Audiometric Decision Support System

by

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Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Technology (Hons)
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CERTIFICATION OF APPROVAL

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Approved by,

_____
(Mrs. Syarifah Bahiyah Rahayu Syed Mansoor)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

July 2004

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

NADIA MOHD ABD RASHID

ABSTRACT

Audiology is one of a medical field which study of hearing and hearing disorders for individuals who have hearing loss. Clinician as a user has proposed one decision support system named Audiometric System. This audiology service is focusing only on industry that handles a business process with machines. Usually, this kind of industry environment is exposing to the noise which can affect employees' hearing.

The objectives of this project are to help clinician reduce time for retrieving appropriate medical history in order to solve hearing problem, to assist clinicians make a correct decision by providing an accurate result from the manipulation of baseline audiogram and annual audiogram, and to provide a prototype for the audiology service.

The problem statements of this project are time-consuming to solve the hearing problem and difficult to provide an accurate result from the baseline audiogram and annual audiogram.

The scope of study is mainly covers on the clinician that have responsibility on clinical management. Clinicians such as doctor or nurse use the audiometric system as an audiology service to solve the hearing problem.

Methodology used in this project is known as Waterfall model which includes information gathering or analysis phase, design phase, development phase, testing phase and evaluation phase.

As a conclusion, a successful implementation of Audiometric System as one of audiology service hopefully is able to help clinicians improve the clinical performance especially in solving the occupational hearing loss of employees. A prototype of Audiometric System is produced through this project.

ACKNOWLEDGEMENT

Praise Allah for His grace and blessings on me. It is a privilege for me to extend my gratitude to all parties that had helped me a lot in accomplishing my Final Year Project. I would like to convey my highest appreciation to:

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ABBREVIATIONS AND NOMENCLATURES

1. CBR	Case Based Reasoning
2. CDSS	Clinical Decision Support System
3. DFD	Data Flow Diagram
4. DSS	Decision Support System
5. ERD	Entity Relationship Diagram
6. NIOSH	National Institute for Occupational Safety and Health
7. UML	Unified Modeling Language

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Hearing impairment is one of the most common occupational disease and also known as occupational illness or injury. According to the research done by H.Skarzynski, stated that hearing impairment is one of the fastest growing diseases in modern societies [1]. From this situation, clinician had to improve the clinical performance in order to solve hearing problem in short time and effectively. One of the audiology services to cater the hearing problem quickly and effectively is by having a computer-based system.

Audiometric System is a Decision Support Systems (DSS) that can help clinicians manage and make decisions on the employees' hearing status once they are being employed. This system is an initiative of measuring occupational hearing loss or hearing impairment by analyzing and comparing the medical history with the current record. This system only caters occupational hearing loss for employees that worked in industry which involve with high noise exposure. Basically, this system identifies any changes in the threshold and hearing impairment due to noise.

In this system, there are two hearing records called Baseline Audiogram and Annual Audiogram. Baseline Audiogram is a basis hearing record stored once the particular employee is being employed. Meanwhile, Annual Audiogram is periodic hearing record that shows the level of employees' hearing after employment. The system analyzes and compares both records in order to produce a result to decide whether the particular employee have a hearing problem or not.

In order to have a correct solution to the hearing problem, clinicians need an accurate result from the audiograms analysis. According to the survey done by Philip C H Lee and Grace S Loo, 28% of clinicians agree to have an accurate result in order to improve the management of clinical performance [3]. Due to this fact, DSS is needed in medical domain in providing accurate result to solve medical problem correctly.

In this project, Case Based Reasoning (CBR) technique is used as an assistant to DSS in solving the hearing problem. A research about *Decision Support System using Case Based Reasoning in Medical Domain* done by Ziad El Balaa, stated that CBR is an efficient tool for DSS in medical domain [2]. Basically, this technique uses previous record and compares with current record in order to provide a solution. Then, CBR save the solution with a record of success or failure for future use.

1.2 PROBLEM STATEMENT

1.2.1 Problem Identification

Time Consuming

- Based on the interview session, Dr. Mohd Abd Rashid (Head of Medical & Health Services Department of Perwaja Steel Sdn Bhd) had explained the manual system of audiometric as illustrated in the ***Figure 1***. In manual system, first employees need to fill up the employee details form before the clinicians test the employees' hearing by using appropriate audiometer. After done with the testing session, clinicians have to plot audiogram graph of each employee manually. Then, the audiogram will be verified by expert person such as doctor specialist in hearing impairment. Basically, with manual system clinicians need to spend about two months to solve hearing problem of employees due to the difficulty in preparing the process of analyzing the baseline audiogram and annual audiogram.

Difficult to Provide Accurate Result

- According to the doctor, the most critical part in measuring the occupational hearing loss is the process of analyzing the audiogram test. Through the manual system, clinicians need to plot graph manually which possibility of human errors is higher. Due to this problem, it is difficult to provide an accurate result during analyzing the audiogram test.

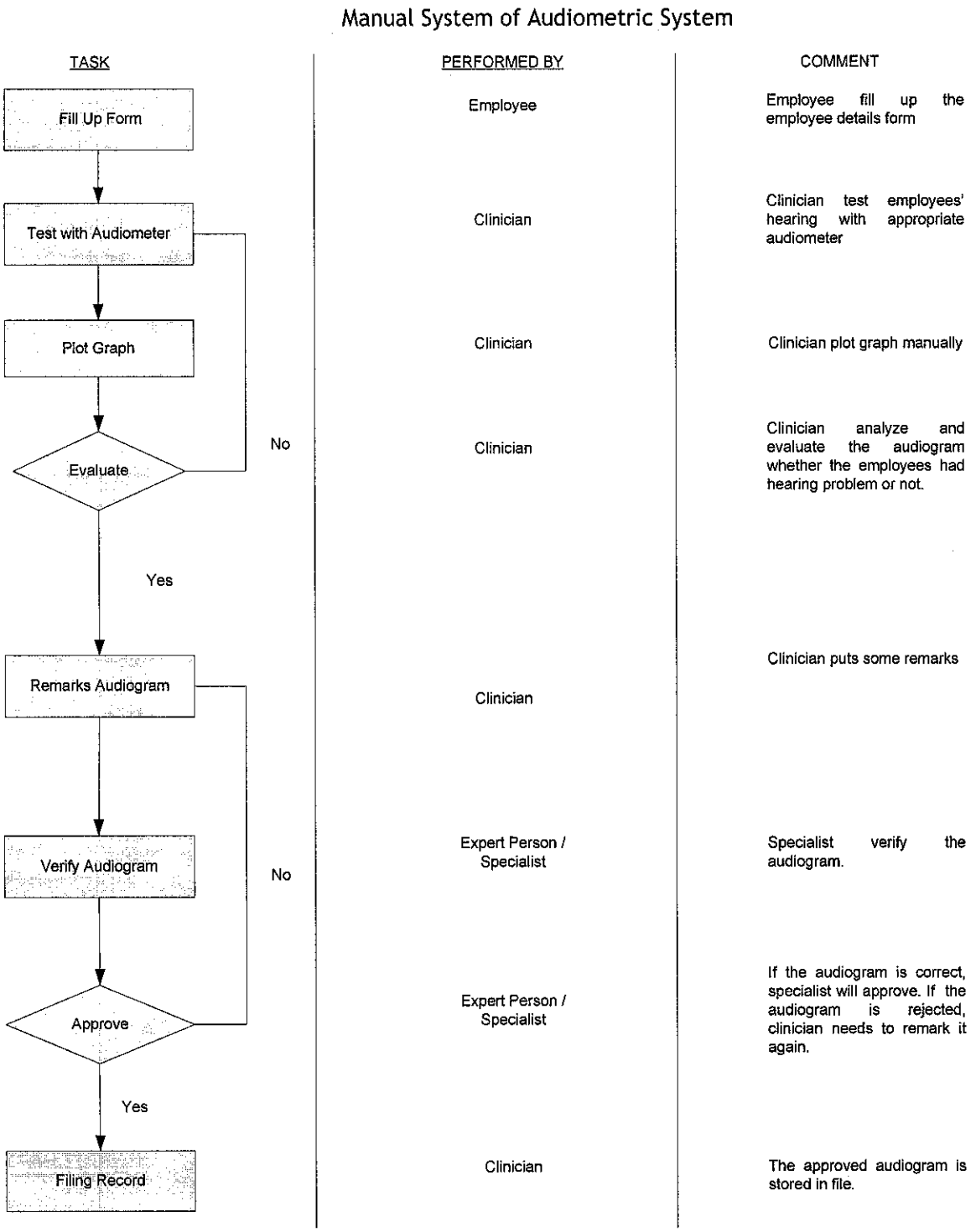

Figure 1: Manual System of Audiometric System

1.2.2 Significant of the project

Audiometric System is needed especially to help clinician improve the clinical performance. By having this kind of DSS in medical domain, clinician can easily manages and makes decision to solve the occupational hearing loss in short time.

In Audiometric System, CBR is used as an assistant to DSS in medical domain. CBR helps clinicians retrieve an accurate result from the process of analyzing baseline audiogram and annual audiogram.

This project also provides an interactive interface to the clinicians where they can track the medical history directly and also can view the updates status of the patient record effectively.

1.3 OBJECTIVES

1.3.1 To help clinicians reduce processing time for retrieving appropriate medical history in order to solve a new problem that faced by the user. Clinician can improve the clinical performance as it takes a short time to search for appropriate solution to the hearing problem.

1.3.2 To assist clinicians make a correct decision by providing an accurate result from the manipulation of baseline audiogram and annual audiogram. Accuracy is an important element in order to provide a perfect result which can help the clinicians make a correct decision to solve the hearing problem.

1.3.3 To provide a prototype for the audiometric system as audiology service.

1.4 SCOPE OF STUDY

The scope of study for this project is on the user of the Audiometric System, known as clinician. Clinicians can be categorized as doctor and nurse. The implementation of DSS in medical domain influences the clinicians' performance in managing and making decision for occupational hearing loss. Basically, this project is for clinicians to measure an occupational hearing loss on employee that worked in industry that expose to noise.

Audiometric system is a DSS in medical domain, which able to analyze and produce an accurate result in order to assist the decision making process in solving hearing problem.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Hearing impairment easily affects worker that expose to the high level noise. Based on the research, Elliott H.Berger said 30 million U.S workers are exposed to hazardous occupational noise level where the regular exposure is above 85 dBA [4]. Now, this disease become serious and need a quick prevention in order to reduce the number of affected workers. Due to the problem, National Institute for Occupational Safety and Health (NIOSH) recommends hearing loss prevention program or audiology service for all workplaces with hazardous levels of noise. The hearing loss prevention program is identified as noise assessments, audiometric monitoring of worker's hearing, appropriate use of hearing protectors, worker education, record keeping and program evaluation.

2.2 Audiometric System

One of the clinician initiatives to prevent hearing loss is by proposing DSS named Audiometric system as audiology service. This system is specifically to cater the occupational hearing loss and also to enhance the clinical performance. Audiometric system is helping doctor or nurse to manage and make decision on the employees' hearing problem.

In this system, there are two hearing records called Baseline audiogram and Annual audiogram. Audiometric analyze employees' hearing by comparing both audiograms in order to measure employees' hearing impairment. Baseline audiogram is a basis hearing record stored once the particular employee is being employed. Meanwhile, Annual audiogram is periodic hearing record that shows the level of employees' hearing after employment. According to Carl Zenz, the author of Occupational Medicine (3rd edition), pre-employment hearing test is

needed in order to establish Baseline audiogram as an initial record of hearing level at the beginning of employment [5]. From the initial record, clinicians will know the status of employees' hearing whether they have hearing impairment at their present place of employment or not. Employee is considered to have normal hearing if the average hearing level for four speech frequencies 500, 1000, 2000, and 3000 Hz is less than 25db.

2.3 DSS in Medical Domain

Audiometric system is designed to directly aid clinical decision making especially on hearing problem. From the research done by Greg Gianforte, stated that DSS in medical domain can reduce the time required to knowledge base and also can increase the accuracy, timeless and effectiveness of knowledge base [6].

Through a survey of DSS beneficial that done by Philip C H Lee and Grace S Loo, about 15% said that DSS in medical domain can improve the quality of clinical decisions [3]. For example, by implementing Clinical Decision Support System (CDSS) in the areas of drug use and preventive medicine, it improves health practitioner's performance and also patients' outcome. Another 85% said that DSS can improve productivity, easy to access patients' information for doctors and provide public health education [3].

As illustrated in the ***Table 1***, there are five criteria (5 Es) to measure DSS performance. From the research done by Philip and others, the first 3Es is advocated by Wilson B. (1984) and another 2Es are added by Checkland and Scholes (1990). Wilson B. used 3 Es such as efficacy, efficiency and effectiveness in order to measure the performance of DSS. Meanwhile, Chekland and Scholes used ethicality and elegance for monitoring and controlling the system [3]. Philip and others used these five criteria to measure the performance of CDSS in the areas of drug use and preventive of medicine.

Criteria	Description
Efficacy	Able to represent knowledge base accurately using artificial intelligence.
Efficiency	Reduce the use of medical resources through better diagnosis accuracy.
Effectiveness	Doctors have more time for patient care when unnecessary mistakes are avoided.
Ethicality	Provide option for doctors to deploy DSS or involve them in development.
Elegance	User friendly computer interface.

Table 1. The 5 Es to measure feasibility of DSS in medical domain [adapted from Philip C H Lee & Grace S Loo]

2.4 Case Based Reasoning (CBR)

In order to implement this system, a suitable technique is necessary in order to ease the analysis process in the system. Based on the research done by M. Frize et al, the appropriate technique accepted for DSS in medical domain is CBR technique [14].

CBR solves new problems by adapting previously successful solutions to similar problems. According to the Aamodt, A & Plaza, E (1994), CBR is a methodology that allows modeling human reasoning and thinking [7]. The important terminology in CBR needs to be understood is a case where it's represents a problem situation. Previous record which can be reused to solve a new problem is known as past case, previous case, stored case or retained case. Meanwhile, a new problem or unsolved problem is known as new case in CBR. Basically, many researchers such as Dr Ian Watson, Rainer Schmidt et al, define CBR as a problem solving technique that retrieve previous case and adapt it to the new case in order to provide a solution to the new problem [7, 8, and 9].

CBR is a systematic cyclic and integrated process of solving a new problem by adapting previous case. From the research done by Aamodt and Plaza (1994), they found four REs in the CBR cycle process such as retrieve previous case, reuse the case to solve the problem, revise the proposed solution and finally retain the successfully solution to be used in the future [7]. These four process also being used by others researchers (Selma Limam Mansar and Farhi Marir) in Business Process Redesign [9].

2.5 CBR Systematic Cycle

The processes involved in CBR can be represented by a schematic cycle as illustrated in the ***Figure 2.*** From research done by Dr. Ian Watson, stated that Aamodt and Plaza (1994) have described CBR as a cyclical process comprising four REs [8]. The initial process is retrieving the most similar case. This process involved with one or more similar cases. Basically, this process is about identifying the problem situation and searching for the best match of previous case based on the new case. Retrieval process is considered complete when the best matching previous case has been found.

The second process is known as reuse the information and knowledge in the previous case to solve the problem. During this process, some analysis had done which focuses on two main aspects such as the differences among the previous and current case and what part of a retrieved case can be transferred to the current case. The reuse process considers similarities between the both cases and transferred the solution of the retrieved case to the current case as a new solution.

The next process after reusing process is revising the proposed solution. Based on the research done by Aamodt, A & Plaza, E (1994), this process is depending on the reuse process where if it is done incorrectly, the changes to fail in the revise

process is higher [7]. There are two subtasks in this process which known as evaluation solution and repair fault.

Retaining is about integrating the useful elements of the new solution with the existing case or knowledge. Basically it involves with selecting the best information from the case to retain, in what form to retain it, the way of indexing the case for future retrieval process and how to integrate the new case in the memory structure. Integrate is the final task of updating the previous knowledge base with the new case knowledge in order to have a better solution to the knowledge case.

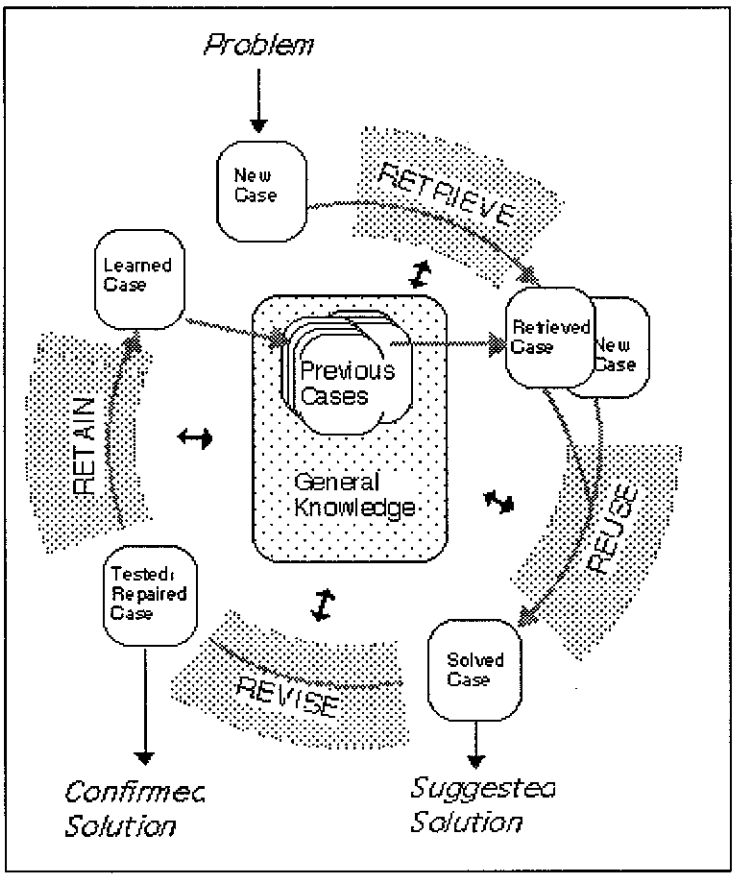

Figure 2. The CBR Cycle [adapted from Aamodt & Plaza, 1994]

2.6 CBR Techniques

Dr Ian Watson (1994) stated that there are three techniques of CBR which known as main tasks such as indexing, retrieval and adaptation [8]. Between these three techniques, the most complicated process is adaptation and some systems avoid the adaptation technique [10].

2.6.1 Indexing

Indexing involves with assigning or sorting the cases in the storage for future used. Basically, this technique is the initial task that needs to be done by CBR in order to facilitate the retrieval process. According to the research done by Dr Ian Watson, stated that there are several guidelines on indexing such as the indices should be predictive, address the purposes for using the case, be abstract enough to allow for widening the future use of the case-based and be concrete enough to be recognized in future [8].

2.6.2 Retrieval

CBR retrieves an appropriate case which similar to the new problem or situation. Watson found that retrieval technique is relies on the indices in order to search the potential cases to solve the new problem. Watson also had identified several methods for case retrieval such as nearest neighbor, induction, knowledge guided induction and template retrieval [8]. All these methods can either work independently or combined into hybrid retrieval strategies.

The nearest neighbor is a method of identifying similarity between previous case and the new case. The process of this method is depending on the weight of case's features. There are two constraints faced by this method such as problems in matching the problem situation and retrieval time. This method can be the best practice when the case base is relatively small [8].

The second method is induction method which able to determine the appropriate feature of the previous case that can be applied to the new case to solve the new problem. Another method is a knowledge guided induction where it is applied to the induction process. This method is done manually to identify case features which can affect the primary case feature. Template retrieval is used before other methods in order to limit the search space to a relevant section of case-base where it's returns all cases that fit within certain parameters.

2.6.3 Adaptation

Another method in CBR technique is adaptation where the solution of the retrieved case is adapted to the current case. In the other words, the adaptation means adjusting a successful solution of a previous similar case to match the current problem. According to Rainer Schmidt et al, the adaptation process will be considered sufficient if there are no significant differences between the current and the retrieved case [10]. There are two kinds of adaptation in CBR, first is Structural Adaptation which adaptation rules are applied directly to the solution stored in cases. Meanwhile, the second adaptation is Derivational Adaptation which reuses the algorithms, methods or rules that use to generate the original solution in order to come out with new solution to the new problem.

2.7 Suitability of Case-Based Reasoning as DSS Tool in Medical Domain

CBR is a concept that is recognized in medical domains. According to the research done by Markus Nilsson et al, stated that CBR has a good potential for many medical application since reasoning from cases is commonly applied in medicine [13]. The simplicity of the CBR process, enable user to easily understand and user also able to apply CBR in various problem solving situation. The other research done by Selma Limam Mansar and Farhi Marir (2003), many are claimed that development of knowledge management system is easier with

CBR technique rather than with others technique [9]. Furthermore, CARE-PARTNER system is the computerized decision support system in medical domain which uses to assists its users in performing clinical tasks by providing decision-support advice [11]. From the research, the good evaluation result of the system at 98.6% indicated that CARE-PARTNER system, has reached an excellent performance [11].

Rainer Schmidt and other researchers had stated, in medical domain there are two types of knowledge, objective knowledge which can be found in textbooks and the other one is subjective knowledge which is limited and changed frequently [10]. The changes of knowledge can cause uncertainty and incompleteness in solving a problem. According to the study by Ramona Friedrich et al, CBR has the ability to handle the uncertainty by using the helpful experiences in order to solve a new problem [12]. However, the solutions suggested have to be seen as a suggestion not as a best practice.

CBR also have an ability of storing data which necessary to any kind of system. According to the researcher done by Ramona Friedrich et al, the main requirement in the system is the ability of storing data. CBR technique allows for straightforward storage in relational database and entry where it has an ability to store experiences [12]. By using CBR, the stored cases also can be updated by end users. With these two elements, CBR can provide efficiency in data management and retrieval of database systems.

Another advantage of the CBR is the ability to choose an appropriate solution to the new case in a short time [12]. With this benefit, users can reduce time during the analysis process in order to produce a solution to the new problem. From the research done by M. Frize et al, CBR also allows the accuracy and the quality of the data in order to improve the time management and the use of the system [14].

CHAPTER 3

METHODOLOGY / PROJECT WORK

3.1 Procedure Identification

Methodology used in the progress of this project includes information gathering through research on internet and also interviewing experienced people in the medical field. The system is developed during the design and development stage. Testing is run regularly to check whether the system runs as expected. Finally, conduct evaluation phase in order to analyze the system performance whether it is meet the user's requirements. All the phases are combined to form one model of development known as Waterfall model.

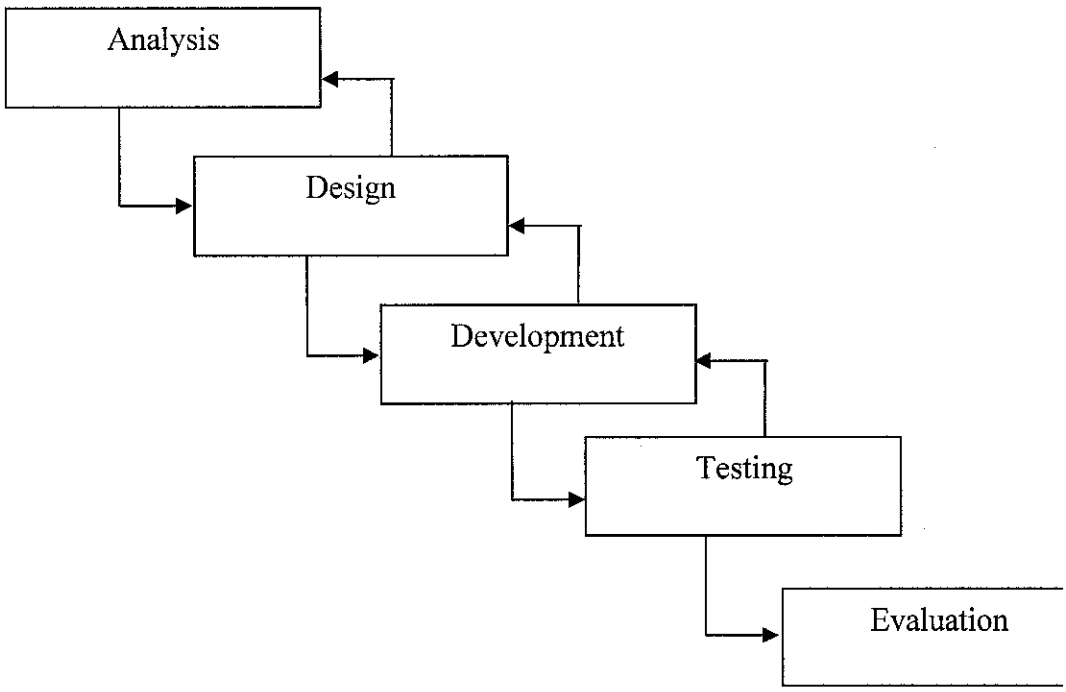

Figure 3: Phases involved in completing Audiometric system

3.2 Analysis

- Define problem statement, objectives, and scope of study.
- Gather information that related to the project through research on internet site such as IEEE search, reading, interview and questionnaire.
- Conduct an informal interview session with experienced people in the medical field in order to know their experiences which related to the project. The attachment of the questions for the interview session is in the ***Appendix 1.***
- User requirement analysis.
- Develop Context Diagram and Data Flow Diagram (DFD).
- Define the methodology and tools used for completing project development.
- Plan project timeline and prepare Gantt chart so that the project could be completed in the given time period. The project timeline is in ***Appendix 2.***

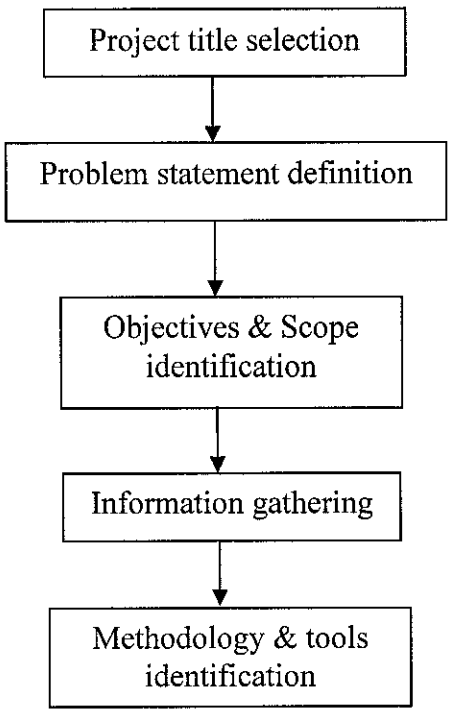

Figure 4: Tasks involved in Analysis phase

3.3 Design

- Design workflow of Audiometric System by using Microsoft Visio.
- Identify entities and attributes. The entities and the attributes of the database are shown in the ***Appendix 3***.
- Design the relational database by using Entity Relationship Diagram (ERD) and Unified Modeling Language (UML) diagrams. The UML diagram is consisted of Use Case, Activity, Sequence, and State Diagram.
- Design system interface.
- User verification.

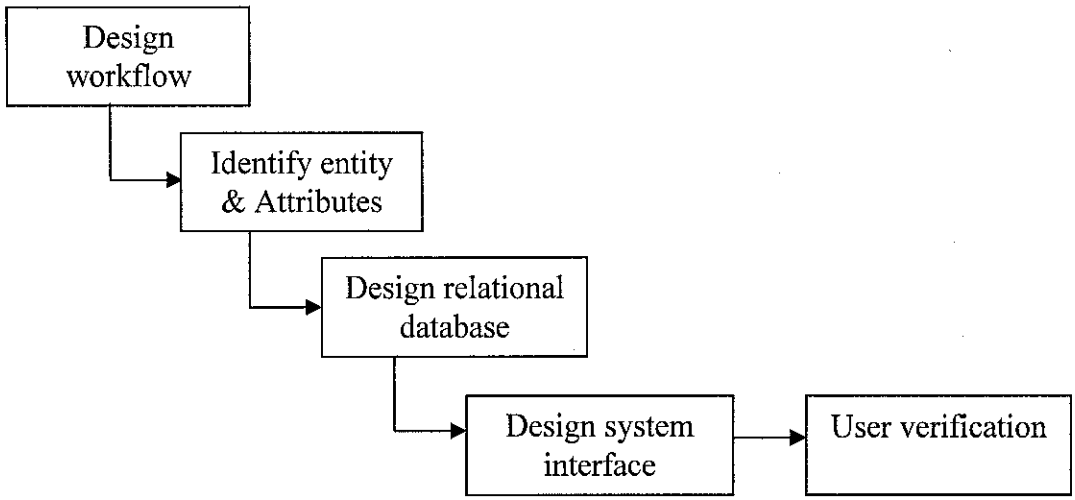

Figure 5: Tasks in Design phase

3.4 Development

- Develop relational database which consists of tables and fields by using Microsoft Access.
- Create rules of the Audiometric system to illustrate the system functions.
- Develop system interface by using Visual Basic Application.
- User verification.

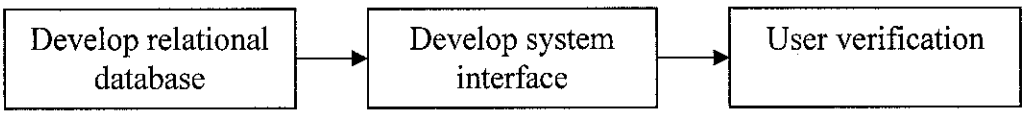

Figure 6: Tasks in Development phase

3.5 Testing

- Review, validate and test the modules created in the system regularly in order to check whether the system runs as expected.
- Changes are made in design, and code is regenerated.
- User feedback.

3.6 Evaluation

Evaluation is the process of determining the value and effectiveness of the project. In this phase, evaluation is performed to the module of the system in order to define the performance of the whole system. The performance evaluation is based on several criteria as below:

- Fails to meet standards
- Adequate
- Meets all standards

The evaluation is done on the functionality of the system, the content, the accuracy of the test result, the efficiency of retrieving data, the currency, the interactivity and the user friendliness of the system. The sample of the evaluation for Audiometric system is shown in the ***Table 2***.

3.7 Tools Required

3.7.1 Software

- Microsoft Access – use to design and develop a database for Audiometric System.
- Visual Basic Application – this software is used to design the interface for the system.

3.7.2 Hardware

- Personal computer

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Analysis

In the analysis part, the data flow of the system has being defined. The data flow of the system is illustrated in Context Diagram and DFD. The DFD is consisted of two level named DFD Level 0 and DFD level 1. Basically, in the Context diagram as shown in the ***Figure 7***, there are two entities and one database system. The entities are clinician and administration. Clinicians enter the test information to the system. Then, the system retrieves the previous record from database system to do analyzing process in order to provide accurate test result to the clinicians. The system records the new solution to the database system for next used. Meanwhile, the administration is used to maintain the system information.

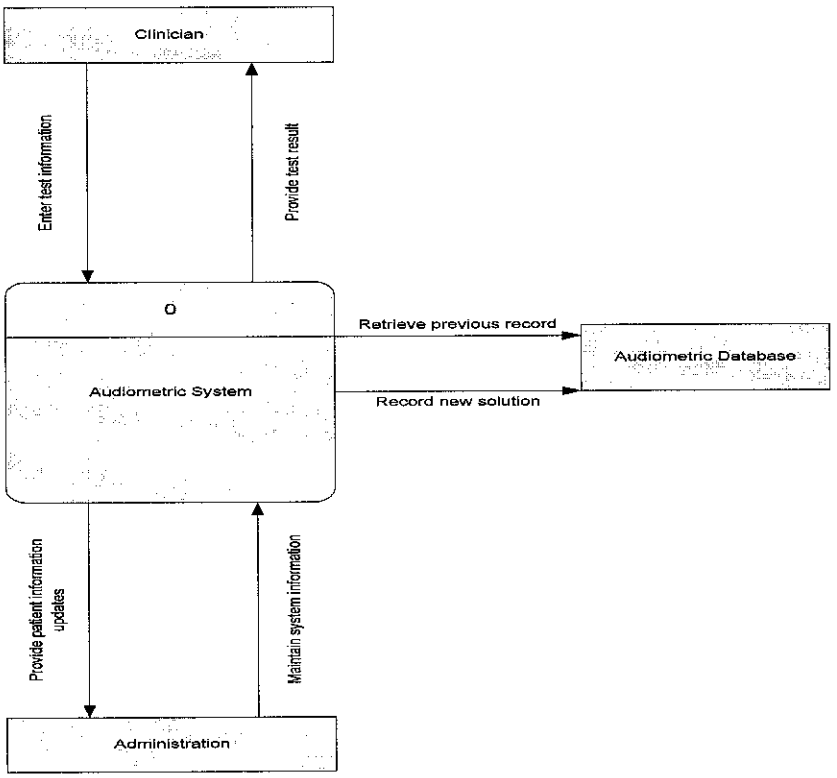

Figure 7: Context Diagram for Audiometric System

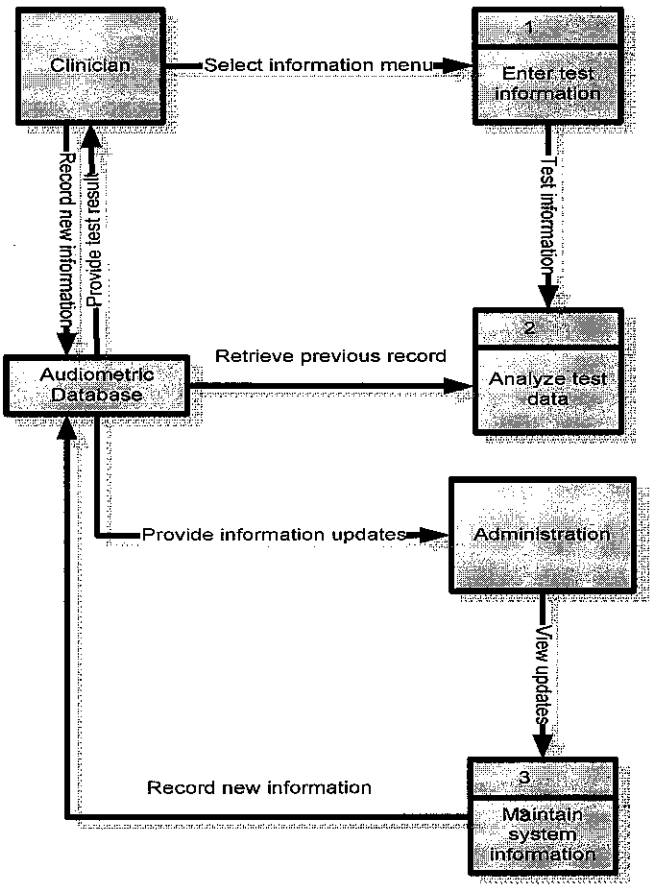

Figure 8: DFD Level 0 for Audiometric System

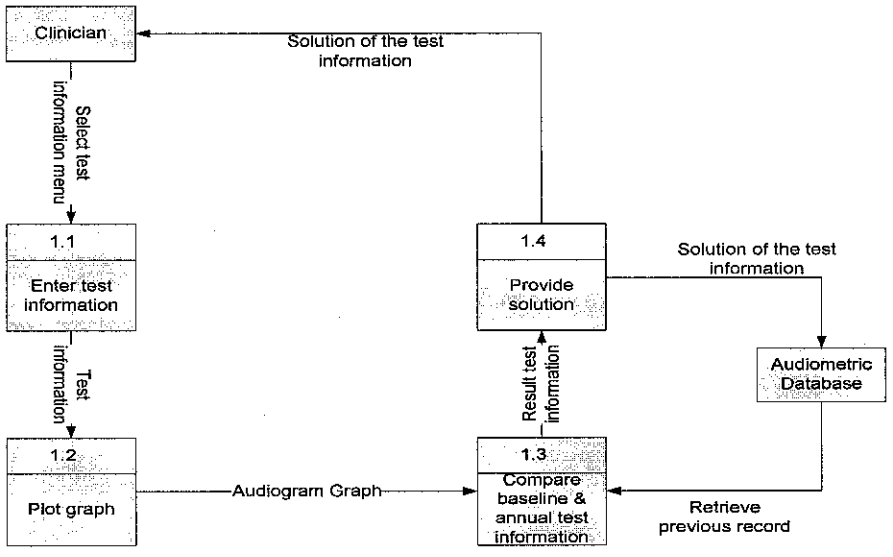

Figure 9: DFD Level 1 for Audiometric System

4.2 Design

4.2.1 Description of Audiometric System Workflow

The flowchart shown in ***Figure 10***, describes the flow of all processes involves in Audiometric System. Basically, the system starts with entering the employees' hearing data (taken from current audiometric test) by clinician. This kind of data is known as annual audiogram. After key-in the data, the system retrieves the previous data known as baseline audiogram from database. Baseline audiogram is an initial data taken once the employee was employed. Then, the system analyzes and compares the baseline and annual audiogram. If the comparison result shown the employee had hearing impairment, the system suggests some solutions as a guideline for preventive action. Then, clinician takes preventive action by considering the solution given by the system. If there is no hearing impairment, the system save the data for the next used.

Audiometric System Process Flow

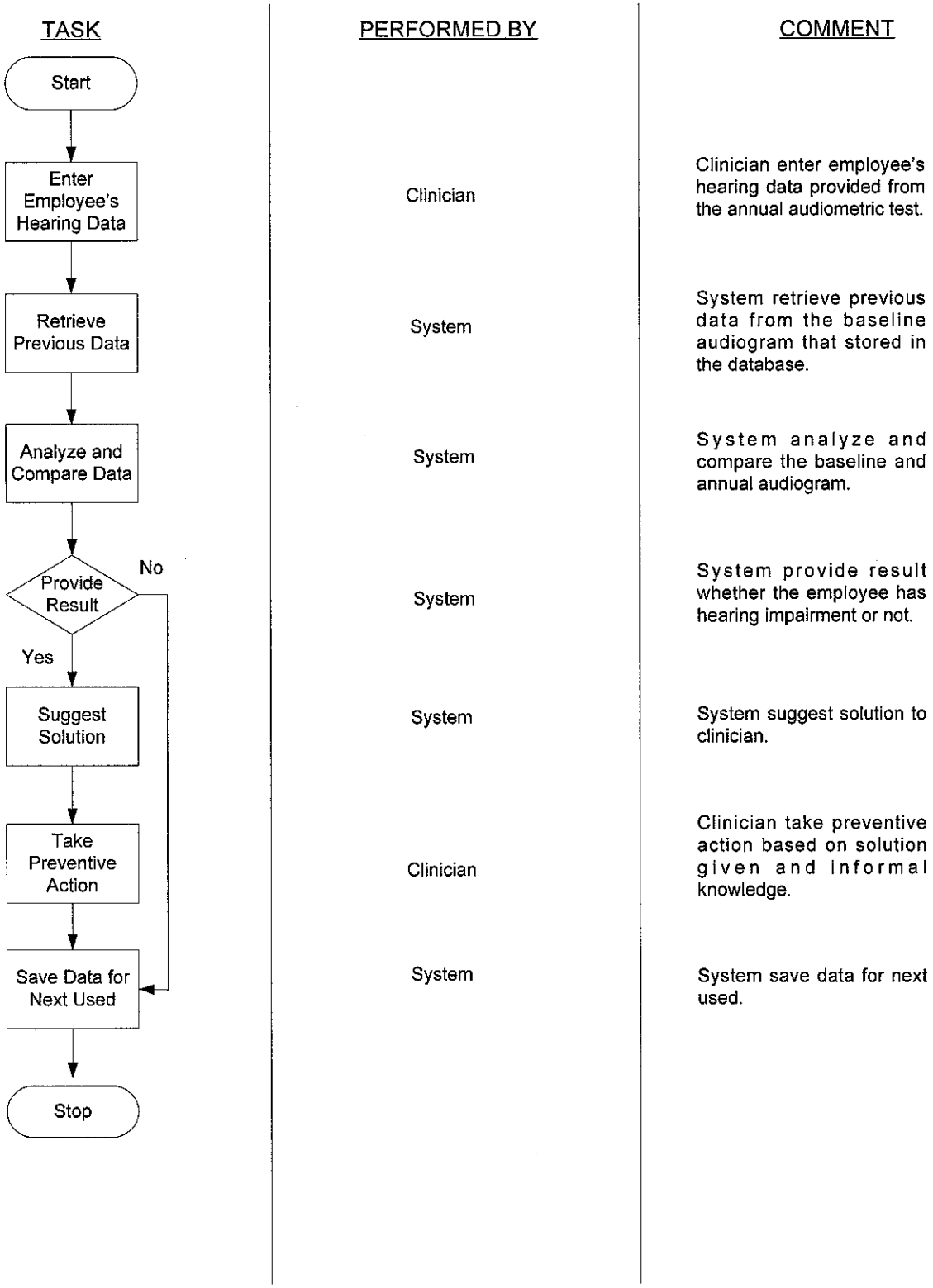

Figure 10: Audiometric Process Workflow

4.2.2 UML Diagram

The relation of entity and attribute of the system is illustrated in ERD and UML diagrams. The UML diagram is consisted of Use Case, Activity, Sequence, and State diagram. As illustrated in the **Figure 11,** there are two users of the Audiometric system. Clinician can access the system and enter the Employee Information, Location Information, Audiometer Information and Test Information accordingly. Then the system analyzes the Test Information and provides a result to the clinician. The administrator can access the system and maintain the system information.

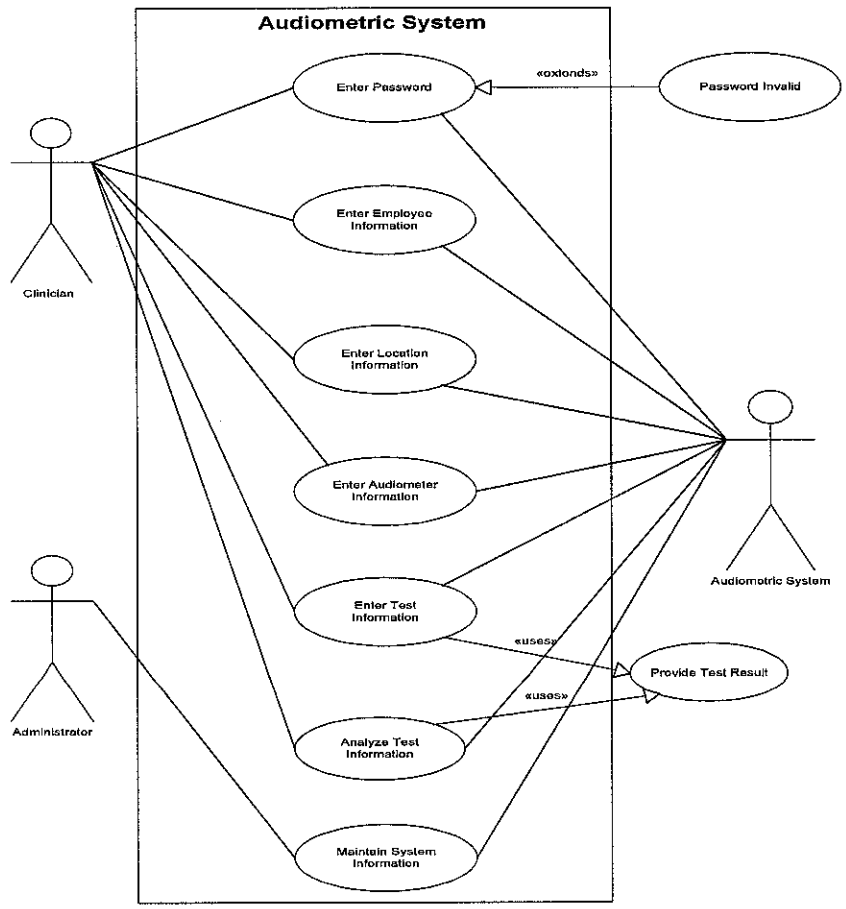

Figure 11: Use Case for Audiometric System

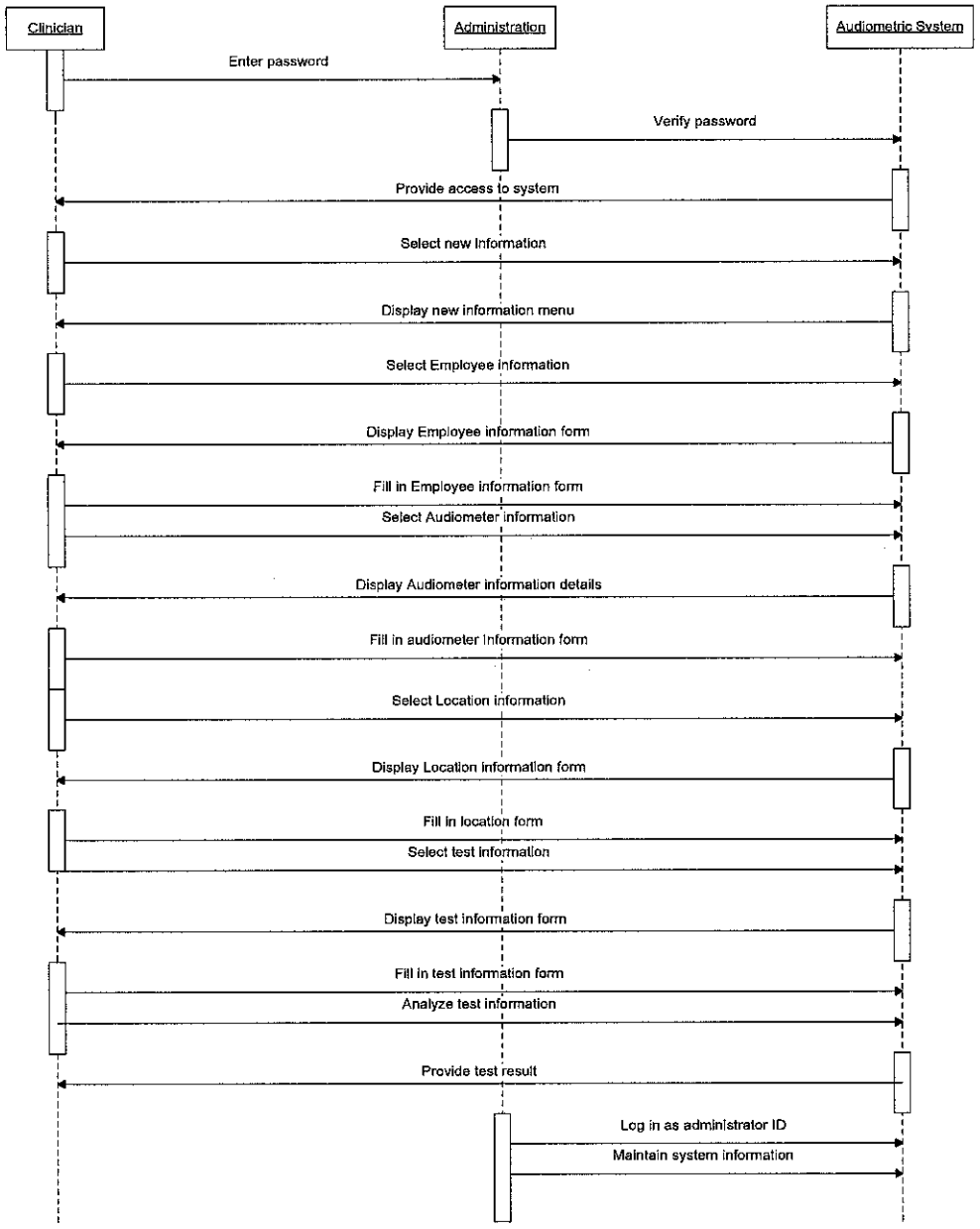

Figure 12: Sequence Diagram for Audiometric System

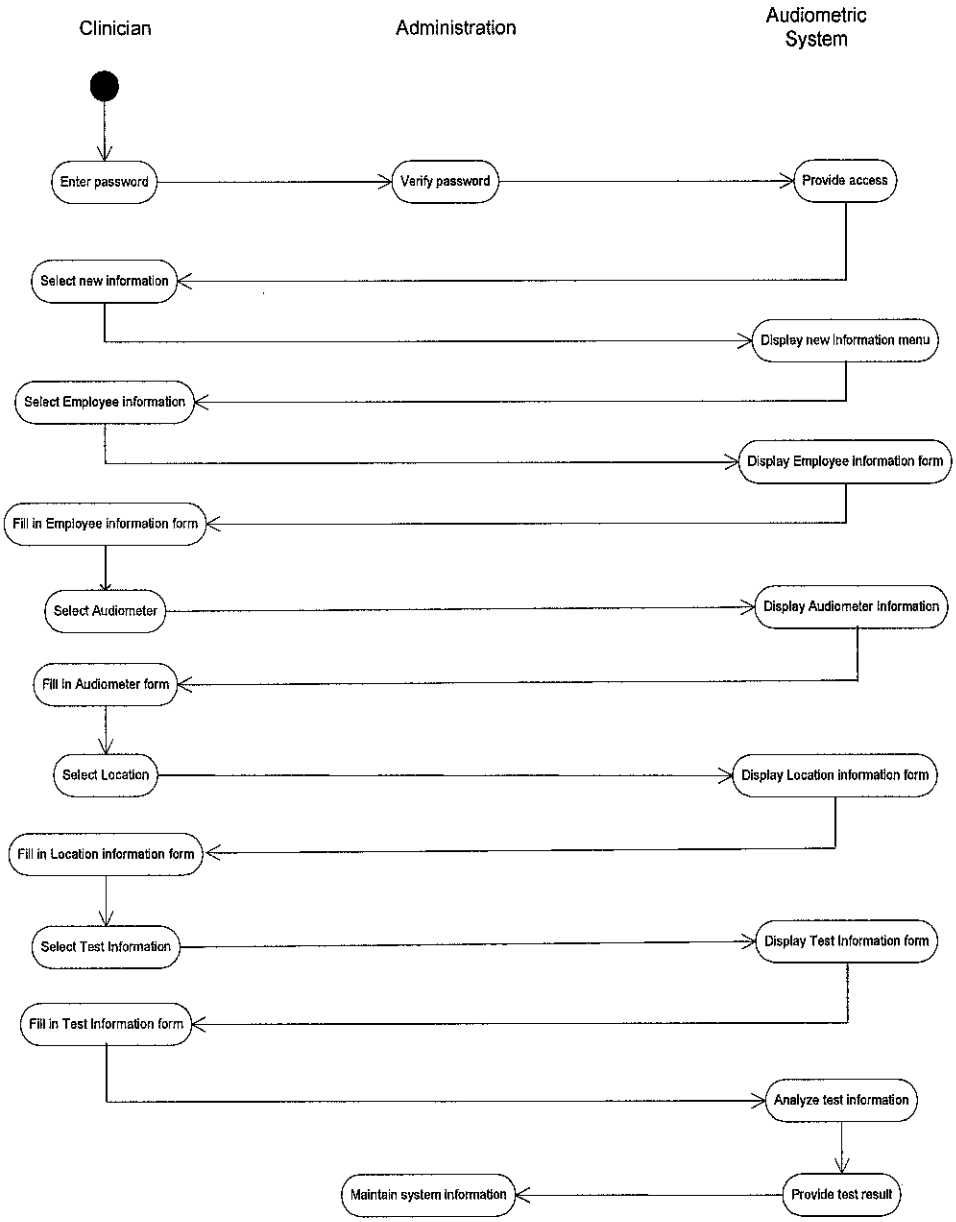

Figure 13: Activity Diagram for Audiometric System

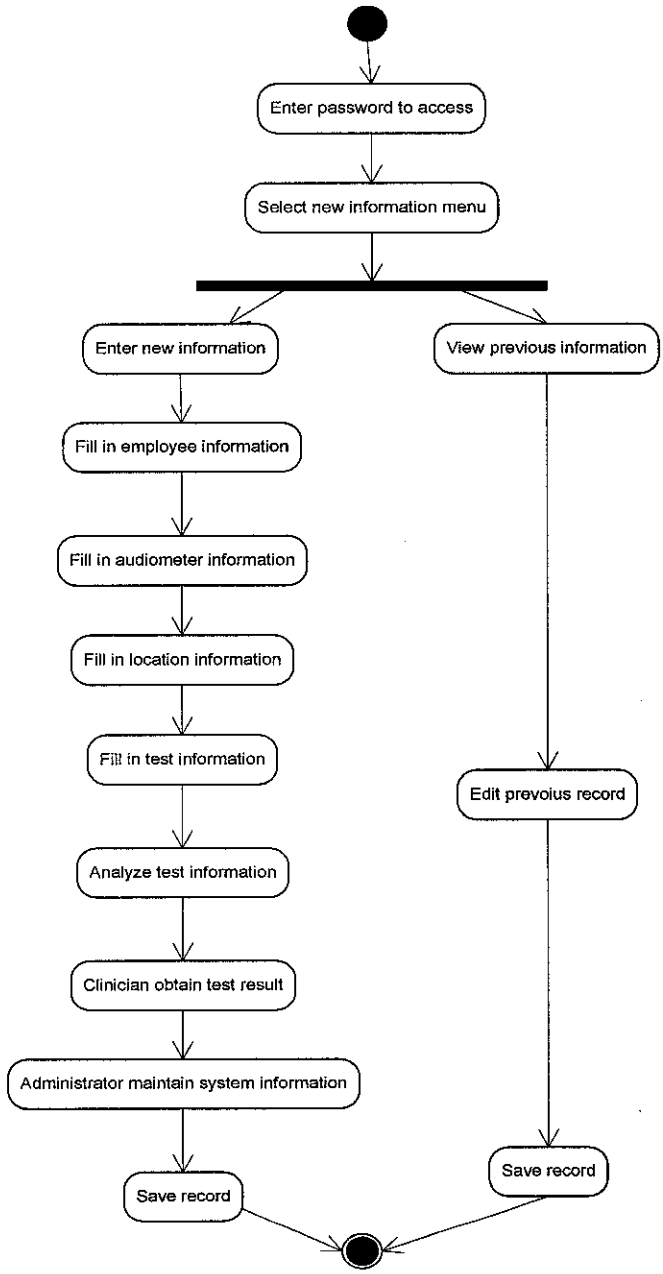

Figure 14: State Diagram for Audiometric System

4.2.3 **Relational Database**

The relational database is designed by using ERD as shown in the ***Figure 15***, which consists of four entities. Each entity has it own attributes in order to describe the fields' information which is essential to the system development. For each table there is one unique attributes is defined as a primary key. In the diagram, there is also stated the cardinality between the entity. There are one to one and one to many cardinalities involved in this relational database.

- Each employee has many test information.
- Many employees worked in one location.
- Each employee is tested by one audiometer.

The primary keys are as below:

Employee_Number for Employee table

Serial_No for Audiometer table

Location_Name for Location table

Employee_Number for Test_Information table

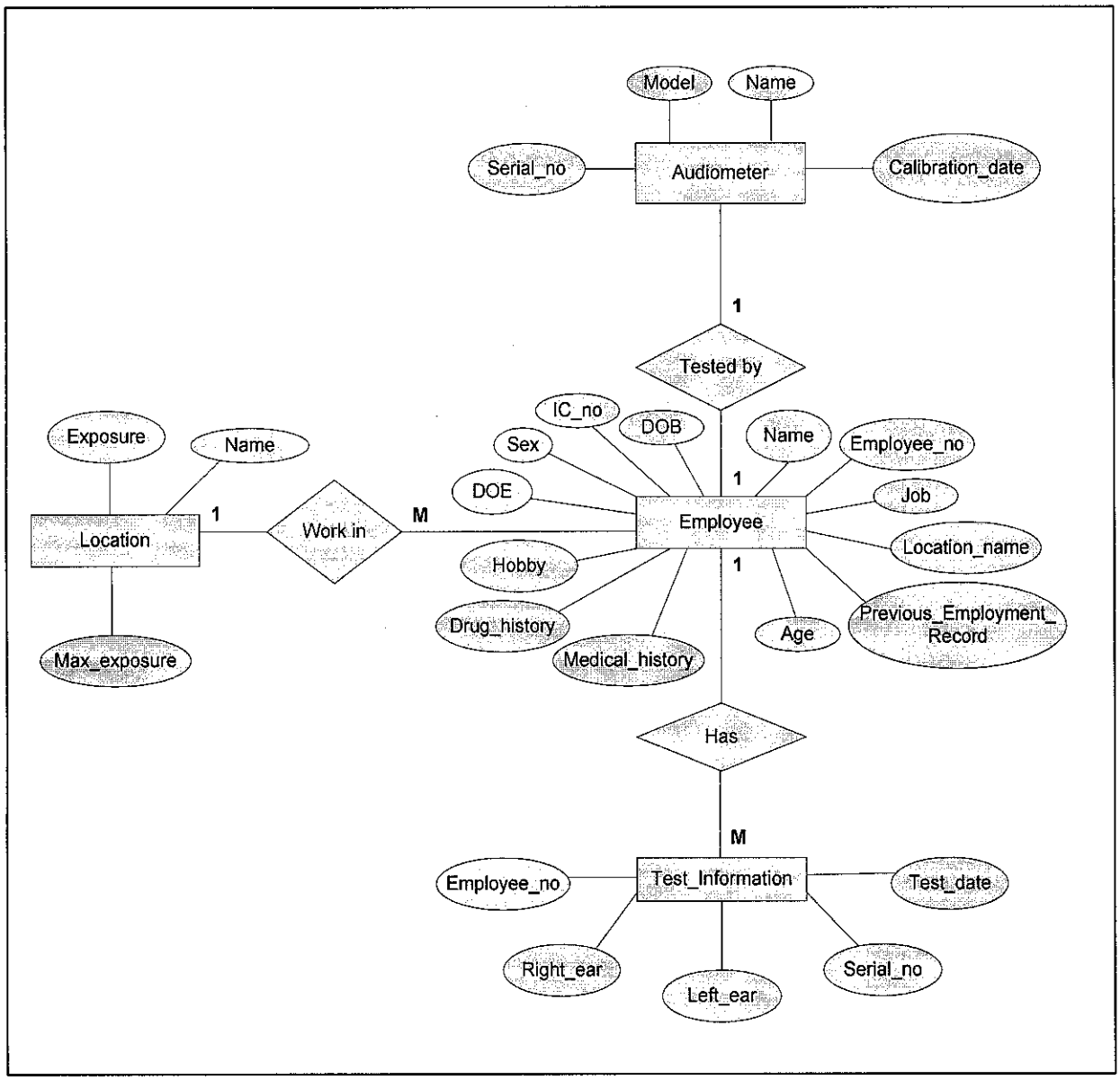

Figure 15: Entity Relationship Diagram (ERD)

4.3 Development

4.3.1 Rules of the Audiometric System

Analyzing Hearing Impairment

Clinician press **AVERAGE** button to compute the average of the hearing data.
Then clinician will press on **RESULT** button to analyze the hearing test data.
If the average at 0.5, 1, 2, 3 > 25dB,

Hearing impairment has occurred. To be provided with hearing protector.

If not

Hearing is normal.

Analyzing Threshold Shift

If the different of average at 2, 3, 4 between baseline and annual > 10dB,

Standard threshold shift occurred,

If not

The threshold shift is remained.

- Assumption – The threshold shift can be shifted to the negative and positive side.
- Assumption – The comparison is done between Baseline audiogram and Annual Audiogram.

Suggested Solution on Hearing Impairment

If hearing impairment occurred,

Need to be tested again and provide with hearing protection,

If not

Do the annual hearing test as usual.

- Assumption – Before clinician took any action on the hearing problem, they also need to consider the employees' details such as hobby, medical history, drug history and previous employment records.

4.3.2 Audiometric Decision Support System

The key factor that influences the development of DSS in Audiometric system is the essence of time and accuracy of the hearing result that used to solve the hearing problem. Both of the factors are important to provide an efficient clinical management in solving the employees' hearing problem. There are two types of users that can access this system:

- Clinician
- Administrator

Clinicians are a main user to the Audiometric system where they can insert new information, view and edit the information. Meanwhile, the administrator is to maintain the system information. There are two parts of the system:

- Insert new information – This part is used for the user to insert new data of the employees and new data of employees' hearing.
- View and Edit information – This part is where the clinician can view and edit all the employees' hearing information.

This system also has a database where all information of hearing problems is stored to be retrieved and updated.

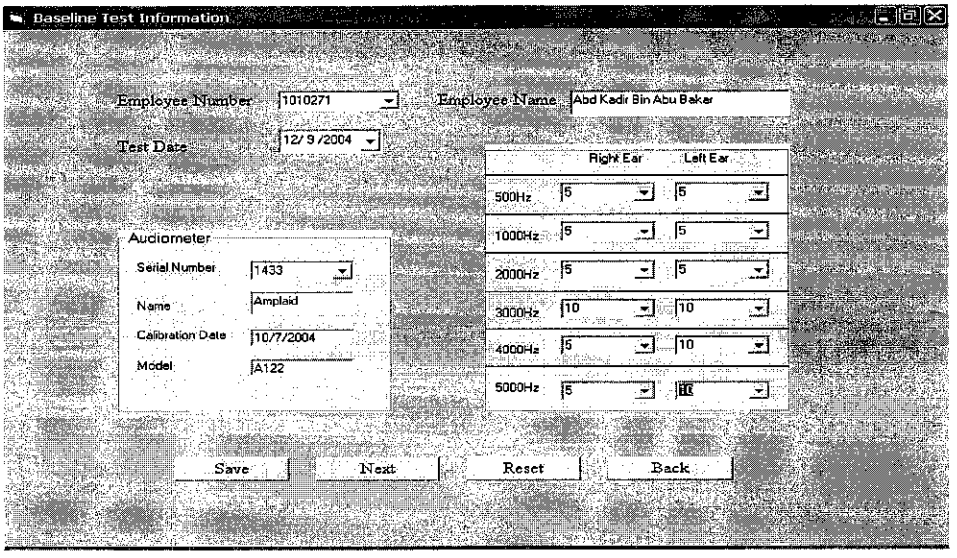

Figure 16: Baseline Test Information

In the Baseline Test Information page as illustrated in the **Figure 16**, clinician need to key in the new employees' hearing data and the audiometer data for adding a new record in the database system. This page is used for adding new employee's hearing data once the employee is employed. The Next button is used to navigate the page to the Baseline Result page.

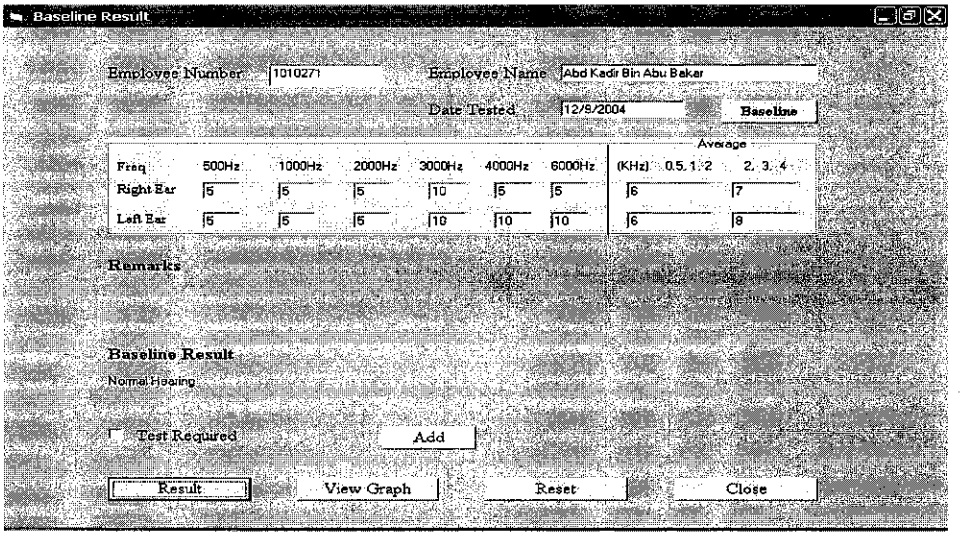

Figure 17: Baseline Result

In the Baseline Result page where the function of DSS is highlighted the most. Using the Baseline button, clinician can retrieve the baseline audiogram based on the employee number in order to calculate the average of the hearing level. The system analyzes the baseline audiogram by calculating the average at the four speech frequencies 500, 1000, 2000, and 3000 Hz. Through the average, clinician can identify the employees' hearing status whether the employee had hearing impairment or not. By using the Result button, clinician can a test result and possible solution. The system assists the clinician in making a decision to solve the hearing problem by providing a result and a solution to the problem. Clinician also can view a baseline audiogram graph in order to see the changes in the employees' threshold.

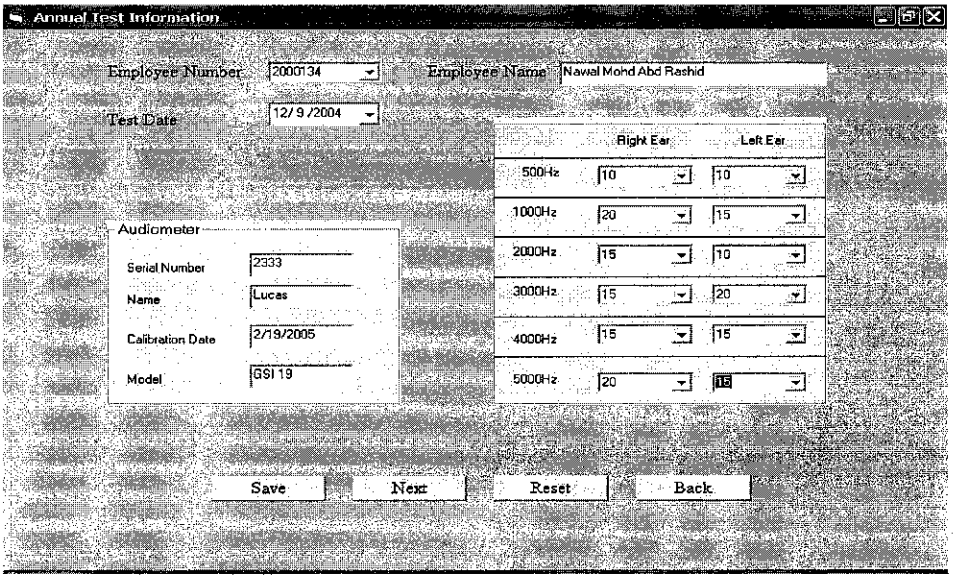

Figure 18: Annual Test Information

In the Annual Test Information page as illustrated in the **Figure 18**, clinician need to key in the annual employees' hearing data and the audiometer data for adding a periodic record of the annual audiogram in the database system. The Next button is used to navigate the page to the Annual Result page.

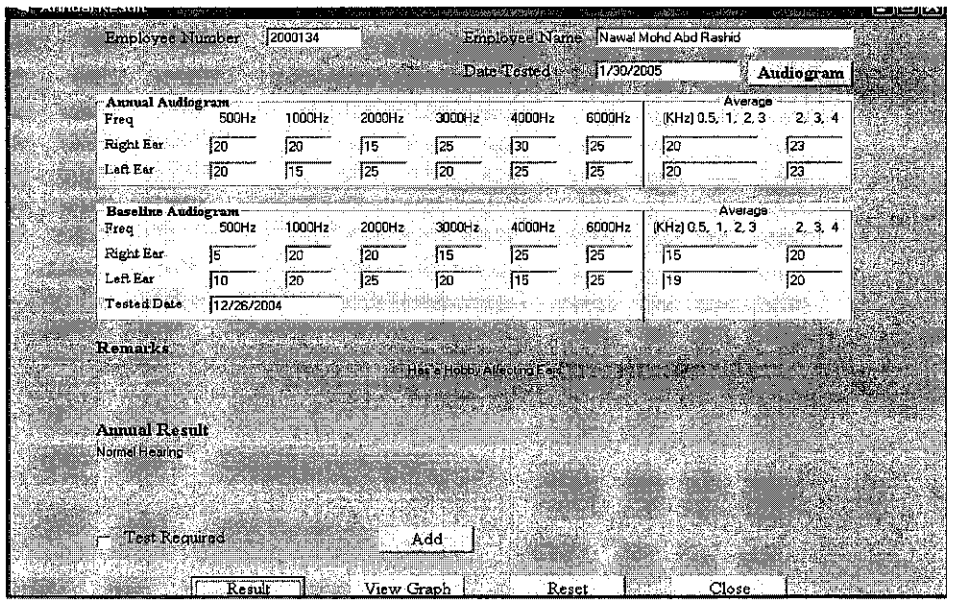

Figure 19: Annual Result

In the Annual Result page the function of DSS and CBR is developed, clinician can retrieve the annual audiogram and the baseline audiogram based on the employee number in order to calculate the average of the hearing level for both audiograms. Average at the first four speech frequencies 500, 1000, 2000, 3000 Hz is used to analyze the hearing impairment. If the average is more than 25db, the employee is considered to have hearing impairment. Meanwhile, the average at the three speech frequencies 2000, 3000 and 4000 Hz is used to identify the standard threshold shift. If the difference of the average between the baseline audiogram and annual audiogram is more than 10db, the standard threshold shift has occurred. The system assists the clinician in making a decision to solve the hearing problem by providing a result and a solution to the problem. Clinician also can view an annual audiogram graph in order to see the changes in the threshold.

Audiometric Decision Support system can help the clinician to reduce time in solving the hearing problem. The clinicians can easily retrieve previous record from the database system in order to compare with the new hearing record. The system also can automatically generate a graph to the clinician in order to analyze whether the employees had a standard threshold shift. Due to these facilities, clinician can save much time to solve the hearing problem. Further more; this system also can assist the clinician make a correct decision by providing an accurate result from the manipulation of baseline and annual audiogram.

4.4 Evaluation

The first part of evaluation for Audiometric Decision Support system performance has been performed by several lecturers as evaluator during the internal presentation. The evaluators had given some comments on the structure of the database and the system data validation function. The database structure needs to be improved in order to ease the manipulation of the data. For the data validation function, it is important to ensure the validity of the data and the system should be able to identify the wrong data before its being saved in the database. The evaluator also gave some suggestion on the data retrieving functionality, where the users can retrieve or view the system information by the variety of parameter such as by status of the employees' hearing; by location; by employee number and etc.

Meanwhile, a second part of evaluation is done by the clinician that worked in Medical & Health Services department of Perwaja Steel Sdn. Bhd. A sample evaluation of Audiometric System is provided in ***Table 2***. From the evaluation process, the user found that the system is able to reduce the processing time of solving the hearing problem. The clinician took less than five days to complete the processing time of analyzing the audiogram test for about 100 records of employees compared to two months with manual system. The system also able to assist the clinician makes a correct decision by providing 90% of accuracy to the result from the manipulation of audiogram test. Another 10% is regarding to the unavoidable factor such as human error during entering the test information.

Elements / Criteria	Meets all Standards	Adequate	Fails to Meet Standards
Functionality		✓	
Content		✓	
Accuracy		✓	
Searching/Retrieving			✓
Currency		✓	
Interactivity	✓		
User-Friendliness		✓	

Table 2: A Sample Evaluation of Audiometric System

4.5 Informal Interview Result

One of initiatives to gather information about audiometric is through informal interview session with Head of Medical & Health Services Department of Perwaja Steel Sdn. Bhd, Dr Mohd Abd Rashid. Information transferring had also done through emails.

From the interview session, Dr Rashid had explained the manual process flow of the audiometric system which is used to solve employees' hearing problem. Employees are considered to have hearing impairment when the average of hearing level is exceeding 25db.

He also mentioned about several drawbacks of the manual system. Currently, clinicians had faced of difficulty in analyzing the hearing problem accurately. The manual system had a limitation to assist clinicians to perform better in managing the hearing problem records. The clinicians have to analyze manually the baseline and annual audiogram which sometimes can cause human errors. They also need to spend about two months to process and solve the hearing problem of employees.

Due to these two main problems, the efficiency of solving employees' hearing problem is decrease. Therefore, by having DSS in audiometric system, clinicians can easily make a correct decision on the employees' hearing problem. At the same time, the performance of managing the hearing problem can be improved.

4.6 Questionnaire Results

Based on the analysis done during the analysis phase, the results and findings gained can be simplified on term of table and charts shown below. The table and charts are merely representing two sections of questions provided in the questionnaire. The sections are:

- Current Audiometric System
- DSS in Audiometric System

The questionnaire results should support any ideas made in this project.

4.6.1 Current Audiometric System

In this section, all the questions asked in the questionnaire are used to support the problem statements of the project. It is also to know the clinicians' respond about the audiometric system that currently used to solve the employees' hearing problem. The questionnaire results were obtained from several respondents; doctors and audiologists in Hospital Besar Ipoh and several private hospitals.

The ***Table 3*** below shows the result of the first question in the first section of the questionnaire where 100 percent of respondents said that they had faced difficulty in analyzing employees' hearing problem accurately due to the lack of facilities in the manual system. The ability of manual system is limited which need an expertise to analyze and produce the result of the hearing problem.

Options	Yes	No
Percentage	100%	0%

Table 3: Questionnaire Result Section 1: Question 1

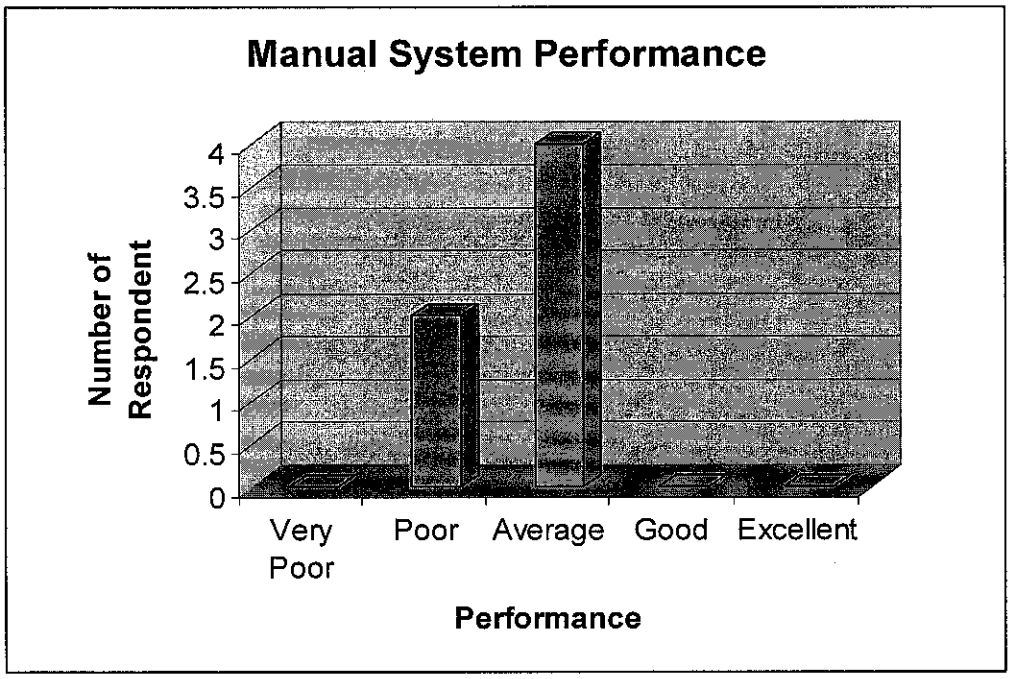

Figure 20: Rating of Manual System Performance

In the graph above, there are five rates of performance which range from very poor to the excellent. Four out of six respondents (67%) answered average and the rest (33%) is answered poor for the manual system performance.

Discussion

From the chart, most of the respondents are not satisfied with the manual system. They rate the performance as average and below because there are lots of problems occurred in solving hearing problem with manual system. The problems are listed below:

- Difficult to retrieve previous employees' hearing record (baseline audiogram).
- Result or findings are dependent on patient's cooperation during test.
- Interpretations of results vary for doctors to doctors based on individual criteria and experience.
- Illegible audiograms – no standardized format
- Test booth – not well calibrated

Due to this, the new system needs to be introduced in order to improve the performance of the audiometric system. All the problems listed above are the reason why the employees' hearing problem can be solved quickly.

4.6.2 DSS in Audiometric System

In this section, all the questions asked are used to know the respond of the target users towards the new implementation of audiometric system and also to support the objectives of the project.

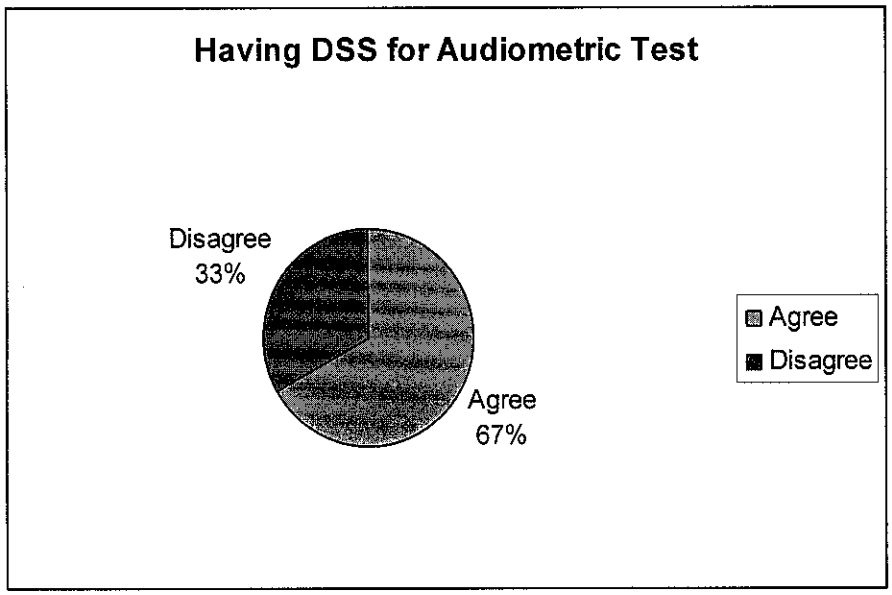

Figure 21: Acceptance of having DSS for Audiometric Test

From the pie chart above, four out of six respondents are preferred to have DSS for audiometric test in order to assist clinicians in decisions making process. Another two respondents are not agreeing to have DSS in Audiometric system.

Discussion

The acceptance among the respondents shows that DSS implementation in Audiometric system is well accepted by the users. It is also shows that the

respondents can see the advantages of DSS which generally can provide a better performance in managing and solving the employees' hearing problem. Meanwhile, the reason for the remaining percentage (33%) that are not agree to have DSS in Audiometric system is because the respondents find that the current system is satisfied enough and they hard to accept the changes.

Options	Yes	No
Percentage	100%	0%

Table 4: Questionnaire Result Section 2: Question 2

The table above shows the result of the second question in second section of the questionnaire where 100 percent of respondents said that they prefer to have visual aid in order to see any changes in threshold clearly.

Discussion

From the table, it shows that visual aid such as graph or table is important in order to show the changes in threshold. By having visual aid, clinicians can see clearly any changes occurred in the threshold for measuring employees' hearing problem. In Audiometric system, graph for baseline and annual audiogram is automatically plotted. Due to this, it can help the clinicians to reduce the time for solving the hearing problem.

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The usage of DSS in medical domain is important to assist the decision making process. By having DSS in Audiometric system, it can increase the user satisfaction as they can maximize the accuracy of the hearing test result and minimize the human error in solving the hearing impairment. This project can helps clinicians to reduce processing time for retrieving the previous hearing records and also can assist the clinician to make a correct decision by providing an accurate result from the manipulation of baseline audiogram and annual audiogram.

As a conclusion, a successful implementation of DSS in Audiometric System as one of audiology service can achieve the overall objectives and overcome all the problem statements. Moreover, the proposed system helps clinicians improve their clinical performance.

5.2 Recommendation

There are several recommendation and suggestion that can be done in the future for the system enhancement.

- Restructure and enhance the database of the system to ease the data manipulation.
- Embed with the test hearing device called audiometer in order to provide more accuracy to the system.
- Integrate with the online feature to the system in order to provide a better collaboration and communication between the clinician and employees in solving the hearing problem.

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APPENDICES

APPENDIX 1

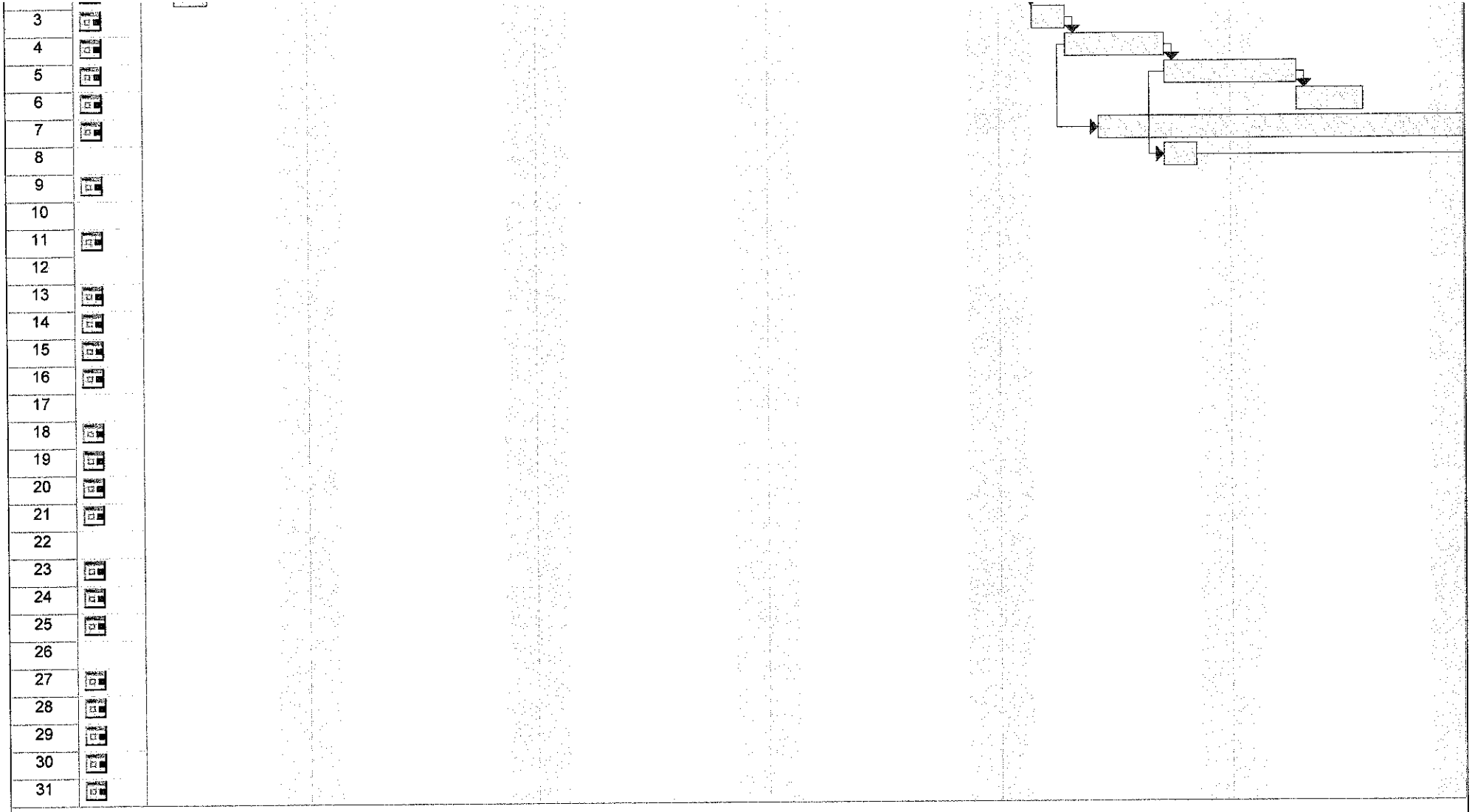
INFORMAL INTERVIEW QUESTIONS

Appendix 1: Informal Interview Questions

1. What is the main function of Audiometric test?
2. How is the process of Audiometric test?
3. How to measure the hearing problem?
4. What is the most important process in Audiometric test?
5. What is the main problem faced by clinicians during the analysis process?
6. Is it easy to get the patient record directly from manual system of Audiometric test?
7. How long is taken to complete the hearing analysis process?
8. What is the other problem faced during Audiometric test process?
9. Is it appropriate to use visual aid such as graph or table in order to show the changes in hearing capability?
10. In what condition, employee is considered to have hearing problem?
11. Do you prefer to have decision support system for Audiometric test in order to assist decision making process?
12. What do you expect from Audiometric System?

APPENDIX 2

AUDIOMETRIC SYSTEM GANTT CHART



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Date: Fri 12/10/04

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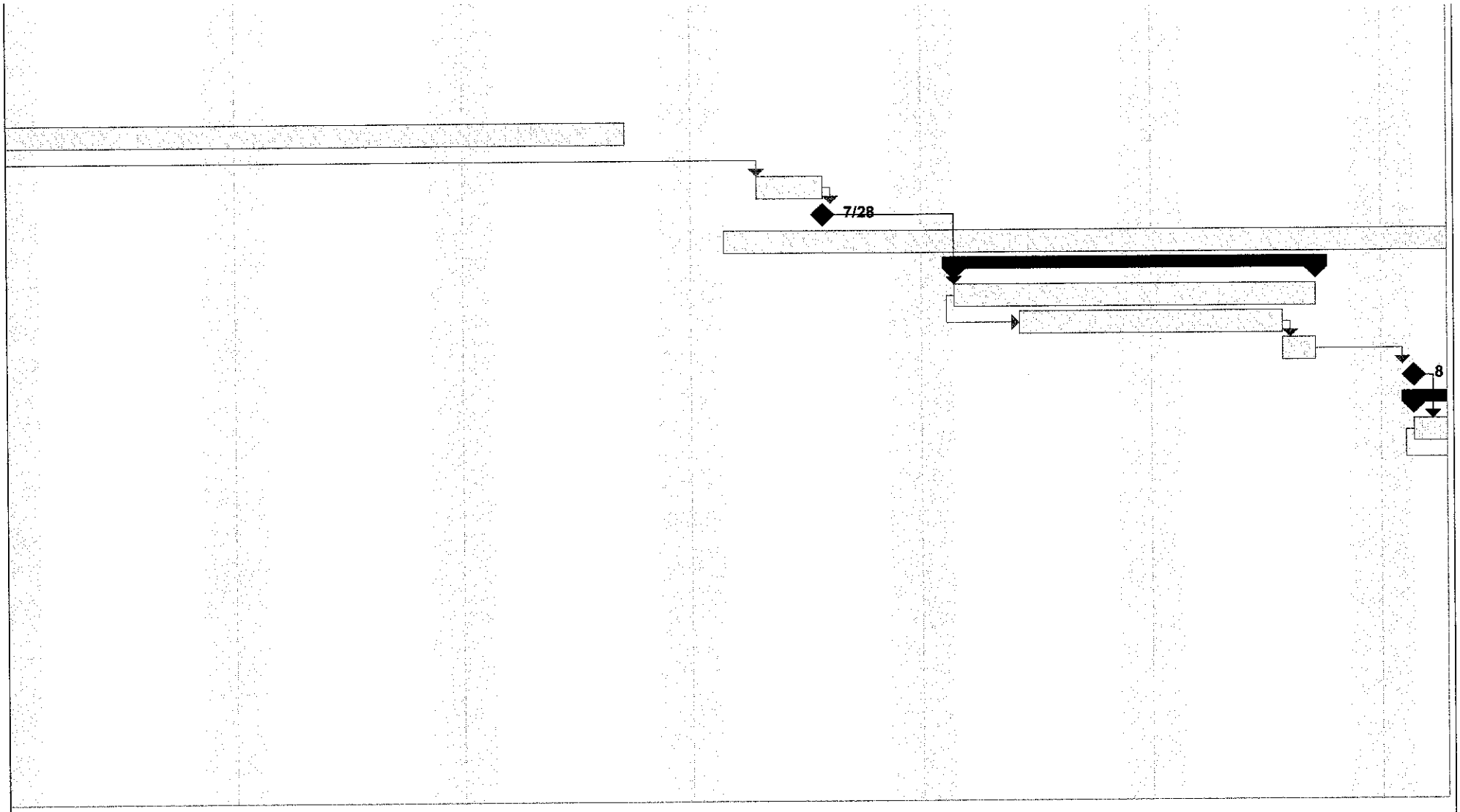
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline



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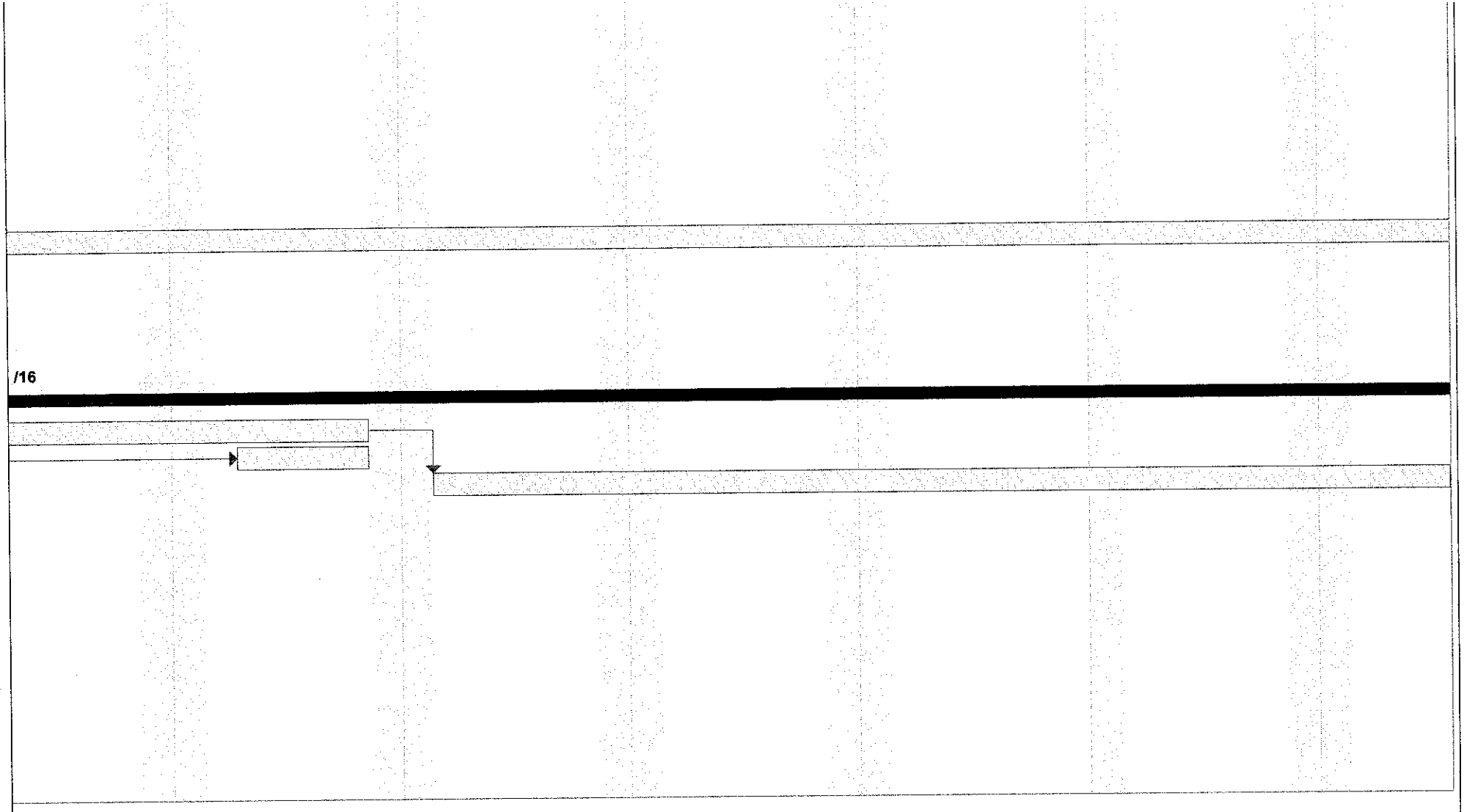
External Milestone
Deadline



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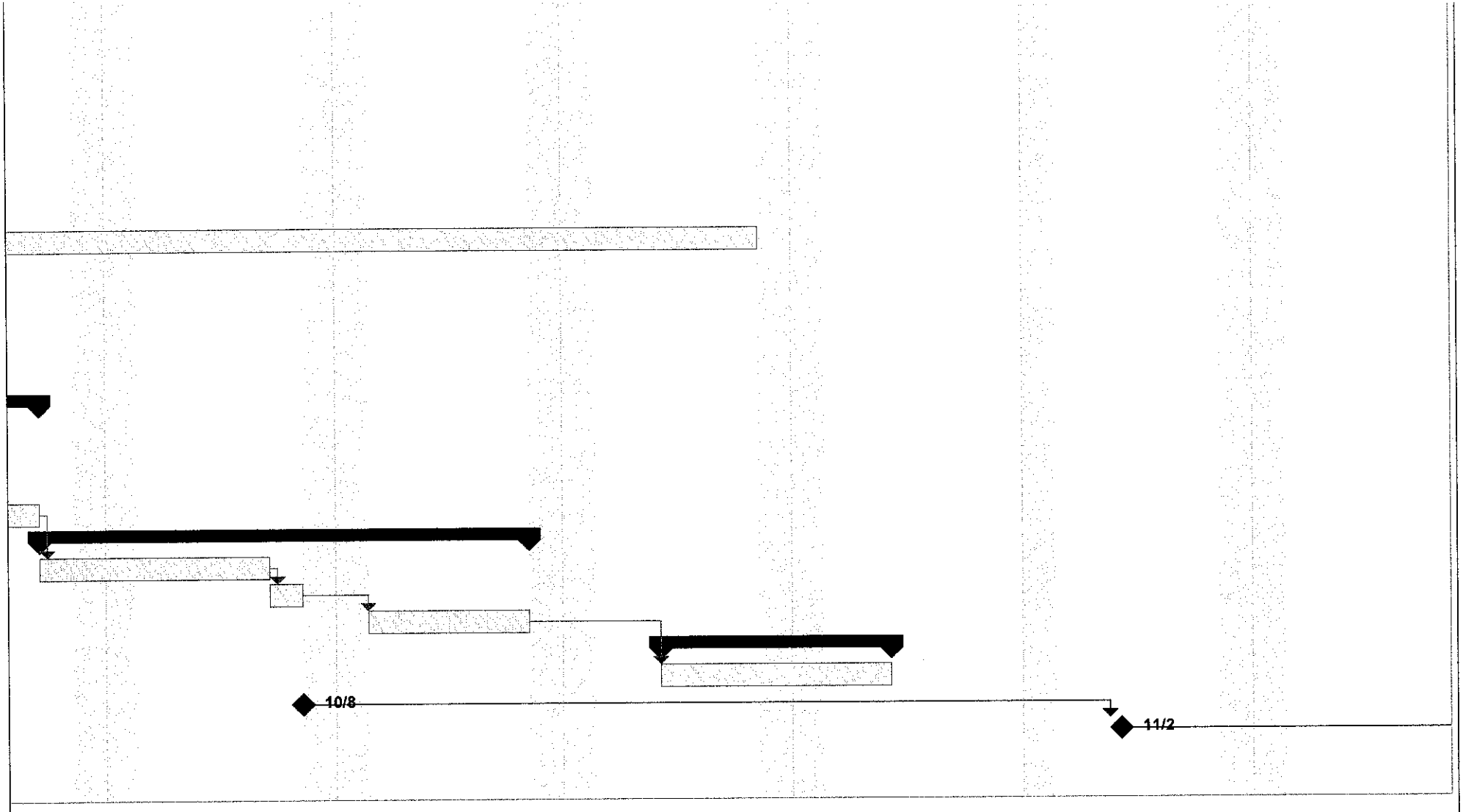

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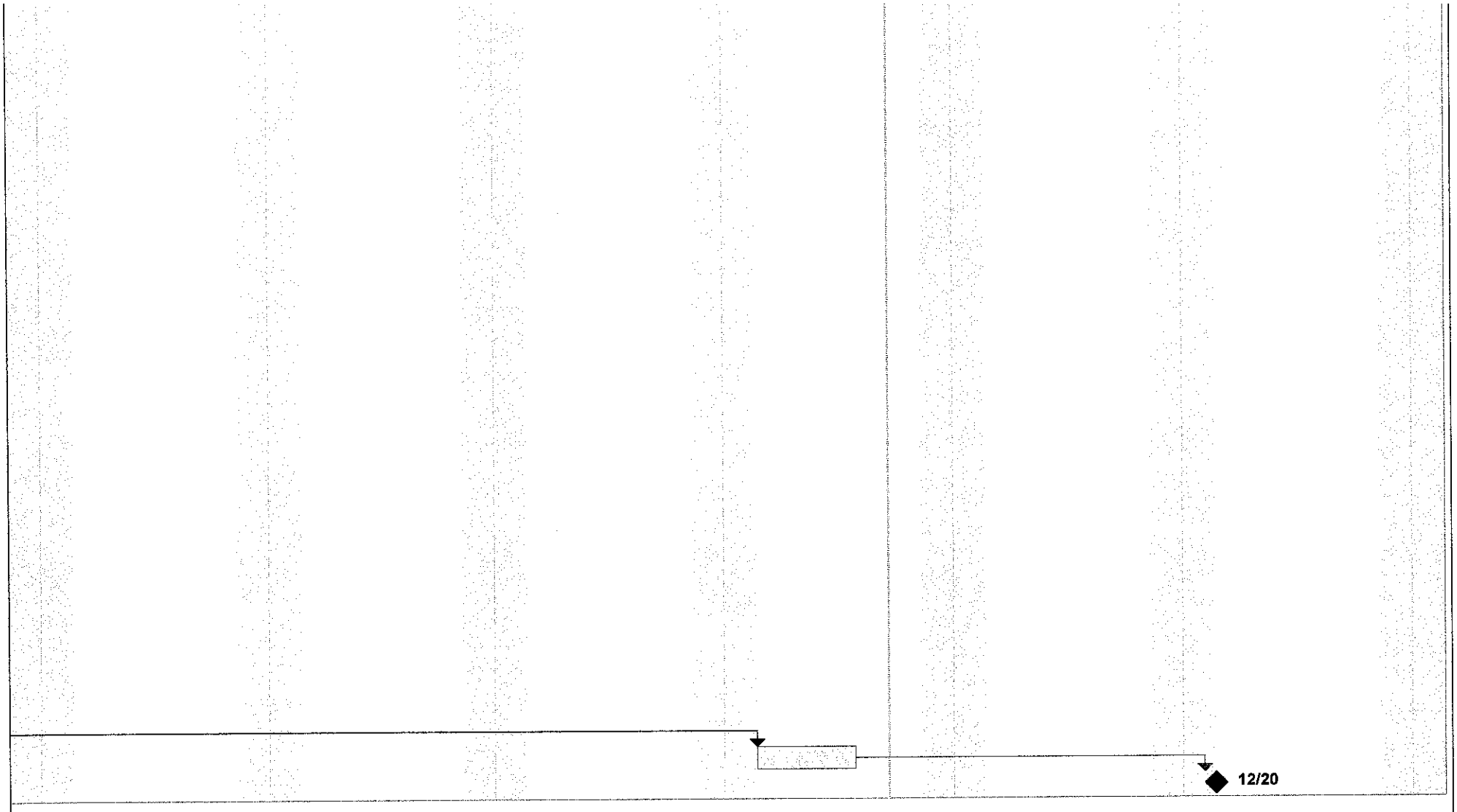
Date: Fri 12/10/04

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	



Project: Audiometric System
Date: Fri 12/10/04

Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline

APPENDIX 3

ENTITY AND ATTRIBUTES OF RELATIONAL DATABASE

Appendix 3: List of Entity and Attribute for Relational Database

Employee

Employee_Number – primary key

Name

IC_No

Sex

Age

Job

Location_Name

Date_of_Birth

Date_of_Employment

Employed_Year

Medical_History – whether the employee got hearing disease

Drug_History – whether the employee has been consume drug for other disease

Hobby – listening to music and swimming can affect hearing ability

Previous_Employment_Records – whether the employee has been exposure to noise in previous workplace.

Audiometer

Serial_Number – primary key

Name

Model

Calibration_Date

Location

Location_Name – primary key

Exposure

Maximum_Exposure

Test_Information

Employee_Number – primary key

Serial_No

Test_Date

Left_Ear

- 500L
- 1000L
- 2000L
- 3000L
- 4000L
- 6000L

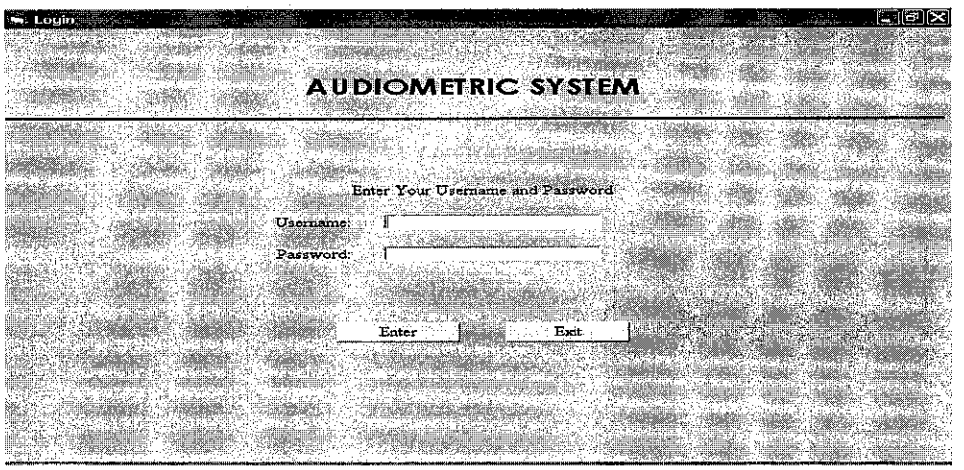
Right_Ear

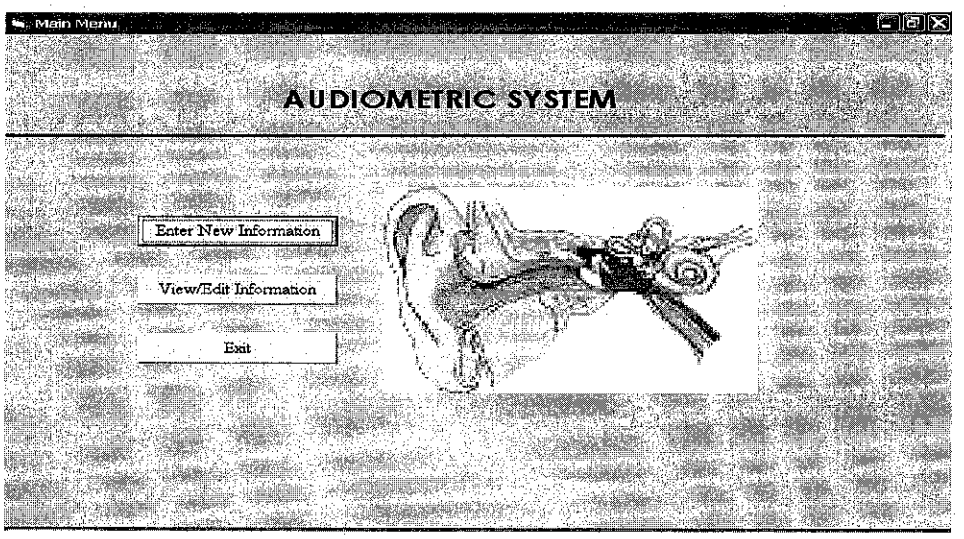
- 500R
- 1000R
- 2000R
- 3000R
- 4000R
- 6000R

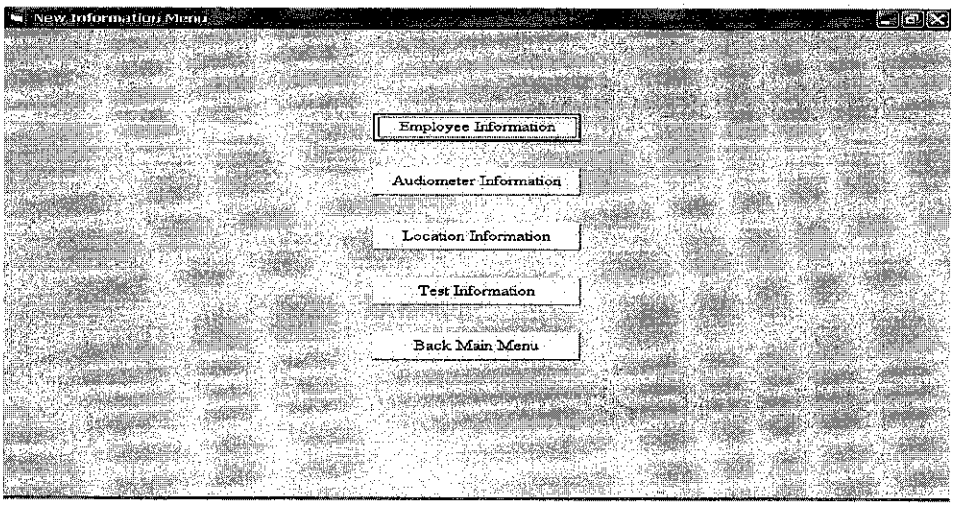
APPENDIX 4

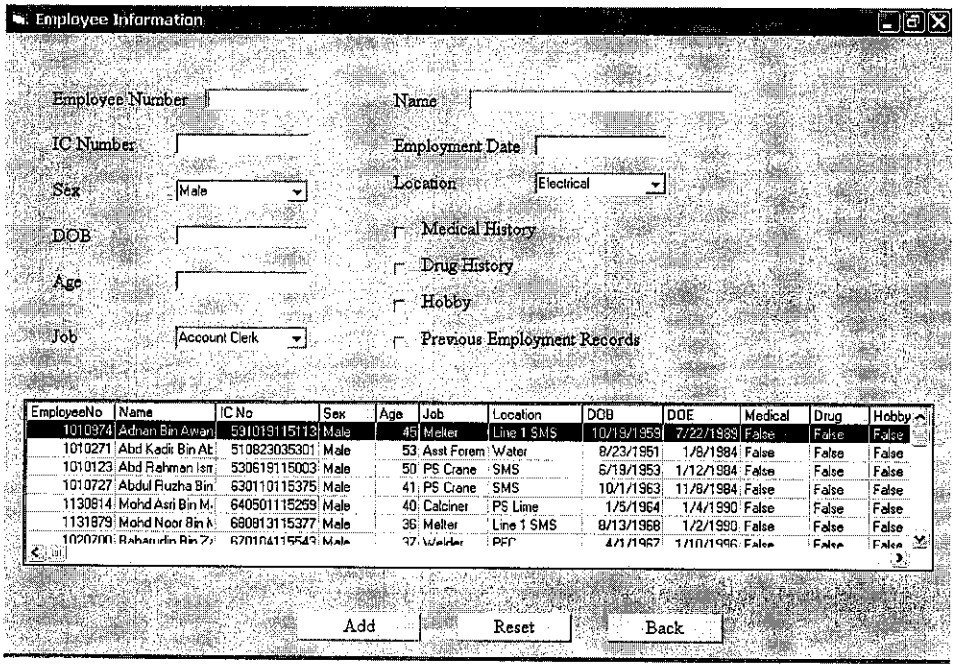
PRINT SCREEN INTERFACE

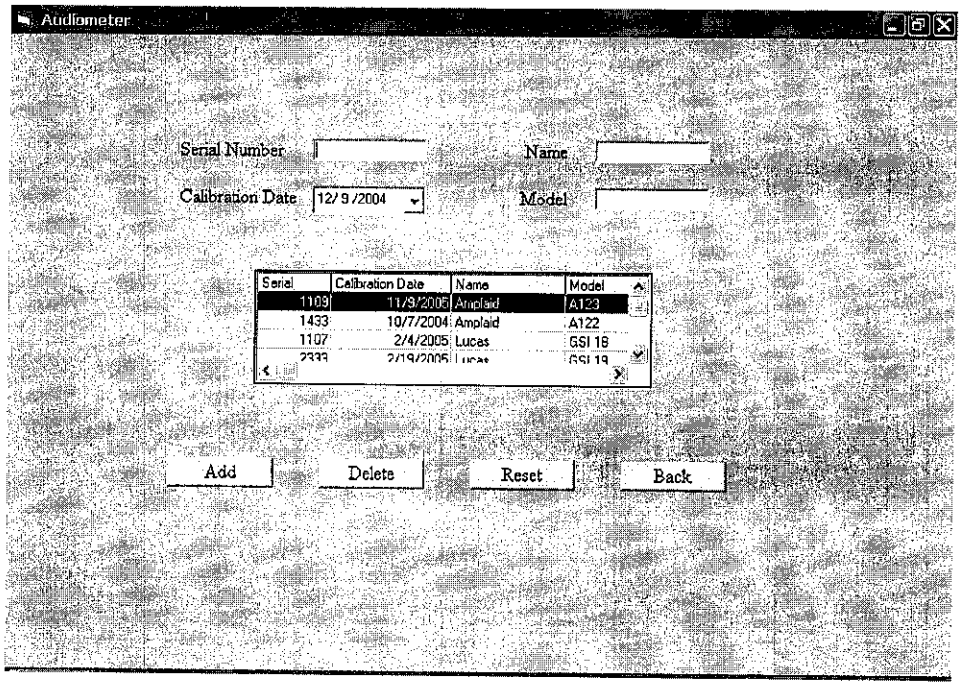
Appendix 4: Print Screen Interface

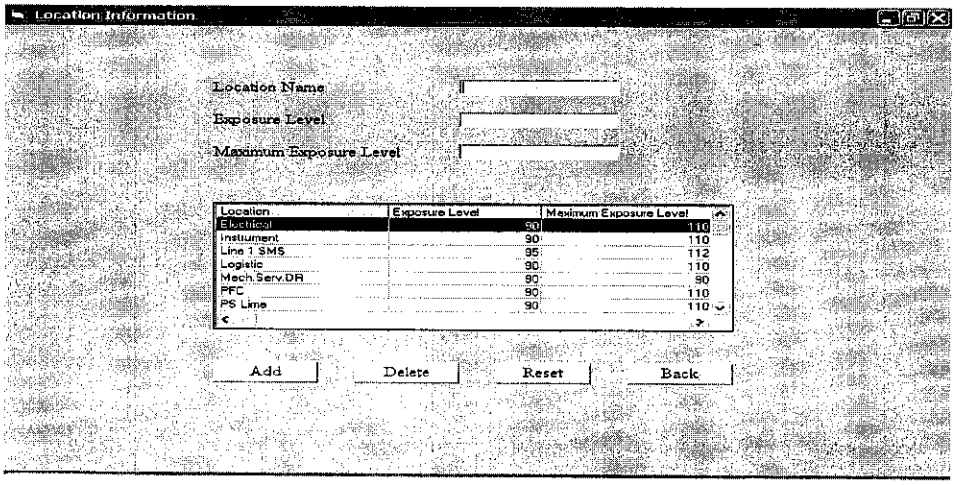


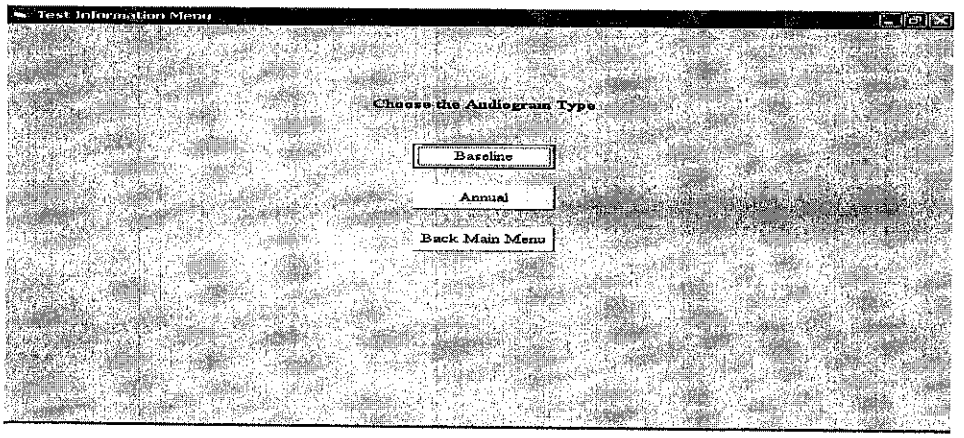


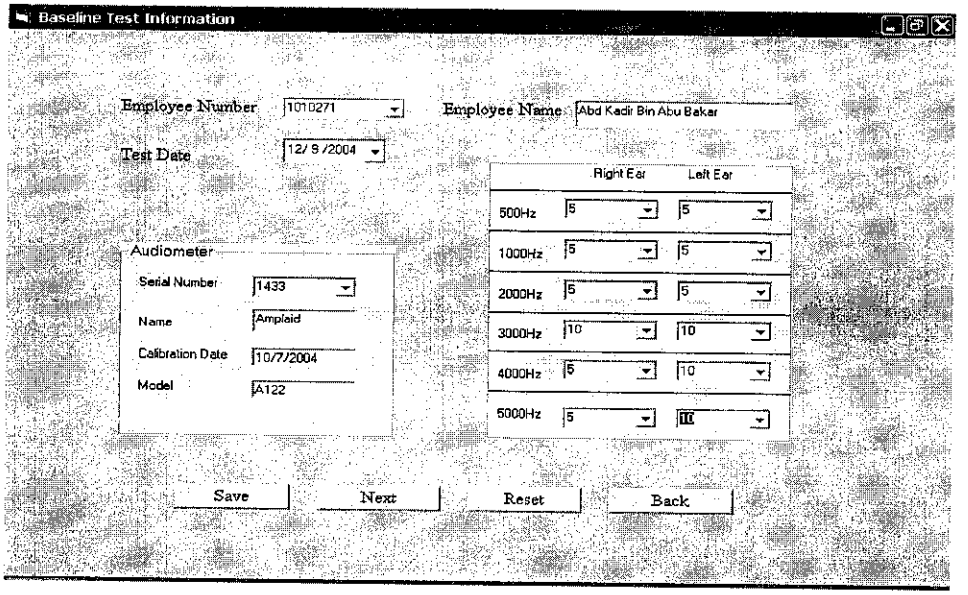



Employee Information
Employee Number
Name
IC Number
Employment Date
Sex
Male
Location
Electrical
DOB
Medical History
Age
Drug History
Hobby
Job
Account Clerk
Previous Employment Records
EmployeeNo Name IC No Sex Age Job Location DOB DOE Medical Drug Hobby
1010974 Adnan Bin Awan 591019115113 Male 45 Melter Line 1 SMS 10/19/1959 7/22/1989 False False False
1010271 Abd Kadir Bin Ab 510823035301 Male 53 Asst Forem Water 8/23/1951 1/8/1984 False False False
1010123 Abd Rahman Isn 530619115003 Male 50 PS Crane SMS 6/19/1953 1/12/1984 False False False
1010727 Abdul Ruzha Bin 630110115375 Male 41 PS Crane SMS 10/1/1963 11/8/1984 False False False
1130814 Mohd Asri Bin M 640501115259 Male 40 Calciner PS Lime 1/5/1964 1/4/1990 False False False
1131879 Mohd Noor Bin A 680913115377 Male 36 Melter Line 1 SMS 8/13/1968 1/2/1990 False False False
Add
Reset
Back


Audiometer
Serial Number
Name
Calibration Date
12/ 9 /2004
Model
Serial Calibration Date Name Model
1109 11/9/2005 Amplaid A123
1433 10/7/2004 Amplaid A122
1107 2/4/2005 Lucas GSI 18
Add
Delete
Reset
Back


Location Information
Location Name
Exposure Level
Maximum Exposure Level
Location
Exposure Level
Maximum Exposure Level
Electrical 90 110
Instrument 90 110
Line 1 SMS 95 112
Logistic 90 110
Mech.Serv.DR 90 90
PFC 90 110
PS Line 90 110
Add
Delete
Reset
Back


Test Information Menu
Choose the Audiogram Type
Baseline
Annual
Back Main Menu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Employee Name
Abd Kadir Bin Abu Bakar
Test Date
12/ 9 /2004
Audiometer
Serial Number
1433
Name
Amplaid
Calibration Date
10/7/2004
Model
A122
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Left Ear
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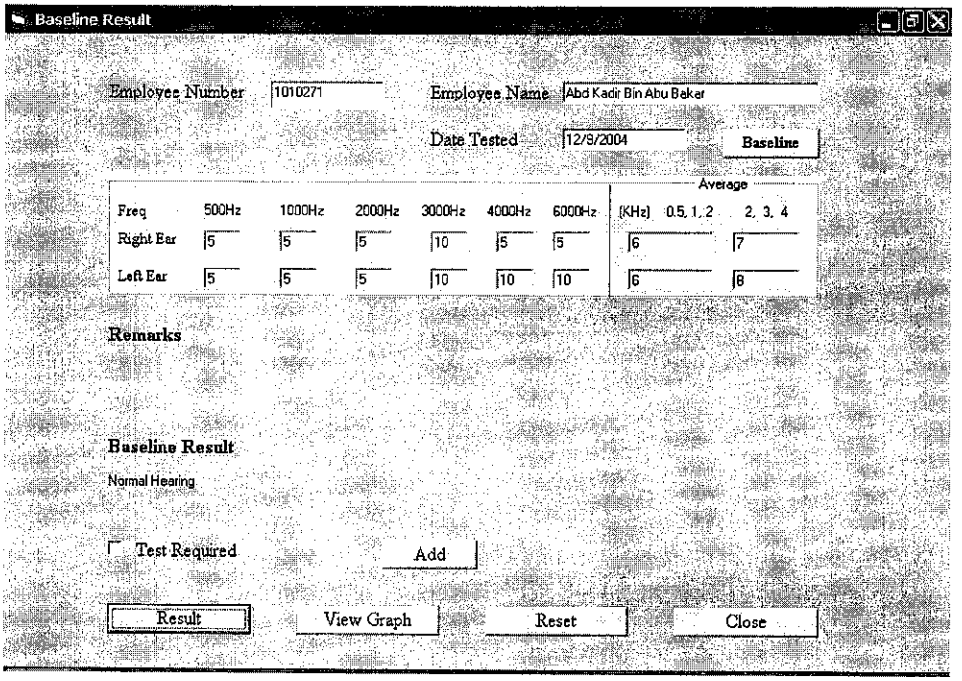
2000Hz 5 5
3000Hz 10 10
4000Hz 5 10
5000Hz 5
Save
Next
Reset
Back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Employee Name
Abd Kadir Bin Abu Baker
Date Tested
12/9/2004
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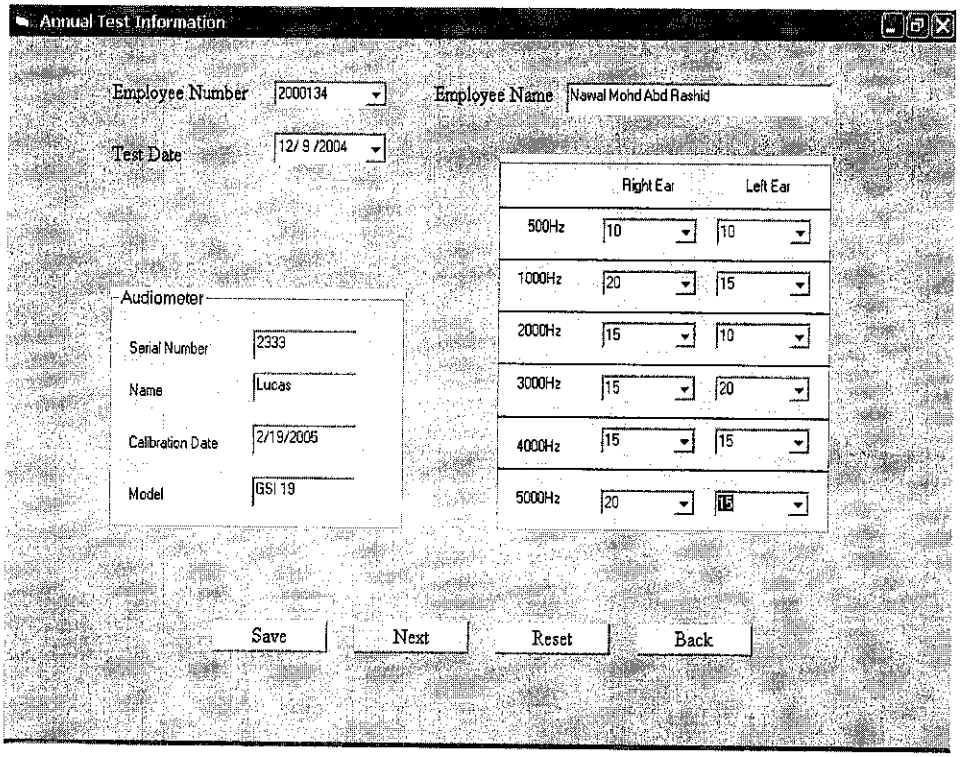
3000Hz
4000Hz
6000Hz
(KHz) 0.5, 1, 2
2, 3, 4
Right Ear
5
5
5
10
5
5
6
7
Left Ear
5
5
5
10
10
10
6
8
Remarks
Baseline Result
Normal Hearing
Test Required
Add
Result
View Graph
Reset
Close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Employee Number
2000134
Employee Name
Nawal Mohd Abd Rashid
Test Date
12/ 9 /2004
Right Ear
Left Ear
500Hz
10
10
1000Hz
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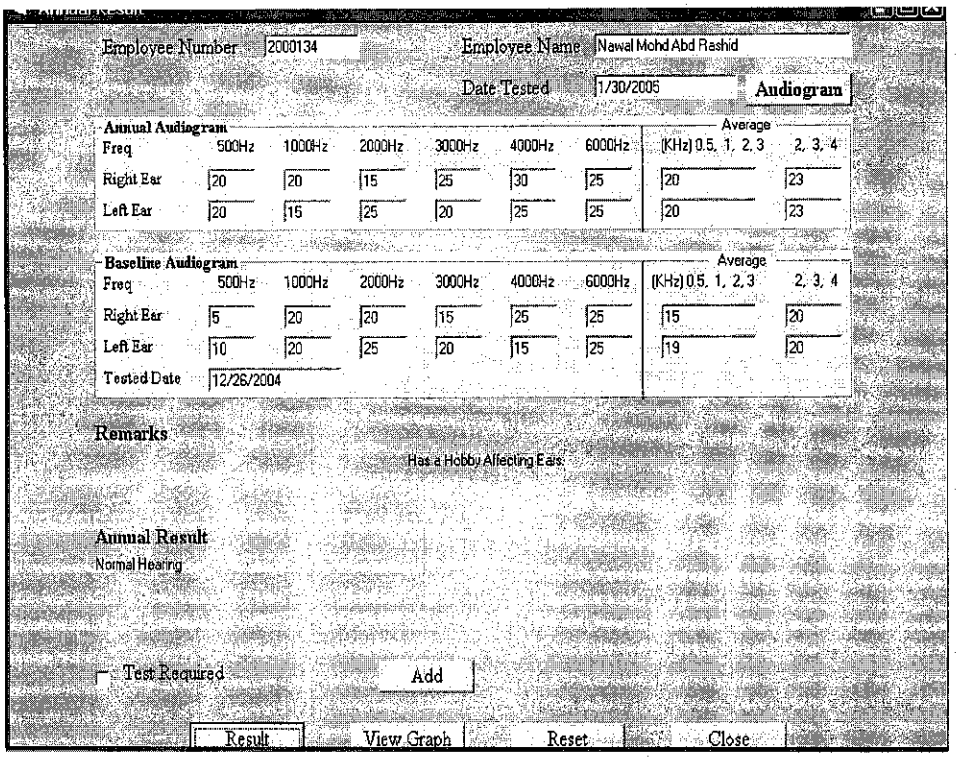
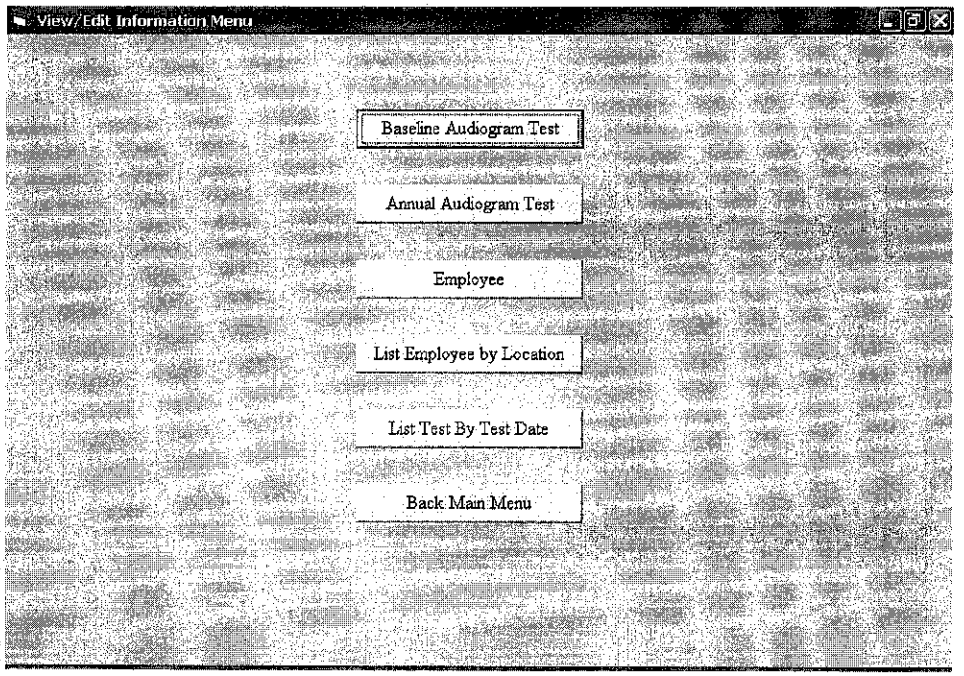
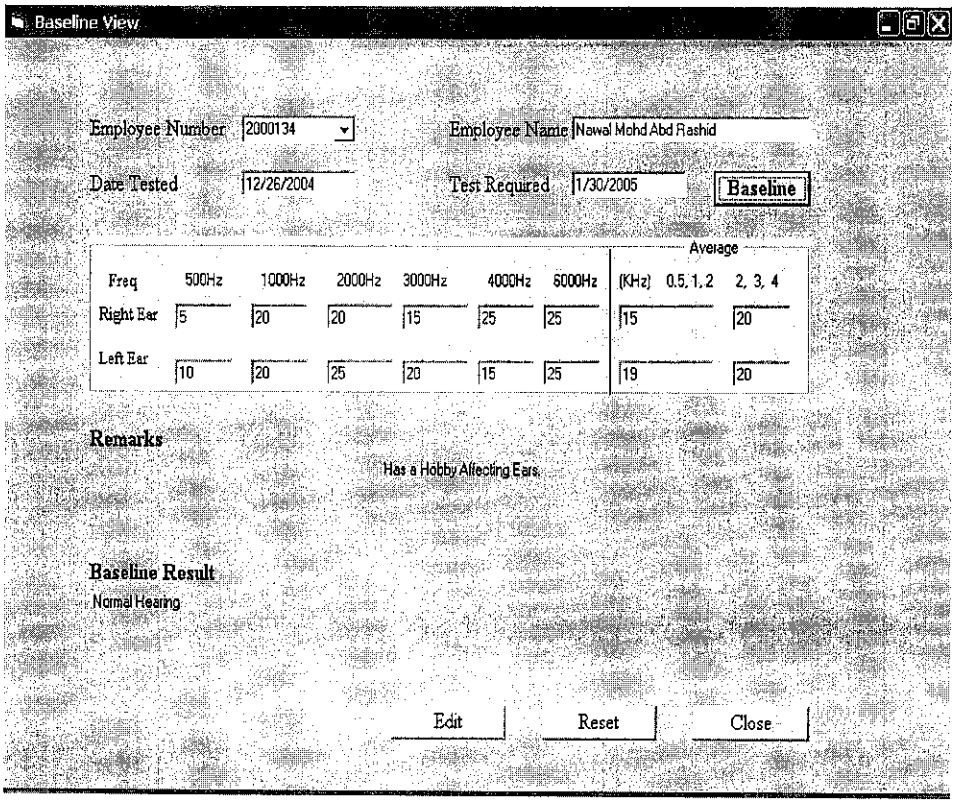
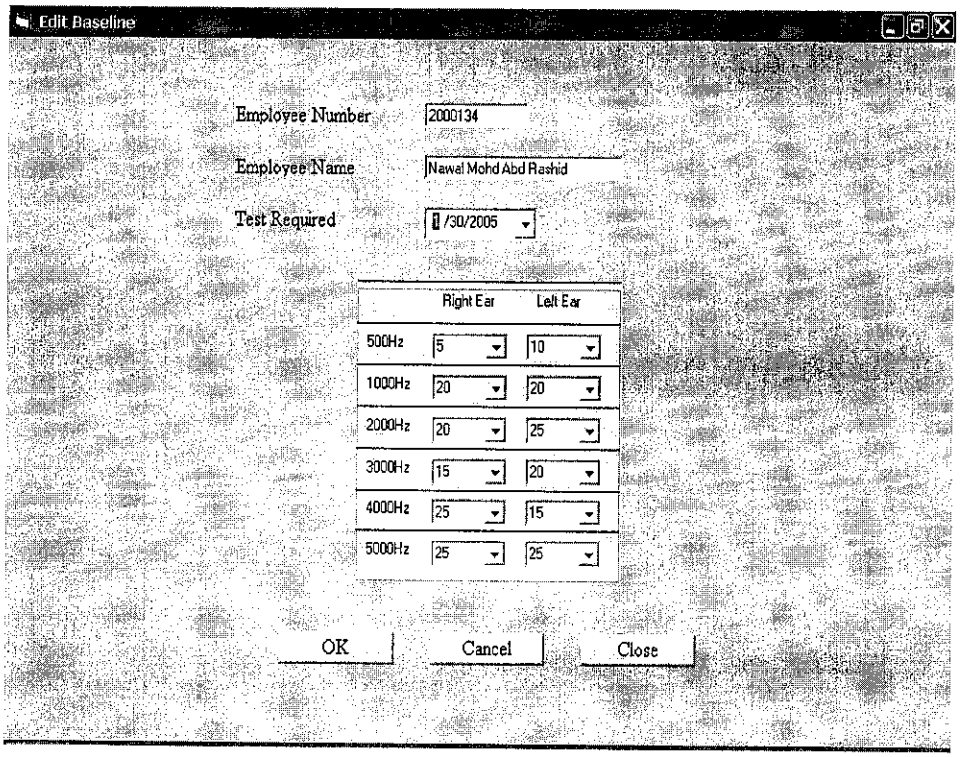
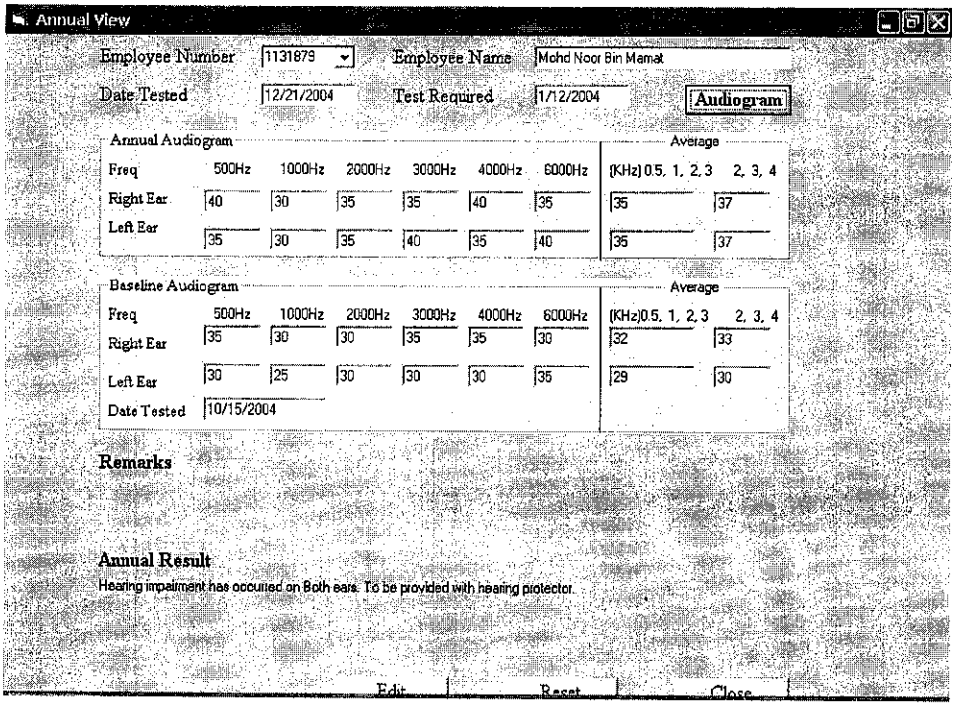
15
2000Hz
15
10
3000Hz
15
20
4000Hz
15
15
5000Hz
20
15
Audiometer
Serial Number
2339
Name
Lucas
Calibration Date
2/19/2005
Model
GSI 19
Save
Next
Reset
Back

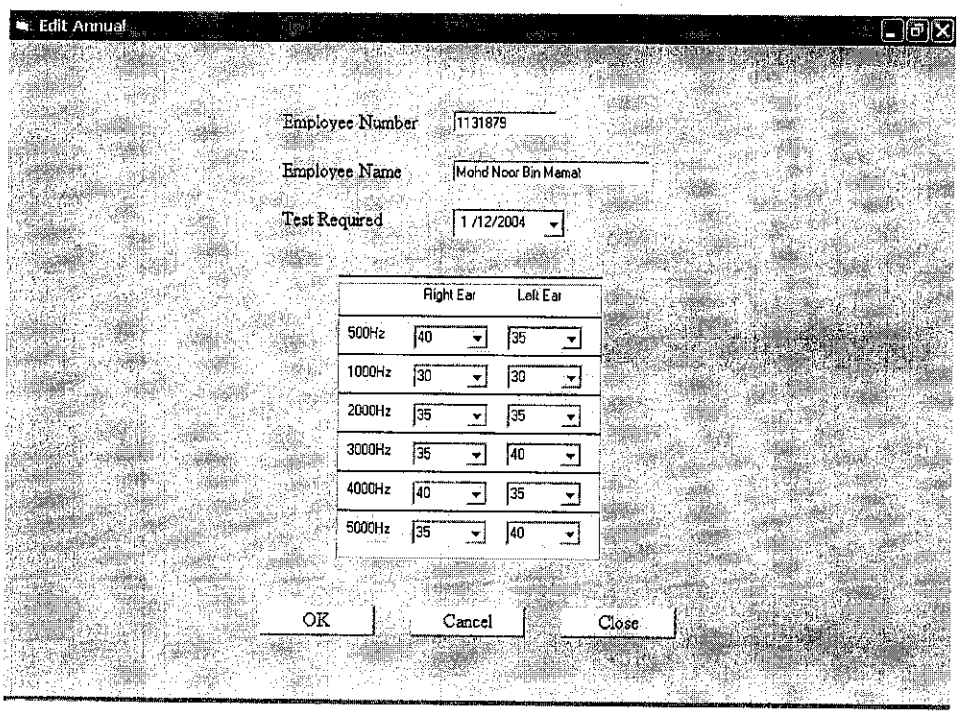

Employee Number
2000134
Employee Name
Nawal Mohd Abd Rashid
Date Tested
1/30/2005
Audiogram
Annual Audiogram
Freq
500Hz
1000Hz
2000Hz
3000Hz
4000Hz
6000Hz
Average
(KHz) 0.5, 1, 2, 3
2, 3, 4
Right Ear
20
20
15
25
30
25
20
23
Left Ear
20
15
25
20
25
25
20
23
Baseline Audiogram
Freq
500Hz
1000Hz
2000Hz
3000Hz
4000Hz
6000Hz
Average
(KHz) 0.5, 1, 2, 3
2, 3, 4
Right Ear
5
20
20
15
25
25
15
20
Left Ear
10
20
25
20
15
25
19
20
Tested Date
12/26/2004
Remarks
Has a Hobby Affecting Ears
Annual Result
Normal Hearing
Test Required
Add
Result
View Graph
Reset
Close

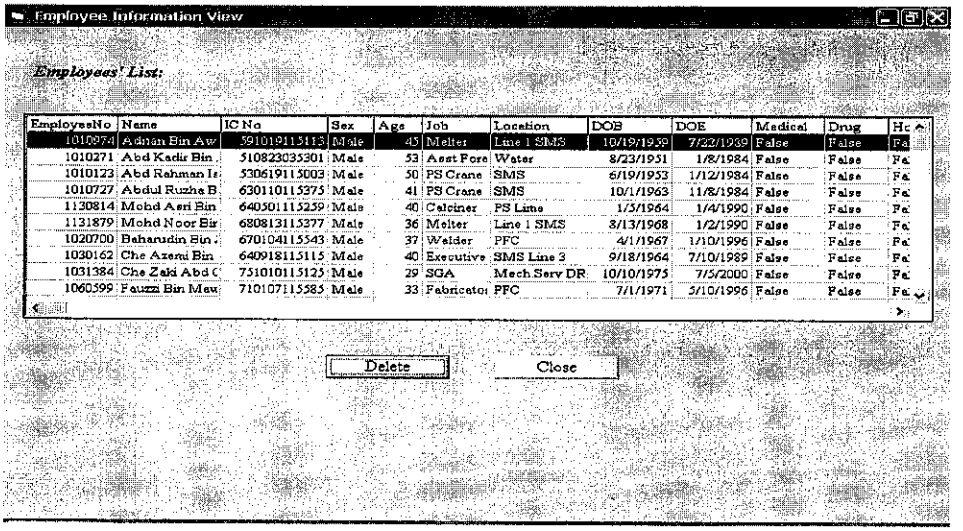

View/Edit Information Menu
Baseline Audiogram Test
Annual Audiogram Test
Employee
List Employee by Location
List Test By Test Date
Back Main Menu

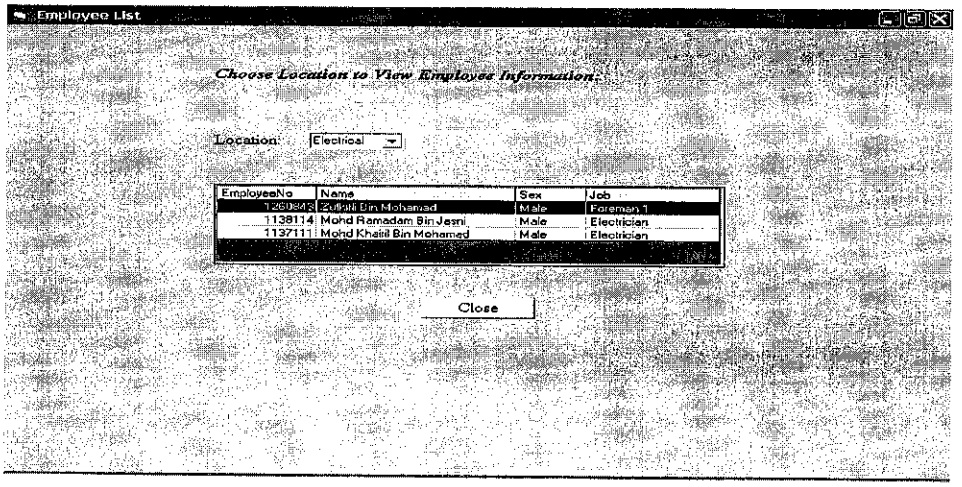

Baseline View
Employee Number 2000134
Employee Name Nawal Mohd Abd Rashid
Date Tested 12/26/2004
Test Required 1/30/2005
Baseline
Average
Freq 500Hz 1000Hz 2000Hz 3000Hz 4000Hz 6000Hz (KHz) 0.5, 1, 2 2, 3, 4
Right Ear 5 20 20 15 25 25 15 20
Left Ear 10 20 25 20 15 25 19 20
Remarks
Has a Hobby Affecting Ears.
Baseline Result
Normal Hearing
Edit
Reset
Close

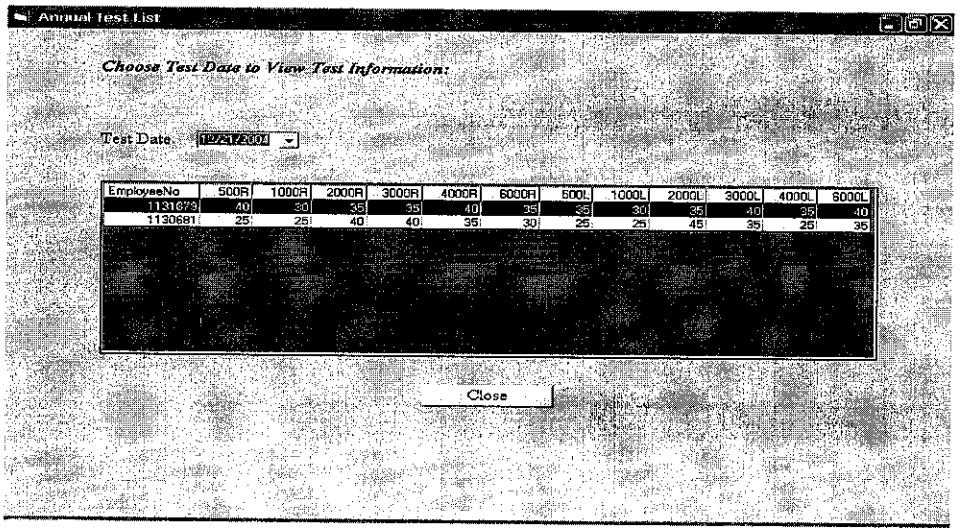

Edit Baseline
Employee Number 2000134
Employee Name Nawal Mohd Abd Rashid
Test Required /30/2005
Right Ear Left Ear
500Hz 5 10
1000Hz 20 20
2000Hz 20 25
3000Hz 15 20
4000Hz 25 15
5000Hz 25 25
OK
Cancel
Close


Annual View
Employee Number
1131879
Employee Name
Mohd Noor Bin Mamat
Date Tested
12/21/2004
Test Required
1/12/2004
Audiogram
Annual Audiogram
Average
Freq
500Hz
1000Hz
2000Hz
3000Hz
4000Hz
6000Hz
(KHz) 0.5, 1, 2, 3
2, 3, 4
Right Ear
40
30
35
35
40
35
35
37
Left Ear
35
30
35
40
35
40
36
37
Baseline Audiogram
Average
Freq
500Hz
1000Hz
2000Hz
3000Hz
4000Hz
6000Hz
(KHz)0.5, 1, 2, 3
2, 3, 4
Right Ear
35
30
30
35
35
30
32
33
Left Ear
30
25
30
30
30
35
29
30
Date Tested
10/15/2004
Remarks
Annual Result
Hearing impairment has occurred on Both ears. To be provided with hearing protector.
Edit
Reset
Close


Edit Annual
Employee Number
1131879
Employee Name
Mohd Noor Bin Mamat
Test Required
1 /12/2004
Right Ear
Left Ear
500Hz
40
35
1000Hz
30
30
2000Hz
35
35
3000Hz
35
40
4000Hz
40
35
5000Hz
35
40
OK
Cancel
Close


Employee Information View
Employees' List:
EmployeesNo | Name | IC No | Sex | Age | Job | Location | DOB | DOE | Medical | Drug
1010971 | Adnan Bin Aw | 591019115113 | Male | 45 | Melter | Line 1 SMS | 10/19/1959 | 7/22/1989 | False | False
1010271 | Abd Kadir Bin | 510823035301 | Male | 53 | Asst Fore | Water | 8/23/1951 | 1/8/1984 | False | False
1010123 | Abd Rahman Is | 530619115003 | Male | 50 | PS Crane | SMS | 6/19/1953 | 1/12/1984 | False | False
1010727 | Abdul Ruzhe B | 630110115375 | Male | 41 | PS Crane | SMS | 10/1/1963 | 11/8/1984 | False | False
1130814 | Mohd Aeri Bin | 640501115259 | Male | 40 | Caleiner | PS Lime | 1/3/1964 | 1/4/1990 | False | False
1131879 | Mohd Noor Bir | 680813115377 | Male | 36 | Melter | Line 1 SMS | 8/13/1968 | 1/2/1990 | False | False
1020700 | Baharudin Bin | 670104115543 | Male | 37 | Welder | PFC | 4/1/1967 | 1/10/1996 | False | False
1030162 | Che Azemi Bin | 640918115115 | Male | 40 | Executive | SMS Line 3 | 9/18/1964 | 7/10/1989 | False | False
1031384 | Che Zaki Abd C | 731010115125 | Male | 29 | SGA | Mech Serv DR | 10/10/1975 | 7/5/2000 | False | False
1060599 | Fauzi Bin Mau | 710107115583 | Male | 33 | Fabricator | PFC | 7/1/1971 | 5/10/1996 | False | False
Delete
Close


Employee List
Choose Location to View Employee Information:
Location: Electrical
EmployeeNo | Name | Sex | Job
1138114 | Mohd Ramadam Bin Jesni | Male | Electrician
1137111 | Mohd Khairil Bin Mohamed | Male | Electrician
Close


Annual Test List
Choose Test Date to View Test Information:
Test Date: 12/31/2004
EmployeeNo | 500R | 1000R | 2000R | 3000R | 4000R | 6000R | 500L | 1000L | 2000L | 3000L | 4000L | 6000L
1131873 | 40 | 30 | 35 | 35 | 40 | 25 | 35 | 30 | 35 | 40 | 35 | 40
1130681 | 25 | 25 | 40 | 40 | 35 | 30 | 25 | 25 | 45 | 35 | 25 | 35
Close

APPENDIX 5

QUESTIONNAIRE

Appendix 5: Project Title: Decision Support System (DSS) in Audiometric System

Questionnaires

I am a Final Year IT student from University Technology Petronas doing my Final Year Project. These questionnaires will help me in getting some response from the clinicians towards the implementation of DSS in Audiometric System. Please take a few moments to complete these questions. Thank you.

Current Audiometric System

1) Is it difficult to analyze hearing problem accurately?

   1. Yes 2. No

2) How long does it take to complete the analyzing process of hearing problem?

   1. _____day(s) 2._____week(s) 3._____month(s)

3) Is it easy to get patient record directly from manual system of audiometric test form?

   1. Difficult 2. Average 3. Easy

4) How do you rate the current system for processing data of hearing problem?

   1. Very poor 2. Poor 3. Average 4. Good 5. Excellent

5) What are the other problems that you faced during analyzing hearing problem with the current system?

   1._____

   2._____

   3._____

   4._____

DSS in Audiometric System

DSS is a computer-based information system that used to assist users in decision making process and it also can improve effectiveness of decision making.

1) Do you prefer to have DSS for audiometric test in order to assist decision making process?

   1. Yes 2. No

2. Is it appropriate to use visual aid such as graph or table in order to show the changes in threshold?

   1. Yes 2. No

3) What do you think if you can analyze hearing problem just by clicking **Enter** button?

   1. Strongly agree 2. Somewhat agree
   3. Neither agrees nor disagrees 4. Somewhat disagree 5. Strongly disagree

4) What do you think if the system can give you suggestion solution in order to solve hearing problem?

   1. Strongly agree 2. Somewhat agree
   3. Neither agrees nor disagrees 4. Somewhat disagree 5. Strongly disagree

5) What do you expect from DSS in Audiometric System?

_____

_____

_____

_____