threat, thus be open with the purpose of study as it will breed suspicion when facts are purposefully hidden from workers. It is important that workers should be informed on what is being studied and why. To ease the worker's suspicion keep on emphasizing that the objective of the study is not merely to improve productivity, but also to increase job satisfaction (International Labour Organisation, 1979)

There are distinct phases to the work sampling technique and it is usually carried out in the following sequence.

- Firstly, the activities to be investigated should be identified. The different states in which a particular operator or machine will go through during the run of the activity should be differentiated and the exact purpose of the study should be clarified. It is more advantageous to record the particulars of more rather than fewer activities (Van Niekerk, 1982).
- Planning of the study and the calculation of the number observations needed to obtain the necessary accuracy levels to make the conclusions drawn up statistically significant. The accuracy depends on the number of observations taken (Van Niekerk, 1982).
- Generating and assigning random time slots for observations to take place during the duration of the study. It is necessary that observations should be conducted in shorter intervals if the activities that are observed are not repetitive and do not have long cycle times. Longer intervals between observations are permitted if the activities are repetitive (Van Niekerk, 1982). Time slot assignments should reflect typical conditions or inaccurate results may occur.
- Design of the activity charts. Headings under which random observations should be classified should be included in the chart. Space for all the required data should be

included, but care should be taken not to add too much details as the chart should be intuitively understandable of the work sampling person (Van Niekerk, 1982).

- Observations should then be conducted. The area in which an observation should be made must be carefully chosen, hopefully at a location that is out of field of vision of the observed workers (Van Niekerk, 1982).

Work sampling as a productivity monitoring technique is often favoured because it is less invasive when compared to a continuous study; it allows for quick analysis and provides statistical backing for any decisions made based on the study. Other advantages include the following categories:

Ease of use advantages

- Operators are not monitored for long periods of time on end, which decreases the discomfort felt by the observed worker.
- Observers experience less fatigue and it is less tedious to conduct the observations.
- Since the observations are not continuous, several operators/machines can be witnessed by a single operator. Thus fewer observers can be used.

Economical advantages

- Some techniques are uneconomical to analyse with a time- or continuous study. These work techniques can easily be observed with a work sampling study.
- Fewer workers translate in to fewer man hours when compared to a continuous time study resulting in a saving in wage expenses. No time measuring devices are needed (Niebel, 2009).

Flexible advantages

- The work sampling study can be conducted with interruptions without affecting the accuracy of the results aversely.

Observation length advantages

- Since observations are not conducted for long periods of time on end, the normal routine is less likely to be altered.

- Observations are conducted over several days or weeks, increasing the statistical accuracy by eliminating day to day variations in operator/machine variation.

Work study situation specific challenges

Since the work sampling study will be applied in more than one situation, it is best to analyse the challenges that each situation presents.

One person / machine one activity

This being the simplest application presents the fewest amounts of challenges to overcome. Only one individual is observed and is confined to an area. The work sampler thus has ample opportunity to observe the activity. Analysing the different sub-categories of activities also becomes easier. The detrimental effect of the observer on the worker becomes increasingly large as the amount of observations made on the worker is large and the worker is thus always aware of the observer. The expectations of accuracy are also raised as management will be aware of the simpler task at hand (Brett, 2012a).

Multiple persons/ machines one activity

Multiple persons or machines participate in the same activity at different stations. This allows the number of observations to be split between the different stations, decreasing the observer's presence at each station, lowering the disrupting effect of being observed on the worker. The forms should be adapted to accommodate several workers/machines. This might cause a shortage of space on the form itself, but gaining statistical insight in to the nature of the activity becomes easier (International Labour Organisation, 1979). Analysing the different sub-categories of activities also becomes easier.

Multiple persons/machines multiple activities

It becomes increasingly difficult to observe multiple activities. Several observers might be needed. The forms in which observations are made should be adapted to incorporate the different activities as well as the different sub-categories. If necessary the different activities can be placed on different sheets but this is not optimal. The number of observations for each activity should be enough to draw statistically relevant conclusions and each activity should

have randomised time slots assigned. Multiple persons decrease the amount of observations necessary per station.

Multiple persons, single activity, not limited to an environment

Since it is not practically possible for the observer to be present every where that the worker is due to the nature of the facility or the nature of the job at hand, allowance should be made for the fact that at an allocated time the worker might not be present. Since no information regarding the person's whereabouts is available, the illegitimacy of the worker's reason for absence should not be assumed. What this means is that the number of observations should be increased. When the statistical analysis of the activity is being conducted, the total number of observations should be reduced to match the total number of observations where the worker is present. An additional statistic surrounding the person's absence from the facility should also be given in order to indicate that the worker has not been present for the entire study. Once again it should be reiterated that absence from the facility does not mean that the worker has been idle (Brett, 2012a).

Multiple persons, multiple activities, not limited to an environment

This would be the most challenging set up. All the hurdles mentioned in the previous section still applies, but the complexity is compounded by several activates that needs to be observed. The modus of operandi remains the same as if it was only one activity. The total number of observations gets reduced by the number of observations that workers were absent. A compounded statistic surrounding the absence of all employees from the facility should be given at the end of the report in order to assure that the full picture is given to management when the results are presented to them (Brett, 2012a).

Database development

When large amounts of data is are gathered as is the case with this project, a database holds several advantages, the most notable of which includes making the data more manageable to handle and presenting it in a manner which allows information to be extracted from it.

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A database system is a complex software system that can meet the requirements placed on it by the user. It is often very large and can occupy various levels of complexity. The utilisation of databases has become common place and is so prevalent that it had become essential to management for most companies.

Several types of databases exist, some of which are utilised more than others, more specialised databases. An Active database is a database is a subset of databases that can respond to input and can process data internally, the uses of which include monitoring activities and statistical gathering and authorisation.

The operational requirements placed on a database in order to effectively support the needs placed on it by the end user, needs heavy support from the database administrator. This is done by making effective use of user interfaces and supportive tools (Wikipedia, 2012a)

It should be clear that a large amount of planning needs to go in to the design of a database in order to fulfil all the requirements and system specifications placed on it.

Systems engineering approach

Systems engineering is a field of engineering that focuses on how complex projects should be managed and coordinated over the life time of the project. Even though this approach was developed to be applicable to large projects with interdisciplinary teams working congruently on the several subcomponents of a larger whole, it still contains clear and logical approaches to tackling smaller scale projects. It deals with both technical and the human centred disciplines of running a project such as project management and organisational studies. Developing a database to accommodate work sampling studies involves several steps, which includes dealing with system and user requirements. This increases the complexity of the project, making the approach more applicable (Wikipedia, 2012c).

Systems engineering focuses on acquiring customer needs and system specifications early in the life cycle of a project when making mistakes has little financial impact on the progress of the study. It then progresses to proceed with solution design, development and synthesis and

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finally proceeding to the post-development phase of the project. This is done while constantly validating the system and considering it as an interrelated whole (Oliver *et al.* 1997).

Techniques exist with which to map the database in the design phase. This allows the programming of the database to be conducted more efficiently and it also permits other database architects to follow the reasoning behind the structure behind the database. It is thus enables other programmers to modify the structure of the database without the help of the original designer (Wikipedia, 2012a).

The tools that are most often used includes the following

Use case diagrams

The Use case diagram is a first of steps that defines the roles between actors and the system in order to ensure that the system goals are met.

Actors can be a person, a company, or abstract concepts such as time. All actors interact with the system in one way or another in a way that accomplishes a goal set by the end user of the database.

The main function of the Use case diagram is that it provides tangible indications of what is expected from the system, where information will be obtained from and how and where output of data should be displayed. It functions as a tool for capturing the functional requirements of the database. It also provides a means of identifying, tracking and controlling the development activities if the system. Use case diagrams are useful in generating user manuals as it already indicates what users might expect from the database system (Bentley and Whitten, 2007)

Entity relationship diagrams

The most common database design method is based upon the Entity Relationship Model. It makes use of a simplistic view that provides a conceptual representation of the database by

dividing the word in to categories: Entities and Relationships that these Entities occupy in relation with one another.

An entity can be defined as anything that is capable of existing independently and that can be uniquely identified. The relationships capture how these elements are related to one another. An easy way to visualise relationships is by thinking of the verbs that link two nouns ("supervises", "owns" etc.) These relationships can be classified, either as a one to many (one supervisor, many workers), one to one (each individual has one personnel card) or many to many (one worker can work at many stations, and each one of the stations have many workers allocated to it).

The Entity Relationship Model provides means for normalisation, which means data can be changed in one location and that changes will be carried through out the database. This is very useful for when a responsive database needs to be developed. It also provides a map of the internal structure of the database. Constructing this diagram is critical to the success of the database (Wikipedia, 2012b).

Dataflow diagram

In order to model how data will flow through the information system, the processes within the database needs to be modelled. A Data Flow Diagram is the graphical representation of information through a system.

The diagram focuses on where input will be received, where the data will be assimilated and where the data will be stored.

Problem Approach

As mentioned earlier in the report, a number of phases are passed through as a project moves from inception to project completion. Since the requirements can be clearly understood and easily formulated, a linear approach will be followed which acknowledges the stability of these requirements (Kossiakoff *et al.* 2003)

Waterfall developmental model

This is a classic linear software development life cycle and is presented in Figure 1. Each phase and how it relates to our problem approach will be discussed in detail.

Waterfall development model for creating a work sampling database
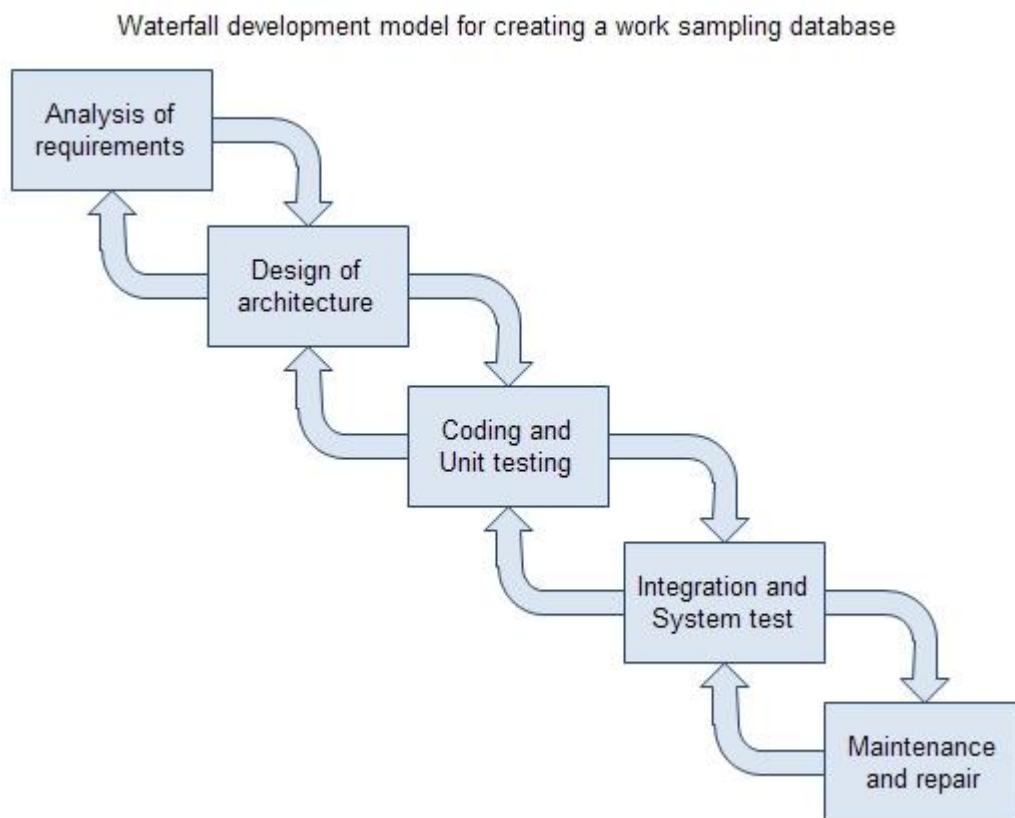
Figure 1 Waterfall model

Analysis of requirements

Ensuring that all the requirements are captured in such a way that it is easily understood is critical for any project. This includes capturing the high level requirements as well as user and system requirements on progressively lower levels of organisation (Kossiakoff *et al.* 2003)

To supplement the analysis of requirements, it is important to obtain data from previous studies to understand the context of the solution that will ultimately be presented.

The steps that were taken to analyse and understand the requirements for this study are listed as follows:

- A collection of work sampling forms are being collected to obtain an idea of how a generalised work sampling form will look like. A previous study has been done for a business unit of the petroleum company, Sasol. The data obtained from this study will be used to structure some parts of the database, though it should be noted that it will not be copied as the data remains confidential.
- Establish system needs, by conducting interviews with Mr Eric Brett, study supervisor and end user of the program solution.
- Establish financial and functional viability.

Design of architecture

Once the requirements of the system have been captured and the solution that is proposed is proven to be a viable option, the design on the study can commence (Kossiakoff *et al.* 2003) . The steps taken are listed below:

- Create a list of activities that will be give guidance for the development of the database. This will give direction to the development of the database.
- Map user interfaces with Use case diagrams. Use case diagrams will be used in order to see how user interfaces will communicate with each other, as well as tracking, identifying and controlling management and system development activities. Since it maps how users will interact with the system, it can be used as a guide for testing the database in terms of creating test plans. (De Vries, 2011b).

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- Map the database system with the Entity relationship diagram. The conceptual simplicity will give future programmers a clear idea of how information is linked with ne another. The tables of the database where data will be stored will be based directly on the graphical model and it eases the design phase of the database model that will be built (De Vries, 2011c). The last but not least significant function that the diagram will fulfil is that it aids in the normalisation of the database. This allows data to be centralised and ensures that the database stays responsive when data is changed or altered (WikiAnswers, 2012b).

Coding and Unit testing

This is the phase where the solution will be developed after extensive design measurements have taken place. Though few steps are included in this phase of database development it is the most time consuming (Kossiakoff *et al.* 2003). These steps include:

- Developing the database

- Extensive testing during development.

- Creating a user manual. Once testing has been finalised and all user requirements have been met, a User manual can be created to reduce the learning curve to using the database.

Implementation and system testing

The system that has been developed during the previous phases is installed in an environment similar to the one in which it will be implemented. It is then tested. Once all tests have been passed successfully, the database is presented to the end user, it is installed. All the steps in this phase include:

- Installation in a sample environment

- Testing once the database is has been set up in the temporary environment. Data obtained from previous studies at the Sasol plant will be entered in to the database. Together with the Use case diagram this will form the backbone of the testing procedure of the database to ensure that it functions as it is supposed to. All glitches that are discovered will be addressed in this phase of the project.

Operation and Maintenance

The system is installed for the end user. For a limited time, all difficulties and adjustments to the database that the end user finds necessary can be addressed. Due to the nature of the project it is not possible to perpetually continue this process.

Solution implementation

Analysis of requirements

Requirement analysis can be divided in to four higher level categories namely: Testing the viability of the system; Interaction requirements of the system; the necessary capabilities of the proposed system and the maintenance requirements of the system. Capabilities of the system can be further divided in to:

- What type of time studies the system must be able to handle
- What functions the system itself must be able to perform

Viability

Solution viability

In order to understand how creating a database will, in fact, be a solution to the problem as presented in this report, a PIECES (Problems, Information, Economic, Control, Efficiency and Service needs) analysis will be done. A PIECES analysis is especially effective when it comes to understanding how a database will solve a particular problem. This understanding is critical when requirements are captured, as the list of requirements needs to address these opportunities for improvement.

Problems to address

- Time consuming to repetitively create time study sheets for each study
- Different environments and businesses have different circumstances making it difficult to transfer the use of one worksheet from one business to another
- The time it takes to do analysis of all the data is excessive
- Current system is difficult to understand making it the sole responsibility of the study leader to oversee all projects (autonomy is less than it could be)

It is within the scope of possibility to design the database in such a way that repetitive, but customisable tasks can be handled.

Information needs

- Data need be compared between different studies

- Data inaccuracies need to be reduced as calculations and data entry can easily be done with a single solution.

- Original data needs to be preserved when analysis is done ensuring that results and processes that lead to a particular conclusion can easily be verified.

The database can capture data in such a way that ensures basic comparisons between studies can be made in future versions of the database. Since many studies differ in nature, a basic analysis may be all that is needed since more complex comparisons would be meaningless.

Economic needs

- Any economic advantages that can be gained will be advantageous to the project

Faster processing can lead to economic advantages as man hours can potentially be saved with the system.

Control needs

- Some level of security is needed to ensure the system performs optimally and to ensure that data remains confidential.

It is possible to control the access to the system with passwords. A more secure system may placate concerns of clients.

Efficiency needs

- Process too slow, analyses take a long time to compile.
- Process tedious

As mentioned earlier repetitive tasks can be handled by a database. Most of the data analyses will be done by the system. It is also possible for the process to become paperless, especially if the database can be sent to a tablet. This reduces steps in the time study process, making it more efficient.

Service

- Any advances in the levels of service provided are welcomed.

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Quicker response times possible with a more efficient system can increase the rate at which services are delivered.

From the PIECES analysis it can be seen that a database would in fact address many of the possible areas of improvement, proving that its viability as a solution.

Interaction requirements

From the PIECES analysis, the following system requirements relating to interaction with the system have become clear:

- Intuitive design of the database

- User-friendliness is critical to improve learning time and ease of use.

- The user must be able to access and modify data if it is needed.

- The user's requests must be fulfilled by the database within a reasonable time frame.

- When multiple users are present on the database, user access needs to be controlled and managed in order to preserve the integrity of the data.

- Different levels of data access should be granted to different persons depending on seniority.

System requirements

From interviews with Mr Eric Brett, information obtained from the PIECES analysis as well as information gathered from a representative work sampling study the following system requirements are in place. Some of these requirements will be discussed and analysed in greater detail.

- The database should be able to perform under various different situations and must be applicable to different companies.

- The study will focus primarily on multiple workers working at multiple stations that are not confined to a particular space. The database should be customisable to downscale the complexity of the observation forms to allow the study of multiple workers confined to a space for both single and multiple activities, single workers confined to a space conducting multiple and single activities.

- Since a level of customisation is necessary, a sample list of activates will be used as a basis for the generation of work sampling charts, with the added functionality of being able to customising the list of activities.

- The database must be able to generate random timeslots for the work sampling study

- The database should generate relevant work sampling sheets with which work sampling studies can be conducted.

- Data must be entered electronically in to the database. In order to reduce confusion, it should be similar to the work sampling sheets that were generated.

- Basic analyses of the data should be done, and the relevant statistics should be presented in a clearly understood format.

- The data must be available for the end user to be utilised.

Randomisation and timeslot assignment

The time slots it which observations will be taken should be randomised and assigned to time slots in the day in order to make sure that a representative sample of the activities will be taken. This includes, taking time slots during both night and day shifts, during breaks and active work sessions.

In order to ensure that samples are completely random observations randomised time slots should be generated automatically by the database. This ensures that a representative sample of observations is taken.

It is worthy to note that randomisation can happen on a two other levels, but will not form part of the solution package.

- Random days during the period of the study can be used to conduct observations. A benefit of this approach is that random time slots will be concentrated in fewer, but randomised days. The practical implication of which is that costs are saved on fuel and labour.

- A smaller time slot can be chosen in which all employees at a station is surveyed, similar to a quick time study (maximum observation length of one minute). This ensures that the disrupting effect of observation by the work study man is negated, and eliminating the probability of a person try to deceive an observer.(Brett, 2012a)

Representations of gathered data

The following statistics should be presented in an easy to understand and clear format:

- The total number of observations should be counted and presented. In addition the number of observations per day, as well as observations per work area should be accounted for.
- Overall productivity for a class of worker or individual worker should be tracked.
- A break down of the total time spent at work should be done for every worker class on an activity to activity basis.
- A break down of the productive time should be done for every worker class on an activity to activity basis.
- A break down of the total planning time should be done for every worker class on an activity to activity basis.
- A break down of the unproductive time should be done for every worker class on an activity to activity basis.

Design of architecture

Determining the number of observations needed

For economic reasons, it is accepted practice to use a confidence interval of 95% for the statistical data that will be obtained. This means that the distribution of data that is randomly obtained will occur by chance only 5% of the time.

The acceptable limit of error is the maximum overestimate and maximum under estimate of sampling and non sampling errors (OECD, 2002). This value is assumed to be 2% (Brett, 2012a) through out the project, but the parameters will be set it a way that it is customisable to adapt to each study.

The number of observations that must be made in each study for each activity can be calculated using the formula

$$n = \frac{3.84 * p * (1 - p)}{l^2}$$

Where n is the number of observations needed and l is the acceptable limit of error as a %. p is a variable that indicate the possible proportion of total observations that an activity can occupy. In order to assure that the best possible outcome is reached p is taken to be 0.5. (Niebel, 2009)

The number of observations necessary can thus be calculated once the parameter is given by the end user.

List of activities

The activities in this list are based on what the University of Pretoria has used for a business unit of Sasol, but it has been modified to ensure that it is applicable to most businesses. The list will give default options open to a study. The database is set up in such a way that these activities can be readily customised to better reflect the needs of each study. Default activities ensure backwards compatibility of the activity list which ultimately enables comparisons to be made with other studies in future developments of the data base. Activity codes will be assigned as the data is entered into the database.

Working

Tools in hand	Assisting	Safety provision
Measurement	Housekeeping	Providing instructions
Accepting instructions	Test or inspection	

Planning

Organizing meetings	Paperwork	Observing
Check diagrams	Check instructions	Check schedule
Check safety provisions	Check materials	Check tools
Check equipment	Check mobile units	

Waiting

For commands	For task completions	For mobile unit

For safety inspection	For safety permit	For safety equipment
For group member	For other workers	For materials
For tools	For equipment	For transportation

Travelling

Between jobs	For materials in area	For materials outside area
For tools in area	For tools in tool room	For tools outside area
To/From break	To/From lunch	To/From showers toilet
Within job		

Lost time

Late start	Early quit	Idle while traveling
Idle in work area	Personal	Unassigned

Plant policy

Medical	Lunch	Smoke
Rest	Clocking in/out	Safety meetings
Weekly meetings		

Mapping user interaction with a Use Case Diagram

The Use case diagram is presented in Figure 2. The notation indicates how actors will interact with the system, or series of use cases. Use cases are actions that are performed within a subsystem (blocks indicate the borders of sub-systems). Arrows that point away from an actor indicates that an actor is initiating the use case. Lines without arrows that lead from a use case to an actor, indicates that the actor is receiving information from the system. As an example, the Study leader generates time study sheets, the Work sampler, in turn receives it and enters data in to the sheet.

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In this Use cases diagram, "Extends", "Uses" and "Depends on" notation is used to indicate additional functionality and to provide a more detailed view of the functionality of the system.

"Extends" is used where a use case extends the base functionality of the Primary Use case. Arrows point toward the base use case. Secondary used cases are specialisations of the Primary use case and will not always be called upon. In this instance managing activities is extended by the ability to add relevant activities. This is not an action that will be performed each time activities are being managed (they can, for example, be selected from the default activities instead)

"Uses" is used where a use case is used by the Primary use case. This is a necessary function and will always be called upon. Arrows point away from the Primary use case. Part of giving the requirements for a study is to specify a station, or location that will serve as the observation area. Each time study specifications are documented, the work area needs to be specified as well.

"Depends on" indicates what functions is necessary before the use case can be performed. A sheet can not be generated before random timeslots are not yet assigned. This also gives an indication of the sequence of events.
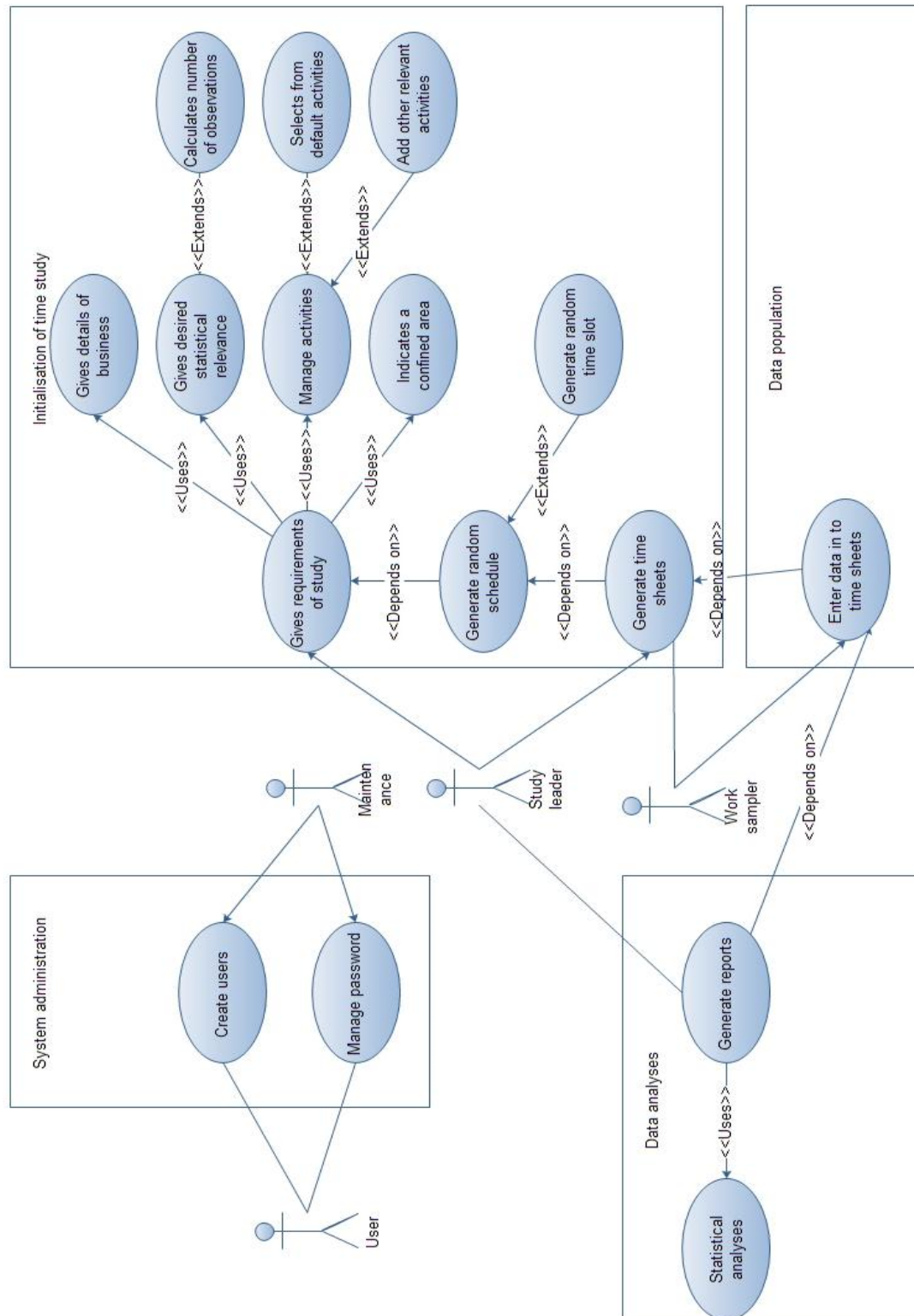
Figure 2 Use Case Diagram depicting user interactions with the system as well as the activities that need to be completed by each role player.

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The ERD is presented in Figure 3. The notation indicates whether an entity has a one, one or zero, zero to many, one to many relationship with other entities. Crows feet notation is used in this diagram. Stripes indicate a "one" relationship, a circle a "zero" relationship and the crows feet indicate a "many" relationship. For example, each activity has many sub activities linked to it. The ERD is normalised to ensure that data integrity is maintained.

The entities in this diagram are populated with attributes. The left column of the entity indicates either a Primary key (PK), a uniquely identifying attribute or a Foreign key (FK), an attribute that relates it to another entity.

Two levels of database exist. The higher level is dedicated to management of the database and thus includes personnel that need to access the information presented by the system. It is for the same reason that a directory entity is present, to ensure that every study can be accessed on its own. The higher level database also provides default activities to which all studies will refer to.

The lower level database contains the entities that will relate to every study and contains the entities to which most data will be sent to.

The database is designed in such a way that each study has its own tables. This reduces the processing time for the computer to sort and select from data as the many readings will be prohibitive if all studies will be saved in the same tables. This is another reason why splitting the database in to two levels is beneficial.

Higher level database

Timestudy Personel

PK	TimeStudyPersonelID
	TSPersonelNR
	TSPersonelName
	TSPersonelSurname
	ID
	CellphoneNR
	Password
	Clearance

Directory

PK	BusinessID
	BusinessName

DefaultActivity

PK	ActivityID
	ActivityName
	ActivityCode
	ActivityDescript
	isDefault
	Delete

Study Directory

PK	StudyID
	BeginDate
	EndDate
FK1	**BusinessID**
	Acceptable Error
	NObserve
	First

Default SubActivity

PK	SubActivityID
	SubActivityName
	SubActivityCode
	SubActivityDescript
FK1	**ActivityID**
	Selected
	Delete

Lower level database

Study

PK	StudyID
	BeginDate
	EndDate
	AcceptableError
	NObserve
	BusinessID

Sampling Sheets

PK	SheetID
	RandomDayGenerate
	ObserveDate
	ObserveArea
	Groupnr
	Sheetnr
	Shiftdescript
	TSPersonelID
	Comments

Random Day

PK	DayID
	RandomDate

ListPersonelJobs

PK	PersonelJobID
	PersonelJob

ObservedPerSheet

PK	ObsSheetID
FK1	SheetID
FK2	ObsPersonelID

Random Timeslot

PK	TimeslotID
	ObservationNR
	Time
FK1	**SheetID**

Observed Personel

PK	ObsPersonelID
	ObsPersonelJob
	ObsPersonelCode
	Selected

ListAreas

PK	ListAreaID
	AreaName

Activity

PK	ActivityID
	ActivityName
	ActivityCode
	ActivityDescript
	IsDefault

Sub Activity

PK	SubActivityID
	SubActivityName
	SubActivityCode
	SubActivityDescript
FK1	**ActivityID**

ObservedPerTimeslot

PK	ObsTimeID
FK1	**TimeslotID**
FK2	**SubActivityID**
FK3	**ObsSheetID**

Figure 3 Entity Relationship Diagram mapping out the database architecture that is followed for the purposes of this study.

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Coding and Unit testing

Microsoft Access 2007 has been used to generate the database. Microsoft Access is readily available on most computers and it integrates easily with other programs from the Microsoft Office suite of programs to create a powerful application (Brett, 2012a).

VBL is the programming language employed to program the more complex functions of the database. It is the language used by all Microsoft Office applications. It allows the database to be created in such a way that it is more user friendly to operate.

All forms are designed in such a way to ensure that it is intuitively understandable to any user with a basic knowledge of work sampling studies.

Database

The created database has means to control access to data in order to fulfil potential client needs of data security. It does this by distinguishing between 2 types of users, "Time study observer" and "Study leader". Time study observers can only access time study sheets that have already been set up by a Study leader, whilst a Study leader has access to the full range of actions that the database offers. To accomplish this, the user has to log in to the system before any other options can be accessed. The "Log in" screen can be seen in Figure 4.

As the Time study observer has fewer options than the Study leader, the functions available to the Study leader will be discussed.
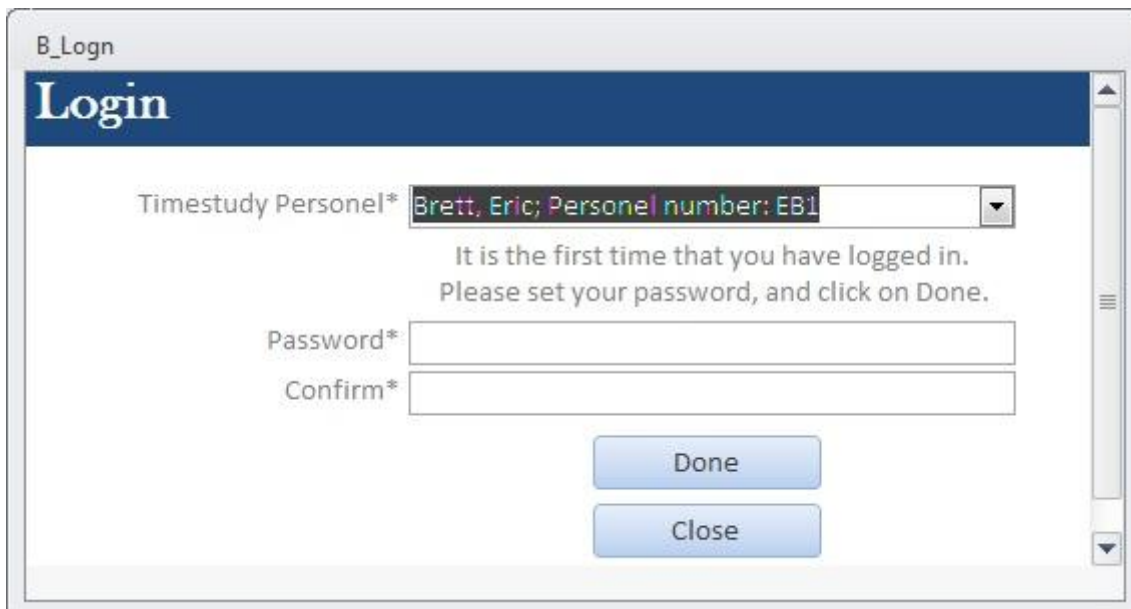
Figure 4 Log in in screen to database

After logging in the user is presented with a main screen, explaining some of the functions available. From this screen user accounts can be managed, Default activities can be managed and time study functions can be accessed. The functions behind each button are explained in commentary boxes linked to it in order to ensure that the user can quickly identify the correct option. This advances the objective to create a user friendly platform from which to conduct time studies. The main screen can be seen in Figure 5.
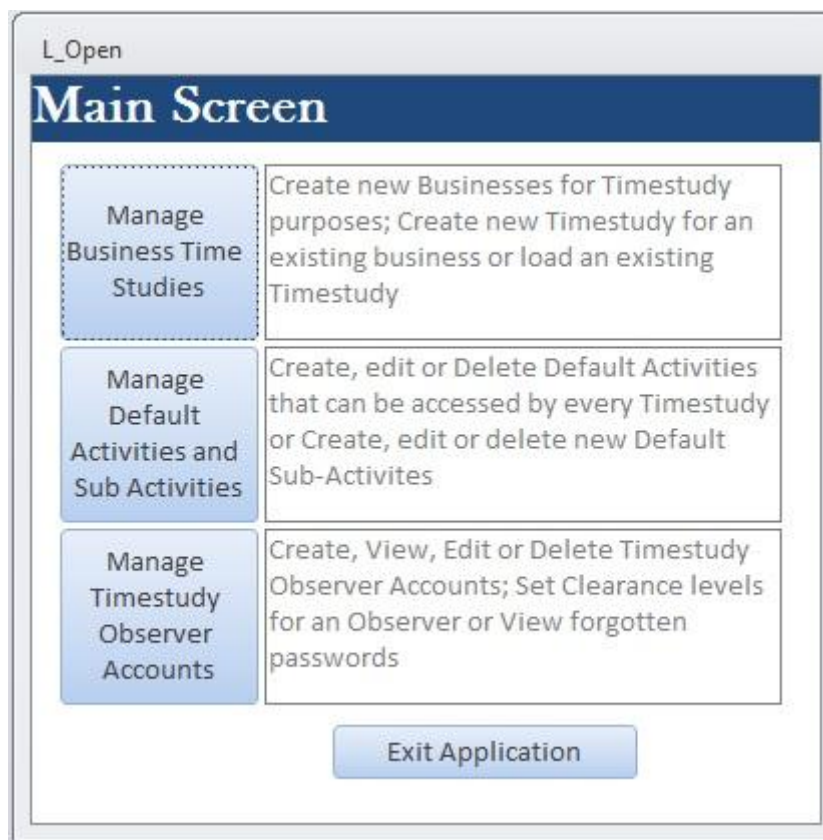
Figure 5 Main screen from which database activities can be conducted

The Time study observer accounts screen allows a user to manage access levels, view passwords, create, edit or delete observer data. In Figure 6 the "Display password" button have been clicked. This function allows a Study leader to view the password of an observer if a password has been forgotten.
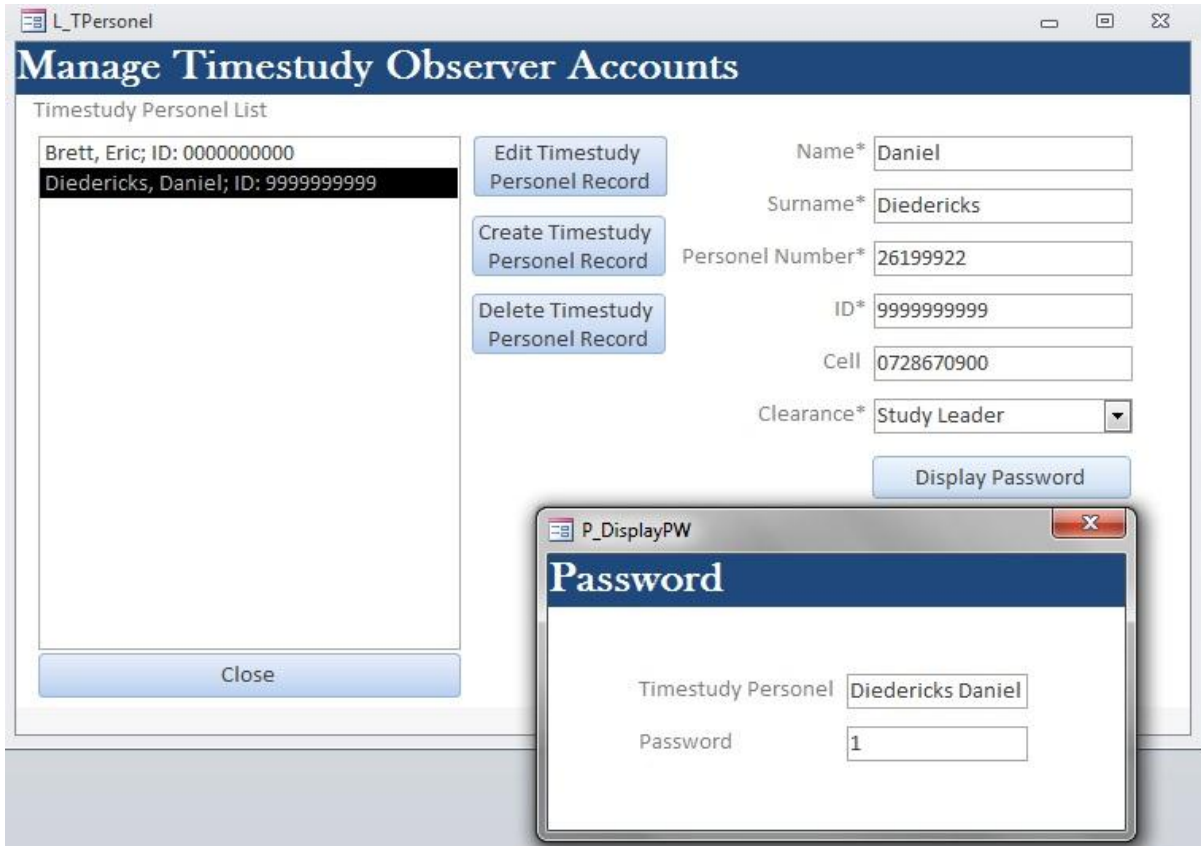
Figure 6 "Manage time study" accounts screen
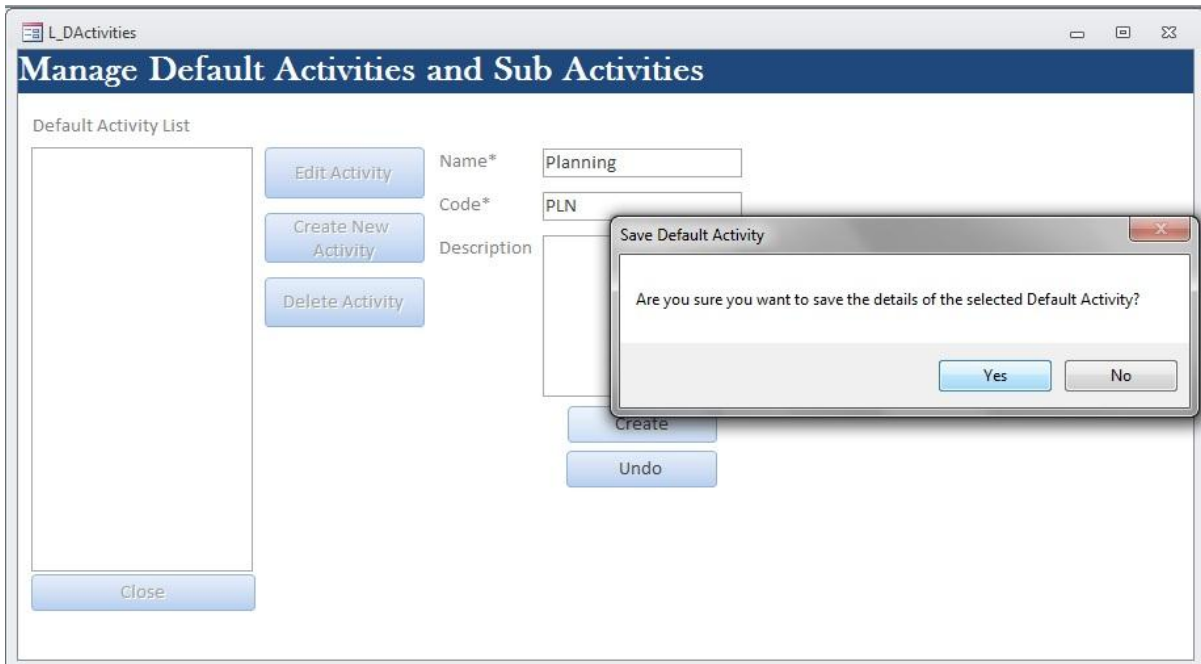
Figure 7 "Manage default Activities and Sub activities" screen

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The "Manage default activities and sub activities" window allows a user to select activities that will act as default options for all studies being conducted. A typical example of a main activity would be "Planning". Sub activities of "Planning" would include actions such as Paperwork, Check instructions etc. This screen is shown in Figure 7 where a saving action has elicited a user prompt to affirm that the action taken was intentional. This has the added benefit that it decreases the chances that a user will be confused by clicking on an option, without knowing what has been done.

The "manage business time studies" window allows the user to create a business for which to do a time study; view administrative information of a study that has been conducted; and the user can open a study that has been created previously. The database allows for more than one study being conducted on a business.

In Figure 8, the user is busy creating a new study for the company, "University if Pretoria". It should be noted that most of the buttons have been disabled. This is a feature that allows a user to be focused on the action that has been taken and it prevents disruption to the underlying data flow of the program. It is important, for example, for a user to be unable to delete a record before that record has been created. Disabling accomplishes this task and increases the overall user experience of the program.
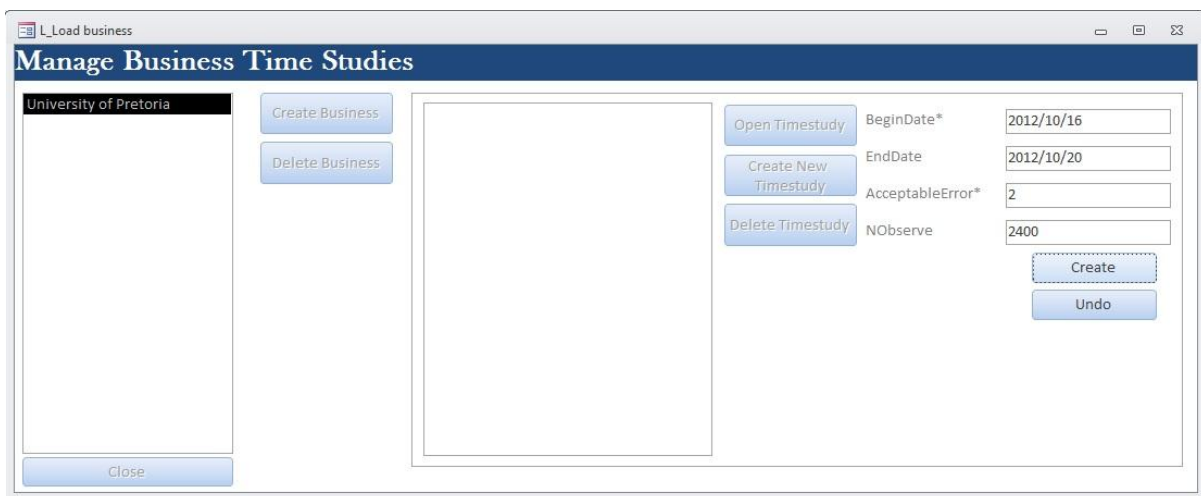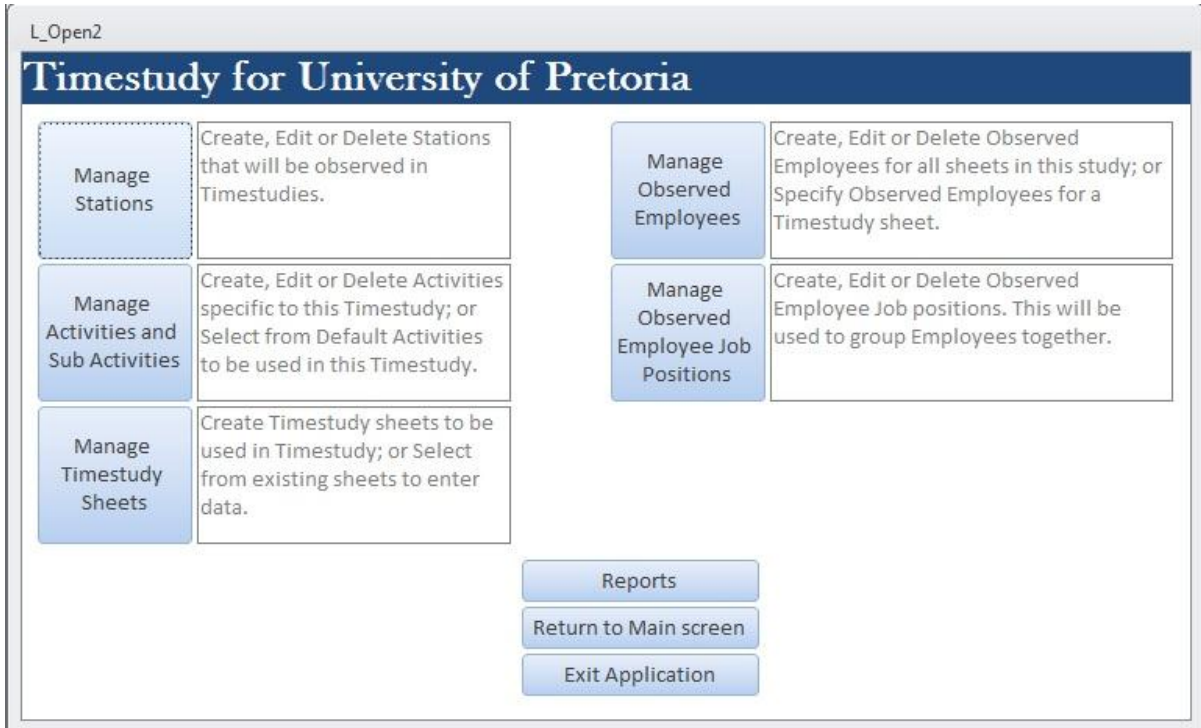
Figure 8 "Manage business time study" screen

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Figure 9 The second main form. Functions pertaining to the selected study are available to the user.
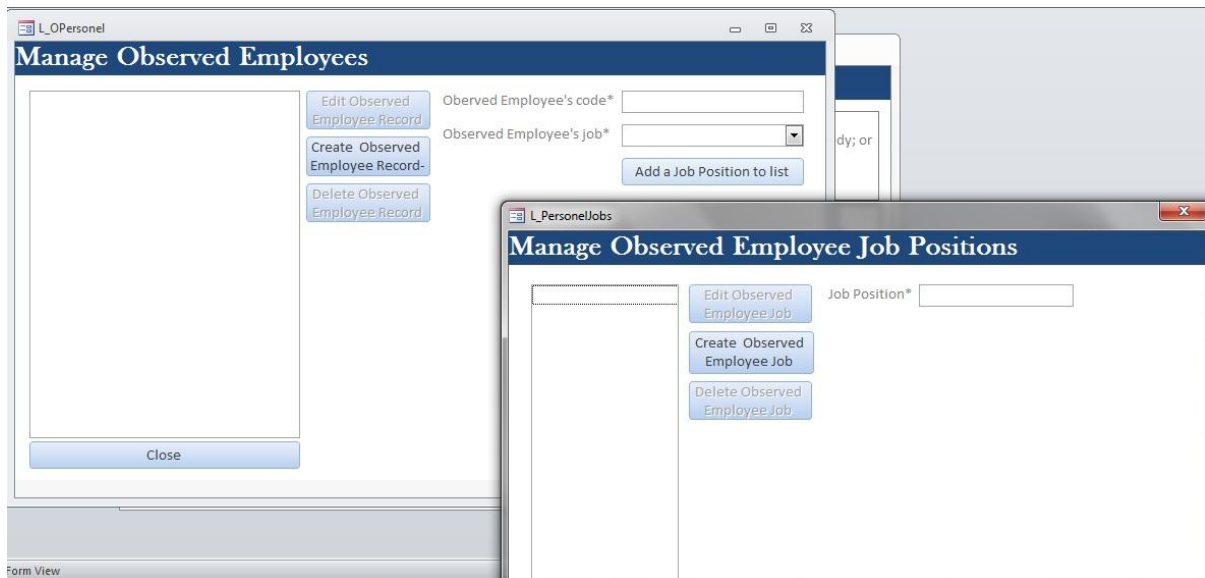
Once the user opens a selected study the second main form in Figure 9 is displayed. This screen provides functions that can be applied to the specific study. All data changes in that can be isolated from other studies. The second main form also allows navigation to the first.

From this screen a user can create edit or delete stations for observation; manage the activities that are applicable to the study, manage observed personnel that will be observed in the study, add work positions available to the study; and manage timesheets.

Figure 10 displays the "Manage observed employees" window. From this window new employees can be added to the system, information can be deleted as well as edited.

Part of specifying detail of an observed personnel member is to adding their job description. Since the order in which a user selects commands from the second main form can not be controlled, the list from which to select may not be populated with the needed information. Usability has been increased in this instance since a command button can instantly add it to the list to be selected. Grouping functions together that makes intuitive sense decreases the learning curve for a user to understand the program.

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The "Manage observed employee job position" form shown in Figure 10 is the same form that is called upon in the main menu and allows a user to create, edit or delete a specific occupation from the list. Figure 11 shows the populated list.

Figure 10 "Manage observed employees" window. The command to add a job position to the list has been called upon.

Figure 11 A populated list on the "Manage observed employees" form.

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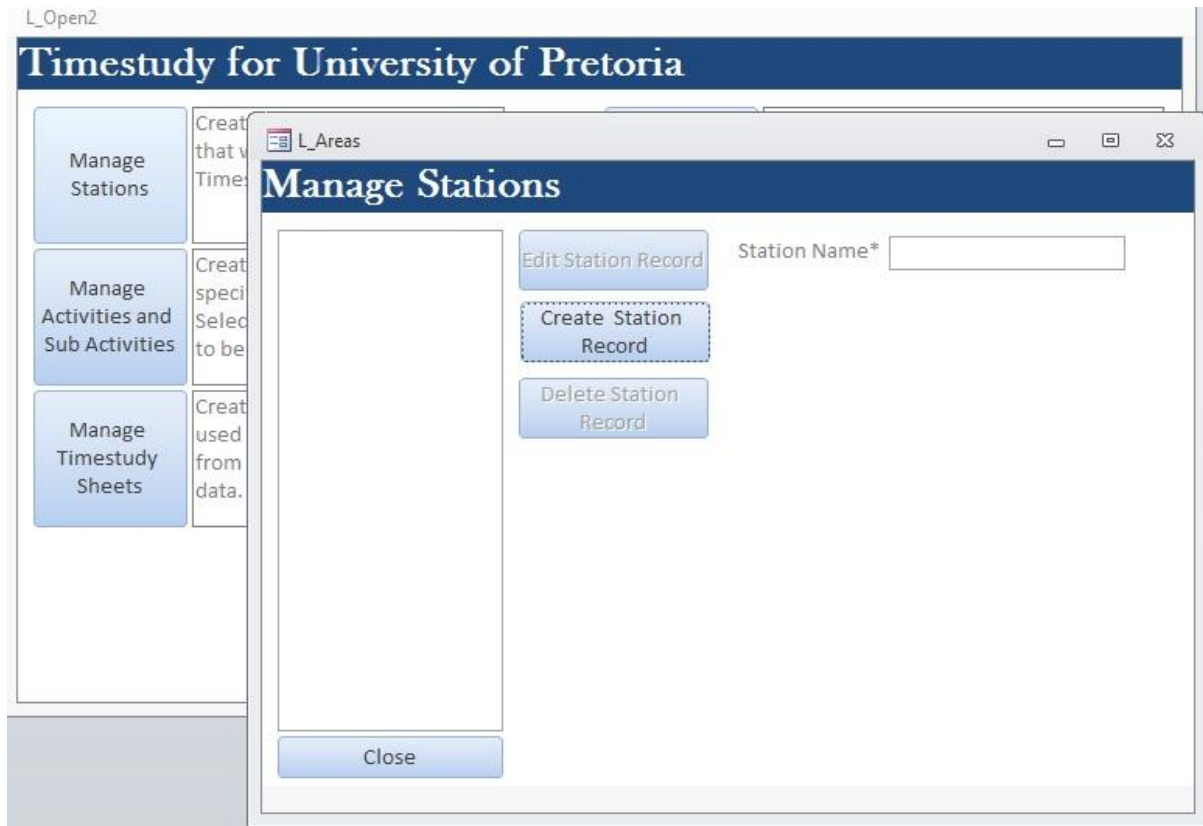
Figure 12 "Manage stations" form

Figure 12 displays the "Manage stations" form from which information regarding the observation area can be added.
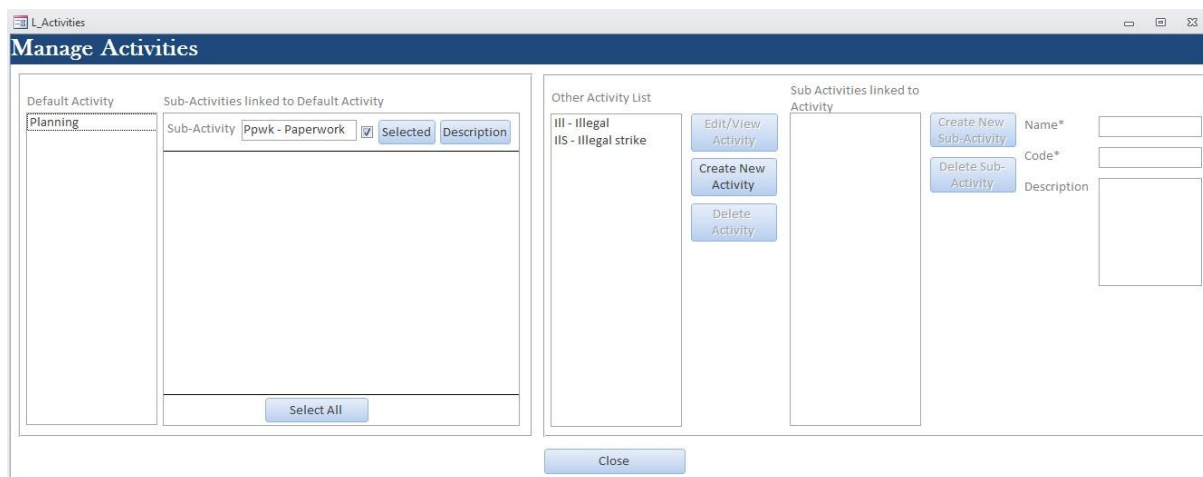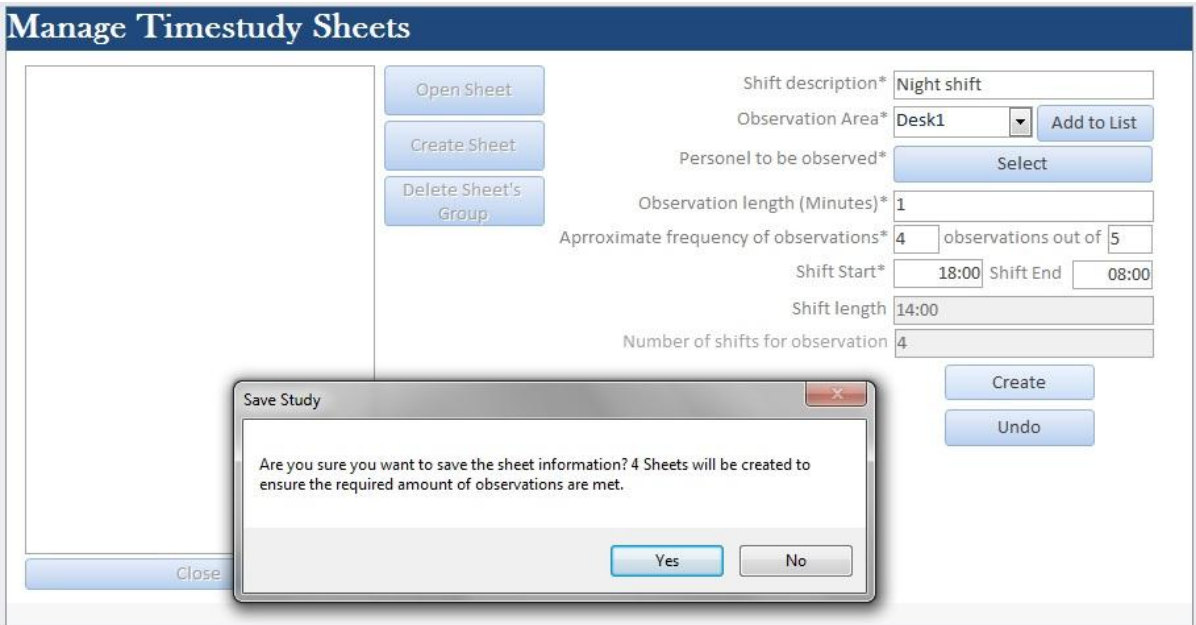
Figure 13 Manage activities form. It should be noted that the form is split in to Default and study specific activities

Managing and selecting the activities is done from the "Manage Activities and sub activities" form shown in Figure 13. Default activities are listed on the left of the window, were they can

be selected if it is applicable to the study. The portion of the window to the right allows any additional activities to be added. This is useful if activities need to be listed that are not necessarily part of every time study project to be under taken. This allows the database to be as standard as possible, which allows for a faster rate of creating a new time study while keeping specific requirements.

The "Manage time study sheet" allows the user to open a pre-existing sheet, as well as creating new sheets. In Figure 14 the form can be seen before sheets are created for the study. The information necessary on the form is used to automatically generate random timeslots for each shift that will be created, where each shift is represented by one sheet. To ensure that enough samples are taken, observing more than one shift may be necessary. The total number of observations is determined from a mathematical formula based on the margin of error desired and dispersed in the way that the user requires. Figure 15 displays sheet that has been generated for a different study.

Figure 14"Manage time study sheets" form which generates time study sheets.

Figure 15 A Time study sheet generated by the database.

On the main form the option to view reports pertaining to data generated in the sampling sheets is available. Gathering a lot of data has little use if there is not a means to summarise it effectively. The Reports window shown in Figure 16 displays the way that data can be summarised. These options are consistent with the research that has been done on the needs of such a work sampling study.

The total number of observations can be given, broken down by area, or by date. It is also possible to view the Sub Activity levels of a specific worker or a class of worker through the reports available. For example, it may be necessary to view the percentage of times that a worker has worked on paper work (Figure 17). By selecting either "Overall activity levels per worker class" or "Overall activity levels per worker" it is possible to view the participation in a larger category of activities such as Planning.

Figure 16 Reports window

Figure 17" Sub activity levels per worker" report

Implementation and Operation

The database went through much iteration to ensure that it behaves as a user should expect it to. Errors have been eliminated and user prompts that are more clearly understood due to its relevancy to the database have replaced the native requests of Access.

The database is packaged in a folder with the user interface and database directory readily available. Instructions surrounding the installation procedure of the database are included in

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the package. The instructions only require elementary computer knowledge to accomplish the task.

Due to the nature of the project, a full implementation with assistance and training to the user is not possible, but the relative ease of understanding the operations should aid greatly in accomplishing this task.

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