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# RDSMS – A South African Research and Development Survey Management System

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**Abstract:** Annual R&D surveys are conducted by the South African Centre for Science, Technology and Innovation Indicators (CeSTII). To improve the current system supporting their business processes for the completion of surveys, the Research and Development Survey Management System (RDSMS) was designed, developed and implement following a design science research approach. The new system provides a novel survey management system which consists of the ability to create unique complex questionnaire layouts, plan and conduct surveys, perform data commutation and imputation actions, and extract data reports. In addition, functionality to perform trend analysis over the results of various surveys is provided. A unique database schema facilitate and support the ability of the system to allow for multidimensional table questions. It is suggested that the system provided by this research is novel and performs better than other survey systems in terms of its ability to create complex questions, its business processes supported.

**Keywords:** Research and development survey, Survey management system, Design science research.

## 1. Introduction

South Africa has been conducting national Research and Development (R&D) surveys since 1966. A short, but comprehensive overview of the history of R&D surveys undertaking in South Africa until 2005 is provided by Blankley and Kahn [1]. Between 1966 and 2001, various entities have been responsible for conducting the surveys including the Council for Scientific and Industrial Research (CSIR), Human Sciences Research Council (HSRC), Foundation for Research and Development (FRD) as well as private consultants [1].

In 2002, the newly formed South African Department of Science and Technology (DST) commissioned a R&D survey for the 2001/2002 financial year which would establish a baseline for future surveys [1]. The responsibility for conducting surveys from 2001/2002 was assigned to the national Centre for Science, Technology and Innovation Indicators (CeSTII) – housed at HSRC.

The Survey Management and Results Systems (SMRS) ICT tool was designed, developed and implemented in 2002 in order to support the business processes implemented by CeSTII to conduct the R&D survey. The system however became ineffective throughout the years as a result of changes in both business process and requirements. In order to address certain shortcomings of the SMRS system, CeSTII had to implement additional systems. In addition, significant changes to questionnaires required technical interventions

 

from the developers of the system. As a result, a decision was made to launch a project with the main objective to establish a new integrated Information Communications Tool (ICT ) tool which would support the required business processes and requirements for conducting annual R&D surveys.

The motivation for conducting the research was therefore situated in the needs of CeSTII to have a new R&D survey system that supports their business processes and provides greater flexibility and longevity which should better serve their current and future needs. Some of the benefits of a the new system includes additional business process support, a flexible system supported by a modern database system which allows for the trending of survey results over various years and a system that does not require extensive technical assistance to manage and create questionnaires.

In the remainder of the article the scientific research methodology for designing a new and improved system as well as the business processes and novelty of the new system is discussed. Concluding remarks are provided in the final section of the article.

## 2. Methodology

In developing the new improved system, a design science research approach was followed. Design science research is considered to be a pragmatic, problem-solving research paradigm which attempts to create and evaluate new innovations in the form of IT artifacts [2]–[4]. These artifacts can be IT constructs, models, methods or systems instantiations [2], [5]. In addition, Gregor and Hevner [6] states that any designed solution that solves a problem in a specified context can be considered as a design science research artifact. It was therefore considered as an appropriate research approach from the conception of the project. The decision was guided by the researcher team's previous work experience of solving problems in a practical manner, believing that truth can be based on a workable, practical solution.

The process of conducting design science research consists of four research cycles [7], namely a *change and impact cycle*, a *relevance cycle*, a *design cycle* and a *rigour cycle* as depicted in Figure 1.

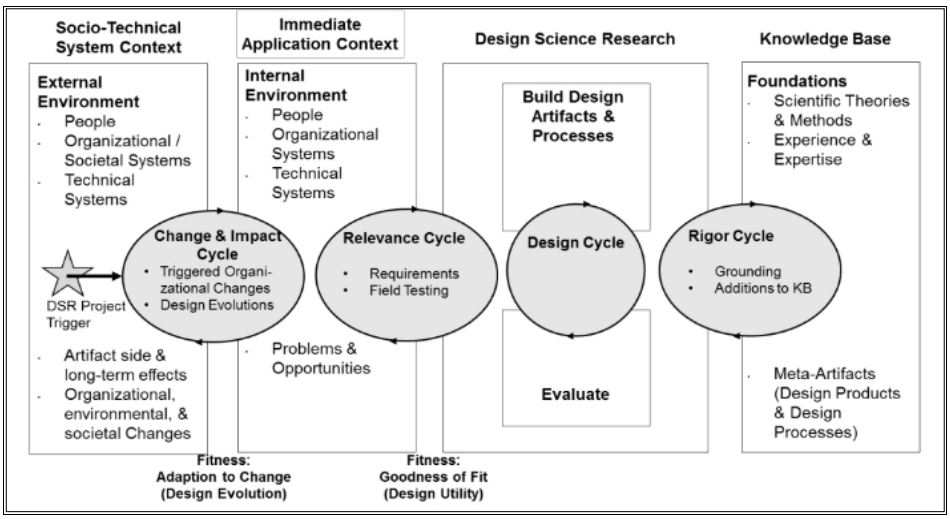


*Figure 1: Design science research cycles [7]*

The *change and impact cycle* considers the impact of the research in a context wider than the immediate internal environment. During the *relevance cycle*, input is provided to the contextual environment of the new IT artifact, which includes the requirements for the new artifact as well as the criteria for evaluating the results of the research. Activities to design, build and evaluate the new or improved artifact takes place during the *design cycle*. In order to ensure research rigour, the *rigour cycle* assure that the design of the artifact is

grounded on a scientific knowledge base and that the new knowledge resulting from the research is contributed back to the scientific body of knowledge.

According to Gregor and Hevner [6], the model provided by Peffers *et al.* [8] defines a process for conducting design science research. The process depicted in Figure 2 consists of six activities, namely *identification of the problem*, *identification of the objectives* of the solution, *design and development* of the solution, *demonstration* of the solution, *evaluation* of the solution and *communication* of the research results.

The entry point for the research was the *identification of the problem* by CeSTII namely that their legacy system did not allow them to effectively expand and align their capabilities for the effective collection of R&D input data. From the identified problem, a set of *objectives where identified* which centred around the provisioning of a new system which would effectively and with minimal technical interventions support R&D survey data collection tasks. With the research problem and objectives in mind, a new solution was *designed and developed.* The design decisions was grounded on a collaboration effort between the CSIR and CeSTII as well as a thorough study into relevant literature and latest technologies. In order to ensure that the research team was on the right track to meet the demands of CeSTII, regular *demonstration* sessions was held to *evaluate* whether the objectives were being met. Based on the evaluations, the design had sometimes to be revisited. Lastly, the results of the research is *communicated* in this article, but more publications are foreseen for the future.

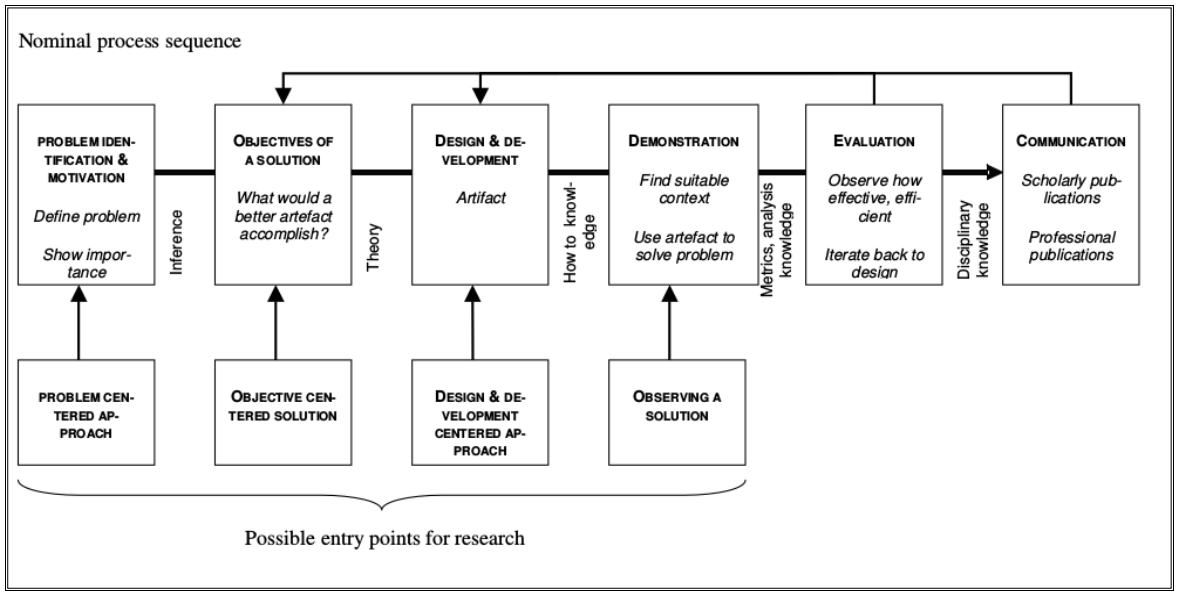


*Figure 2: Design science research process model [8]*

The previous sections of the article discussed background information to the research, the problem of the research and the methodology followed. In the next section, the result of the research, namely the newly developed RDSMS solution, is discussed.

## 3. Research and Development Surveys Management System (RDSMS)

The newly developed RDSMS system is discussed in this section with regards to the business processes supported by the new system as well as its novelty.

### *3.1 Business Processed Supported by the New RDSMS System*

The aim of the Research and Development Survey Management System (RDSMS) is to provide a facility to manage the process of conducting surveys on research and

development aspects effectively and efficiently in compliance to the South African Statistical Quality Assessment Framework (SASQAF). The framework provides a structure for the assessment of the quality of statistics and enables the certification of statistics as official [9]. The structure includes 8 dimensions which defines the quality, namely *relevance*, *accuracy*, *timeliness*, *accessibility*, *interpretability*, *coherence*, *methodological soundness*, and *integrity*.

The RDSMS system supports the processes related to the planning, management and execution of R&D surveys. The RDSMS system consists of 8 components in order to effectively support the survey processes. The processes and interactions between them are depicted in Figure 3.

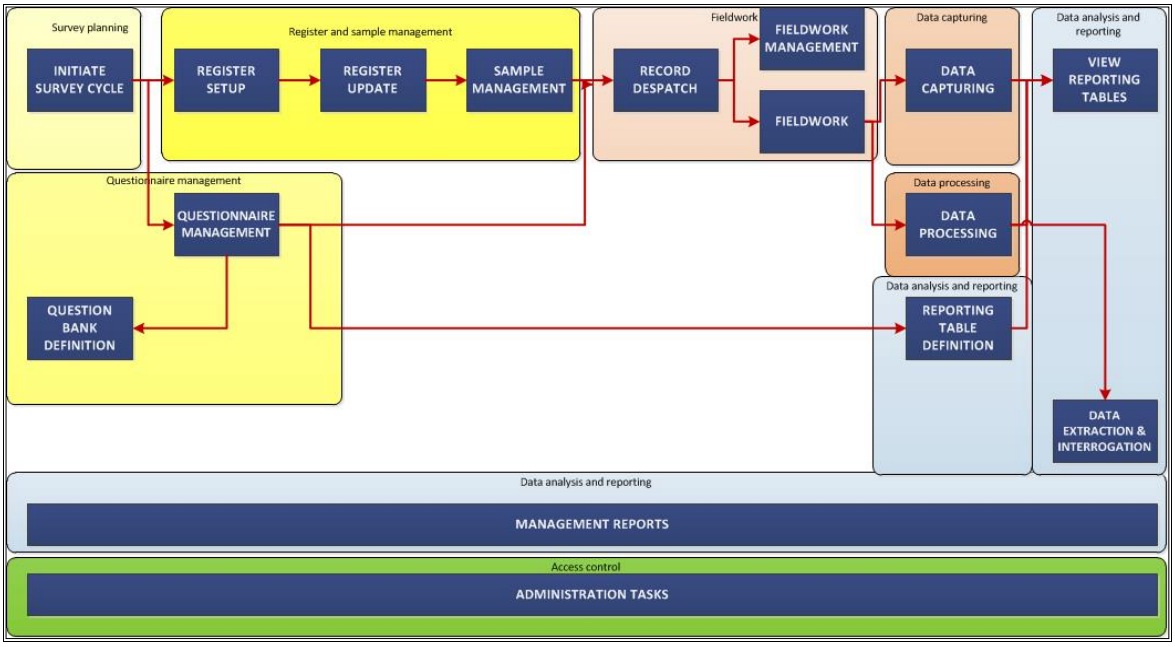


*Figure 3: RDSMS Business process interactions*

*Survey Planning*

The survey planning component supports activities related to the definition of a survey cycle and the planning thereof in order to deliver the results within the time frame of the client. The definition of a survey cycle includes the definition of the survey period, the selection of sectors to be surveyed as well as the management of the status of the survey cycle. The planning activities include the definition of the required survey phases, the associated survey milestones and the survey tasks that must be completed to achieve the milestones. These definitions include that specifications of start and end dates for phases, milestones and tasks.

*Questionnaire Management*

The questionnaire management component enables the definition of a collection of questions that can be surveyed in any survey cycle as well as the selection of the questions to be surveyed in a specific survey cycle. The collection of questions that can be surveyed in any survey cycle is stored in a question bank. The purpose of the question bank is to enable the reuse of questions over multiple survey cycles in order to perform temporal trend analysis. The selection of the questions to be surveyed in a specific survey cycle and the definition of the questionnaire will be used in the subsequent processes in the survey cycle namely *data capturing*; *data processing*; and *data extraction and reporting*. The user can layout the questions according to their needs.

The system supports the layout of questions with multiple dimensions, including multidimension tables. The system is built with a unique data structure to support complex layouts of questions. The questionnaire layout is integrated with other components of the

system, and the same layout will be used in various components, such as *data capturing*, *data update*, *commutation*, *imputation* and *data analysis and reporting* (without the need of further technical assistance).

In addition, it is possible to define validations on cells in the answered questions. The user could for instance indicate if certain cells should add up and if one cell should be smaller or greater than another cell.

*Register and sample management*

The register and sample management component enables the management of the register and sample (organisations to include) of a specific survey cycle. This includes the definition of a register (either from the ground up or by copying a register from a previous survey cycle), defining categories for a specific sector and the management and confirmation of organisational information.

*Fieldwork*

The fieldwork component enables the management of the fieldwork activities including despatching of questionnaires to respondents; receiving and checking of completed questionnaires and logging of interactions with respondents throughout the survey cycle. The register and sample managed in the register and sample management component is used to perform the fieldwork activities.

*Data Capturing*

The data capturing component enables the capturing process of completed questionnaires into the system. The capturing tool is generated by the definition of the questionnaires in the questionnaire management component as well as the register defined in the register and sample management component. The capturing process includes the capturing of the results from the completed questionnaires. If the data capturing is set to "double capturing" the system will allow the same completed questionnaire to be captured twice in the system. If the two captured versions do not match, it will be indicated and users with appropriate privileges will be able to resolve the mismatches. In addition, if the values in completed questionnaires violate any validation rules set up in the questionnaire, the discrepancies will be highlighted and users with appropriate privileges will be able to resolve the discrepancies. The values of captured questionnaires may be updated when there are no mismatches of discrepancies by users with appropriate privileges.

*Data Processing*

The data processing component enables commutation and imputation of questionnaires for respondents who did not return completed questionnaires in a survey cycle. These two process can be viewed as an estimation of possible values answers to questionnaire questions. The commutation process uses the questionnaire definition from the questionnaire management component, register information captured through the register and sample management component, and data captured in previous survey cycles through the data capturing component. The commutation process creates commuted questionnaires for respondents with completed questionnaires in the previous survey cycle. The commutation process includes the definition of a commutation model, the application of the commutation model to create a commuted questionnaire for respondent and the management of the commuted questionnaires. The imputation process creates imputed questionnaires for respondent who did not have completed questionnaires in the previous survey cycle. The imputed questionnaire for a respondent will be captured through the normal data capturing process but will be managed through the imputation management function.

*Data Analysis and Reporting*

All the data captured during the survey cycle activities as well as the results of a survey cycle is available for data analysis and reporting purposes. This includes the definition and viewing of management reports to track the status and performance on activities in the

execution of a survey cycle; the definition and viewing of reporting tables from the captured survey results in order to produce the required products and the analysis of survey results (current and historic) in response to special requests and further research purposes.

*Access Control*

The access control component enables authorised users to manage the users in the system and the privileges assigned to them. The privileges assigned to a specific user will dictate what privileges the user have access to when logged into the system and what information can be seen or edited.

Having discussed the business processes to support CeSTII's annual survey conduct, the next section will take a look at what makes the new system novel.

### *3.2 Novelty of the New RDSMS System*

Some of the top available survey management systems include SurveyMonkey, SoGoSurvey and Novi Survey [10]. RDSMS supports functionality provided by these tools, and more. The uniqueness and novelty of the RDSMS, manifests in the following:

- RDSMS supports and is in compliance with the South African Statistical Quality Assessment Framework (SASQAF) and the Frascati methodology. The Frascati methodology in particular standardises definitions and data collections on research expenditures [11].
- The layout of questions and database design allows for complex multidimensional table questions as depcted in Figure 4. Reporting on complex questions are also supported.
- The setup and ability to re-use dimensions allows for data analysis and trend analysis across any number of survey cycles.
- The RDSMS has built-in functionality to compose models to commute or impute values for questions that have not been completed.
- The system supports all the daily tasks of the client, including respondent interaction log, and survey planning.
- The RDSMS is a comprehensive system that supports all functionality of a traditional survey management system, but also allows for other features such as question commution and imputation, management reports, access control and more.

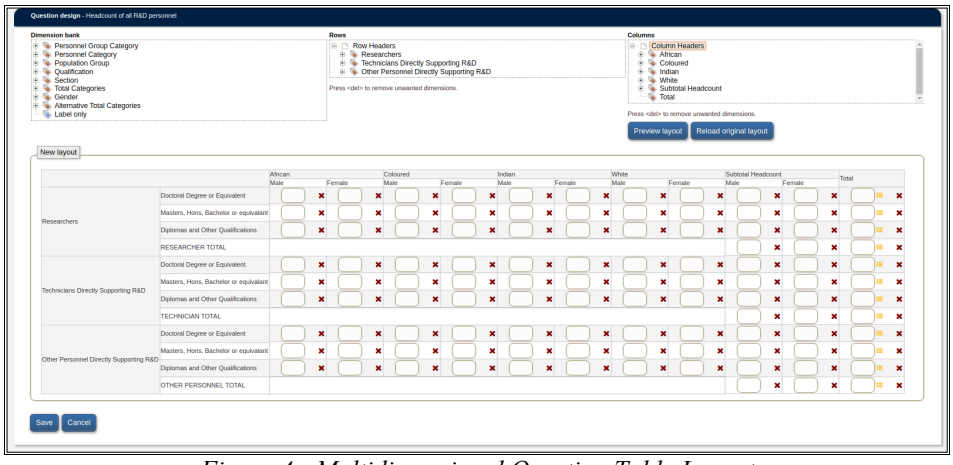


*Figure 4: Multidimensional Question Table Layout*

In addition to supporting a comprehensive set of survey processes, the system allows for the creation of complex questions such as depicted in Figure 4.

A multi-dimensional database structure was designed in order to support the type of more complex question layout depicted in Figure 4. The design of the database structure to support a question with multiple dimensions is depicted in Figure 5.

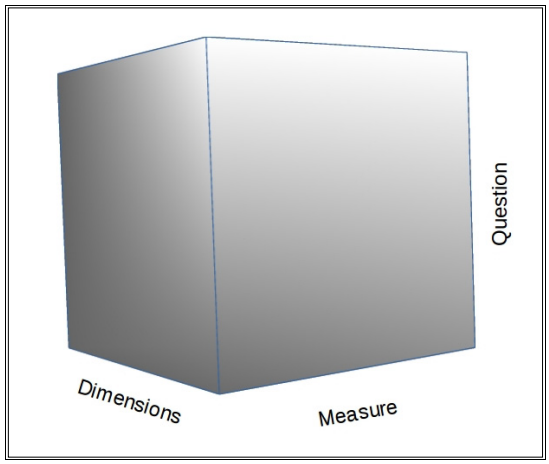


*Figure 5: Survey answered viewed as a multidimensional cube*

Each of the individual answer cells depicted in Figure 4, are comprised of a multidimensional cube as seen in Figure 5. Each answer has a *measure* which can be any variable type including numbers, characters and true/false values. For every answer, there are also a number of dimensions defined. Headcount of personnel can for instance be considered according to personnel types as well as race group *dimensions*. Lastly, each answer is also associated for a specific question – for instance Headcount of all R&D personnel as in the example.

Relational database tables exist in the system for each of the dimensions which defines an answer. An answer can be associated with one question, one measure and multiple dimensions. In addition, the system caters for questions changing over years, by keeping the state of a question. This ensure that trend analysis over years can be performed, although a question may change.

Having discussed the development, processes and novelty of the RDSMS system, the next section will conclude this article.

## 4. Conclusion

In order to develop a new survey management system for CeSTII, a design science research approach was followed. The product of the research is the new RDSMS system. As part of the design science research process, it is required that the solution be demonstrated an evaluated.

During the course of the project, the technology has been demonstrated more than 5 times (at CSIR Meraka Institute as well as at the HPRS, CeSTII offices in Cape Town).

Demonstrations included demonstrations to the client – on individual components as well as the integration of the different components. A complete demonstration was given to the client when all components were functionally implemented. In addition to various demonstrations to the client, training has been provided on all components of the technology. The system is now deployed operationally and successfully in use by the client. It is envisaged that the RDSMS system will have an impact on Research and Development in South Africa. The system supports R&D by facilitating research on R&D performed in various sectors in South Africa. In the long term, the system could impact the quality of R&D services and funding by the Department of Science and Technology of South Africa

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