COMMON DEVELOPMENT TOOLS FOR AN INTEGRATED DECISION SUPPORT SYSTEM FOR MID-LIFE UPGRADE ANALYSIS

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Abstract

The global budget climate has laid restrictions on the design and development of new military aircraft to meet the demands of enhanced mission capabilities. To enhance mission capabilities, mid-life upgrade of in-service aircraft, involving placement of advanced technology mission systems onboard, is acknowledged as a cost-effective option. To facilitate the mid-life upgrade process, a "Decision Support System" is required to identify the State-of-the-Art mission systems that will provide the enhanced mission capabilities. In this paper, an "Integrated Decision Support System" (IDSS) that analyses the mission requirements holistically, to identify mission systems that enhance the capability of the aircraft is presented. A brief outline of the IDSS framework developed by a systems approach is presented initially, followed by a detailed discussion on software development tools that can be used in the development of IDSS.

1 Introduction

During the service life of military aircraft, mission systems onboard undergo major technological advancements [1]. These advanced mission systems are designed to enhance the mission capability of the aircraft [2 and 3]. As the design of a new aircraft with the advanced systems onboard to enhance mission capability is a costly venture, mid-life upgrade of in-service aircraft with these advanced systems is the preferred option [4].

Sinha et al. [5-8] adopted a system approach to develop a 'Mid-life Upgrade System' (MLUS) to facilitate the mid-life upgrade process. The MLUS was conceptualised in an 'input-process-output' configuration [9]. The approach considered the operational needs and the environmental conditions of the aircraft as the key 'inputs'. The 'process' identified the advanced systems for aircraft upgrade; and the 'outputs' were the mission capabilities derived from the system. The identified mission systems were then considered from an upgrade design perspective. The upgrade design was conceptualised as a 'system of systems methodologies' [9] that evaluated the following design parameters on which the upgrade design decision were dependent: (a) mission capability derived; (b) flight performance drop; (c) system reliability; (d) system maintainability; and (e) upgrade cost.

The generic methodology developed by Sinha et al. [5-8] for upgrade design decision was further explored for automation by Kusumo et al. [10-15] to provide time-based "mission system analysis" and upgrade design decision. A framework of an automated "Integrated Decision Support System" (IDSS) was formulated to address mid-life upgrade of maritime helicopters. The IDSS framework comprised of a series of sub-models, synergistically integrated to facilitate user-system interaction and mission system analysis. The IDSS sub-models were the following: (a) Man Machine Interface; (b) Mission System Identification; (c) Mission Payload Design; (d) Database; (e) Multi-Parameter Analysis; (f) Upgrade Decision Support; and (g) Decision Robustness Analysis.

In this paper the overview of IDSS is presented, followed by the studies of suitable 'Common Development Tools' (CDT) for the design of IDSS. CDTs are software that features tools required to develop the functions and capabilities of IDSS.

2 Integrated Decision Support System

2.1 System Methodology

The generic system methodology for mid-life upgrade of aircraft, developed by Sinha et al. [7] was configured in a conventional input-process-output configuration (Flood & Jackson 1991), as a platform to structure a "Mid-Life Upgrade System" (MLUS). The system configuration for the development of the MLUS structure is presented in Figure 1. The operational needs and the operational environment were studied to identify the mission requirements and also the mission capabilities to be derived from the MLUS, as outputs of the system (Table 1). The MLUS structure was then developed to identify the following system elements: (a) components; (b) attributes; and (c) relationships. The MLUS structure is presented in Figure 2. The MLUS comprises of three components – Armed; Attack; and Utility. The attributes assigned to the components were based on the mission requirements of MLUS. The relationships identified were inter and intra – components and components; components and attributes; and attributes and attributes.

The mission systems for capability enhancement of the aircraft through upgrade, were identified by a systematic development of the "System Hierarchy" (SH). The partial SH of the MLUS formulated by Sinha et al. [7 and 8], for maritime missions is presented in Figure 3. The appropriate mission systems for upgrade were identified at the last level of SH – Level IV.

The identified mission systems for upgrade were then considered from a design perspective to address the various design parameters for an optimum upgrade design. The design parameters considered were the following: (a) mission capability; (b) flight performance; (c) reliability; (d) maintainability; and (e) cost. The systems methodology summarising the design process as a 'system of systems methodologies' is presented in Figure 4.

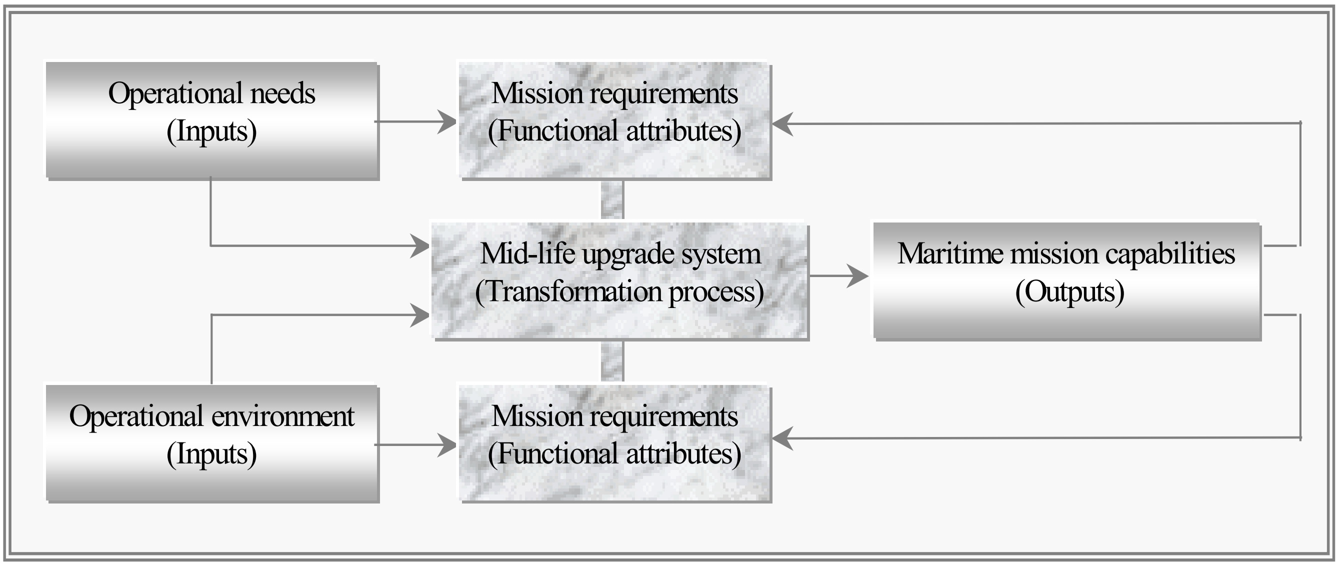

Figure 1. Mid-life Upgrade System Configuration

Table 1. Mid-life Upgrade System Configuration

Operational needs (Inputs)	Mission requirements (Attributes)	Mission capabilities (Outputs)	
Offensive	Fire power	Offensive warfare sub-mission capabilities	Maritime Mission capability
	Tactical flying		
	Communicating		
	Operator activity		
Defensive	Fire power	Defensive Warfare sub-mission capabilities	
	Reconnaissance & Surveillance		
	Aerial assault & extraction		
	Tactical flying		
	Communicating		
	Operator activity		
Logistics	Search	Utility support sub-mission capabilities	
	Aerial replenishment		
	Transportation		
	Aid civil authorities		
	Evacuation		
	Tactical flying		
	Communicating		
	Operator activity		

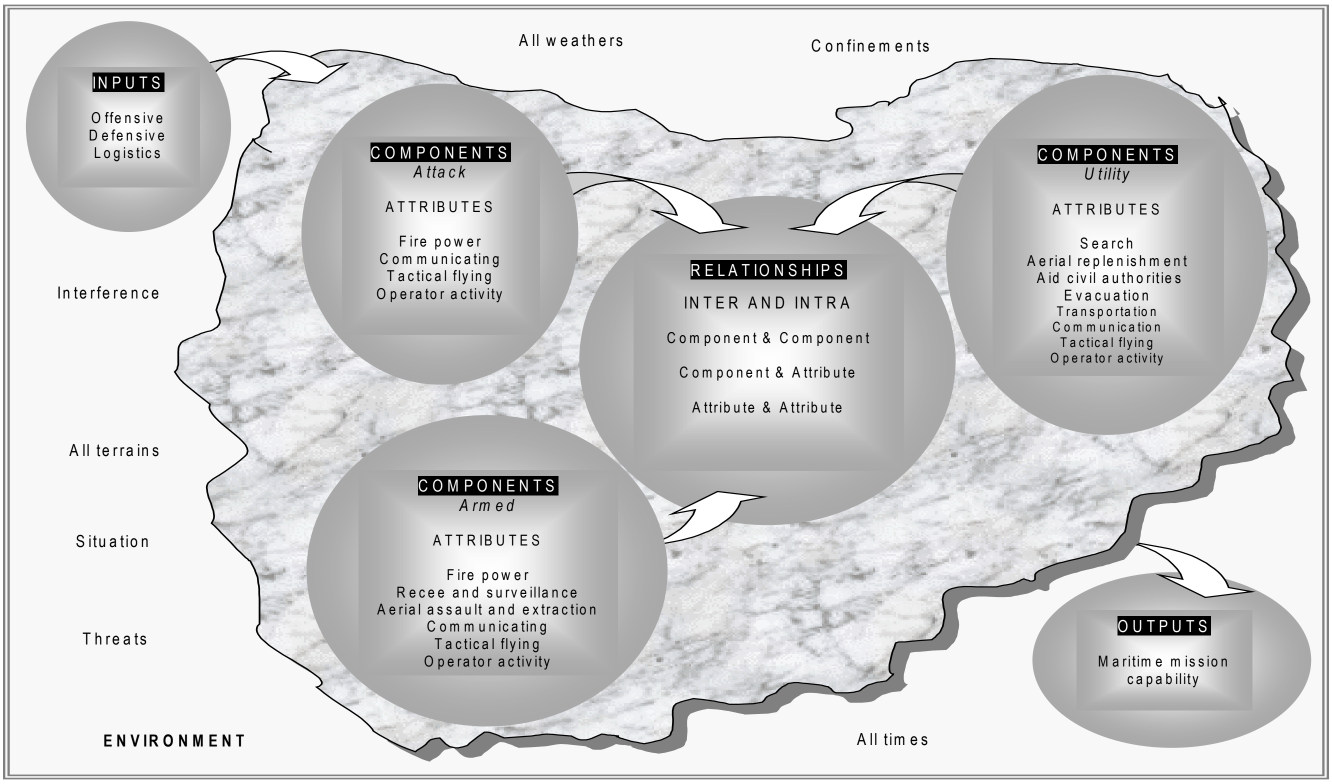

Figure 2. Mid-life Upgrade System Structure

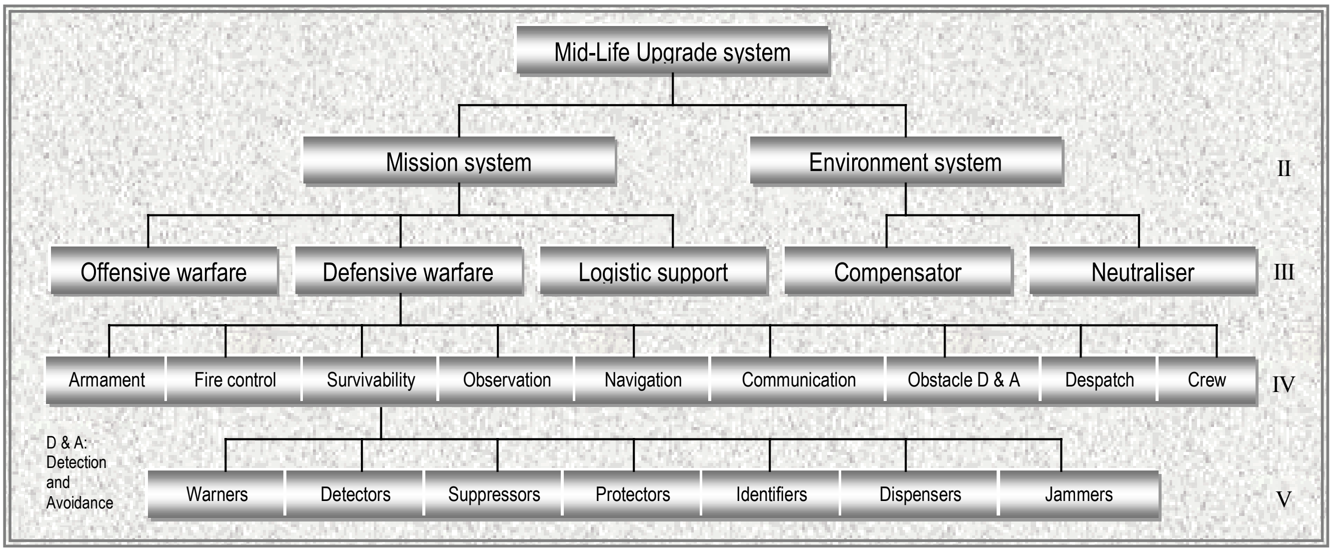

Figure 3. Partial System Hierarchy of Mid-life Upgrade System

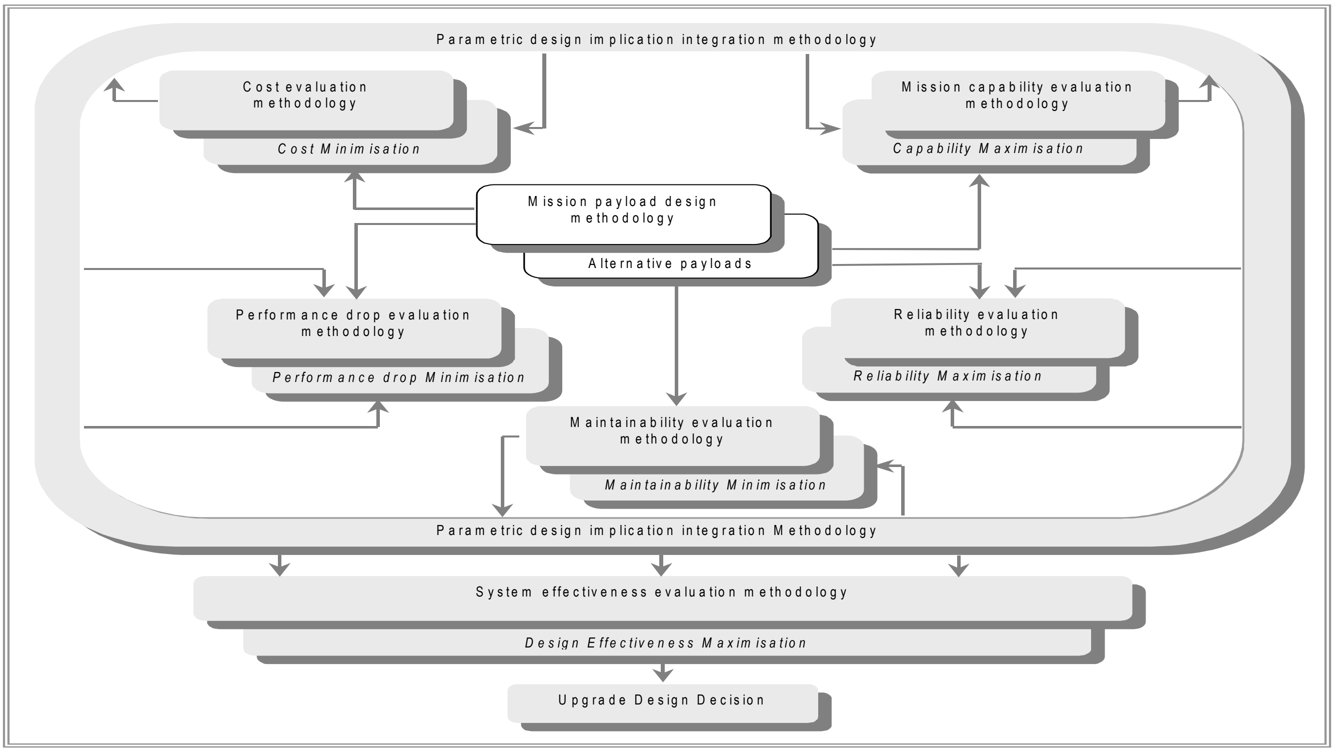

Figure 4. Systems of System Methodologies for Optimum Upgrade Design

2.2 Automation of System Methodology

To automate the system methodology developed by Sinha et al. [5-8], an 'Integrated Decision Support System' (IDSS) was formulated by Kusumo et al. [10-15]. The IDSS consisted of three base-line sub-models with the following designated functions:

- **'Man Machine Interface' (MMI):** To provide user-system interaction;
- **'Analysis, Synthesis and Decision Support System' (ASDSS):** To identify state-of-the-art mission systems from defined operational and environmental needs and to evaluate system effectiveness of the upgraded helicopter for decision support; and

- **'Database' (DB):** To store and manage operational, mission systems and helicopter data.

The ASDSS base-line sub-model functions were defined to identify the sub-models required for automation of analysis to support decision. The sub-models of ASDSS and their slated functions were as follows:

- **Mission System Identification (MSI):** To translate operational and environmental needs to mission requirements, and identify state-of-the-art mission systems for upgrade;
- **Mission Payload Design (MPD):** To prioritise the mission systems based on their relative functional dependence and degree of contribution towards mission accomplishment. To provide upgrade options by composition of alternative 'sets of mission systems' (mission payload);
- **Multi-Parameter Analysis (MPA):** To evaluate the degree to which the system design parameters (mission capability, flight performance, reliability, maintainability and cost) are met by the alternative mission payloads;
- **Upgrade Decision Support (UDS):** To evaluate the system effectiveness of the upgrade options by considering the results of the MPA and to identify the optimal upgrade option, for design decision; and
- **Decision Robustness Analysis (DRA):** To test the robustness of the design decision against temporal uncertainties and to validate the design.

The IDSS framework for automation of the system methodology for mid-life upgrade is presented in Figure 5. The framework represents the sub-models integrated accordingly to the stipulated functions and the inputs/output requirements.

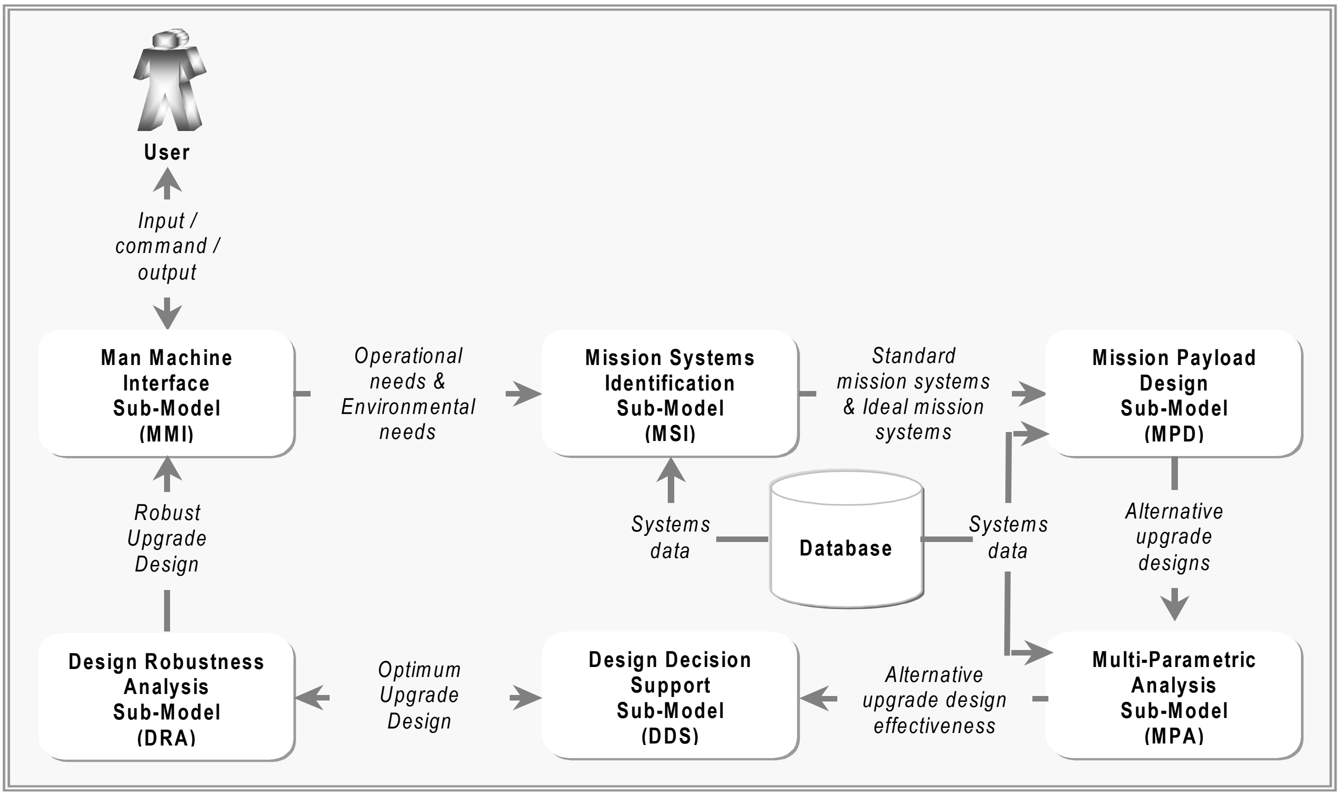

Figure 5. Framework of an Integrated Decision Support System for Automation of Systems Methodology for Mid-life Upgrade

3 Common Development Tools

The system framework of IDSS was developed to establish the computational process. Holsapple and Whinston [16] explained that in the process of Decision Support System development, the developer needs to select a tool and then work within the limits of the techniques it offers. There are various off-the-shelf development tools available to facilitate the development of efficient DSSs, ranging from software that utilises 'Artificial Intelligent' techniques up to common development tools (CDT) such as Microsoft products [17-21]. A survey of the development tools was presented [22], in which the development tools are classified into three categories, based on their capabilities to perform complex computations and the degree to which the DSS can be automated. The classifications of the development tools are as follows:

- **Intricate:** Development tools with the ability to self-learn and self-modify. DSS construction using this tools requires minimum inputs from the developer;
- **Moderate:** Development tools that is based on stored knowledge and rules; and
- **Procedural or Basic:** Development tools that construct DSS based on fixed procedural instructions or codes. DSS constructed has minimum ability to self-learn and self-modify.

To develop an IDSS, the development tool needs to be highly customisable, inherit the capabilities to conduct complex computations and be user-friendly to construct and utilise. Off-the-shelf CDTs with 'Moderate' classification are the most suited for the development of an IDSS, due to the high-level language utilisation and inbuilt flexibility for desired computations. There is a wide range of readily available CDTs, ranging from Java Development Kit to CLIPS, to even simplistic tool such as Microsoft Excel. Based on merits of Microsoft Excel over other CDTs in regards to availability, cost, functions and programmable features; it was selected as the CDT for the development of IDSS. The full capabilities of Microsoft Excel are barely explored in normal day-to-day spreadsheet application. To develop an application for IDSS, the full capabilities of Microsoft Excel needs to be completely understood for appropriate application.

Over the pass 15 years, spreadsheets software has evolved from simple accounting worksheets to highly powerful applications. Microsoft Excel in addition to spreadsheets includes capabilities in the area of application development, especially in application that uses 'Visual Basic for Applications" (VBA). Additionally, there are many other components in Microsoft Excel, which makes it highly customisable, capable of conducting complex computations and are user-friendly [17]. These features provide Microsoft Excel with the capabilities to define the 'Originating Requirements' of IDSS. Furthermore, being widely available and expandable, the utilisation of Microsoft Excel provides larger flexibility and circumvents the necessity of obtaining additional software.

To develop a non-complicated and yet an effective automated IDSS, three key components of Microsoft Excel are considered. These key components are to facilitate the development of IDSS subsystems, and their components and attributes, which were identified in IDSS system framework (Figure 5). The key features of Microsoft Excel considered are the following [17]:

- **VBA Language:** Comprehensive library of objects for complex computations and systems commands;
- **Spreadsheet Functions:** Inbuilt mathematical expressions and functions in the spreadsheet, often referred as mage formula for speedy computations; and
- **User Interface:** Control Toolbox, forms, animation features and sound

feedback to customise application display, menu, shortcuts and user-friendly interface development.

3.1 Application Architecture

With the features and capabilities offered by Microsoft Excel identified, the architecture of IDSS is formulated. The architecture of IDSS application designates the key components of Microsoft Excel for the development of the IDSS subsystems. The functions of the key components of Microsoft Excel utilised in the development of IDSS are as follows:

- **VBA Language:** To automate functions of the IDSS process;
- **Spreadsheet Functions:** To conduct the mid-life upgrade computations for design decisions; and
- **User Interface:** To provide interactive and user-friendly interface for user-system communication.

The architecture of the IDSS developed using Microsoft Excel is presented in Figure 6. The architecture has three pathways to cater for user-system interaction, data management, and design analysis. These are integrated functionally and the relevant Microsoft Excel features are applied. It is apparent from the architecture that the complete application of IDSS can be built using a single CDT. The utilisation of singular CDT provides uniformity in IDSS subsystems; thus, preventing complications during system integration. Additionally, Microsoft Excel is equipped with inbuilt links between spreadsheets and workbooks, which increases the efficiency, performance and decreases the computational process [17].

4 Results and Discussion

The detailed design analysis produced comprehensive architectures for the development of IDSS. The architectures provide the basis for the identification of CDTs to facilitate the development of IDSS. There are various CDTs that are suitable for the development of IDSS. The features of the CDTs required for IDSS development are the following: (a) Provision of 'Graphical User Interface'; (b) Automated decision making; and (c) Capabilities to compute complex mathematical equations. Due to its ease-to-use features in application development, implementation and utilisation, the Microsoft Excel with its VBA capabilities was selected for the development of IDSS. Additionally, unlike other applications such as Java, the key features of Microsoft Excel provide the avenue to develop a simplistic application that does not require additional software to operate.

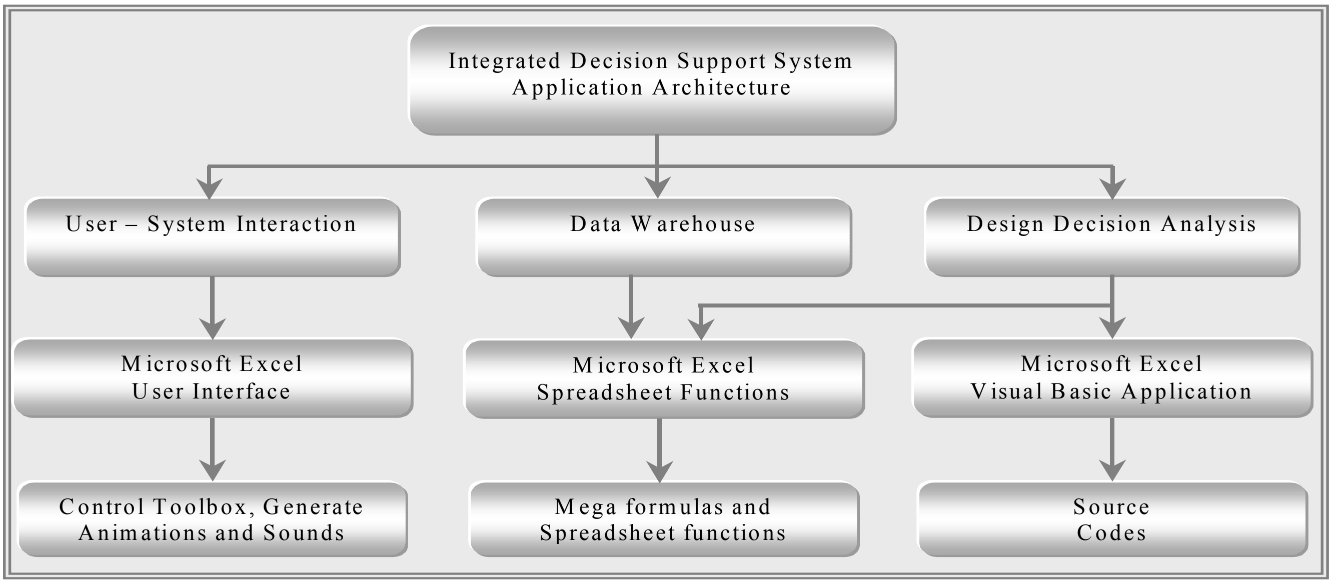

Figure 6. IDSS Application Architecture

5 Conclusion

The study of various off-the-shelf CDT functions and capabilities provides a promising avenue to address the complex development of IDSS. The system architecture developed by adopting a systems approach considers the various CDT features to automate IDSS. With these CDT features, the IDSS inherit the capabilities to handle mass data, extract information, apply knowledge to integrate the information, derive alternative courses of action, and assess outcomes.

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