SCENARIO MANAGEMENT: PROCESS AND SUPPORT

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Keywords: DSSG, Decision Making, Scenario Planning

Abstract: Scenario planning is a widely accepted management tool for decision support activities. Scenario planning, development, organisation, analysis, and evaluation are generally quite complex processes. Systems that purport to support these processes are complex and difficult to use and do not fully support all phases of scenario management. Though traditional Decision Support Systems (DSS) provide strong database, modelling and visualisation capabilities for the decision maker they do not explicitly support scenario management well. This paper presents an integrated life cycle approach for scenario driven flexible decision support. The proposed processes help the decision maker with idea generation, scenario planning, development, organisation, analysis, and execution. We also propose a generalised scenario evaluation process that allows homogeneous and heterogeneous scenario comparisons. This research develops a domain independent, component-based, modular framework and architecture that support the proposed scenario management process. The framework and architecture have been validated through a concrete prototype.

1 INTRODUCTION

In the decision sciences, scenarios have been defined as a management tool for identifying a plausible future (Alter, 1980; Porter, 1985; Schwartz, 1991; Tucker, 1999) and a process for forward-looking analysis. Scenarios have also been defined in many other ways e.g. it is a kind of story that is a focused description of a fundamentally different future (Schoemaker, 1993); that is plausibly based on analysis of the interaction of a number of environmental variables (Kloss, 1999); that improves cognition by organising many different bits of information (De Geus, 1997; van der Heijden, 1996; Wack, 1985); that is analogous to a "what if" story (Tucker, 1999). It can be a series of events that could lead the current situation to a possible or desirable future state. Scenarios are not forecasts (Schwartz, 1991), future plans (Epstein, 1998), trend analyses or analyses of the past. It is for strategy identification rather than strategy development (Schoemaker, 1993) and to anticipate and understand risk and to discover new options for action. Ritson (1997) agrees with Schoemaker (1995) and explains that scenario planning scenarios are situations planned against known facts and trends but deliberately structured to enable a range of options and to track the key triggers which would precede a given situation within the scenario.

Decision makers have been using the concepts of scenarios for a long time, but due to its complexity, its use is still limited to strategic decision making tasks. Scenario planning varies widely from decision maker to decision maker mainly because of lack of a generally accepted principle for scenario management. Albert (1983) proposes three approaches for scenario planning, namely, Expert scenario approach, Morphological approach and Cross-Impact approach. Ringland (1998) describes three-step scenario planning – namely brainstorming, building scenarios, and decisions and action planning. Schoemaker (1995) outlines a ten-step scenario analysis process. Huss and Honton (1987) identify three categories of scenario planning. The literature still lacks a suitable approach for planning, developing, analysing, organising and evaluating the scenario using model-driven decision support systems. Currently available scenario management processes are cumbersome and not properly supported by the available tools and technologies. Therefore, we introduce a life cycle approach based scenario management guideline.

Generation of multiple scenarios and sensitivity analysis exacerbate the decision makers problem.

Daud Ahmed M. and Sundaram D. (2005).
SCENARIO MANAGEMENT: PROCESS AND SUPPORT.
In *Proceedings of the Seventh International Conference on Enterprise Information Systems*, pages 50-57
DOI: 10.5220/0002525600500057

The available scenario planning tools are not suitable for assessing the quality of the scenarios and do not support well**,** the evaluation of scenarios through a comparison process. We introduce an evaluation process for comparison of instances of homogeneous and heterogeneous scenarios that will enable the user to identify the most suitable and plausible scenario for the organization. Considering the significance of scenarios in the decision-making process, this research includes scenario as a decision-support component of the DSS and defines Scenario-driven DSS *as an interactive computer-based system, which integrates diverse data, models and solvers to explore decision scenarios for supporting the decision makers in solving problems.*

Traditional DSS have been for the most part data-driven, model-driven and/or knowledge-driven but have not given due importance to scenario planning and analysis. Some of the DSS have partial support for sensitivity analysis and goal-seek analysis but this does not fulfil the needs of the decision maker. In most cases, the available scenario analysis tools deal with a single scenario at a time and are not suitable for development of multiple scenarios simultaneously. A scenario impacts on related scenarios but currently available tools are not suitable for developing a scenario based on another scenario. Generation of a scenario and its analysis are not sufficient for decision support environment.

To address the problems and issues raised we followed an iterative process of observation/evaluation, theory building, and systems development (Nunamaker, Chen and Purdin, 1991). Wherein we proposed and implemented a flexible framework and architecture for a scenario driven decision support systems generator (SDSSG). A prototype was developed, tested and evaluated using the evaluation criteria for quality and appropriateness of scenarios (Schoemaker, 1995) and principles of DSSG framework and architecture (Collier, Carey, Sautter and Marjaniemi, 1999; Geoffrion, 1987). The conceptual framework as well as the prototype was modified on the basis of the findings and the process continued until a satisfactory result was achieved.

In the rest of this paper, we first introduce a life cycle approach for management of scenarios including a detailed discussion of handling homogeneous and heterogeneous scenarios. We then propose a scenario-driven flexible decision support framework and follow this up with a discussion on how it realises the scenario management process. We then present an n-tiered architecture that details the SDSSG framework. Finally we discuss the implementation platform and domain within which the proposed process, framework, and architecture were validated.

2 SCENARIOS: A DEFINITION, AN EXAMPLE, AND A MECHANISM FOR STRUCTURING SCENARIOS

2.1 Definition of a Scenario

The definitions given in the previous section do not give a complete picture of scenario modelling as they do not entail the exact scenario structure. Therefore, we define a proper implementation level definition that addresses the structure of the problem situation and its dynamic behaviour. A scenario is a situation that is comprised of one or more problem instances. A change in one scenario might have chain effects on related scenarios. The basic structure and behaviour of the scenario is similar to the decision support system components *model* and *solver* respectively. Hence we define scenario as a complex situation analogous to a model that is instantiated by data and tied to solver(s). Data, model and solver take part in a complex hierarchical relationship in scenario planning.

2.2 An Example Scenario

Before we discuss, scenario management, we discuss an example that will be used during the discussion of implementation. For example, the mortgage management includes a series of external environment sensitive inter-related scenarios. AMP (2001) describes a mortgage scenario wherein median wage and home price increases and the interest rate drops. What is the impact of this change or any other changes on individual buyer as well as on the mortgage market? The change in interest rate, average income of the people, demand and supply of the home, etc. highly influence the mortgage markets.

This scenario broadly depends on several other scenarios e.g. affordability scenario, loan scenario, and payment scenario. Affordability scenario helps in understanding the borrower’s eligibility to get a loan and capacity to repay the loan. The loan scenario analyses the cost of financing, loan amount, and instalment. Depending on the loan type, this analysis process can differ widely. The payment scenario analyses instalment, interest payment, principal repayment, and loan balance. The payment scenario addresses the entire life cycle of the loan repayment. Affordability scenario is a constraint to the loan analysis scenario. Each of these scenarios can again be disintegrated into several smaller scenarios e.g. affordability scenario depends on the income scenario and expense scenario while income scenario may be sub-divided into personal income scenario and family income scenario. All these scenarios are inter-related and the higher level scenarios are dependent on the lower level scenarios. Sensitivity analysis and goal-seek analysis of these scenarios would greatly enhance the decision making process.

2.3 Structuring Scenarios

In view of addressing the complexity and inter-relatedness of scenarios, we propose to divide larger scenarios into multiple simple scenarios having independent meaning and existence. In this context we identify three types of scenarios, namely:

- Simple Scenarios – The simple scenario is not dependent on other scenarios but completely meaningful and usable.
- Aggregate Scenarios – The results from multiple scenarios are combined/aggregated together to develop a more complex scenario.
- Pipelining Scenarios – One scenario is an input to another scenario in a hierarchical scenario structure. In this type of scenario, lower-level scenario can be tightly or loosely integrated with the higher-level scenario.

The decision maker may combine simple as well as complex scenarios together using pipelining and aggregation to develop more complex scenarios.

3 SCENARIO MANAGEMENT: A LIFE CYCLE APPROACH

We introduce a scenario management process using life cycle approach that synthesises and extends ideas from Ringland (1998, 2002), Schoemaker (1995), Albert (1983), Huss and Honton (1987), van der Heijden, (1996), and Wright, (2000). The proposed life cycle approach for scenario management process addresses a variety of problem scenarios. The life cycle process starts with scenario idea generation and finishes with the usage of scenario for decision support as illustrated in Figure 1. The following sections present all the phases of the life cycle approach for scenario management.

3.1 Idea Generation

The scenario planner foresees the key issues that exist within the scenario and analyses the concerns for identifying the influential driving forces and parameters for the scenarios. In addition the planner may also use the existing scenario from the scenario pool. The leading factors, which could be either internal and/or external, could lead to various changes on the system. The decision maker as a domain expert predicts the possible changes of the indicators that would guide to the development of ideas for scenario planning.

3.2 Scenario Planning, Development and Analysis

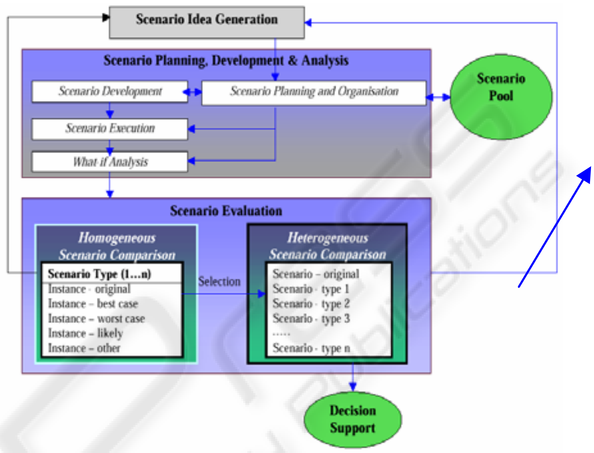

Figure 1: Scenario management: A life cycle approach

In this phase, the decision maker will carry out the tasks of scenario planning and organisation, scenario development, scenario execution, and what-if analysis. Existing scenarios could also act as inputs to this phase apart from the ideas generated from the previous phase.

3.2.1 Scenario Planning and Organisation

Scenario planning includes the activities of identification of the structure and components of scenarios, sequence of scenario development and execution as well as selection of scenarios for analysis. The scenario organisation activities include making available of already developed scenarios at runtime and storing and retrieval of scenarios for future use.

The components of the scenario can be either pre-customised or loosely coupled. For a pre-customised scenario, the relationships between data, model, and solver as well as with other dependent scenarios are fixed which is defined during scenario planning. So the scenario components are tightly integrated and the relationships are not exposed for the decision maker. For a loosely coupled scenario, the scenario components namely, the data, model, solver, and dependent scenarios remain independent. A mapping component is used to define the relationship at runtime during scenario development.

The existing and newly developed scenarios are cached in a runtime pool for developing pipelining or complex scenarios. The developed scenarios and the executed scenarios are stored in a scenario pool for future use.

3.2.2 Scenario Development

Scenario planning and scenario development stages are highly dependent on each other. Scenario development is the process of conversion and representation of planned scenarios into fully computer based scenarios. Chermack (2003) argues that scenarios have rarely been applied to develop alternative processes. The proposed life cycle approach supports development of alternative process models and scenarios. In this stage, the decision maker organises the related data, model, solver, and dependent scenarios for constituting the relationships among them to develop scenario(s). The decision maker could potentially use pre-customised and/or loosely coupled scenarios. The scenarios are developed in mainly two steps. In step 1, the basic scenarios of the domain are developed, and in step 2, scenarios related to what-if (goal seek and sensitivity) analysis are developed.

3.2.3 Scenario Execution

Our proposed scenario development process ensures that the scenario can be executed and analysed for determining plausibility. The models are instantiated with the data, and then the model instance is executed using the appropriate solver(s). Model selection is completely independent while one or more solvers may be used for a model execution. A flexible mapping process bridges the state attributes of the model and solver to engage in a relationship and to participate in the execution process. For a complex scenario, the decision maker may need to apply several models and solvers to analyse various aspects of the scenario.

3.2.4 What-if Analysis

What-if analysis can be divided into two categories, namely sensitivity analysis and goal-seek analysis. Sensitivity analysis assesses the impact of an increase or decrease in any parameter or scenario value over other scenarios. Sensitivity analysis allows changing one or more variables/scenarios at a time and analyses the impact on the related scenarios. The main objective of sensitivity analysis is to identify and analyse the amount of impact on the related scenarios. Goal-seek analysis accomplishes a particular task rather than analysing the changing future. This analysis is just a reverse or feedback evaluation where the decision maker supplies the target output and gets the required input.

3.3 Scenario Evaluation Process

Scenario evaluation is a challenging task (Chermack, 2002) but some end-states are predetermined dependent upon the presence of an interaction of identified events (Wright, 2000) which can be used to devise an evaluation process. The decision maker can develop many scenarios. The question is – do all these scenarios represent a unique situation? Each scenario might appropriately draw the strategic question; represent fundamentally different issues; present a plausible future; and challenge conventional wisdom. Schwartz (1991) and Tucker (1999) discourage too many scenarios and advocate for the use of best-case scenario, worst-case scenario and most-likely scenario. The evaluation is done through scenario execution and comparison of the executed results. The comparison may take place among homogeneous scenarios or heterogeneous scenarios as shown in Figure 2. This two-phase comparison process is detailed in the following sections.

3.3.1 Homogeneous Comparison

Homogeneous scenarios are a similar type of scenario but the instances are quite distinct from one another. The decision maker selects a scenario instance on completion of each homogeneous scenario comparison. For example, in Figure 2, five outer ellipses represent five different scenarios while small ellipses e.g. $\mathbf{T_1I_1}$, $\mathbf{T_1I_2}$ and $\mathbf{T_1I_3}$ represent three instances of type 1 scenario and the ellipse containing **Original** represents the current instance of type 1 scenario**.** These $\mathbf{T_1I_1}$, $\mathbf{T_1I_2}$, $\mathbf{T_1I_3}$ and original instances are compared and select the best plausible scenario instance, which is $\mathbf{T_1I_3}$ as shown in the Figure 2. If none of the instances is plausible, or do not have an optimal result, then the decision maker can repeat the whole processes. From this homogeneous scenario comparison, the decision maker can select at least one scenario instance for each type of scenario. In Figure 2, the selected scenario instances are $\mathbf{T_2I_3}$, $\mathbf{T_3I_1}$, $\mathbf{T_4I_2}$, and $\mathbf{T_nI_1}$ for scenario type 2, 3, 4 and n respectively.

3.3.2 Heterogeneous Comparison

Heterogeneous scenarios are different types but inter-related scenarios as shown in the big middle circle in Figure 2. It is almost impractical to compare heterogeneous as the attributes of these scenarios are widely varied from one another. The decision maker can only compare them by presenting the executed scenario outputs using some common attributes. If the decision maker finds that a specific instance of the scenario is not suitable for heterogeneous comparison, then the whole process can be repeated to identify a new instance for that scenario. This gives the decision maker an excellent picture of the entire decision problem and the probable solutions. For example as shown in the Figure 2, instance of five scenarios i.e. T_1I_3, T_2I_3, T_3I_1, T_4I_2, and T_nI_1 have been compared with the instance of the current situation during heterogeneous comparison.

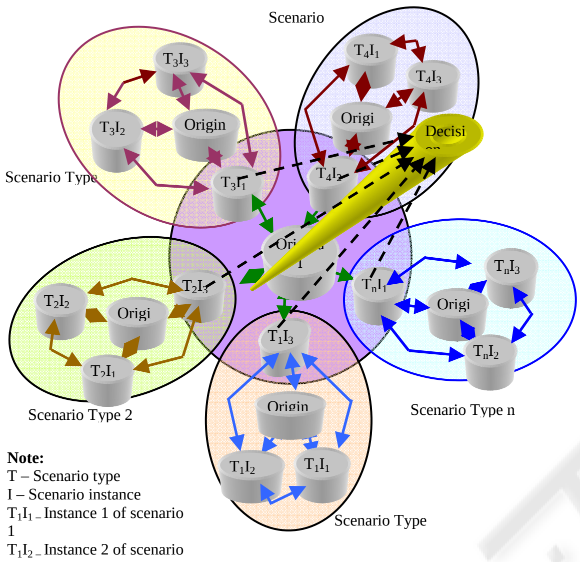

Figure 2: Scenario Evaluation Process

3.4 Decision Support

The above described scenario planning, development, and evaluation through comparative analysis results in improved participant learning (de Geus, 1988; Shoemaker, 1995; Godet, 2001) and help decision makers re-perceive reality from several point of view (der Heijden et al., 2002) and thereby better support for decision making.

The following section proposes a framework that realises the proposed scenario management process.

4 SCENARIO DRIVEN FLEXIBLE DECISION SUPPORT SYSTEMS FRAMEWORK

Few of the DSS frameworks emphasise fully featured scenario planning, development, analysis, execution, evaluation and their usage for decision support. DSS components such as data, model, solver, and visualisation have been extensively used in many DSS framework design but they did not consider scenario as a component of DSS. Scenario plays such an important role in the decision-making process that it is almost impractical to develop a good decision modelling environment while leaving out this component. Scenario systems need to be modelled. So they are more closely related to model-driven DSS but the scenarios are more complex than models. Therefore, the scenario-driven DSS might add scenario as an independent component in addition to existing decision-support components of data, model, solver and visualisation.

The scenario does not have a separate existence without its base components. It means that every scenario is built up from a unique nature of the problem (model) that can have a number of alternative unique instances (data) and each instance can be interpreted, executed or implemented using one or more alternative methods (solver).

To overcome the problems and address the issues mentioned above we propose a scenario-driven decision support systems generator (SDSSG) framework as illustrated in Figure 3. The SDSSG components are separated into the following two categories:

- Decision-support components (DSC) that include the data, model, solver, scenario and visualisation. These components have a direct relationship with the data pool, model pool, solver pool, scenario pool, and visualisation pool.
- Integration Components (IC) that include Kernel, Component Set, Mapping, and Validation Component.

In this framework, the DSCs and ICs are independent of each other. The DSCs communicate via the kernel component. Mapping component develops the correct path of communication between data and model, and model and solver, while the validation component tests the correct matching of the component interface and the proper communication between the components.

The data, model, solver, scenario, and visualisation can be stored in different component pools as shown in Figure 3 and the framework allows retrieving these components from the component pools. The related model, data and solver can be combined together to develop a scenario. This scenario can be saved to the scenario pool for future use. This also allows using the scenario(s) as an input for developing a number of simple, aggregate, and pipelined scenarios. Every instance of the scenario can be termed as a specific decision support system. Therefore, the framework is a generator of scenarios as well as the decision support systems.

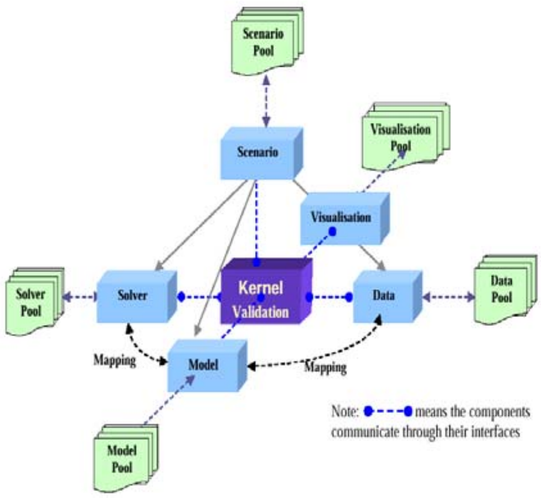

Figure 3: SDSSG framework

Scenario information can be saved and retrieved to and from the scenario pool and the same can again be customised using models and solvers. The scenario instances can be used as complex data for input to the next level of model for further analysis. Different scenarios can be computed simultaneously and sensitivity and goal-seek analysis can be done using different scenarios. The framework is suitable for analysing internally coherent scenarios or scenario bundles, and examining the joint consequences of changes in the environment for supporting the decision maker's strategy.

5 REALISATION OF THE SCENARIO MANAGEMENT PROCESS USING THE SDSSG FRAMEWORK

In this section we discuss and illustrate (Figure 4) the mechanisms through which the Scenario Management Process is realised using the SDSSG framework. Specifically we discuss the means by which the framework supports all the life cycle phases of the proposed scenario management process. The key features of this framework are as follows:

- ***Supporting Idea Generation:*** Allows retrieving the required data, model, solver, and scenario from the respective pools. The decision maker develops a scenario that uniquely represent an instance of a scenario type through establishing the relationships among these retrieved scenario components. A problem can be represented by different models and various solvers may be used for their execution. Therefore it supports generation of multiple instance of a scenario through various combinations of constituent components.
- ***Scenario Planning:*** Supports the planning of modelling-based scenario structure, pre-customised and loosely coupled scenario.
- ***Runtime Scenario Organisation:*** Incorporates a runtime only temporary storage system named Runtime Scenario Pool (RSP) to store the completed scenarios. The completed scenario(s) can be pulled from the RSP to develop complex scenarios and this completed scenario can again be stored in the RSP.
- ***Scenario Storing and Retrieving:*** Allows saving, retrieving, updating or deleting the scenarios from the scenario pool using the data access component. The RSP is linked with the component set through the Kernel and data components. So the scenario can be saved to the scenario pool of the component pool.
- ***Scenario Development:*** The basic scenario is developed using building blocks such as data, model, solver, and previously executed scenarios. The sensitivity scenario and goal-seek scenario analysis processes use the original data source, user input data regarding the changes of scenario parameter, dependent scenario values from the runtime scenario pool with related sensitivity model(s) and solver(s).
- ***Development of Aggregate and/or Pipelined Scenarios:*** In a pre-customised pipelining system, scenarios are pre-defined as a chain from lower level to upper-level scenarios. The upper-level scenarios directly receive the executed value of the lower-level scenarios. But in loosely coupled scenarios, a top-level scenario uses the values of the lower-level scenario from the runtime scenario pool.
- ***Scenario Selection:*** The framework allows the user to select any scenario depending on the suitability and appropriateness of the scenario.
- ***Scenario Execution:*** The framework facilitates instantiation of model with the data and execution of the instantiated model with appropriate solvers.
- ***Scenario Evaluation:*** The framework supports evaluation of scenarios through visualising the output of basic, sensitivity, and goal-seek scenarios in a comparison table or graphs.
- ***Decision Support:*** The framework supports Simon's (1960) decision making phases. These phases are comparable to scenario generation, analysis, comparison, and selection of plausible scenarios. Scenario analysis and evaluation using the comparison process increase the cognitive knowledge of users which in turn supports and leads them towards the final decision.

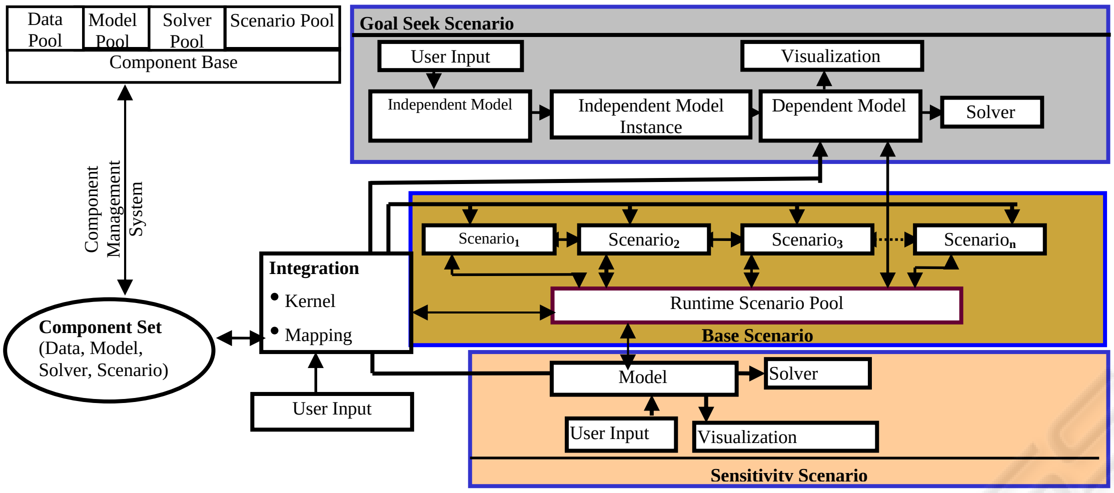

Figure 4: Realisation of the scenario management process using the SDSSG framework

6 SDSSG ARCHITECTURE

In order to implement the SDSSG framework we develop a component-based layered architecture as shown in Figure 5 that is suitable for implementation as an n-tiered system. The proposed architecture is comprised of the user services tier, application tier, and component base tier and the layers are user services, integration, data access, decision support services, application customisation, and component pool. The component pool layer stores data, model, solver, and scenario. The data access layer provides components' management services. The decision support services layer provides the service of model, solver, scenario, and visualisation. The integration layer provides validation and mapping services during integration, instantiation and execution of decision support components.

The architecture separates the decision-support components from the integration components. It

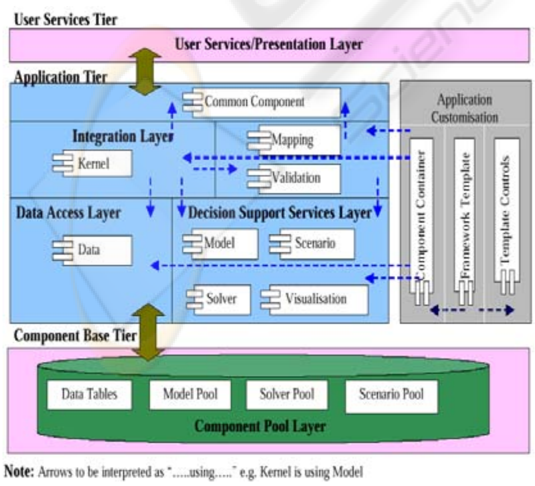

Figure 5: SDSSG architecture

supports independent development and use of the components, flexible scenario modelling, scenario manipulation and integration, flexible mapping between different DSS components, flexible integration of DSS components, and finally scenario analysis. Pre-customised and customisable modelling system can be achieved through pre-defined relationships and the mapping component respectively. This mapping component facilitates dynamic communication between model-data, model-solver, and model-visualisation.

7 IMPLEMENTATION

The framework and architecture can be implemented using any platform that supports component-based development. Object-orientation is the central focus of the SDSSG framework and architecture. Since scenario planning has been centred on business cases (Ringland, 2002), the SDSSG framework and architecture were implemented and tested within the context of the mortgage domain provided in section 2.2. We implemented base scenarios e.g. affordability scenarios, lending scenarios, payment scenarios, etc. We then explored a number of alternative scenarios including the best-case and worst-case scenarios through sensitivity analysis and evaluated the executed instances of homogeneous or heterogeneous scenarios through comparison.

Within each of these scenarios we explored sensitivity and goal-seek analyses. The system was tested and evaluated for sensitivity analysis for refinancing from different lending sources, and increase or decrease of the interest rate, loan amount, initial payment, instalment, and pay period. Apart from this we also explored sensitivity analysis on complex interlinked scenarios which in turn were made up of sub-scenarios. The prototype supports different level of users. A DSS builder may configure the SDSSG system and develop and store different scenarios as well as specific DSS for future use by the naïve users.

8 CONCLUSION

Current scenario planning and analysis systems are very complex, not user friendly, and do not support modelling and evaluating multiple scenarios simultaneously. To overcome these problems we propose a scenario management life cycle, and a framework and architecture that support the lifecycle. The lifecycle as well as the framework and architecture are validated through a concrete implementation of a prototype. Key phases of the life cycle are idea generation, scenario planning, organisation, development, execution, analysis, evaluation, and finally decision support. The process hides external factors and complexities of the scenario and allows the seamless combination of decision parameters for appropriate scenario generation. This research also proposes a generalised scenario evaluation process that allows homogeneous and heterogeneous scenario comparisons among the multiple instances of similar and dissimilar scenarios respectively.

This research develops a generic scenario driven flexible decision support systems generator framework and architecture that supports the above-mentioned scenario management processes. Scenario has been introduced as a new DSS component.

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