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Multi-tenant Database Framework Validation and Implementation into an Expert System

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Abstract: **Expert Systems (ES) is a branch of Artificial Intelligence (AI) that makes extensive use of specialized knowledge to solve problems at the level of a human expert. It uses a computer program that represents and reasons with knowledge of some specialist subject with a view to solving problems or giving advice. These systems represent a programming methodology by which a computer can be instructed to perform tasks that were previously considered to require the intelligence of a human expert. The development of the Multi-Tenant Database (MTD) adoption framework involved the accumulation of extensive specialised knowledge of experts, hence there is a need for this to be implemented in an ES. This paper presents a forward chaining method used in the implementing of the MTD framework into an expert system. A free web-based expert system shell called ES-BUILDER was adopted. The framework was validated via a survey and analysed with the aid of SPSS software. The findings obtained from the validation procedure indicate that the framework is valuable and suitable for use in practice since the research shows that the majority of respondents accepted the research findings and recommendations for success. Likewise, the ES was also validated using a survey with the majority of participants accepting it and embraces the high level of its usability.**

Keywords – Expert System; Artificial Intelligence; Multi-Tenant Database; Forward Chaining; Validation

I. INTRODUCTION

An Expert System (ES) is a computer program that represents and reasons with knowledge of some specialist subject with a view to solving problems or giving advice [1]. To solve expert-level problems, expert systems will need efficient access to a substantial domain knowledge base, and a reasoning mechanism to apply the knowledge to the problems they are given and they will also need to be able to explain, to the users who rely on them, how they have reached their decisions [2]. Expert system is a branch of Artificial Intelligence (AI) that makes extensive use of specialized knowledge to solve problems at the level of a human expert [3]. An expert is a person who has expertise in a certain area. That is, the expert has knowledge or special skills that are not known or available to most people. Expert systems represent a programming methodology by which a computer can be instructed to perform tasks which were previously been considered to require the intelligence of a human expert [2]. An expert system is a computer program designed to imitate a human expert, mimicking the knowledge base and the decision making process of a human expert. An ES is different from a conventional program because it can explain its behaviour to the human expert and receive new information without new programming.

An expert system is a computer system with the capability of performing at the level of human Experts in some particular domain. It is possible to build expert systems that perform at remarkable Levels [4]. While there are several methods for designing expert systems, rule-based systems have emerged as the popular architecture. Deriving their knowledge from relatively easily understood facts and rules, rule-based systems offer surprising power and versatility. Any knowledge based system (referred to as an expert system) essentially emulates the acquired knowledge and thought processes of an expert in arriving at decisions and/or solutions concerning a problem.

Maher [4] explained that expert systems or knowledge based expert systems are interactive computer programs with built in judgement, experience, rules of thumb, intuition, and other expertise to provide knowledgeable advice and solutions on different subjects. Minkarah and Ahmad [5] provide us with a more specific definition of an expert system as a computer program that uses expert knowledge to reach a level of performance akin to that achievable by highly skilled experts. This is supported by Ye and Wu [6] states that expert systems are software systems that imitate the decision-making ability of human experts. It is observed that a main distinction of experts and novices in a specialty field is experts' possession of vast amounts of heuristic knowledge acquired and accumulated over many years of experience in the field. Therefore, expert systems are designed to address complex problems and to explain the reasoning process, in which the knowledge is represented symbolically rather than numerically. Wijesundera and Harris [7] describe further the implementation of an expert system as a simulation for a consultation process between an expert of a particular field and a non-expert. Typically, the non - expert is the end user and the computer model is the expert.

The Multi-Tenant Database (MTD) adoption framework proposed by Matthew et al [8] makes use of very extensive specialised knowledge acquired from the experts during the survey. Based on this, this paper presents the implementation of the framework into an ES. The validation processes of both the framework and the ES of the framework were also presented.

The structure of this paper is as follows: Section 2 briefly introduces the concept of MTD and its adoption. Section 3 provides the background details of the MTD framework and the stages of its modification based on a series of survey conducted in the research. Section 4 introduces the Expert System (ES) concept and the development of the framework into an ES. The method and the shell used are also presented with the results in this section. Section 5 presents the detailed validation processes for the framework and the ES. The result of the validation is also presented in this section. Section 6 presents the conclusions and ideas for future work.

II. THE CONCEPT OF MTD AND ITS ADOPTION

A MTD refers to a principle where a single instance of a Database Management System (DBMS) runs on a server, serving multiple clients (tenants). Multi-tenant database is one which provides database support to a number of separate and distinct groups of users, also referred to as tenants. A tenant is simply any logically defined group of users that requires access to its own set of data. This definition was substantiated by Bezemer et al [9] as an architectural pattern in which a single instance of the software is run on the service provider's infrastructure, and multiple tenants access the same instance. This reduces effort made in production and the cost incurred in the development. In a multi-tenant enabled service environment, user requests from different organizations and companies (tenants) are served concurrently by one or more hosted application instances and databases based on a scalable, shared hardware and software infrastructure [10]. Such database systems must be able to maintain or even increase their performance or efficiency level under larger operational demands. A MTD is a way of deploying a Database as a Service (DaaS). This is gaining momentum with significant increase in the number of organizations ready to take advantage of the technology. The concept of multi-tenancy was developed from the service providing technology known as Software as a Service (SaaS). SaaS is a form of cloud computing that involves offering software services in an on-line and on-demand fashion with the Internet as the delivery mechanism [11].

Organisations incur huge cost on the acquiring and maintaining dedicated database system which ranges from cost of infrastructures, software licences, maintenance, monitoring, managing and upgrading. The adoption of MTD will eliminate most of these costs. However, there are some important factors needed to be considered before the MTD adoption. These factors are examined by Matthew et al [12]

II. REVIEW OF MTD FRAMEWORK

The Multi-tenant Database (MTD) framework was developed from the Matthew et al [8] paper based on the postulates derived from the thorough literature reviews carried out in that research. These postulates are based on the factors that influence the decision towards the adoption of the concept MTD. In this framework, the possible directions of the decision about MTD are shown. The following factors; cost and growth point to one direction of adoption, security points to one direction of rejection while regulation points to both directions. This is shown in Figure 1 below.

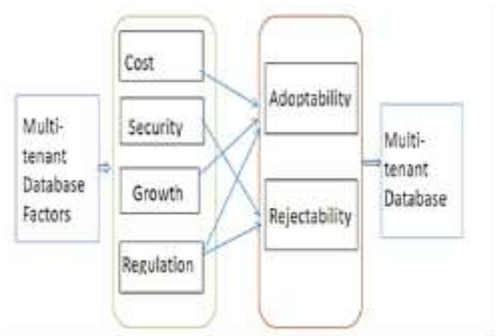

Figure 1 – MTD Adoption Framework [8]

In Matthew et al [13] data analysis, which covers data surveyed from a set of expert in the field of database was carried out. Questionnaires were administered online and responses were received from across the world including every continent. There was a total of 41 participants in the survey. The reason for low participation has to do majorly with the level of technicality of the questionnaire, since the response is expected from a certain set of experts in the concept of MTD. This research on MTD is largely quantitative and is concerned with measurement of mainly the nominal and ordinal variables. The data from the survey were coded into SPSS and represented in numerical values. These data were subjected to statistical tools which include Percentage Frequency Distribution, Relative Importance Index (RII) and Cross Tabulation. The results from these analyses resulted in the new framework shown in Figure 2 below. In the framework, the factors were grouped into four, which are economic, security, growth and regulation. Economic, growth and regulation lead to adoption while security leads to rejection. Once MTD adopted it will also have to consider what type of model ranging between Shared Machine (SM), Shared Process (SP) and Shared Table (ST).

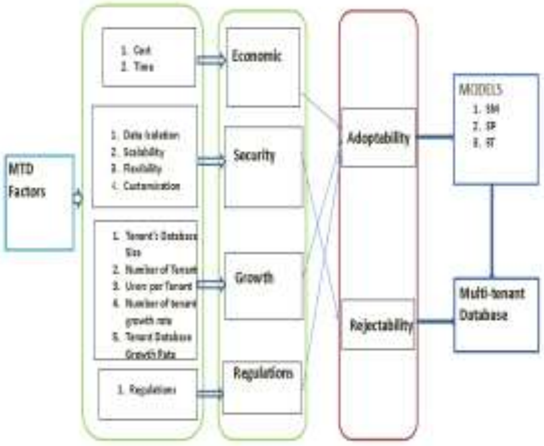

Figure 2 – The New Framework [13]

The combinations of two or more factors were also considered in Matthew et al [13] which brings about a modification of the initial framework. The result was derived from the combination of results from the RII analysis carried out in Matthew et al [13]. The RII analysis shows the degree of impact each factor has towards the adoption of MTD. And the average of any combination will indicate the degree of impact and the direction it tends to. The new Modified Framework is shown in Figure 3 below.

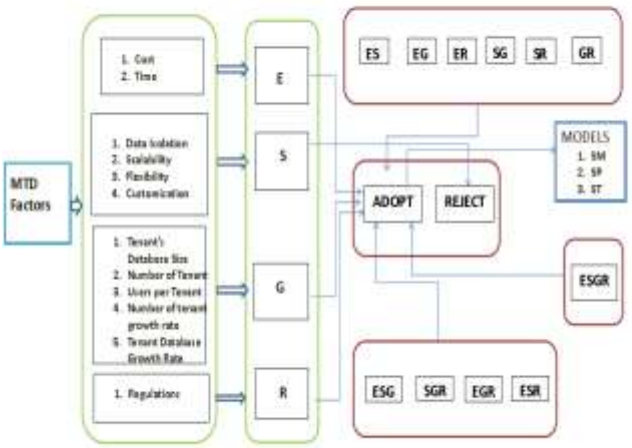

Figure 3 - The Modified New Framework [13]

The next section shows how the modified new framework is developed into an expert system. The method, the tool and the interface the ES will also be illustrated.

III. Development of MTD Framework into an ES

There are two main components of an expert system [6] which are the knowledge base and the inference engine, which performs knowledge-based reasoning to make decisions. During knowledge-based reasoning, the expert system uses a working memory to keep given or inferred facts. Knowledge in the knowledge base can be directly acquired from human experts or extracted through mining data.

The third component of an expert was identified by Sun et al [2] as the Expert System Interface which is the part of the system that interacts with the users of the system.

The Knowledge Base is where the information is stored in the expert system in the form of facts and rules (basically a series of IF statements). This part of the ES has a structure of rules in the form of IF condition THEN consequence, which is also, called “Rule Base” [6]. This means that when the IF condition(s) are satisfied THEN the consequence will take place. This is where the programmer writes the code for the expert system. This contains necessary information to solve the problem and this information is obtained from human experts. This is a collection of heuristics which are represented in some manner in the knowledge base.

The inference engine applies the facts to the rules and determines the questions to be asked of the user in the user interface and in which order to ask them. This is the 'invisible' part of the expert system, which is active during a consultation of the system (when the user chooses to run the program). Castillo et al [14] expatiated that the inference engine is the heart of the every ES with the main purpose of drawing conclusions by applying the abstract knowledge to the concrete knowledge. While Ye and Wu [6] explain an inference engine as the aspect of ES that applies knowledge in the rule base to facts in the working memory and make inferences for the goal of making a decision. The conclusions drawn by the inference engine can be based on either deterministic knowledge or probabilistic knowledge [14]. An expert system can use two different methods of inferencing which are Forward Chaining and Backward Chaining.

Backward Chaining is also called goal directed reasoning [6]. Works with the system assumes a hypothesis of what the likely outcome will be, and the system then works backwards to collect the evidence that would support this conclusion. Expert systems used for planning often use backward chaining. This is a top- down approach in which rules are chained together so that the action parts of subsequent rules provide information concerning the validity of the condition part of the preceding rule.

Ye and Wu [6] called forward chaining as data driven system reasoning, which simply means gathering facts (like a detective at the scene of a crime) until enough evidence is collected that points to an outcome. This is the reasoning from the facts to the conclusions resulting from those facts. Forward chaining is often used in expert systems for diagnosis, advise and classification, although the size and complexity of the system can play a part in deciding which method of inferencing to use. Here the condition part in each rule is checked against the database to establish the validity.

The Shell or User Interface is where the user interacts with the expert system. Castillo et al [14] defines user interface as the liaison between the ES and the user while Giarratano and Riley [3] define it as the mechanism by which the user and the ES communicates. The incorporation of efficient mechanisms to display and retrieve information in an easy way makes ES an effective tool. In other words where questions are asked, and advices are produced. As well as the advice that is output, the user interface can output the justification features of an expert system. Examples of information to be displayed are the conclusions drawn by the inference engine, the reasons for such conclusions, and an explanation for the actions taken. When there are no conclusions reached by the inference engine, the user interface provides a vehicle for obtaining more information needed from the user that will further help the inference engine to get a conclusion. A good and effective ES must provide avenues for this through the interface otherwise the quality of the ES will be in doubt [14].

A. *Method*

This section examines the Expert System shell used in this research to implement the framework. The choice of this shell is largely based on its free access and use of the software. It is also a web based expert system shell. This is called ES BUILDER [15]. ES-Builder is an Expert System Shell application. The software is used to design expert systems that may be accessed dynamically as web pages and incorporated as a knowledge base in any web site. ES-Builder features a decision tree modelling process for developing the logic of the expert system (ES). The ES-Builder program was built in order to assist expert system developers by providing a simple interface for implementing and modelling expert systems that may have been pre-designed using a suitable design process. This type of expert system is developed using a process of deductive reasoning. This means that the expert system provides an interface to test a series of attributes, which through the process of deduction allows the user to arrive at a conclusion. This conclusion is logically correct based on the values chosen by the user for every attributes involved.

Building an expert system with ES-Builder is easy, because it uses a simple web interface which can be easily accessed by anyone familiar with the internet. The user constructs the expert system using a decision tree interface where attributes, values and conclusions are added as leaf nodes on the tree. Each node has a small integrated data set which is used to form the content of the expert system when it is accessed online. When the expert system is completed and made available on the internet, the user simply has to click on an option from a list presented on a page for each attribute. Attributes are displayed in sequence with only values appropriate to the current search shown.
Creation of an expert system (ES) in ES-Builder is only possible for registered users of ES-Builder Web. Firstly, this involves creating a user account via the ES-Builder Web User Registration page. Each user must supply a unique email address for registration as a username. User email addresses and passwords are stored in the database. This registration is confirmed by the supplied email address before a user may login in to the system.

B. *Results*

1. *Project Details*

There is what is called Project Details page. This is where the user defines a title for their expert system, defines the Universe of Discourse, may define an image to display on the title page, and edit other settings for the expert system. All these are shown in the Figure 4 below

Figure 4 – MTD Project Details Page

2. *Decision Tree*

The deductive logic of the ES is created through the Decision Tree View by entering the title details, attributes, values, and conclusions into a decision tree. Each step in the decision tree is called a node. A node that branches out of another node in the decision tree is called a branch node. A node may have branches to further nodes, and so on, until the decision tree is complete. There are a number of basic rules about how the tree can be formed and which branch nodes a particular type of node may accept. The nodes at the very ends of branches are called leaf nodes. The decision tree for this MTD evaluation framework is shown in the Figure 5 below.

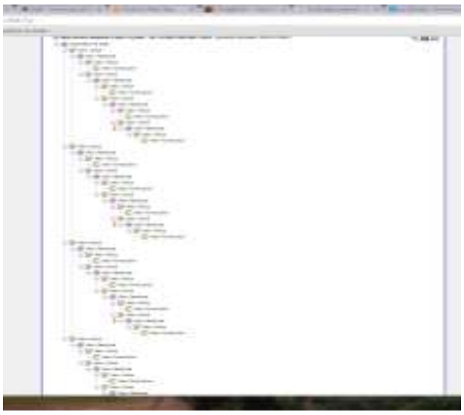

Figure 5 – MTD Decision Tree

The first (or root) node in any decision tree is the Universe of Discourse (UofD). Details about UOfD are entered by the user when they create the project including:

- The name of the ES.
- The identifier to be used to refer to each conclusion in the ES.
- A phrase to be used as a starting link at the beginning of the ES.
- A longer description of the ES to be presented on the home page of the ES. This longer description can be created using HTML tags to improve presentation in the browser.
- An image to be displayed on the home page of the ES to improve presentation

The second node (or first branch) of the decision tree must be an attribute which is displayed with an 'A' icon. Attributes are characteristics of possible conclusions that are to be tested in the ES. Each Attribute must have at least two branch nodes in the completed system. The only type of branch node accepted by Attribute nodes are Value nodes.

Each Value nodes represents the most correct response to an Attribute for a particular conclusion. Value nodes may have two possible types of branch node. When a further Attribute needs to be tested, the branch node of a Value will be another Attribute node. When a final conclusion has been made, the branch node of the Value will be a Conclusion node. Value nodes may have only one branch node.

A Conclusion node must be a leaf node. No branches are accepted from Conclusion nodes.

For each node apart from the first (UofD) node, three data items can be added. Each Attribute, Value, or Conclusion node may have:

- a detailed definition (this allows the designer to use a short identifier in the tree to keep the design process neat and simple)
- a paragraph of help notes to inform users about the process of the ES and to give more detailed information about possible conclusions.
- An image to be displayed in the ES to assist users in the process and to give detailed visual information about possible conclusions

3. *Knowledge base*

The knowledge base is captured in Figure 6 below showing information stored in the ES in the form of facts and rules. This part of the ES has a structure of IF condition(s) THEN consequences. This means once IF statements are satisfied the THEN will take place. This is just some part of the knowledge base. For full view of the knowledge base and a good look at the ES as a whole kindly follow the link below.

http://www.mcgoo.com.au/esbuilder/viewer/viewES.php?es=252e59e9368580a68e0b52630b4c6f27

1	**IF** WHICH OF THESE FACTORS IS MOST IMPORTANT TO YOU? ECONOMICS **AND** ECONS ONLY YES **THEN** the MTD Adoption or Rejection is **ADOPT MTD**.
2	**IF** WHICH OF THESE FACTORS IS MOST IMPORTANT TO YOU? ECONOMICS **AND** ECONS ONLY NO **AND** AND SECURITY ONLY YES **THEN** the MTD Adoption or Rejection is **ADOPT MTD**.
3	**IF** WHICH OF THESE FACTORS IS MOST IMPORTANT TO YOU? ECONOMICS **AND** ECONS ONLY NO **AND** AND SECURITY ONLY NO **AND** AND GROWTH ONLY YES **THEN** the MTD Adoption or Rejection is **ADOPT MTD**.
4	**IF** WHICH OF THESE FACTORS IS MOST IMPORTANT TO YOU? ECONOMICS **AND** ECONS ONLY NO **AND** AND SECURITY ONLY NO **AND** AND GROWTH ONLY NO **AND** AND REGULATIONS ALSO YES **THEN** the MTD Adoption or Rejection is **ADOPT MTD**.
5	**IF** WHICH OF THESE FACTORS IS MOST IMPORTANT TO YOU? SECURITY **AND** SECURITY ONLY YES **THEN** the MTD Adoption or Rejection is **REJECT MTD**.
6	**IF** WHICH OF THESE FACTORS IS MOST IMPORTANT TO YOU? SECURITY **AND** SECURITY ONLY NO **AND** AND ECONS ONLY YES **THEN** the MTD Adoption or Rejection is **ADOPT MTD**.

Figure 6 – MTD Knowledge base

IV. VALIDATION OF THE MTD FRAMEWORK AND ES

There are three options considered for carrying out the validation, which include focus group, interview and online surveys. The online survey constraints of restrictive nature of the questionnaire and lack of opportunity to clarify respondents' unclear views were handled by carefully designing the questionnaire. The online survey was now chosen over focus group and interview because of time and cost constraints. A copy of the research framework and a link to the web-based expert system were attached to the survey for clarifying any misunderstandings the respondents may have.

It is important to validate the findings with stakeholders in the market of DaaS, to determine if the findings were valid and the recommendations useful in respect to their experiences. Based on this reason, a covering letter was sent via email to the participants that were initially involved at the early stage of the research including participants who participated in the focus group and the online participants. The use of the previous participants is based on their prior involvement in the earlier survey which makes them familiar with the research and possibly ensures a good response rate. Taking one's findings back to the subjects being studied where they can verify the findings has been argued by Silverman [16] as being the one that can be more confident of their validity. This method is known as respondent validation [16].

Also, validation of the framework helps to ensure that the research has actually identified key factors affecting MTD adoption amongst organizations in the public sector and has sought to assess the extent to which the framework endeavours to enable intending users to make an informed decision about its adoption. That is, if the framework has provided accurate steps to take in evaluating and accessing the concept with respect to its adoption and effective use by both users and providers. The next section therefore describes the validation process and the conclusions drawn from the findings. This would also help to predict if the usefulness of the research outcome was below, about or above average.

A. Method

There are two general methods for the validation process in research, which include external and internal validation. For the purpose of this research both methods were adopted.

External validation aims to address the accuracy of a model in a domain using a different but plausibly related population, which may be defined as a selected study population representing the underlying domain [17]. Yin [18] describes external validity as determining the limits to which the findings of the research could be generalised. Brinberg and McGrath [19] state that the essence of external validation is to gain confidence in the findings and what they mean. In other words, it is the extent to which the results of a study can be generalized to other situations and to other people. It is about ensuring the robustness of the research and about assessing its generalisability [20]. External validity is the degree to which the conclusions in a study would hold for other persons in other places and at other times.

External validity was achieved in this research by comparing the findings with similar findings from previous studies [21]. Participants who took part in the first and second phases of the research were invited to share their opinions on the research findings and recommendations using a questionnaire. Although the sample size used for this validation exercise is relatively small, the feedback received is generally encouraging and suggests that the research findings and recommendations have the potential of being well received. The outcomes suggest that the findings and recommendations are useful in terms of motivating users towards the adoption of MTD. The feedback also creates assurance that the developed framework could assist the intending users, service providers as well as other stakeholders in increasing the adoption and effective utilisation of MTD in the public sectors.

The tables below present a summary of the results that were obtained from the participants who responded to the questionnaire. Indeed, results from the questionnaire and some of the positive recommendations made by a number of the participants acknowledged that the framework is useful and would serve as a detailed guide for the major groups that are involved with MTD adoption and usage.

The validation survey was conducted online using Google form. 21 responses were received. Out of the 21, 16 were made up of database experts that participated in the initial survey. While 5 were other experts of database from different organisations other than the 16. The interview stage comprises of 2 experts, one from the category of those that participated in the initial survey where the organisation of this participant is in use of MTD while the second interviewee is not part of those that participated in the initial survey but works for a MTD user organisation.

The data was analysed using SPSS to determine the frequency and percentage to which respondents at least agree to the research outcome. The majority of the participants were in favour of the outcome indicating that the framework is capable of assisting individuals and organisations in taking an informed decision about the adoption of MTD. The responses also show that majority agree to the outcome that the framework has incorporated all aspects needed for the decision making process. Finally, the majority also agree that the expert system is simple and user friendly enough for the intending tenant(s) to support their process of making decision in regards to MTD.

This study has adopted some measures to achieve internal validity. The first measure adopted was feeding back responses and findings to the participants as suggested by Easterby-Smith et al [22]. This enabled the participants to check the accuracy of their responses i.e the accounts of the participants are factually correct. This also presented an opportunity to the participants to provide feedback to the researcher's interpretation. The feedback has enhanced the study's interpretive validity as argued by Maxwell [23].

It is also important to note that some findings of this research have been presented and published in a number of international peer reviewed journals and conference proceedings. And most of the arguments and findings of the research were supported by comprehensive literatures.

Publication of articles in international academic journals and conference proceeding is a means of disseminating research findings to the academic community. This involves a review and assessment of the validity of research and its finding by independent referees. A total of four articles have been published which include two journals and two conference articles, with one currently under review. Xiao [24] states that peer review in this manner provides an opportunity for the methodologies, meanings and interpretation of the research to be questioned. Runeson and Loosemore [25] refer to this dissemination process as a process of critical inquiry which is meant, in theory, to provide an informed, fair, reasonable and professional opinion about the merits of the research. Fenn [26] has observed that peer review is used as the gold-standard throughout academia in the UK. Feedback from such a process helps to enrich research work and potentially improves its findings [27]. The feedback provided by referees always shows the reasons for their points and views. All these points raised either trivial or fundamental were incorporated in this study to improve the validity of the research.

B. Results

All the results received were to a large extent positive and the summaries from SPSS are presented as shown in Tables 1, 2 and 3 below. The results were presented in percentages. And each validation question has five response options which are strongly disagree, disagree, neutral, agree and strongly agree. For instance in Table 1, cost has 7 responses for agree which is 33.3% and 14 responses are for strongly agree which is 66.7%. This shows that all respondents agree and strongly agree that cost is a factor.

TABLE 1 – VALIDATION OF RESEARCH FINDINGS (FREQUENCY-PERCENTAGE)

Item (Question)	Strongly Disagree(1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
Cost	0 (0%)	0 (0%)	0 (0%)	7(33.3%)	14(66.7%)
Time	0 (0%)	0 (0%)	3(14.3%)	9(42.9%)	9(42.9%)
Economic	0 (0%)	0 (0%)	0 (0%)	7(33.3%)	14(66.7%)
Economic Impact	0 (0%)	0 (0%)	0 (0%)	12(57.1%)	9(42.9%)
Growth	0 (0%)	0 (0%)	3(14.3%)	9(42.9%)	9(42.9%)
Growth Impact	0 (0%)	1(4.8%)	6(28.6%)	5(23.8%)	9(42.9%)
Security	0 (0%)	0 (0%)	0 (0%)	9(42.9%)	12(57.1%)
Security Impact	0 (0%)	1(4.8%)	0 (0%)	9(42.9%)	11(52.4%)
Regulation	0 (0%)	1(4.8%)	3(14.3%)	7(33.3%)	10(47.6%)
Regulation Impact	0 (0%)	0 (0%)	2(9.5%)	11(52.4%)	8(38.1%)

TABLE 2 – VALIDATION OF RESEARCH RECOMMENDATIONS

Item (Question)	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
Experts	0 (0%)	0 (0%)	1(4.8%)	12(57.1%)	8(38.1%)
Economics Consideration	0 (0%)	0 (0%)	1(4.8%)	5(23.8%)	15(71.4%)
Level of Security	0 (0%)	0 (0%)	0 (0%)	10(47.6%)	11(52.4%)
Growth Rate	1(4.8%)	1(4.8%)	6(28.6%)	8(38.1%)	5(23.8%)
Regulation Balance	0 (0%)	1(4.8%)	2(9.5%)	8(38.1%)	10(47.6%)
MTD Model Choice	0 (0%)	0 (0%)	0 (0%)	9(42.9%)	12(57.1%)
Framework Completeness	0 (0%)	2(9.5%)	2(9.5%)	11(52.4%)	6(28.6%)
ES Friendliness	0 (0%)	0 (0%)	1(4.8%)	9(42.9%)	11(52.4%)

TABLE 3 – VALIDATION OF RESEARCH FRAMEWORK CAPABILITY

Item (Question)	Not sure of its capability (1)	No, not capable (2)	Neutral (3)	Yes, Capable (4)	Yes, Highly capable (5)
Framework Capability	0 (0%)	0 (0%)	1(4.8%)	13(61.9%)	7(33.3%)

Based on the responses received on the research findings, it shows that majority of the respondents agree or strongly agree to the findings. The response from all items have more than 80% combined percentage score for both agree and strongly agree except in the case of Growth Impact which has a combined percentage value for both agree and strongly agree of 66.7%. Therefore, the overall research findings were largely accepted by all the respondents.

The results with respect to the research recommendations are presented in Table 2. The results from recommendations put forward to support intending users and service providers of MTD were all accepted by the respondents. This shows that the findings and recommendations are all valid. In terms of the framework completeness in Table 2 which has to do with the framework fully incorporated all the aspects needed for this decision making process, there is a combined value of 81% for agree and strongly agree. From the same table, the ES Friendliness which has to do with the simplicity and user friendliness of the ES for the intending tenants has a combined percentage value for agree and strongly agree of 95.3%. In addition, as observed in Table 3, most of the respondents agree that the framework is capable of supporting users in taking decision about MTD with a combined value of 95.2% for both agree and strongly agree. All these suggest that the research would be regarded as a very useful tool for decision making as more than 65% of the participants' opinions in all items were in favour of the research findings. This represents a positive contribution to the body of knowledge.

Interviews were also conducted with some managers, database administrators and users of an organisation where MTD is used to make their own assessment of the research framework and the ES, to also offer suggestions on how the framework or ES could be improved. Some of these respondents re-emphasised that the research findings have high potential of achieving its purpose.

There were a few interesting assessments made which are noted below:

> *"Your research is well structured and relevant to the adoption of Multi-tenant database by intending individuals or organisations. I couldn't have thought of anything better than your new framework*" [Service Provider - Manager].
>
> "*The findings and recommendations show that an in-depth research, consultation and analysis have been done. This will be very useful in the process of adopting Multi-tenant database model"* [Organisation – DBA].
>
> "*Your framework in conjunction with the ES will be very helpful. I hope organisations and tenants consider a number of the recommendations you have put forward in your research and use it as a guide to ease the process of Multi-tenant database adoption*" [IT Officer].

Some of the participants made a few suggestions:

> "*The framework is very detailed and will be useful but I think maintainability should be incorporated into the framework*" [Database User].
>
> A respondent also notes that:
>
> "*The framework and the ES are very resourceful and should made available to the public for easy access*" [IT Manager].

V. CONCLUSION

There is a need for public sector organisations and general IT investors to embrace the MTD platform as means of securing data because of the cost savings associated with it compared to investing on a dedicated database managements system (DBMS) and staff to maintain them. This paper has presented all the stages of modification that an MTD adoption framework has undergone as a result of series of surveys conducted in this research. The final framework has also been incorporated into an Expert System (ES). The expert system was developed using a web based development tool called ES-BUILDER for easy access and use. All the stages involved in the ES development and the results were presented in this paper. The validation of the research findings, framework and expert system are presented in this paper. This validation process includes both external and internal validation. The internal validation was based on academic validation which involved the publication of some aspects of the research findings in journals and conference proceedings. In these papers, a significant number of references have been cited to support the different arguments. Moreover, the concepts, methodology and findings of this research have been found to be reasonably supported by the extensive use of literatures in support of the study. The external validation involves respondents who participated in the empirical data gathering phase who were invited to share their opinions on the outcomes. The views from both areas were reported within this paper. The results from the analysis of the participants' responses indicate that the findings reported in the research are valid and can be generalised across the world of DaaS.

Likewise, the majority of the respondents who shared their opinions with regard to the findings, to a large extent agreed with the results.

Further research could be done in the area of the framework, which should be validated in different contexts and other parts of the world to extend the generalisability and contribution of the framework. Also, there could be further investigations that can extend the framework as new factors could emerge after some time. A research team should be adopted in further study where different persons will handle different locations. This will give room for comparative analysis of the different results in order to reach formidable and more generalised findings.

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