

# 2011

Final year Project: Final Report  
***A Decision-making tool for the  
evaluation and selection of Project  
Management Information System  
(PMIS) Software***



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2011/10/03

# Acknowledgements

I would like to thank the following people for contributing towards a successful project:

- Prof C.S.L. Schutte, for guidance in the execution of the project and encouragement to make independent decisions and broaden my thinking
- Liezl van Dyk, for kindly helping with questions on Analytic Hierarchy Process (AHP) methods and overall motivation
- Pierre Rautenbach & Christine Rautenbach, my parents, for the opportunity to study at the University of Stellenbosch and the support and encouragement during the long working hours
- Dempers Meyer, for company on the late nights and weekends spent working, for insight, encouragement and emotional support
- The Schoombee's for providing accommodation and support during the vacation
- My friends and classmates for encouragement and understanding
- Finally, all honour to my Heavenly Father for critical breakthroughs, insight, and much needed rest in pressing times

# Declaration

I, the undersigned, hereby declare that the work contained in this final year project is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

.....

Ona Rautenbach

.....

Date

# ECSA Exit Level Outcomes Reference

The following table includes references to sections in this report where ECSA exit level outcomes are addressed.

Exit level outcome	Section(s)	Relevant Tools
<b>1. Problem Solving</b>	<i>1, pp.1-3</i>	<ul style="list-style-type: none"> <li>- Development of a problem solving methodology</li> </ul>
<b>5. Engineering Methods, Skills &amp; Tools including Information Technology</b>	<i>2, pp.6 -9</i> <i>3, pp.10-20</i> <i>4, pp.26-36</i> <i>Appendix B</i>	<ul style="list-style-type: none"> <li>- Information systems</li> <li>- PMBoK areas of knowledge (Project Management)</li> <li>- Analytic Hierarchy Process (Operations Research)</li> <li>- Excel Visual Basic programming (Industrial Programming)</li> </ul>
<b>6. Professional and Technical communication</b>	<i>Entire document</i>	The technical content of this project is communicated professionally in this document as well as at an oral presentation
<b>9. Independent learning ability</b>	<i>2,pp. 4-24</i> <i>4, p p.26-36 &amp;</i> <i>Appendix A</i>	<ul style="list-style-type: none"> <li>- Performing a literature study</li> <li>- Analytic Hierarchy Process (AHP) methods were not covered in detail in Operations Research and had to be investigated &amp; understood independently</li> </ul>
<b>10. Engineering professionalism</b>	<i>Entire report</i>	<ul style="list-style-type: none"> <li>- A thorough explanation of why choices were made is provided at all stages</li> <li>- Areas for improvement are identified in situations where decision-making and design fall beyond current competence</li> </ul>

## Abstract

The use of a Project Management Information System (PMIS) provides many benefits to organizations involved in project work. These systems can be seen as information managers that integrate and control information flows to assist management in gaining an overview of past and present events, as well as enable them to make future predictions. However, with organizational needs varying, and features provided by these systems covering different project management areas, finding the correct fit between the organization and the most comprehensive system is difficult. The vast amount of evaluation criteria, and the variety of software packages on the market, further complicates the problem.

This report addresses this problem by developing a decision-making tool based on multi-criteria decision-making methods, more specifically, the Analytic Hierarchy Process (AHP). A structured development methodology was followed to develop the tool. It includes the initial attainment of knowledge of the Project management, and management information system environments. Next the criteria on which the model would be based was selected from these environments in terms of functional-, organizational-, and software acquisition requirements, resulting in fourteen specific criterions. The final decision-making tool was then developed by utilizing the AHP methods as well as Visual Basic programming in Excel. The criteria were structured in a hierarchy, and alternatives were measured against each of these criterions to obtain a weighted rank of the alternatives.

The final result can be seen as an easy-to-use tool that covers a comprehensive range of decision-making criteria. The tool can be used in collaboration with other methods to aid users in PMIS software selection. An evaluation of the tool by experts confirmed that the tool could be used successfully in the project management environment, provided some adjustments are made. The valued opinion of these experts and the entire development process was document to allow future expansions and improvements.

# Opsomming

Projekbestuur-inligtingstelsels word gereeld in maatskappye gebruik wat projekte uitvoer. Hierdie stelsels voeg waarde tot die maatskappy se aktiwiteite deur die vloei van inligting beide te integreer en te beheer. Die gestruktureerde vloei van inligting, stel die bestuur van die maatskappy in staat om 'n oorsig te verkry van die huidige en geskiedkundige stand van sake en ook om vooruitskattings te kan maak.

Maatskappye se behoeftes verskil, en daarmee saam verskil die spesifikasies van die projekbestuur-inligtingstelsels. Daar is ook so 'n wye verskeidenheid stelsels op die mark, dat die besluit om die regte stelsel vir 'n spesifieke maatskappy te kies baie, kompleks is. Hierdie verslag spreek die komplekse probleme aan, deur die ontwikkeling van 'n besluitnemingsinstrument wat 'n verskeidenheid kriteria in ag kan neem. Die instrument is gebaseer op die Analitiese Hiërargiese Proses (AHP) metode. 'n Metodologie is gevolg gedurende die ontwikkeling van die instrument, wat eerstens bestaan uit deeglike navorsing oor die projekbestuur omgewing en bestuurs-inligtingstelsels. Na dié kennis bekom is, kon daar veertien spesifieke kriteria geïdentifiseer word uit hierdie twee omgewings – funksionele-, organisatoriese-, en sagteware aankoop kriteria. Uiteindelik kon hierdie kriteria in 'n hiërargie geplaas word, waarna die AHP metode en "Visual Basic" programmering daarop toegepas is om verskeie alternatiewe teen mekaar op te weeg.

Die eindproduk kan beskou word as 'n gebruikersvriendelike instrument wat 'n omvattende reeks besluitnemingskriteria in ag neem. Die instrument kan in samewerking met ander metodes gebruik word om projekbestuurders met die besluitnemingsproses te help. Die instrument is uiteindelik deur kenners uit die projekbestuur omgewing geëvalueer en die gevolgtrekking was dat die instrument wel in die industrie gebruik sal kan word, gegewe 'n paar veranderinge. Hierdie moontlike veranderinge en ander waardevolle insigte van die kenner, asook die hele ontwikkelingsproses, is vasgelê in die verslag. Sodoende sal toekomstige uitbreidings en verbeteringe maklik aangebring kan word.

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# Glossary

AHP	Analytic Hierarchy process
ANP	Analytic Network Process
IS	Information System
MIS	Management Information system
PMI	Project Management Institute
PMIS	Project Management Information System
TAM	Technology Acceptance Model
TCO	Total Cost of Ownership

# 1. Introduction

The PMIS is an all-encompassing system that is increasingly being used in a variety of industries to aid companies and project managers in successfully completing tasks and projects. These systems have a variety of functions and can be utilized in all areas of an organization, from financial management to the flow of physical materials. It directs the collection, control and distribution of information flows in an organization to ensure everyone involved is up to date with the current standing of projects etc. It can also be used to predict future situations by exploiting information from previous projects.

The software market is currently flooded with a variety of PMIS packages, each claiming to be the answer to all of the information flow needs of an organization (Wei *et. al*, 2004:161). There are commercial off-the-shelf packages, web-based packages as well as packages designed to customer specifications. The different alternatives present both pros and cons, and it is up to the organization to decide which alternative to choose. Organizations often don't know what factors to look for in a PMIS package, and may choose a package not well suited to the organization's needs. This wrong choice together with a lack of training and other factors lead to the sub-optimal use of the specific package. As a result, there has been an overall negative attitude towards the implementation of PMIS software packages in the industry. This is a disappointment as the use of these systems could improve both the organization's day-to-day tasks as well as long-term decisions. The potential for PMIS's are clearly not being exploited (Ahlemann, 2009:19).

This report is concerned with the complex decision-making process involved in selecting the most comprehensive PMIS package for a specific organization. A tool has been developed to aid project managers in this regard. Analytic Hierarchy Process (AHP), which involves pairwise comparisons, was utilized to create an easy-to-use tool. This tool should be used in conjunction with other tools for optimal results. The method used in developing this tool will be outlined below and discussed in detail in the sections to come.

## 1.1 Methodology used in developing the Decision-making tool

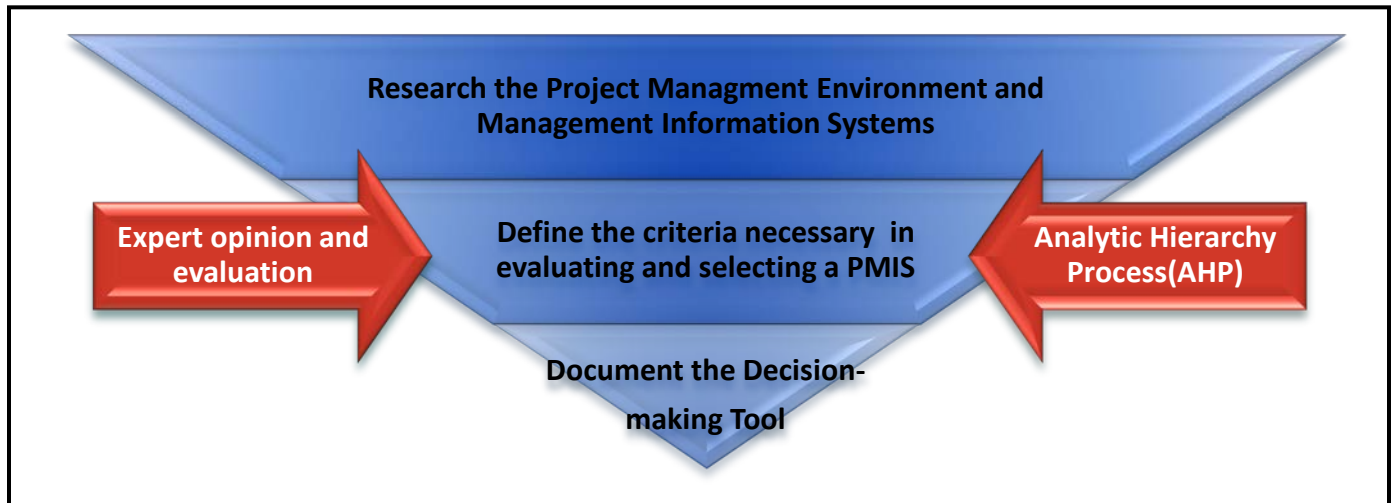


Figure 1 - Decision-making tool development methodology

A thorough literature study was done on the project management environment as well as on management information systems as these aspects form the basis of the PMIS. The nature of information flows, especially those in the project environment, needed to be understood to define exactly what the role of the PMIS is and to ensure that all aspects would be taken into account when developing the final decision-making tool. Gaining a broad overview of the field made it possible to make essential decisions on the criteria that would describe a comprehensive PMIS.

The main criteria identified as important in evaluating and selecting a comprehensive PMIS were technical requirements, organizational requirements, as well as the software acquisition requirements of the organization. The literature provides accounts of many different criteria examined by Gerogiannis *et. al.* (2010:368), Wei and Wang (2004:162), Jaafari and Manivong (1998:252). This specific mix of criteria was selected to support the functions of the decision-making tool. After a broad perspective of PMIS was obtained, it was possible to expand the main criteria into sub-criteria, by using the background knowledge acquired in the literature study.

The expansion of the main criteria resulted in fourteen sub-criteria that had to be evaluated by the decision-making tool. This is a large number of criteria. After considering many alternative multi-criteria decision making processes it was decided that using Analytic Hierarchy Process (AHP) method would be the most suitable approach for developing the decision-making tool. An introduction to this process was

obtained in Operations Research 344. Further research into the methods allowed for Excel sheets to be set up to perform the pairwise comparisons necessary in the AHP approach. The importance of the criteria relative to each other could then be determined, as well as comparisons made of user-specified software packages relative to each criteria. Finally, through matrix multiplication, the software packages could be ranked.

Before the Decision-making model was finalized, the preliminary model was presented to experts in the project management environment for evaluation. They were asked to use the tool and comment on the efficiency and accuracy of the output. Their feedback was used to improve the final tool. This step is critical, as acceptance by experts at the development stage should improve the chances of this tool being accepted in organizations.

The expert opinions were analyzed and, where possible, alterations were made to the model. The methods and processes used to develop the tool were documented. Documentation of the entire development process is very important, for both future users, and developers to use as building block in improvement.

## 2. The Project Management Information System (PMIS)

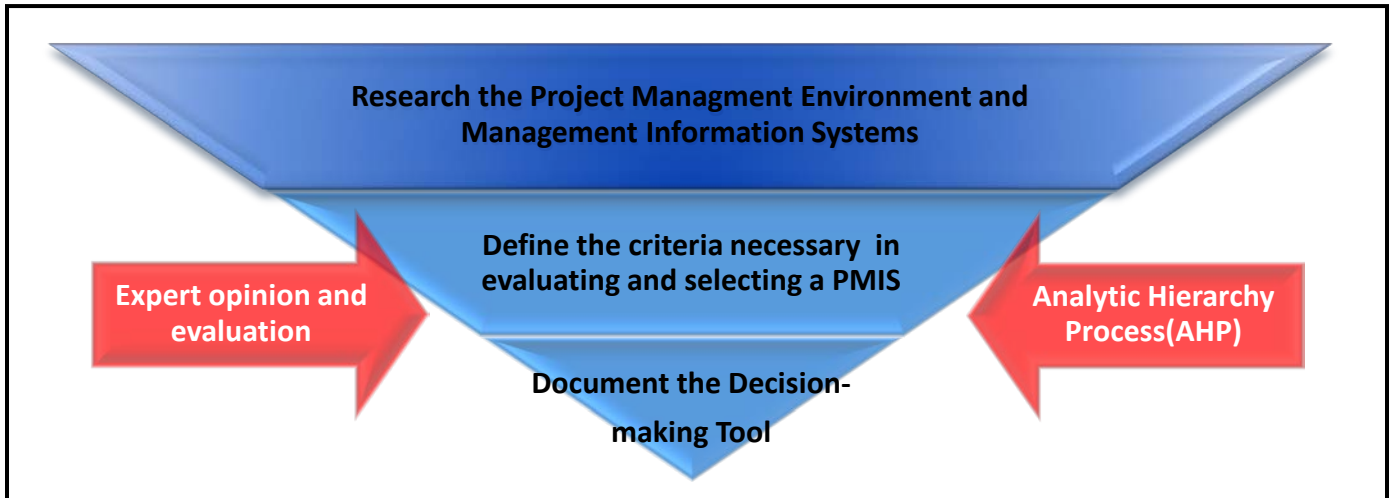


Figure 2 - First phase of Decision-making tool development

The first phase of the methodology used to develop the decision-making tool was to focus on the existing literature covering both the project management environment and the Management Information System (MIS). Various authors have investigated these fields and the development process benefitted from their immense knowledge.

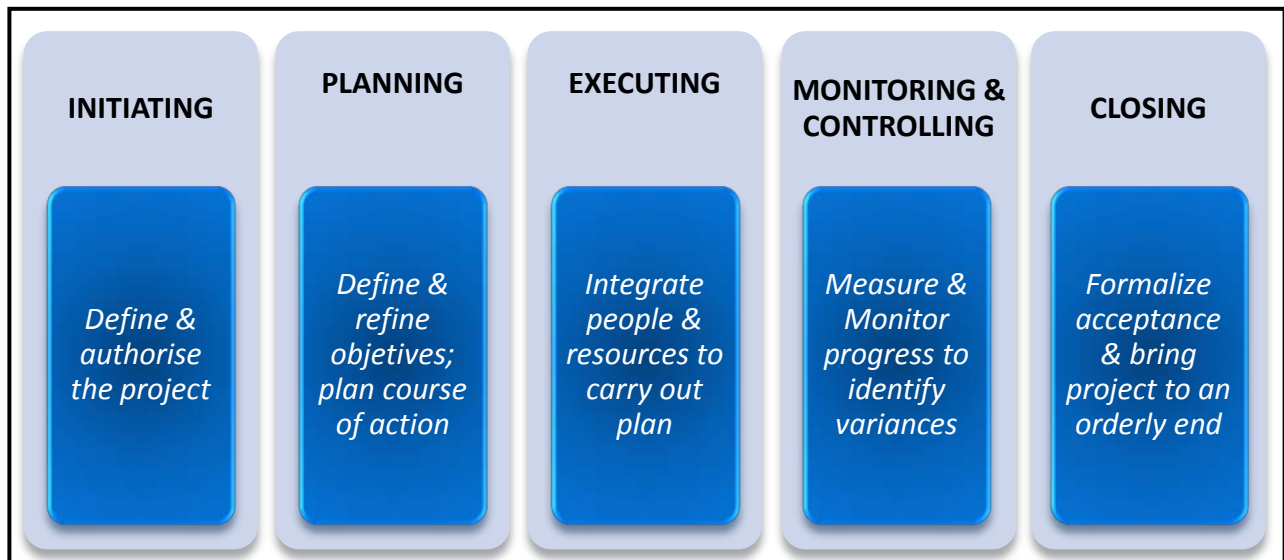
### 2.1 *The Project Management Environment*

Projects can be seen as unique temporary endeavours in which multifunctional and multidisciplinary teams work together to collaboratively accomplish tasks within the agreed constraints of time, cost and quality (Cicmil, 2005:157). They are delivery vehicles for products and services in a global economy (Jackson, 2008:329). A project is composed of many activities, that each have to be described in terms of a completion time, areas it will influence, persons responsible, goals, resources necessary, input/output requirements as well as organizational constraints that might influence it. Many different teams and resources are involved in a project, resulting in a large amount of information flowing between the teams.

Information is seen as a resource (Kendall, 2011:29). It is often of greater use when integrated with other pieces of information though. This is also true for the project environment, where there is a great

need for integration of activities between the different organizational units and different role-players on different levels of the project. This integration can only take place through sharing of information between parties. During a project, documents are produced and transmitted instantaneously to support a real-time representation of the current project status (Nicoletti, 1998:115). Since all activities are running concurrently, projects will not permit face-to-face interaction and as a result, information flows generated by information technologies are utilized to increase efficiency. Information flows should be consistent, accurate and ready for submission due to the urgent nature of projects.

Companies often take on a diverse range of projects at the same time. All of these projects are composed of many functions that have to be performed, and in some cases, these functions have sub-functions. Keeping track of all the associated functions and elements is the role of the project manager. Project management can be seen as the application of knowledge, skills, tools and techniques to tasks to meet project requirements. The Project Management Institute (PMI) identifies processes through which the project manager can manage the project to completion (Project Management institute 2004). They include initiation, planning, executing, monitoring, controlling and closing (*Figure 3*).



**Figure 3 - Project Management Process groups**  
**SOURCE: Project Management Institute, 2004, p.40**

Defining the project scope is the initiating step. This enables boundaries to be established and identifies people, processes, and resources to be involved in the project. At this stage, information gathered from previous as well as current projects, guide management teams in decision-making (Amami, 1993:26). Proceeding from the planning phase to the executing phase, all the objectives and goals set by the



management team have to be accurately communicated to all role-players, inside and outside the organization/ project space. Work in the project is broken down through a Work Breakdown Structure (WBS), allowing for the sorting of information by engineering and design area, major techniques, priorities etc. Only after this has taken place, integration between the functions can commence. Data is then integrated from different sources and in different formats. Information, as the driving force of the project, is stored in an interactive database allowing project managers to access it when needed. This information (in the form of text, graphs and networks) can then be used in planning, communicating, scheduling, budgeting and procuring resources. The real-time analysis of projects is in focussing on critical factors relating to the project.

It is essential to monitor the progression of the project as well as formalise closing procedures as the processes in *Figure 3* indicates Performance indicators & measures must be communicated to different functional units, who can in turn, monitor the progress and investigate & clarify variances. All information generated here should be stored in a database to benefit future project management.

In conclusion, it is clear how project management can benefit from an information system. Data from previous projects can be utilised to highlight the interdependence of tasks and roles in decision-making.

## ***2.2 Management Information System (MIS)***

Information Systems (IS) can be seen as a combination of hardware, software, infrastructure and trained personnel organized to facilitate the handling of data (Business Dictionary, 2011). Most businesses have one or more IS in place: transaction-processing systems, process control systems, office automation systems, management IS, decision support systems or executive IS (Kendall, 2011:30). These types of systems were already implemented in the 1960s, but at the time, access and usage thereof were limited to a small number of wealthy companies. Today, in an age of globalized communication and control, computers are a part of everyday work. The World Wide Web has granted individuals and companies easy access to a wide range of information.

Each of the above IS provides specific information in the organizational context. In most cases, the specific information needs to be shared with other agents. Like any valuable resource, it is of critical importance that the information flows between role players are managed effectively and that control be

exercised over it. The integrated management information system (MIS) fulfills this function (Davis, G.B. 2000).

By using a MIS, data can be gathered quickly from sources both internal and external to the organization. The data can then be processed, integrated, and stored in a centralized database. This allows for the generation of real time feedback in the form of reports to management and other role players; updating of information; and easy access to information for authorized individuals (Business Dictionary). The MIS ensures that data messages are exchanged efficiently among the different IS and eliminates the need to visit separate systems to obtain comprehensive information.

This centralization and consistency of data decrease the occurrence of redundant data being stored (Qirui, 1993:285). The MIS creates an environment where hierarchical, functional, and individual actors receive support in the decision-making process. Merging information from a variety of sources/functions/departments, allows the formulation of a more objective view of the decision situation. It also enables creative ideas, which might improve the decision ultimately made by the user and management (Nutt, 1986:153).

### ***2.3 Project Management Information Systems***

In the 1990s globalization and increased competitiveness in the business environment led to shifts in business management and ways of thinking. As projects were seen as vital to the performance and the survival of companies, there was an increase in the number of projects undertaken. Delivering these projects on time, within budget, meeting all customer specifications and still managing risk was what was required of project managers on a regular basis. To control the increased uncertainty and complexity of projects, the need for project management became apparent. But keeping track of information on all the different tasks in a project life-cycle, the different role-players performing them, resources involved, cost and budgets to be scheduled as well as finding a way to keep all stakeholders satisfied, is extremely difficult. Wastage in projects could frequently be traced back to less than optimum information handling and exchange. The information was inadequate, inaccurate, inappropriate, inconsistent, late or a combination of these (Stewart, 2004:470). This is worrying as information received affects the managers' perceptions of the project task and related work environment. It might also affect their actions and performance in future tasks.

The success of companies was measured by their project management capabilities and companies had to utilize all resources to remain competitive. The PMIS was one of these resources (Snyder, 1985:74). PMIS can be seen as important building blocks in project management. The PMIS is valuable to project managers, improving their effectiveness and efficiency in managerial tasks. In addition, increased productivity and timelier decision-making has also emerged because of the use of the PMIS (Snyder, 1985). These systems have changed from MIS only focussed on scheduling and resource management, to wide-ranging systems supporting the entire life cycle of projects, programmes and portfolios. They take into account the unstable and complex nature of the project environment, as described above, and provide management with the ability to detect warning signals and take early corrective action (Snyder, 1985:73).

Timely management of information flows enables the project manager to control activities during the project life cycle. Through situational information, decision makers gain a broader understanding of what exactly is going on in the project and are then more inclined to act on insights gained (Bendoly, 2007:617). With the monitoring of the execution of activities, unwanted situations can be avoided by planning and implementing corrective actions, as in many cases the information that is generated by one activity, generates information flows in other activities. With each project being original and differing substantially from others, there is always the potential for innovation, uncertainty and risk (Turner, 2000:66). "The importance of information is directly proportional to its improbability", as Jerry Pournelle the American science fiction writer stated (Pournelle, s.a.). Thus the more uncertain a situation, proposal or idea, the more important it is to gather information to support or explain it. The integrated project management environment described above constitutes one of these uncertain environments. This shifting environment calls for a large amount of information. Investment in a PMIS that increases information visibility is therefore very valuable.

If the on-site information that is shared can be improved to always represent the correct status of the occurring problems in activities, integrate relevant project information and satisfy the demand for activity evaluation, project success would increase significantly (Tsai, 2009:323). A PMIS, as an information manager, integrates and controls information flows to assist management in gaining an overview of the organisation. It stores information in centralized databases and allows the generation of documentation in a form that the users desire. A survey done by Raymond & Bergeron (2007) investigated the elements contributing to the impact of the PMIS on project success. Even though the PMIS itself did not directly influence the system, the use thereof was shown to make a positive

contribution to the success of the project. PMIS quality was found to be a strong predictor of information quality obtained from the system, with available, reliable, precise, comprehensive and secure information being the result of a high-quality PMIS.

The need for the PMIS has enabled it to progress significantly from the 1990s to today. Software development techniques and resources have improved and as a result, the quality of the systems in the 20<sup>th</sup> century is of high standards. There are a variety of packages available, each with different features and specifications.

## 2.4 Current PMIS software available

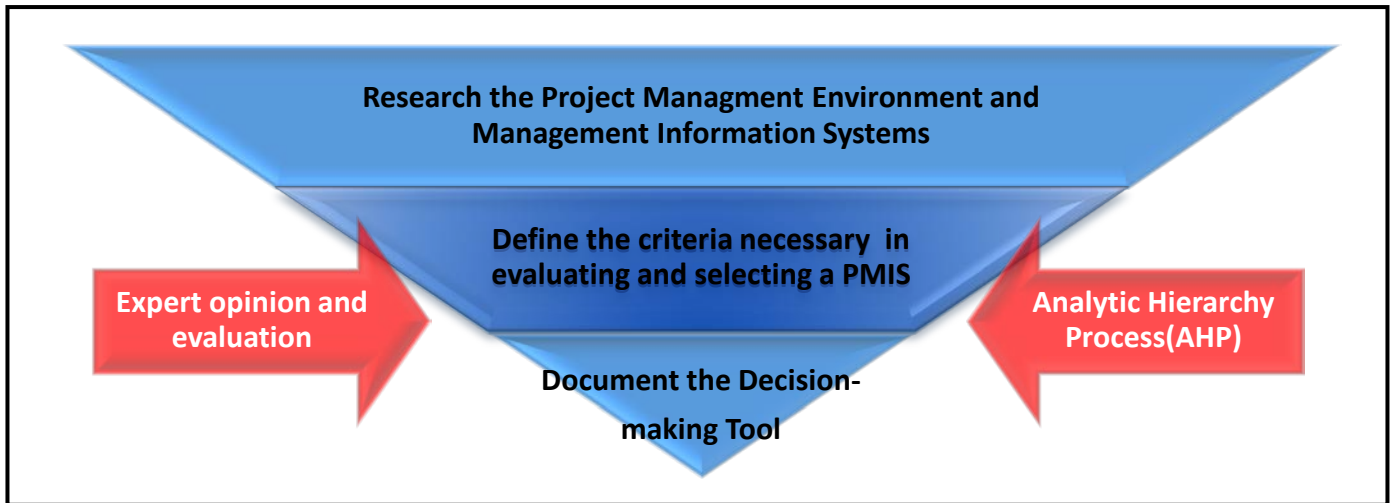
PMIS currently employed in the project environment are one of three types: Commercial-off-the-shelf software, custom developed in-house software or web-based project management systems. When commercial software doesn't meet the specific requirements of an organisation, some firms will often develop their own software in-house. Web-based systems are becoming increasingly popular as they are readily available from any location, and there is no initial purchasing cost. The list of PMIS currently available (*Table 1*) is just a small portion of the actual PMIS available. Developers are continuously improving previous versions or creating interfaces between different software packages, therefore it is difficult to obtain an exact list of all software packages available.

**Table 1 - PMIS currently available (Commercial & Web-based)**

PSNext	PeopleSoft Enterprise Program Management
Project Insight: Web based Project Management Software	Primavera P6 Enterprise Project Portfolio Management
Projectron BCS 6.2	Oracle Projects: Oracle Project management
AMS REALTIME Projects	Acumen Fuse
project.net	AstaPowerproject
easyprojects.net	Deltek Enterprise Project Management: Cobra
Workplan	Dekker PMIS
Minute Man Project Management Software	iPlan Project Management
Jonas Software: Project Management	Panview: Project portfolio management
Micro Planner: X-Pert	Artemis: Views
MS Project 2010	]project-open[ OSS Project Management
Omniplan	

**SOURCE: Project Management Software Dictionary, s.a.**

### 3. Decision-making criteria for PMIS selection



**Figure 4 - Second phase of Decision-making tool development**

The research in the previous section gave insight into the value of PMIS in an organization. It highlighted some of the many roles the system plays. As the decision-making tool supports project managers in choosing the right PMIS, the tool had to be based on the right criteria. With a comprehensive PMIS in mind, various articles that explore these criteria and the reason for their importance were analyzed.

Gerogiannis (2010:368) identifies technical, managerial and organizational needs as important for an organization. Similarly Wei and Wang (2004:162) select the strategic ability, technical requirements, vendor support, change management- and project management methodologies as aspects companies usually consider. Jaafari and Manivong (1998:252) focus on real time management functions, processing and reporting, inter-operability and compatibility, information integration and information management in the capability requirements of a PMIS. All of these criteria were considered, and the final criteria were selected in such a way that they cover the majority of the above-mentioned criteria and more. The main criteria for the decision-making tool were selected as technical requirements; organizational requirements; as well as the software acquisition requirements of the organization.

Each selection criterion was investigated and refined into sub-criteria. The main criteria and the sub-criteria, as well as the reason for their selection, are discussed in detail below.

### 3.1 Technical criteria

The technical requirements of a PMIS should be associated with the project management functions that have to be performed by the software package. As the project management environment is so broad, with so many requirements, it was decided to evaluate different project management methodologies in order to identify the one methodology most inclusive of the required project management functions. These functions are an integral part of the PMIS.

In the investigation process it became apparent that many project management methodologies exist, including Prince, PMBoK, Scrum and many more (Alleman, 2002). These methodologies document and define the different areas that are critical in project management and describe how to go about successfully completing a project using specific tools and methods. Some of the definitions encompassed by these methodologies overlap, but each methodology has a unique approach. Each of the methodologies has its advantages and disadvantages, but their most important feature is that the processes and methods they include cover the majority of the life cycle of the project. It can therefore be stated that they lead the project team from the project initiation stage, through to the closing stage, to deliver what the client wants. A consulting team from North American company – KLR Consulting- describes the PMBoK (Project Management Body of Knowledge) - and PRINCE2® (Projects IN Controlled Environments) methodologies as the strongest contenders among the countless choices of methodologies (Selecting the right project management methodology, s.a.). In *Table 2* these methodologies are compared (PMI Westchester Chapter, 2004). Warrilow (2009) also describes these two methodologies as most popular of eight methodologies.

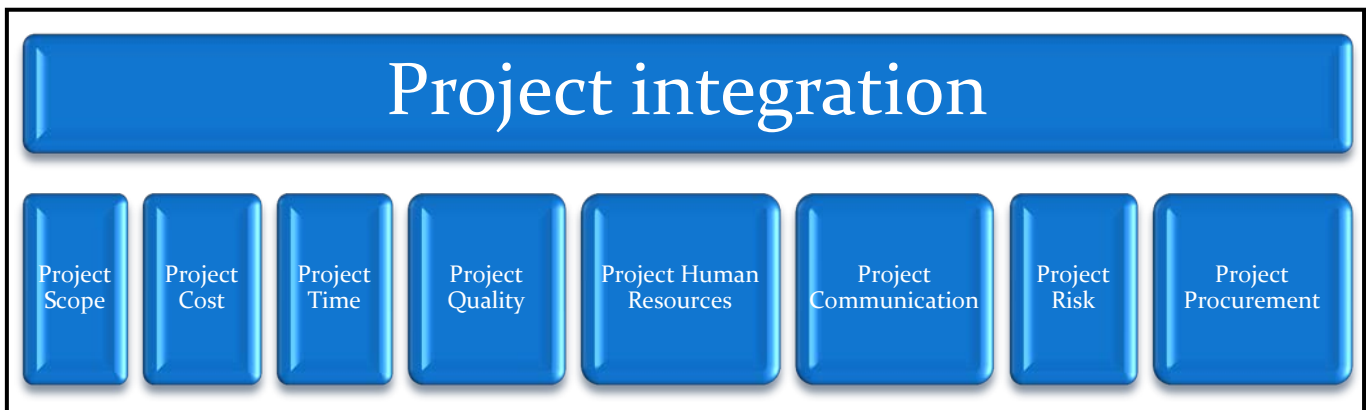
**Table 2 - PMBOK compared to PRINCE 2 Project management methodologies**

PMBOK	PRINCE2®
Comprehensive	Focus on key risk areas only; doesn't claim to be complete
Largely descriptive, prescriptive on a high level	Highly prescriptive, especially on Process Structure, but adaptable to any size project
Core and facilitating processes; need to be scaled to needs of project	All processes should be considered; also need to be scaled
Customer requirements driven	Business case driven
Sponsor and stakeholders	Clear project ownership and direction by senior management
US/ International standard	UK standard

SOURCE: <http://www.pmiwestchester.org/downloads/Prince2PMBOK.pdf>

For the technical criteria to be used in the decision-making tool, it was necessary to choose between these two methodologies that would be the foundation. As *Table 2* above shows that PMBoK is more comprehensive, based on international standards of the PMI and customer focussed. On the other hand, PRINCE2® is focussed on business cases and it includes all processes, not merely the core and facilitating processes like PMBoK. Gerogiannis (2010:363) mentions a market analysis on Project and Portfolio management information systems that found that most PMIS try to offer support for all the areas described in PMBoK. This prominent focus on PMBoK, together with the basic knowledge of it obtained in the Project management 412 Course, made it the choice of reference in this report.

The PMBoK methodology comprises process and knowledge areas describing the sum of knowledge encompassed by the project management profession. It illustrates knowledge unique to the project management environment that overlaps with other management disciplines. The information in the PMBoK is a generally accepted as best practice, but not uniformly applied to all projects (Project Management Institute, PMI). Thus, a PMIS covering this body of knowledge would be able to effectively manage almost all projects.



**Figure 5 - Nine PMBoK Knowledge areas**  
**SOURCE: Project Management Institute, 2004**

*Figure 5 and Table 3* below was taken from the PMI’s latest edition of “A guide to the Project Management Body of Knowledge”. This matrix of the project management process groups and the project management knowledge areas is a good indication of what the PMBoK methodology includes. The nine knowledge areas described in *table 3* can be seen as a definition of the different components present in a project. All areas are interrelated and not optional, and all are present in each project to different extents. Consequently, the nine knowledge areas were chosen as the first set of criteria – the technical criteria. What each area entails will be discussed in detail below.

Table 3 - PMBOK knowledge areas and processes

	<b>Project Management Process groups</b>				
<b>9 Knowledge Areas</b>	<b><i>Initiating</i></b>	<b><i>Planning</i></b>	<b><i>Executing</i></b>	<b><i>Monitoring &amp; Controlling</i></b>	<b><i>Closing</i></b>
<b><i>Project Integration Management</i></b>	Project Charter; Preliminary Project Scope statement	Project Management Plan	Direct and Manage Project Execution	Monitor & Control project work; Integrated Change control	Close Project
<b><i>Project Scope Management</i></b>		Scope plan; Scope definition; Create WBS		Scope verification; Scope control	
<b><i>Project Time Management</i></b>		Activity definition; Activity sequencing; Activity Resource estimating; Activity Duration estimating; Schedule development		Schedule Control	
<b><i>Project Cost Management</i></b>		Cost estimate; Cost Budget		Cost Control	
<b><i>Project Quality Management</i></b>		Quality planning	Perform Quality Assurance	Perform Quality Control	
<b><i>Project Human Resource Management</i></b>		Human Resource Planning	Acquire & develop project team	Manage Project team	
<b><i>Project Communications Management</i></b>		Communications planning	Information distribution	Performance Reporting; Manage Stakeholders	
<b><i>Project Risk Management</i></b>		Risk Management planning; Risk identification; Qualitative risk analysis; Risk response planning		Risk Monitoring & Control	
<b><i>Project Procurement Management</i></b>		Plan purchases & acquisitions; Plan contracting	Request Seller responses; Select Sellers	Contract Administration	Contract Closure

SOURCE: Project Management Institute, 2004, p.70



### **3.1.1 Project Integration Management**

Integration is defined as the processes and activities needed to integrate the various elements of project management, which are identified, defined, combined, unified, and coordinated within the Project Management Process Groups (Project Management Institute, 2004). The project environment has already been identified as an environment that covers many departments, functions, systems and activities, and therefore integration management is necessary to attain close coordination between all these areas.

Integration management is a central function of project management, and as can be seen from *figure 5*, this knowledge area incorporates all others. It is the only knowledge area with processes to be performed in each process group (Table 3). A project manager might see the integration of a whole project as a daunting task, but the processes included in this knowledge area can be seen as enablers for project managers. The processes allow them to keep a broad overview of the project and its strategic focus, as a result not losing sight of the detail of single activities to be performed.

Integration creates an environment that supports decision-making on where to concentrate resources and skills on a daily basis. With the big picture in mind, project managers can make trade-offs among competing objectives and alternatives, and also anticipate potential issues and deal with them while they are manageable (e-ProjectCoach, 2006). The PMBoK highlights three processes critical in integration management: (Project Management Institute 2004)

- Project Plan Development: *integrating all project plans to create a coherent document*
- Project Plan Execution: *performing the activities included in the project plan & developing alignment among the major stakeholders*
- Overall change control: *coordinate changes across the entire project*

The inclusion of these processes in PMIS software is important. The software should also integrate the work done in the project with the on-going organizational work, including the deliverables received from the different functional areas in an organization.

### **3.1.2 Project Scope Management**

Scope management includes processes that control the project scope. A scope statement is set up to establish the constraints of the work required to complete a project successfully. It positions project

boundaries within which the processes and activities in the project can interact (Darnall, 2001). Included in the scope statement is a Scope of Work (SOW) document that divides tasks into smaller activities. By doing this the project manager and project stakeholders can develop and maintain a common understanding of what products or services the project will deliver. Scope management in a PMIS should include the following processes: (Project Management Institute, 2004)

- Initiation – *the authorization of the project/ a phase*
- Scope Planning – *The development of the detailed scope statement*
- Scope Definition – *Subdividing project tasks into more manageable components (SOW)*
- Scope Verification – *Formalizing the acceptance of the project scope*
- Scope Change Control – *Controlling changes to the project scope*

Historical information about previous projects (errors, omissions etc.) should be considered during the scope definition. The PMIS should therefore have a suitable database for the storage of information on previous projects.

### **3.1.3 Project Time Management**

The time management knowledge area incorporates all the actions required to ensure that projects are delivered in a timely manner. The development and management of a project schedule that will complete the project on time is a primary responsibility of the project manager. This plan should be realistic and it should be effectively managed (Darnall, 2001). The Project Management Institute states that time management on a project should be broken down into the following processes:

- Activity definition – *Identification of specific activities to be performed for project completion, usually done through a Work Breakdown Structure (WBS)*
- Activity sequencing – *Identification & documentation of dependencies between activities*
- Activity duration estimation – *Estimating time required to complete individual activities*
- Schedule development – *Creating a project schedule by analyzing activity sequences, durations and resource requirements*
- Schedule control – *Controlling deviations from the schedule*

Project management software, like the PMIS, is widely used to aid in schedule development and control. The mathematical analysis of the plans, as well as the balancing of resources over different activities is

automated in these products. The software allows the visualization of the plan and the tracking of planned and actual dates, thus enabling the project manager to immediately adapt to schedule deviations. Project files, commercial duration estimation databases, as well as project team knowledge should be incorporated into the database of the PMIS, as with project scheduling, forecasting can be made from this information (Project Management Institute, 2004: 65)

### **3.1.4 Project Cost Management**

Project cost management consists of the processes required to ensure that the project is completed within the approved budget. This is done by the setting of cost constraints and by establishing estimates for costs and resources (Egeland, 2011). The costs considered in the budget cover all aspects of the project - from staffing to equipment and software. Third-party services like subcontractors and miscellaneous expenses are also considered. The budget is however not the only aspect cost management is concerned with. The following processes all fall under cost management: (Project Management Institute, 2004)

- Resource planning— *Determining what resource needs & quantities are necessary in the project*
- Cost estimating— *Developing an estimate of the costs involved for these resources*
- Cost budgeting— *Allocating the overall cost estimate to individual work activities*
- Cost control— *Controlling cost deviations and taking corrective action against trends*

Similar to project scheduling, project management software (like the PMIS) is often used to track planned costs vs. actual costs relative to the progress of work, and to simplify the calculation of cost estimates to complete the work. The structured and standardized approach followed in the software also provides an unbiased view of the cost situation in the organization, whereas different stakeholders may measure cost in different ways and at different times. The PMIS should make information available to everyone in the same format. The accuracy of the budget is directly proportional to amount of information available to the team (Darnall, 2001). Historical information regarding the types of resources required for similar work on previous projects should be made available to allow teams to make accurate estimates.

### **3.1.5 Project Quality Management**

Projects are always undertaken to fulfil a certain need. Quality management processes are performed to ensure that the project satisfies these needs and meets its quality requirements. Overall project performance is measured, and project results are monitored and compared to the quality standards set out in the project-planning process, to ensure customer satisfaction. Processes necessary are (Project Management Institute, 2004):

- Quality planning— *Identifying relevant standards and determining how to satisfy them*
- Quality assurance— *Evaluating overall project performance on a regular basis to provide confidence that the project will satisfy the relevant quality standards.*
- Quality control— *Monitoring specific project results to determine if they comply with relevant quality standards and identifying ways to eliminate causes of unsatisfactory performance.*

By building quality checkpoints into the project schedule, the project manager can monitor the level of quality throughout the delivery using software like the PMIS. An important function performed by a package like this would be a cost/benefit analysis to guide trade-offs and compromises. Quality cannot be over emphasized in any environment.

### **3.1.6 Project Human Resource Management**

In this knowledge area, a strategy is created for attracting, selecting, motivating, and managing all the people involved in the project, from the delivery team to the stakeholders and sponsors. The processes involved form an organizational structure that can make effective use of all the people involved in the project. Each individual in the team requires the use of different communication styles, leadership skills, and team-building skills, which makes it very difficult for the project manager. Human capital management enabling processes include (Egeland, 2011):

- Organizational planning— *Identifying, documenting, and assigning project roles, responsibilities, and reporting relationships.*
- Staff acquisition— *Getting the needed human resources assigned to and working on the project.*
- Team development— *Developing individual and group skills to enhance project performance.*

Combining all of these processes into one software package could improve the efficiency of the employees and, as a result, also the quality of the work they perform. Access to information on all

participants will provide the project manager with an accurate view of the team s/he is working with. S/he would be able to see where the team is lacking functional and/or process expertise, and what the reasons are for a possible decline in performance. Keeping a database of workers and their performance will also enable project managers to assemble a diligent team with sufficient skill for the next project.

### **3.1.7 Project Communications Management**

Communication management is not merely the day-to-day skills used by management to communicate. Rather, it can be seen as the processes required to ensure timely and appropriate generation, collection, dissemination, storage, and ultimate disposition of project information. These processes seek to ensure that all project information including project plans, risk assessments, meeting notes, and more are collected, documented, and distributed to the appropriate stakeholders. Keeping stakeholders and sponsors informed and involved throughout the life of the project are key success factors. Communication takes at least 90% of a Project Manager's time and it consists of: (Project Management Institute, 2004)

- Communication planning— *Determining information and communication needs of stakeholders*
- Information distribution— *Making needed information available to project stakeholders in a timely manner*
- Performance reporting— *Collecting and disseminating performance information through status reporting, progress measurement, and forecasting*
- Administrative closure— *Generating, gathering, and disseminating information to formalize phase or project completion*

The rapid growth of technology has led to an increase in communication technologies available. A variety of compatible devices, software, service providers, and global communication in different time zones can result in an information overload (Hitt, 2009). For this reason planning and managing the communication in a project, to ensure that only necessary information is distributed, is of critical importance in a PMIS.

### **3.1.8 Project Risk Management**

Project Risk Management can be seen as the processes concerned with identifying, analyzing, and responding to project risk. Projects often fail because of failure in assessing and preparing for risks. As

projects are complex environments, project managers are expected to look beyond the technical to the organizational and external environment. They then have to maximize the probability and consequences of positive events and minimize the probability and consequences of adverse events to project objectives. A platform to evaluate such situations is formed by combining the following processes: (Project Management Institute, 2004)

- Risk management planning— *Deciding on the approach to and planning of risk management*
- Risk identification— *Identifying likely risks that might affect the project as well as their features*
- Qualitative risk analysis— *Performing a qualitative analysis of risks and creating conditions to prioritize their effects on project objectives*
- Quantitative risk analysis— *Measuring the probability and consequences of risks and estimating their implications for project objectives*
- Risk response planning— *Developing procedures and techniques to enhance opportunities and reduce threats from risks to the project's objectives*
- Risk monitoring and control— *Monitoring residual risks, identifying new risks, executing risk reduction plans, and evaluating their effectiveness throughout the project life cycle.*

Organizations will often combine several of these processes into one process with the main purpose of identifying all the risks and developing responses for those with the greatest consequences to the project objectives as quickly and efficiently as possible. Planning for risk early on in the project and putting mitigation measures in place could save a project from premature termination (Darnall, 2001). Project managers are required to educate and reassure their teams (and clients) about the risk processes and help them understand that risk management is an essential element of any project area. The PMIS could be an enabler in this regard.

### **3.1.9 Project Procurement Management**

Procurement can be defined as the acquisition of goods and services from outside the organization. Procurement management is the art of soliciting those goods and services, selecting the best provider and material, and ensuring that contracts are drawn and enforced fairly and effectively. The project manager is the buyer of the goods or services from a supplier or contractor, and the following processes are examined from this perspective (Egeland, 2011).

- Procurement planning— *Determining what to procure and when*

- Solicitation planning— *Documenting product requirements and identifying potential sources*
- Solicitation— *Obtaining quotations, bids, offers, or proposals, as appropriate*
- Source selection— *Choosing from among potential sellers*
- Contract administration— *Managing the relationship with the seller*
- Contract closeout— *completion and settlement of the contract, including resolution of any open items*

Projects under good management can sometimes fall behind because of external service providers or product availability performing below the required standards. Therefore keeping record of actions, tenders, vendors and all elements present in procurement management is crucial. These functions can be performed by a PMIS.

In conclusion, the knowledge areas discussed above, especially the detailed understanding of what they entail, are essential to every project manager. They have been accepted by the Project Management community, and for this reason they are acknowledged as comprehensive criteria for evaluating the technical requirements of a PMIS.

### ***3.2 Organizational criteria***

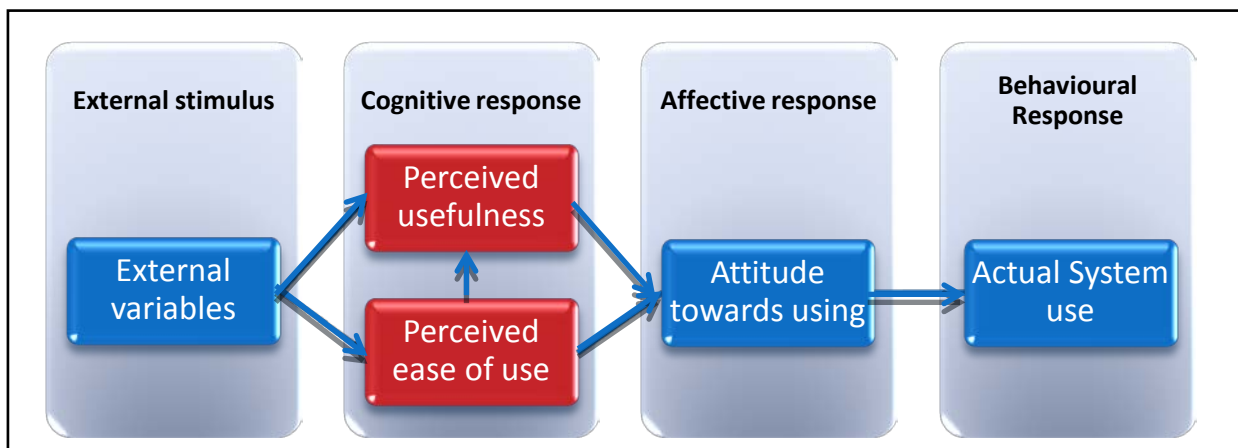
The technical criteria discussed in the previous section are of vital importance to project managers when choosing a PMIS. These criteria also create a platform for software developers to start from when developing new packages and systems. Despite the inclusion of these technical features in a package, there must be commitment to the system on the part of the user (Snyder, 1985:74). All the planned advantages and improvements the PMIS could provide to the organization are of no use if the software package is not used. For this reason, the correct approach to the people inside the organization is equally important in any PMIS.

Gerogiannis (2010) suggests the application of a technology acceptance model to support an organization in setting up the new software package. This model explores the relationship that exists between a system's usefulness and its ease of use. The two factors highlighted by this model – perceived ease of use and perceived usefulness - can serve as the organizational criteria in the decision-making model. This will allow project managers to select a PMIS with high probability of acceptance by the rest of the members of the organization.

### 3.2.1 The Technology Acceptance Model (TAM)

Fishbein & Ajzen (1975) developed the Theory of Reasoned Action (TRA) in the social psychology literature. This theory suggests that the attitude towards behaviour (decision-making) is determined by beliefs about the consequences of the behaviour and the effective evaluation of those consequences. Since 1975, many specific models have been derived from TRA. The technology acceptance model (TAM) developed by Davis (1993) is one of them, focussing more on information technology.

TAM addresses the reasons why users accept or reject information technology, and it diagnoses design problems before users have experience with a system. Davis emphasizes that user acceptance is a pivotal factor in determining the success or failure of any information system project. The model hypothesizes that the actual use of the system is determined by the attitude a user has towards using the system. This, in turn, is a function of perceived usefulness and perceived ease of use. Perceived ease of use also has a causal effect on perceived usefulness. Both of these beliefs are however originally influenced by the actual design features, or external variables as can be seen in *Figure 6* (Davis, 1993).



**Figure 6 - Davis's Technology Acceptance Model (TAM)**  
**SOURCE: Davis, 1993:476**

Lack of acceptance from users is a barrier to the potential success of a software package. PMIS endeavour to improve the current organizational structures and performance, but this attempt is lost if the package isn't accepted and implemented in the organization.

Davis (1993) defines perceived usefulness as *"the degree to which an individual believes that using a particular system would enhance his or her job performance"*. The user judges the efficiency of the system, even before usage and what the model indicates is that the user will still use the system even though he/she might not like it, simply because it will possibly increase job performance. On the other



hand perceived ease of use is defined as the *"the degree to which an individual believes that using a particular system would be free of physical and mental effort"* (Davis, 1993). The causal effect of perceived ease of use on perceived usefulness indicates that a user will always choose the system that is "easiest" to use, despite the fact that they might have identical functionality. This is understandable and beneficial to the organization as the user will become more productive with his/her usage of the "easier" system and as a result will improve overall performance. In the process of validating the TAM, Davis *found* a stronger relationship between perceived usefulness and the attitude toward behaviour than between perceived ease of use and attitude toward behaviour. The reason for this was the "mediation role" perceived usefulness plays between perceived ease of use and the attitude towards using (Dillon A, 1996).

Perceived usefulness and perceived ease of use have been selected as the organizational criteria in the decision-making tool. Their significant impact on a user's attitude toward the system is defined as feelings of favourableness and impartiality toward the organization's decision on whether they will use the proposed package. By including these factors in the tool, an honest opinion of how the tool-user evaluates the package will be obtained. Authority alone cannot be used as a motivational factor to ensure technology is being used, but focussing on these two factors at least render predictability of acceptance to some extent (Dillon, 1996).

The tool is currently primarily for project manager use, which might limit the insights gained by these two criterions. In the case of the tool being available to the lower levels in the organization - the people that will actually use the tool - a clearer representation of the user perceptions could possibly be obtained. The reality is that the employees on a lower level won't necessarily have the specialized knowledge to utilize the rest of the decision-making tool. Future improvement of the tool should take this into consideration when putting together the criteria. Improvements could possibly include trade-offs between the criteria or different tools for the different levels of management in the organization.

### ***3.3 Software acquisition criteria***

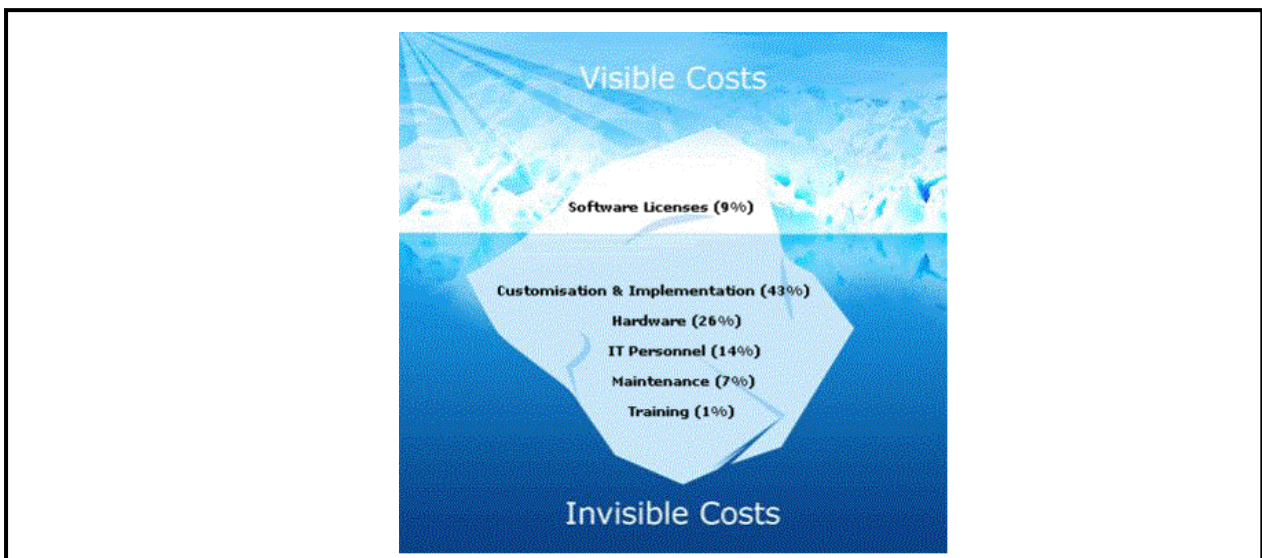
The technical and the organizational criteria have been defined and the reasons for choosing the nine knowledge areas and perceived usefulness and ease of use have been stipulated. From a management viewpoint both of these categories are very important, but a crucial area that can be seen as the "make or break" of decision-making in many cases is the costs implications. Whether it is annual planning or

software acquisition, like in this case, a considerable amount of time is always allocated to budgeting or analysing financial statements etc. To ensure the decision-making tool provides an accurate representation of all factors present in software acquisition decision-making, it was decided to investigate the total costs of ownership (TCO).

### **3.3.1 Total Cost of Ownership (TCO)**

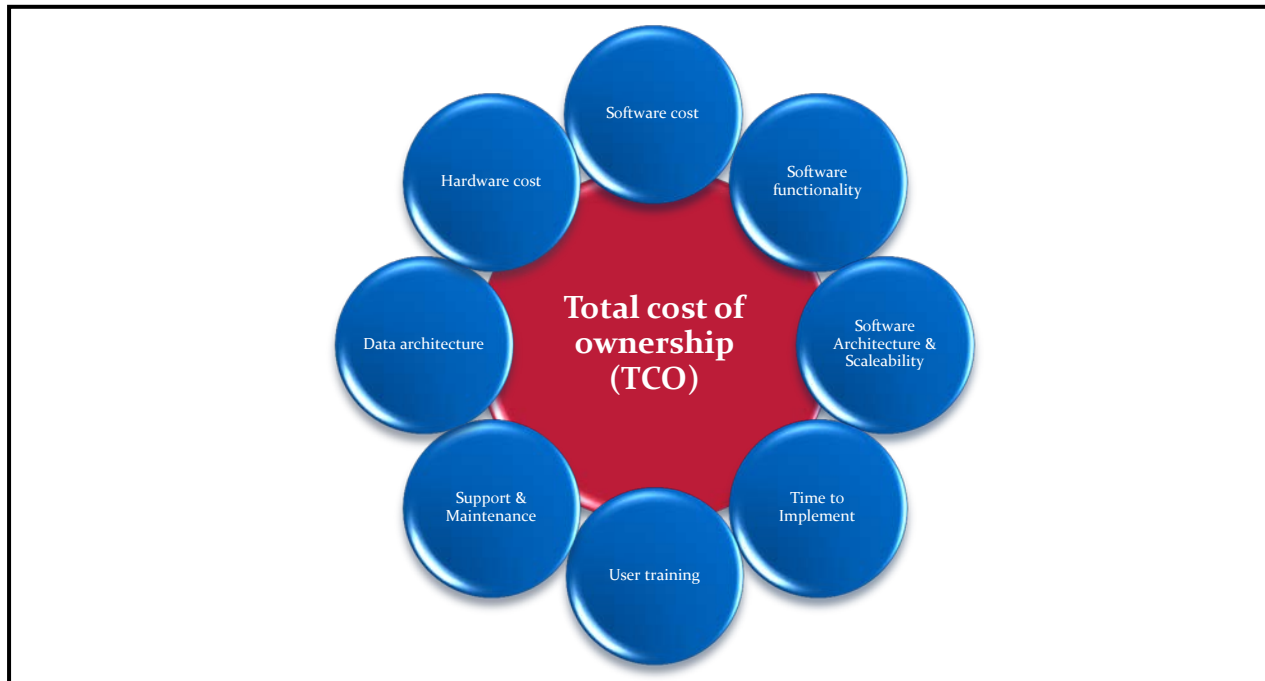
Total cost of ownership (TCO) is more than just the initial purchasing price of the product/service. It is the present value of all costs incurred from purchase to disposal, including repair, insurance, training etc. (Schmidt, 2011). While the most expensive system at the decision point might meet most of organizational requirements, the TCO over the life cycle of the system also has to be taken into account. Similarly choosing the least expensive package, because of the emphasis on initial costs, might lead to implementation risks and low functionality. By rather utilizing a TCO analysis, informed financial decisions can be made.

Elements included in the TCO analysis can be specified according to the particular needs of an organization and the requirements that they wish to include. Open Options, a product of the Northwest Regional Educational Laboratory (2005), defines price, opportunity costs and other costs to be the factors included in the TCO analysis when choosing between open source and commercial software. Another example is the analysis done by Gartner Inc., an information technology research and advisory firm, who made the estimates, as reflected in *Figure 7*, for actual cost of equipment for wireless pervasive connectivity.



**Figure 7 - Actual cost of equipment for wireless connectivity**  
Source: <http://davidhoglund.typepad.com>

The TCO analysis for information technology generally includes the elements in *figure 8*.



**Figure 8 - Total Cost of Ownership (TCO)**  
**Source: Allied data technologies, 2008**

### **3.3.2 Weighted TCO element importance**

As the organization will eventually perform a TCO analysis in the process of software acquisition, it was decided to include criteria in the decision-making tool that would ultimately provide analysts with the weighted importance of different elements in the TCO analysis to support their calculations.

The final weighted importance of the functional criteria, in *section 3.1*, can provide the relative importance of the software functionality, software architecture and Scaleability and data architecture - elements of TCO. If, for example, the functional criteria were weighted much higher than the organizational criteria in the calculations, management would then know that the TCO costs related to the functional characteristics of the software package would be more than the costs relating to the “selling of the package to the company” in the long run. Budgets can be updated accordingly and management will then have a better idea of the possible benefit the package could provide.

Compressing the TCO elements in *Figure 8*, in the category of software acquisition - software cost, maintenance & support, and implementation & training were chosen as criteria. Software cost was defined as the actual purchasing cost associated with the new acquisition of the package/system,

including additional hardware costs. These costs are usually stipulated in documents provided by the various competing vendors; otherwise, it should be made available to the organization. Maintenance & support covers the service provision from the vendor required by an organization. This often includes a service plan or guarantee, and a customer service department. Finally, implementation & training includes the initial start-up support provided by the vendor, comprehensive training sessions and complete user manuals. By evaluating the importance of these factors, and actually obtaining a numerical weight, companies will have a better perspective when having to choose between competing software packages.

From this section, it should be apparent that none of the criteria was chosen without a clear understanding of the environmental requirements. Each main criteria group covers a specific area important in the project management environment. It should however be said that this tool by no means covers all possible criteria, and as a result might be found lacking in some areas. For the purposes of this report however, it was necessary to limit the endless possible areas that may be evaluated to the final criteria.

## 4. Decision-making Tool for Project Management Information System (PMIS) Selection

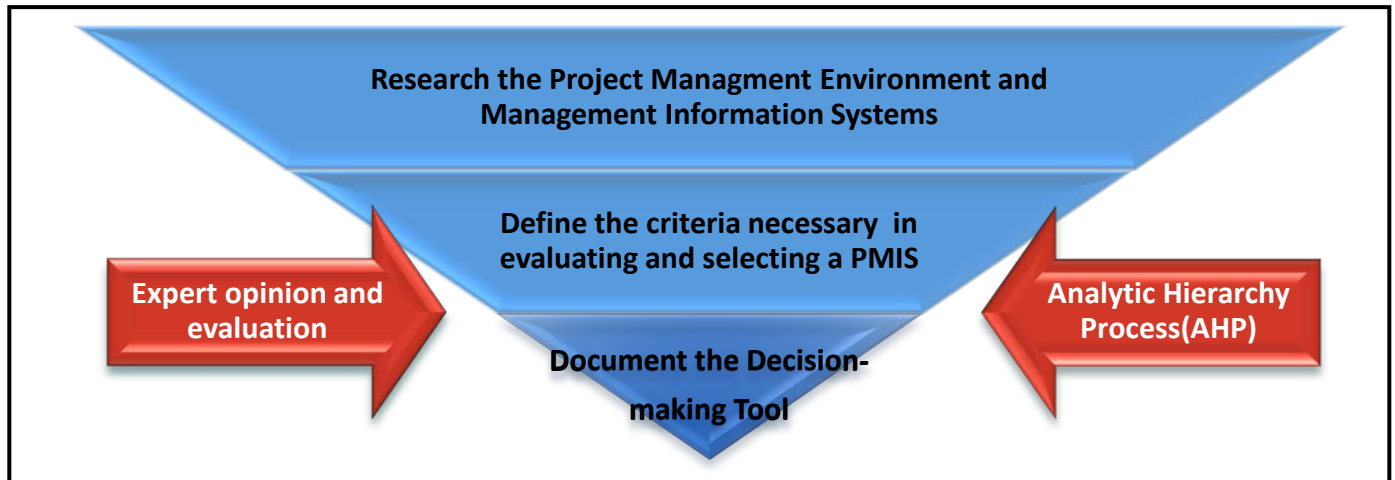


Figure 9 - Third phase of decision-making tool development

### 4.1 Analytic Hierarchy Process (AHP) in the evaluation and selection of Project Management Information Systems

The fourteen criteria selected in the previous section together form the foundation of the decision-making tool. This is quite a large number of criteria to evaluate. An approach to decrease this number was developed by Ceberio (2011). Their approach attempts to reduce the decision space by building preference constraints (according to customer requirements) and then using standard techniques to solve the problem. This relatively new method aims to decrease decision-making time and increase accuracy. It has however not been sufficiently validated to date, and for that reason can't be utilized to decrease the selected criterions. It was therefore necessary to explore multi-criteria decision-making methods.

Numerous multi-criteria decision-making (MCDM) methods were explored to decide on the best approach to include in the decision-making tool. Most MCDM tools are based on utility theories. These theories assign a utility value, between  $U [0, 1]$ , to each criterion. Utility based approaches to MCDM include using the Maximax & Maximin approaches, weighted sum approach, and Non-additive approaches. The Maximax and Maximin approaches only consider a single criterion, the absolute

highest utility and the absolute lowest utility respectively, but aren't able to reflect any position in-between. However, as trade-offs are regularly made, it's necessary to combine the utilities of multiple criteria and take all of them into account. It is the ability of AHP to take these conflicting objectives into account, which sets it apart from the rest and makes it an excellent choice. It has also been proven successful in the evaluation of software packages in the past (Vaidya, 2006).

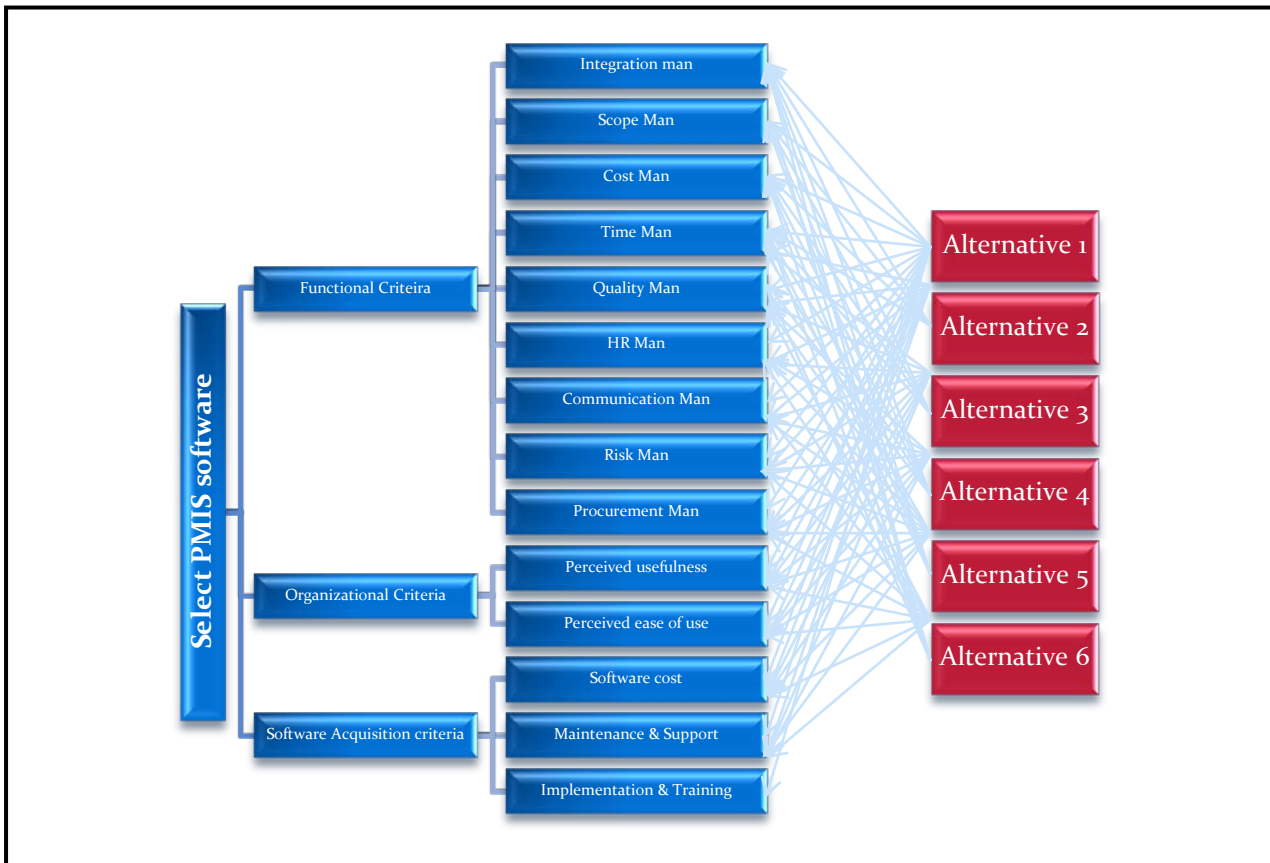
Thomas L. Saaty introduced AHP in 1980. This Hierarchy process uses pairwise comparisons and the judgements of experts to develop priority scales. These scales are then utilized to measure intangibles relative to each other (Saaty T.L, 2008). The AHP process attempts to mirror the human decision process where the problem is identified, and the criteria for the solution is then broken down into sufficient detail to include all stakeholders affected, and finally one of many alternative solutions is chosen. AHP can be applied to both qualitative and quantitative criteria, which ensures that it provides an accurate representation of both the subjective perceptions of the people in the organization as well as the cognitive factors in data and statistics. Saaty outlines steps in the AHP process. A description of these, in terms of the decision-making tool, will follow.

#### **4.1.1 Define the problem and determine the knowledge sought**

The problem was defined in the introduction as the need for a tool to help project managers select a suitable Project Management Information System (PMIS) software package. The goal of the AHP process can as a result be seen as the selection of the most suitable software package. AHP has been used to compare software requirements (Finnie, 1993) and commercial-off-the-shelf products (Wei, 1997) in various cited articles. In terms of knowledge, an introduction to the AHP process was obtained in Operations Research 344 and a literature study was performed on the PMIS environment.

#### **4.1.2 Structure the decision hierarchy**

The final decision hierarchy is shown on the next page (*figure 10*). The goal of the decision, stated above, was placed at the far left. The main criteria identified in the previous section – Functional-, organizational, and software acquisition criteria – are then placed to the right of the main goal. These elements can be seen as the objectives that have to be met for the final decision to be made. Next, the relation between the 14 criterions and the subsequent elements on which they depend is shown. The criterions determine the measure of achievement of the objectives. The final level consists of the different alternatives that will be evaluated, in terms of the criteria.



**Figure 10 -AHP comparisons to select PMIS software**

This hierarchical decomposition of the problem supports better understanding of the overall decision-making process (Gerogiannis, 2010). Requirements that might have been overlooked in other methods, only focussing on the main problem, are allowed to surface. Often these unnoticed areas are of critical importance to the organization, and problems resulting from the wrong choice of software will only become apparent later, at great expense to the organization.

At a later stage, Saaty developed the Analytic Network Process (ANP) (2001). There is a strict relation between ANP and AHP, but ANP is often considered the better method as it takes into account the interrelations between criteria and sub-criteria (Yazgan, 2009). For the decision-making tool, AHP methods were rather chosen, as the interrelations between the criteria are very small.

#### **4.1.3 Construct the pairwise comparison matrices**

As the word “pairwise” suggests, the essence behind the AHP calculations is the relationship between two elements. To perform these comparisons two questions are raised – Which of the two elements is more important, with respect to the criteria, and how many times more important is it? A scale to rate the intensity is displayed below (Coyle, 2004). A basic assumption is made concerning reciprocals of the

ratings in Saaty's Scale. It states that if attribute A is absolutely more important (9) than attribute B, attribute B must be absolutely less important than A (1/9). With this scale as a guideline, the comparison matrices could be set up.

**Table 4 - The Saaty rating Scale**

Intensity	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience & judgement slightly favour one
5	Much more important	Experience & judgement strongly favour one
7	Very much more important	Experience & judgement very strongly favours one
9	Absolutely more important	Evidence favouring one over the other is of the highest possible validity
2,4,6,8	Intermediates values	When compromise is needed between the above

**SOURCE: Saaty, 2008:86**

The mathematics behind these matrices is explained in appendix A. The first basic reciprocal matrix is shown in *Table 5* below. In this table, Criteria 1 is absolutely more important than all other criteria (from criteria 2 to criteria 14).

**Table 5 – An example of a Pairwise comparison of the fourteen criteria**

	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6	Criteria 7	Criteria 8	Criteria 9	.....
Criteria 1	1.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	
Criteria 2	0.11	1.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	
Criteria 3	0.11	0.11	1.00	9.00	9.00	9.00	9.00	9.00	9.00	
Criteria 4	0.11	0.11	0.11	1.00	9.00	9.00	9.00	9.00	9.00	
Criteria 5	0.11	0.11	0.11	0.11	1.00	9.00	9.00	9.00	9.00	
Criteria 6	0.11	0.11	0.11	0.11	0.11	1.00	9.00	9.00	9.00	
Criteria 7	0.11	0.11	0.11	0.11	0.11	0.11	1.00	9.00	9.00	
Criteria 8	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.00	9.00	
Criteria 9	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.00	
.....										

The Total Number of pairwise comparisons to be performed can be calculated by using the following formula: (with n equal to the amount of criteria)



$$\# \text{ comparisons} = \frac{n(n-1)}{2} \dots\dots\dots(4.1)$$

For the decision-making tool  $n=14$ . The number of comparisons can be calculated as 91, which is a tedious process. To ensure the user-friendliness of the tool, it was decided not to simply provide the user with a matrix to fill in. It is not visually appealing and easy to get lost in the different rows and columns, because of the big matrices. Instead visual basic programming was done in Excel to create a userform that users can complete with minimum effort.

An easy to use HOME screen, from where users can navigate, was developed. It is shown in *Figure 11*. The tool prompts the user to choose between three numbered alternatives: Evaluate Criteria; Evaluate Alternatives; and Show summary of results.



**Figure 11 - Decision-making tool (HOME interface)**

The first step is the evaluation of the criteria through pairwise comparison. If this option is selected a set of instructions appear, explaining to the user how to use the tool. Next the userform in *Figure 12* appears asking the user to perform the pairwise comparisons between the fourteen criterions identified. The layout of the comparisons was designed to allow the user to easily slide the handle of a scrollbar to the desired position. This is an easy method that makes the tedious process of doing 91 comparisons more manageable. After the completion of each tab in the “Evaluate Criteria Userform”, the user clicks on the “Submit” button. The ratings are then automatically entered into a matrix on an Excel sheet, and the next tab appears for the next part of the evaluation.

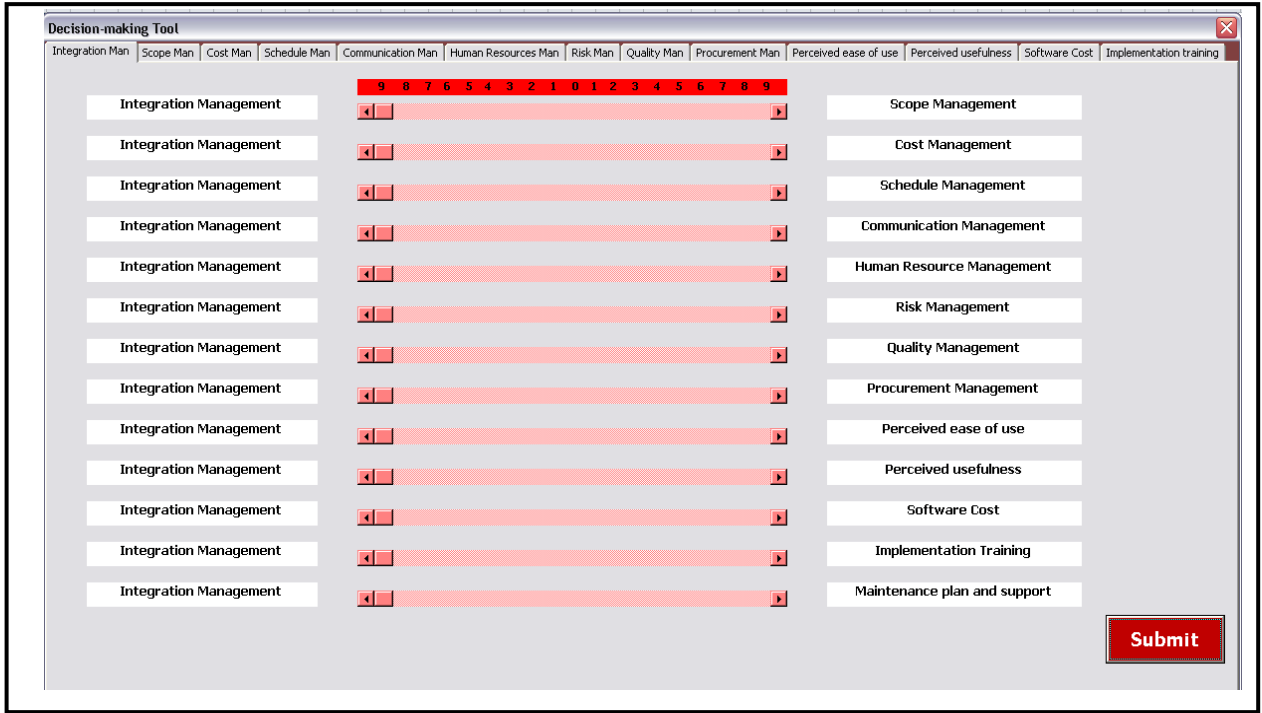


Figure 12 - Evaluate Criteria userform

On the Excel sheet with the matrices, a list of the relative ranking of priorities ( $w$ ) is calculated automatically as the matrix is completed. This is achieved by satisfying the following equation: (Coyle, 2004)

$$Aw = \lambda_{max}w \dots\dots\dots (4.2)$$

Where  $A$  is the comparison matrix for the  $n \times n$  criteria- the priority matrix- and  $w$  is the  $n \times 1$  normalized Eigenvector also called the priority vector. The calculation behind the ranking of priorities and the determination of  $w$  can be found in Appendix A. The result obtained, is the normalized eigenvector  $w$ . The detail of the visual basic programming that makes this possible is also shown in Appendix B.

When the “submit” button on the last tab is clicked, the userform closes and the HOME interface is again available. The pairwise comparisons are not complete yet. From the HOME interface the next button “Evaluate Alternatives” should be clicked. This will again open a userform, but this time for evaluating the different alternative software packages with respect to each of the criterions. The initial tab of the userform prompts the user to enter the names of the software packages he would like to evaluate. When the “Initialize Alternatives” button is clicked, the pairwise comparison starts.



Figure 13 –Decision-making tool (HOME interface 2)

It was decided to allow the user to evaluate up to six packages of his/her choice. As a result, the user can tailor the choices to packages he/she is familiar with. A default choice of a Diary was set as the first alternative. The user can evaluate as few as two packages, should he/she wish to.

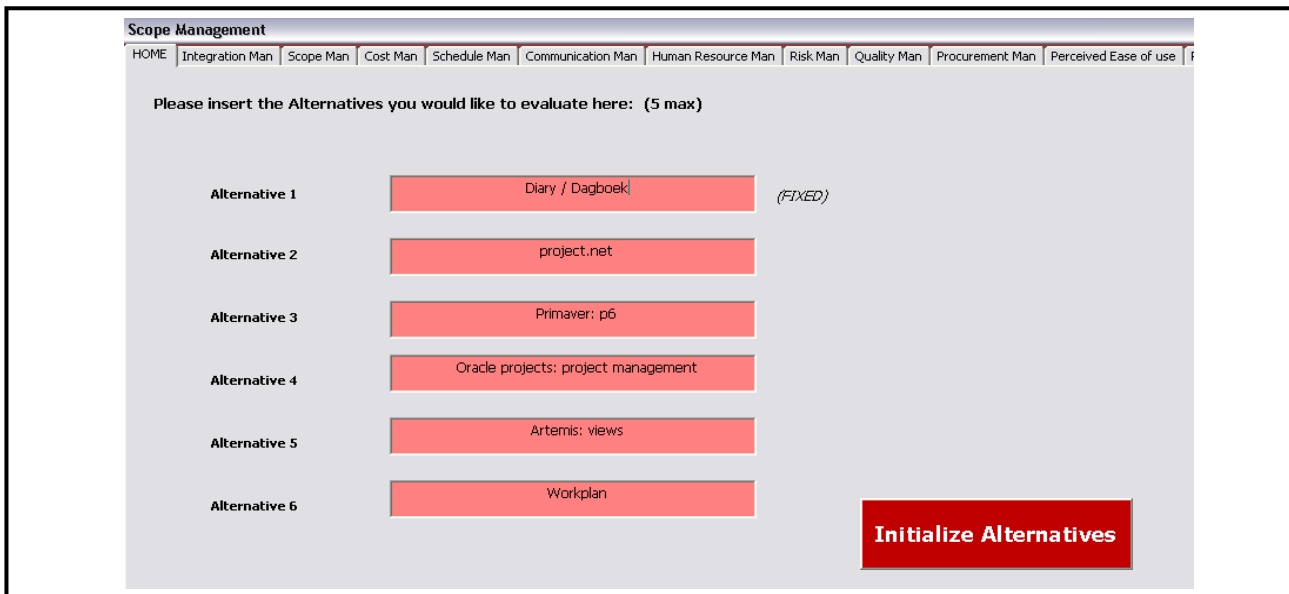
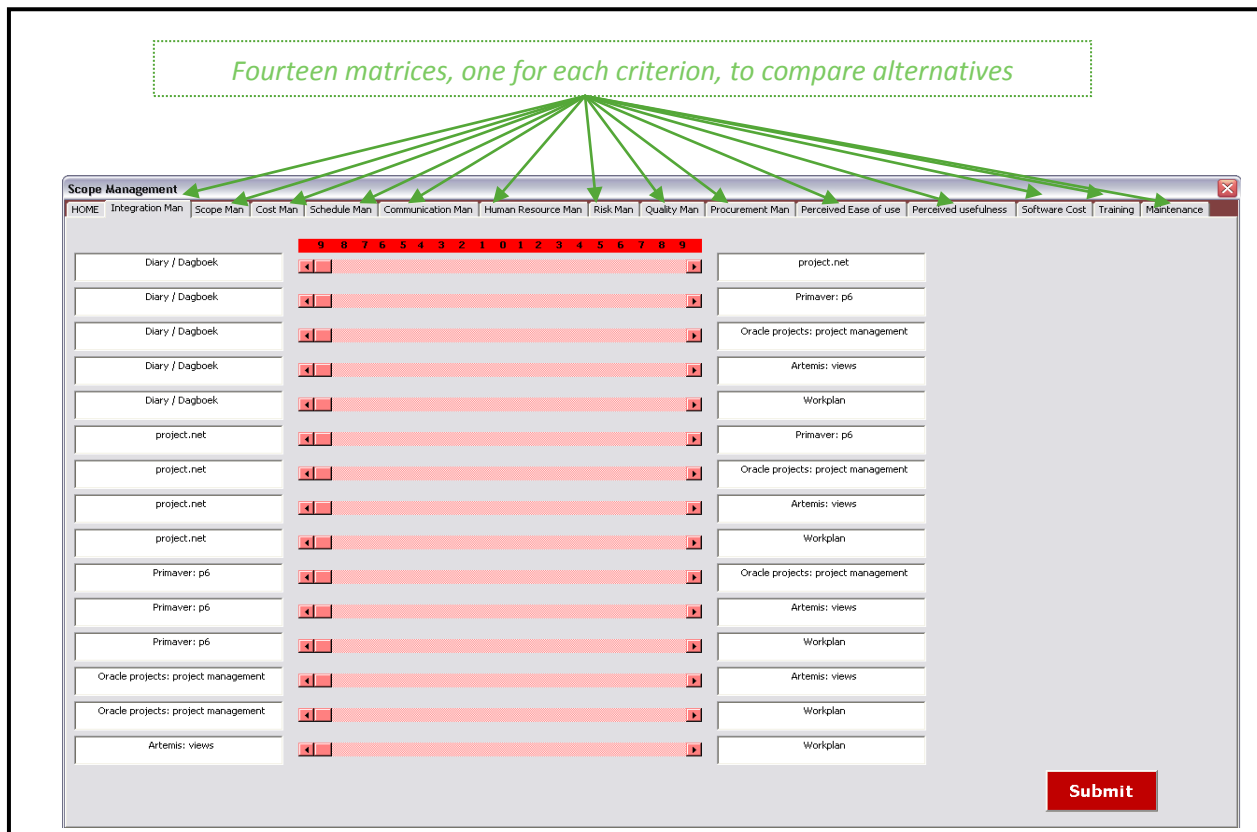


Figure 14 - Userform tab for Initializing Alternatives

The pairwise comparisons of the different alternatives in terms of the fourteen criteria are then performed in the same manner as shown above. Fourteen more matrices are set up, one for each criterion. This allows the evaluation of the capability of the different alternatives to perform the requirements expected from them in each criterion.



**Figure 15 - Evaluation of six alternatives in term of Criteria 1**

As an example, in *Figure 14*, six random alternatives are initialized, and in *Figure 15*, they are rated. The diary was rated absolutely more important (9) than all other alternatives etc. The matrix showing these results is shown in *Table 6*. The normalized eigenvector is also automatically calculated for each criterion. The final priorities in the last level of the hierarchy have thus been determined.

**Table 6 - Evaluation matrix of six alternatives in terms of Criteria 1**

	<i>Alt 1</i>	<i>Alt 2</i>	<i>Alt 3</i>	<i>Alt 4</i>	<i>Alt 5</i>	<i>Alt 6</i>		<i>w</i>
<b><i>Alt 1</i></b>	1.00	9.00	9.00	9.00	9.00	9.00	6.24	0.53
<b><i>Alt 2</i></b>	0.11	1.00	9.00	9.00	9.00	9.00	3.00	0.25
<b><i>Alt 3</i></b>	0.11	0.11	1.00	9.00	9.00	9.00	1.44	0.12
<b><i>Alt 4</i></b>	0.11	0.11	0.11	1.00	9.00	9.00	0.69	0.06
<b><i>Alt 5</i></b>	0.11	0.11	0.11	0.11	1.00	9.00	0.33	0.03
<b><i>Alt 6</i></b>	0.11	0.11	0.11	0.11	0.11	1.00	0.16	0.01

Should fewer alternatives be initialized, there would automatically be empty areas in the “Evaluate Alternatives” userform, and as a result zero values in the Evaluation matrix. Once the “Evaluate Alternatives” userform is completed and all fourteen matrices are filled and their normalized eigenvectors determined by Excel, the final evaluation of the best alternative can start.

#### 4.1.4 Identify the best alternative

The normalized eigenvectors for each criterion, as well as the initial eigenvector resulting from the criterion comparisons, are now used. The last step in ranking the alternative software packages is completed through matrix multiplication. Excel was programmed to copy each criteria-specific  $w$  entry assigned to an alternative in a designated column, to form a specific column for each alternative with its weighting in terms of a criterion. This is shown in *Table 7*.

The weights in terms of criteria 1, as calculated in table 6

**Table 7 - Columns of alternative capabilities relative to criteria**

Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	.....	$w$	Alt 1 ( $w$ )	Alt 2( $w$ )	Alt 3( $w$ )	Alt 4( $w$ )	Alt 5( $w$ )	Alt 6( $w$ )	
<b>Criteria 1</b>	1.00	9.00	9.00	9.00	9.00	7.69	0.27	0.53	0.25	0.12	0.06	0.03	0.01
<b>Criteria 2</b>	0.11	1.00	9.00	9.00	9.00	5.62	0.20	0.53	0.25	0.12	0.06	0.03	0.01
<b>Criteria 3</b>	0.11	0.11	1.00	9.00	9.00	4.11	0.15	0.53	0.25	0.12	0.06	0.03	0.01
<b>Criteria 4</b>	0.11	0.11	0.11	1.00	9.00	3.00	0.11	0.53	0.25	0.12	0.06	0.03	0.01
.....													

Final ranking: Sum product of these columns

The ranking of the alternatives is now performed by summing the product of the initial  $w$ , with each of the  $alt (w)$  columns. This outcome is a final weighted ranking for each alternative. Excel was also programmed to perform these calculations. The next step after finishing the “Evaluate Alternatives” step, is clicking on the “Show summary of results” button. This will take the user to the final sheet where a detailed summary of the ranking of the criteria, as well as the ranking of the alternatives can be found.

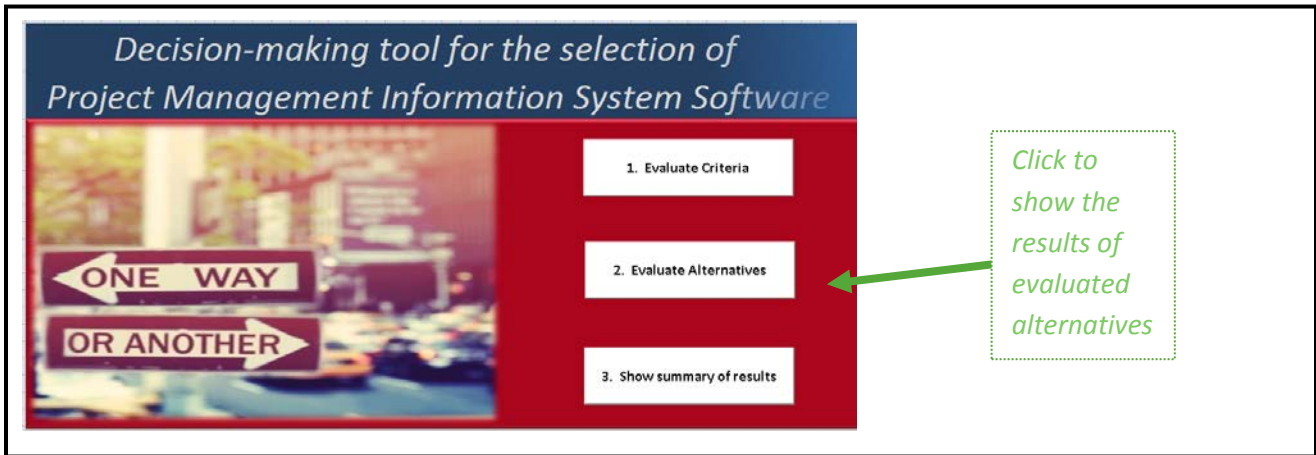


Figure 16 - Decision-making tool (HOME interface 3)

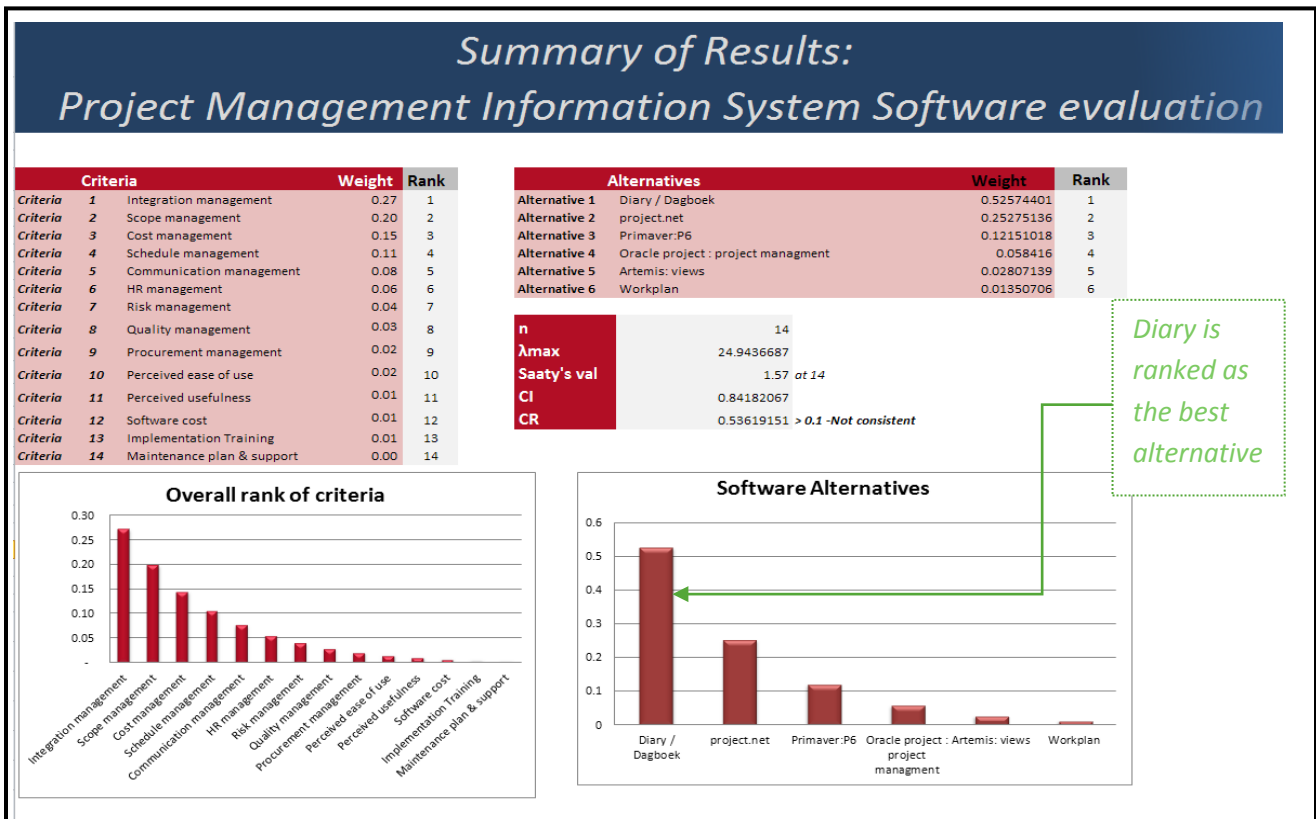


Figure 17 - Summary of results of the sotware evaluation process performed by AHP

As can be seen from the results in *Figure 17* the Diary is identified as the best alternative. This is highly unlikely in a real life situation, but it corresponds to the AHP comparisons that were made. The same can be said for the ranking of the criteria.

An advantage of AHP is that relative pairwise comparisons are used instead of the definition of an arbitrary percentage and weight to each decision element. This allows the decision-maker to focus on the comparison of only two criteria at a time , which decreases the effect of personal perceptions and external influences (Gerogiannis, 2010). The calculations performed from these matrices inexorably lead to logical consequences, as it is very difficult to complete the seemingly unrelated comparisons to get a predetermined result (Coyle, 2004). Also present on the results sheet is a consistency ratio.

**4.1.5 Evaluation of the consistency of ratings**

It is important to realize that inconsistency may arise in the ratings. AHP allows inconsistency, but provides a measure of this inconsistency - a consistency ratio (CR). Reasons for inconsistency are: (Forman, 2001)

- Clerical errors and lack of concentration when entering the ratings
- Lack of information on one/more alternatives being compared
- The real world isn't always consistent – X can be better than Y and Y better than Z, but Z then is better than X, which is contrary to consistency
- Inadequate model structuring where the order of magnitude for comparison is too high

These inconsistencies shouldn't be the main driver of decision-making, as an inconsistent rating can still lead to adequate decisions. The CR of the selection and the judgements involved are derived from the estimation of the eigenvalue of the decision matrix. Following equation 1, in the consistent case  $\lambda_{max}$  will be as close as possible to n. This value can be determined by the following equation, using the values from the  $\lambda$  column in table 8:

$$\lambda_{max} = \frac{1}{n} [\lambda_1 + \lambda_2 + \lambda_3 + \dots + \lambda_n] \dots\dots\dots (4.3)$$

The consistency index (CI) , defined by Saaty, can then be determined by using the following equation:

$$CI = \frac{\lambda_{max} - n}{n - 1} \dots\dots\dots (4.4)$$

**Table 8 - Consistency Ratio matrix to determine  $\lambda_{max}$**

A	Criteria 1	Criteria 2	Criteria 3	...	w	{A} * {w}	$\lambda$	Used to determine $\lambda_{max}$					
								Alt 1	Alt 2	Alt 3	Alt 4		
Criteria 1	1.00	9.00	9.00	...	7.69	0.27	6.82	24.9947	0.68	0.23	0.08	0.03	...
Criteria 2	0.11	1.00	9.00	...	5.62	0.20	4.98	24.9945	0.68	0.23	0.08	0.03	...
Criteria 3	0.11	0.11	1.00	...	4.11	0.15	3.64	24.9943	0.68	0.23	0.08	0.03	...
Criteria 4	0.11	0.11	0.11	...	3.00	0.11	2.66	24.9940	0.68	0.23	0.08	0.03	...
Criteria 5	0.11	0.11	0.11	...	2.19	0.08	1.94	24.9935	0.68	0.23	0.08	0.03	...
Criteria 6	0.11	0.11	0.11	...	1.60	0.06	1.42	24.9929	0.68	0.23	0.08	0.03	...
Criteria 7	0.11	0.11	0.11	...	1.17	0.04	1.04	24.9921	0.68	0.23	0.08	0.03	...
Criteria 8	0.11	0.11	0.11	...	0.85	0.03	0.76	24.9910	0.68	0.23	0.08	0.03	...
Criteria 9	0.11	0.11	0.11	...	0.62	0.02	0.55	24.9895	0.68	0.23	0.08	0.03	...

In order to derive a significant understanding of the of the consistency index, Saaty simulated random pairwise comparisons for different size matrices, and calculated the consistency indices, creating an average consistency index for random judgments for each size matrix. These Random judgements can be seen in *table 9* below. Combining the consistency index for a particular set of judgments, to the average consistency index for random comparisons for a matrix of the same size, the consistency ratio (CR) can be determined (Forman, 2001).

**Table 9 - Saaty's Random Index for different size matrices**

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14
R.I	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57

It is defined as the ratio of the consistency index for a particular set of judgments, to the average consistency index for random comparisons for a matrix of the same size.

$$CR = \frac{CI}{R.I. \text{ value}} \dots\dots\dots (4.5)$$

Since a set of perfectly consistent judgments produces a consistency index of 0, the consistency ratio will also be zero. The larger the value, the more inconsistent the judgments. Judgements greater than 0.1 are seen as untrustworthy because judgments were not made intelligently, but rather at random.



Should the CR substantially exceed 0.1, the final rankings can still be used as a relative measure, but it would be better to repeat the exercise. Finally, the process of ranking the alternatives and determining whether the ratings were consistent is completed. The user can now move on with the software evaluation process. This tool in no way claims to be the be all and end all, and should always be used in conjunction with other tools for optimal results.

## 4.2 Expert opinion and evaluation of the decision-making tool

The tool was developed by following a well-formulated methodology. This allowed a broad view of the environment the tool would be implemented in as well as the requirements the tool would have to adhere to. The physical construction of the tool was aided by AHP. The final step before the documentation of the tool was to let the tool be validated by experts in the Project Management environment. The validation was performed by both the evaluation of the output generated by the use of the tool, as well as an evaluation form the expert had to complete. This step was critical as the final users would be people like these experts, and acceptance at this stage would improve chances of acceptance in organizations.

### 4.2.1 Evaluation of decision-making tool output

The final model was presented to three experts to allow them to voice their opinions and evaluate the tool. They were asked to use the tool in the evaluation of the software packages of their choice. Table 10 is a summary of the output obtained from one expert’s use of the tool.

**Table 10 – Summary of Expert rating of six alternatives**

CRITERIA	FUNCTIONAL									ORGANIZATIONAL		ACQUISITION			OVERALL
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
<i>Global weights</i>	<b>0.28</b>	0.17	0.09	0.09	0.04	0.04	0.05	0.11	0.05	0.02	0.02	0.01	0.01	0.01	
<i>Diary</i>	0.04	0.04	0.03	0.03	0.03	0.07	0.05	0.06	0.07	0.06	0.02	0.29	0.5	0.04	<b>0.05</b>
<i>MS Project</i>	0.04	0.06	0.16	0.21	0.03	0.06	0.03	0.05	0.05	0.2	0.07	0.07	0.1	0.31	<b>0.08</b>
<i>MS Project server</i>	0.1	0.22	0.2	0.19	0.17	0.16	0.18	0.16	0.16	0.07	0.28	0.03	0.03	0.28	<b>0.16</b>
<i>Scitor Sciforma</i>	0.16	0.21	0.26	0.37	0.26	0.25	0.32	0.25	0.31	0.27	0.32	0.04	0.06	0.17	<b>0.23</b>
<i>phpProject</i>	0.32	0.21	0.18	0.1	0.25	0.21	0.21	0.24	0.2	0.17	0.15	0.29	0.14	0.09	<b>0.23</b>
<i>dotProject</i>	0.34	0.26	218	0.09	0.25	0.21	0.21	0.24	0.2	0.22	0.15	0.29	0.18	0.09	<b>0.24</b>

The actual output of his evaluation is shown on the screenshot of the summary page that can be seen below.

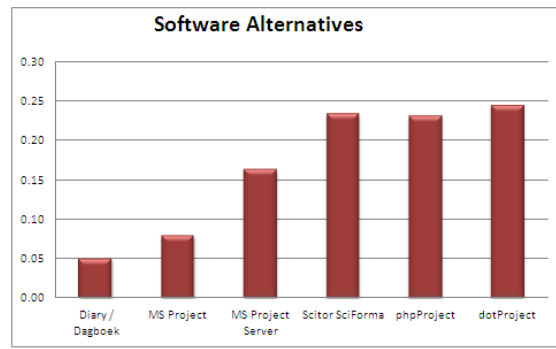
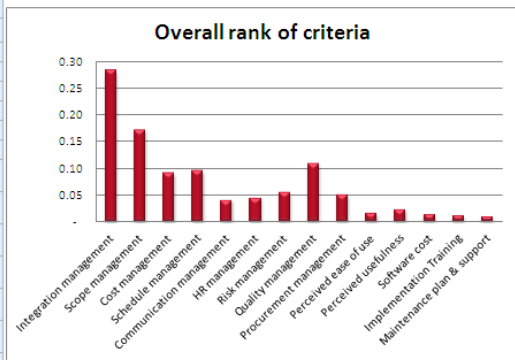
## Summary of Results: Project Management Information System Software evaluation

Criteria	Weight	Rank	
Criteria 1	Integration management	0.28	1
Criteria 2	Scope management	0.17	2
Criteria 3	Cost management	0.09	5
Criteria 4	Schedule management	0.09	4
Criteria 5	Communication management	0.04	9
Criteria 6	HR management	0.04	8
Criteria 7	Risk management	0.05	6
Criteria 8	Quality management	0.11	3
Criteria 9	Procurement management	0.05	7
Criteria 10	Perceived ease of use	0.02	11
Criteria 11	Perceived usefulness	0.02	10
Criteria 12	Software cost	0.01	12
Criteria 13	Implementation Training	0.01	13
Criteria 14	Maintenance plan & support	0.01	14

Alternatives	Weight	Rank	
Alternative 1	Diary / Dagboek	0.05	6
Alternative 2	MS Project	0.08	5
Alternative 3	MS Project Server	0.16	4
Alternative 4	Scitor SciForma	0.23	2
Alternative 5	phpProject	0.23	3
Alternative 6	dotProject	0.24	1

n	14
$\lambda_{max}$	17.14421317
Saaty's val	1.57 at 14
CI	0.241862551
CR	0.15405258 > 0.1 -Not consistent

[Back to HOME screen](#)



**Figure 18 - Summary of results obtained from expert evaluation**

As can be seen from the summarized table and the figure above criterion 1 – integration management was the most important factor to the expert. Conversely, the acquisition criteria (criterion 12-14) – software cost, implementation & training, and maintenance & support – were not seen as important with an overall ranking of merely 0.01. The alternatives, the expert chose to compare were MS Project, MS Project server, Scitor SciForma, phpProject and dotProject PMIS packages. As the “Overall” column in *Table 10* indicates three packages stood out – Scitor SciForma, phpProject, and dotProject. Although there wasn’t an obvious package that was head-and-shoulders above the rest, the variety had at least been reduced. When considering the consistency of the expert’s evaluation, the CR is critical. As can be seen in *Figure 18* above, the CR is shown to be just above the 0.1 standard. This indicates that the entries are valid and that the results obtained can be used in further software selection processes.

Another expert chose to evaluate OpenProj, MS Project and Primavera PMIS packages. The output generated by the tool indicated that OpenProj and was the best PMIS package. Other than the previous expert, this expert also rated software cost as a significant factor.

Considering the collective results of the expert use of the tool it could be seen that the rankings of the systems differ from one individual to the next. To the expert evaluating six packages MS Project wasn't a good contender at all, but to the expert only evaluating three packages MS Project was the second best PMIS package. As a result it could be concluded that no comparison could be made between users comparing different packages, as well as a different number of packages. Should many users from one company each use the tool, it should be insured that they evaluate the same packages. As stated earlier, the tool should be used in conjunction with other methods. Ideally further, more detailed evaluations of the identified packages could be done with the executive managers of the organization. These methods could be applied to the reduced number of packages, identified by the decision-making tool.

The experts were then provided with a short questionnaire (Appendix C) they had to complete, allowing them to comment and make recommendations to be implemented immediately or at least at a later stage, to improve the tool.

#### **4.2.2 The evaluation form and feedback on the Decision-making tool**

The evaluation form handed to the experts after the use of the tool resulted in the feedback that could be taken into account. According to the experts, the instructions provided for the usage of the tool was unambiguous and clear. The instructions together with the scrollbar-format of the tool enabled them to complete the evaluation without additional help. The complete decision-making process was however still seen to be very time-consuming. It should be kept in mind that an actual software acquisition process may take anything from a few days to a few weeks, because of the large number of considerations to be made and information on different packages to be processed. In light of this, one could afford to spend at least a day, already in the initial phase, using the tool to make the detailed comparisons and decrease the variety of packages.

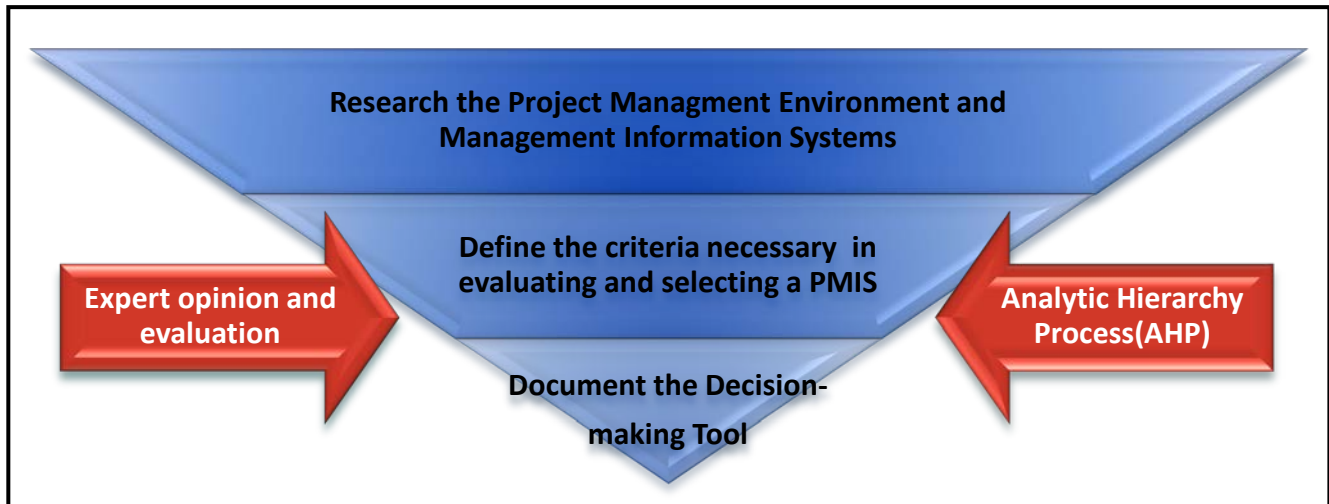
Another valid point made by the experts was that the tool assumes that the user has detailed knowledge of five of these packages. This could create problems. In the initial design of the tool, this was considered. It was however decided that as the tool would only be one of many methods used in the acquisition process, the user should be in a position to take time to obtain the specifications and features of the different packages. Where a potential software purchaser would usually get overwhelmed by all the features and specifications of the packages, the tool allows a more structured approach. The user of the tool will be guided to look at specific features in isolation.

With reference to the criteria covered by the tool, suggestions were that an evaluation on a more detailed level be performed. “As PMIS’s are applied on different levels in projects – Macro, Meso, and Micro – the evaluation should also include even more detailed features”, stated by an evaluating expert. This suggestion was considered, but the time constraint as well as a lack of knowledge of these detailed functions, discouraged changes to the tool. An investigation into these detailed areas should be considered in the future refinement of the tool as it would further aid users in only selecting detailed features relevant to the specific organization.

The overall feedback on the tool was positive and the experts stated that the tool could be implemented in the project management environment successfully, provided some adjustments – like those mentioned above- are made.

## 5. Conclusions

### 5.1 *Reflection on the Methodology and how it was executed*



The structure of this report corresponds directly to the methodology used in developing the decision-making tool. As the funnel shape in the representation of the methodology above indicates, the methodology was used to narrow down the information on PMIS as a whole and concentrate on functions that would aid project managers in selecting PMIS software packages. This provides certainty that all aspects of project management were covered and that all relevant information was included in the tool. The arrows indicate the help utilized from outside the PMIS environment, with the use of AHP and expert evaluation. The methodology followed allows a structured progression that is easy to grasp. The detailed documentation of the development process ensured that the methods and processes followed are clear. This is very important for users and for developers to further develop and improve the tool in future.

### 5.2 *Summary of conclusions*

#### 5.2.1 *The PMIS in general and the use of PMBoK for determination of requirements*

Through the literature study, PMIS was found to be an even more complex construct than initially expected. The array of functions it performs, together with its areas of integration, revealed it to be a system that any company would benefit from having. This benefit was found to be limited to few companies who made the correct initial choices when selecting a PMIS. A challenge found facing

organizations was the selection of one system from the variety of PMIS software packages available on the market. This challenge together with the possible benefit the PMIS could provide emphasized the relevance of the decision-making tool.

The selection of PMBoK as the standard for determining the technical criteria of the tool proved to be sufficient. The use of the PMI's latest edition of "A guide to the Project Management Body of Knowledge" provided a detailed description of the important aspects of the project management environment that could be incorporated in the tool.

### **5.2.2 The use of AHP in the development of the tool**

An integral part of the tool is the use of the AHP method. The results obtained using this method exceeded initial expectations. The clear advantages the AHP method provides became apparent in the simplicity of the comparisons as well as the consistent outputs obtained from the expert evaluation. Another multi-criteria decision-making method considered was ANP, which was found to be unnecessarily complex because of the additional relationships between the criteria. With the Visual Basic programming done for the AHP already being demanding, the extra relationships would only increase the complexity. The amount of comparisons needing to be performed would escalate, and the evaluation process would take very long.

### **5.2.3 The relevance of the expert evaluations**

The evaluation of the tool by experts was performed to verify that the right criteria were chosen and that the results obtained from the tool were accurate. This step was relevant as the experts possess the required knowledge to suggest improvements and make critical inputs to the model. The experts approached were all familiar with at least three PMIS software packages. Each expert evaluation generated different results and each individual provided different insights into how the tool could be improved.

The consistency ratios of the outputs from the different experts were all found to be consistent, verifying that they were capable to perform the evaluations. The feedback from experts working in the project environment everyday is incredibly valuable.

### ***5.3 Future recommendations***

The final product is the author's representation of the important factors requiring consideration when choosing PMIS software. Additional factors, more important to specific organizations could exist, but decisions had to be made to keep the model within certain boundaries. Recommendations for future developments of the tool include:

- **Include more detailed criteria**

Currently the fourteen criteria selected only scratches the surface of the PMIS environment. There are long lists of more detailed requirements under each of the criteria, including specific documentation and activities. These details were not included in this tool, for a sense of simplicity and ease of use. Future iterations of the tool should however consider the inclusion of these details.

- **Form an interactive rating system of all the PMIS software packages available**

As this tool assumes that users have detailed knowledge of at least five software packages, the use thereof is limited. Individuals who are familiar with the project management environment won't necessarily be able to use the tool. A suggestion is that the tool be developed on a more general level, with no actual comparisons of the software packages. This universal tool can then be used to simply determine the exact needs of the user for a software package. In addition to this tool, an integrated rating system that compares all software packages available, according to the criteria, can be set up. The software can then be ranked according to its strengths in different areas. The user would then simply be able to input his/her requirements (obtained from the universal model) and select a software package from the list that fulfils these requirements.

As technology develops and processes change, the decision-making tool should also be adapted to incorporate these developments. The detailed documentation provided will enable the inclusion in the tool of developments beyond current boundaries.

## ***5.4 Personal Development***

The final year project was an excellent opportunity to apply the knowledge obtained over the course of the industrial engineering degree. Not only was the author's system perspective tested, but additional challenges like mastering the AHP method and Visual basic programming were also faced.

The project also posed many challenges to the author on a personal level – determination, self-discipline and independence were all crucial in completion of the project. It was necessary to adjust ways of thinking to have a systematic approach as well as focussing on the details of each step of the process followed. Receiving positive feedback on the tool from experts in the project management environment was a rewarding experience and made the journey worthwhile.



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## Appendix A – AHP calculations

The basic calculations involved in the Analytic Hierarchy Process (AHP) have been highlighted in *section 4*. A detailed explanation of what the method implies will be provided below:

$n$  Elements are compared to denote their relative priorities. A square matrix, of the order  $n$ , is formed. This matrix is called the reciprocal matrix as  $a_{ij} = 1/a_{ji}$  for all  $i \neq j$  and  $a_{ii} = 1$ .

$$A = \begin{pmatrix} 1 & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & 1 & \dots & \dots & a_{2n} \\ a_{31} & \dots & 1 & \dots & a_{3n} \\ \dots & \dots & \dots & 1 & \dots \\ a_{n1} & a_{n2} & a_{n3} & \dots & 1 \end{pmatrix}$$

A vector of ranking of priorities ( $w$ ) is developed next. This is done by multiplying together all entries in the reciprocal matrix and taking the  $n^{\text{th}}$  root of this product. Next the  $n^{\text{th}}$  roots are summed and the sum is used to normalize the vector elements to sum to 1:

$$n^{\text{th}}_1 = (1 \times a_{12} \times a_{13} \times \dots \times a_{1n})^{(1/n)} \quad \& \quad w_1 = n^{\text{th}}_1 / (n^{\text{th}}_1 + n^{\text{th}}_2 + n^{\text{th}}_3 + \dots + n^{\text{th}}_n)$$

This vector is of order  $n$ , such that it satisfies the following equation, and it is called the eigenvector (with  $\lambda_{\text{max}}$  being the eigenvalue):

$$Aw = \lambda_{\text{max}}w$$

For a consistent matrix  $\lambda_{\text{max}} = n$ , otherwise  $\lambda_{\text{max}} \geq n$  and the judgements are inconsistent. This  $\lambda_{\text{max}}$  can be determined by first multiplying the  $A$  matrix by the  $w$  vector, and then dividing this answer by the  $w$  vector.

$$\begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \dots \\ \lambda_n \end{pmatrix} = \begin{pmatrix} 1 & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & 1 & \dots & \dots & a_{2n} \\ a_{31} & \dots & 1 & \dots & a_{3n} \\ \dots & \dots & \dots & 1 & \dots \\ a_{n1} & a_{n2} & a_{n3} & \dots & 1 \end{pmatrix} \begin{pmatrix} w_1 \\ w_2 \\ w_3 \\ \dots \\ w_n \end{pmatrix} \quad \& \quad \lambda_{\text{max}} = \frac{1}{n} [\lambda_1 + \lambda_2 + \lambda_3 + \dots + \lambda_n]$$

Once  $\lambda_{\max}$  has been determined the consistency of the judgements can be determined. First the consistency index is calculated (CI), then the consistency ratio (CR) through using *table 9 – Saaty’s random ratings*.

$$CI = \frac{\lambda_{\max} \cdot n}{n-1} \quad \& \quad CR = \frac{CI}{R.I. \text{ value}}$$

Saaty argues that a  $CR > 0.1$  indicate that judgements are at the limits of consistency. But these values greater than 0.1 have to be accepted sometimes (Coyle, G. 2004).

In the case that there are different alternatives that have to be compared in terms of the A reciprocal matrix criteria, an additional step is necessary. Since the alternatives are being compared, the desired end result would be a weighting for each of the alternatives to enable the user to select the most appropriate alternative. In order to do this, matrices have to be set up for each criteria, within which the alternatives are compared to each other in terms of this criteria. Resultantly n more matrices are set up, with n sets of additional w vectors.

**Criteria 1:**

$$\begin{aligned} n^{th}_1 &= (1 \times a_{12} \times a_{13} \times \dots \times a_{1n})^{(1/n)} & \& \quad w_{1 \text{ alt } 1} = n^{th}_1 / (n^{th}_1 + n^{th}_2 + n^{th}_3 \dots + n^{th}_n) \\ n^{th}_2 &= (a_{12} \times 1 \times a_{13} \times \dots \times a_{1n})^{(1/n)} & \& \quad w_{1 \text{ alt } 2} = n^{th}_2 / (n^{th}_1 + n^{th}_2 + n^{th}_3 \dots + n^{th}_n) \\ \dots & & & \quad \dots \\ n^{th}_n &= (1 \times a_{12} \times a_{13} \times \dots \times a_{1n})^{(1/n)} & \& \quad w_{1 \text{ alt } n} = n^{th}_n / (n^{th}_1 + n^{th}_2 + n^{th}_3 \dots + n^{th}_n) \end{aligned}$$

**Criteria 2:**

$$\begin{aligned} n^{th}_1 &= (1 \times a_{12} \times a_{13} \times \dots \times a_{1n})^{(1/n)} & \& \quad w_{2 \text{ alt } 1} = n^{th}_1 / (n^{th}_1 + n^{th}_2 + n^{th}_3 \dots + n^{th}_n) \\ n^{th}_2 &= (a_{12} \times 1 \times a_{13} \times \dots \times a_{1n})^{(1/n)} & \& \quad w_{2 \text{ alt } 2} = n^{th}_2 / (n^{th}_1 + n^{th}_2 + n^{th}_3 \dots + n^{th}_n) \\ \dots & & & \quad \dots \\ n^{th}_n &= (1 \times a_{12} \times a_{13} \times \dots \times a_{1n})^{(1/n)} & \& \quad w_{2 \text{ alt } n} = n^{th}_n / (n^{th}_1 + n^{th}_2 + n^{th}_3 \dots + n^{th}_n) \end{aligned}$$

The process above is repeated in each matrix, but to obtain the combined result the following should be done:

$$\begin{aligned} w_{\text{alt } 1} &= (w_{1 \text{ original}} \times w_{1 \text{ alt } 1}) + (w_{2 \text{ original}} \times w_{1 \text{ alt } 2}) + (w_{3 \text{ original}} \times w_{1 \text{ alt } 3}) + \dots + (w_{n \text{ original}} \times w_{1 \text{ alt } n}) \\ w_{\text{alt } 2} &= (w_{1 \text{ original}} \times w_{2 \text{ alt } 1}) + (w_{2 \text{ original}} \times w_{2 \text{ alt } 2}) + (w_{3 \text{ original}} \times w_{2 \text{ alt } 3}) + \dots + (w_{n \text{ original}} \times w_{2 \text{ alt } n}) \end{aligned}$$

with  $w_{1 \text{ original}}$  being the weight of the first initial criteria compared.



## Appendix B – Visual Basic programming: AHP model

The analytic hierarch process (AHP), utilized in the development of the Decision-making tool, was implemented through Visual Basic programming in Excel. A large amount of coding was performed, but only the basic syntax will be explained below.



Figure 19 - HOME screen of Decision-making tool

Once the user clicks on the “Evaluate Criteria” button, an information screen pops up explaining how the tool works and what the user should do.

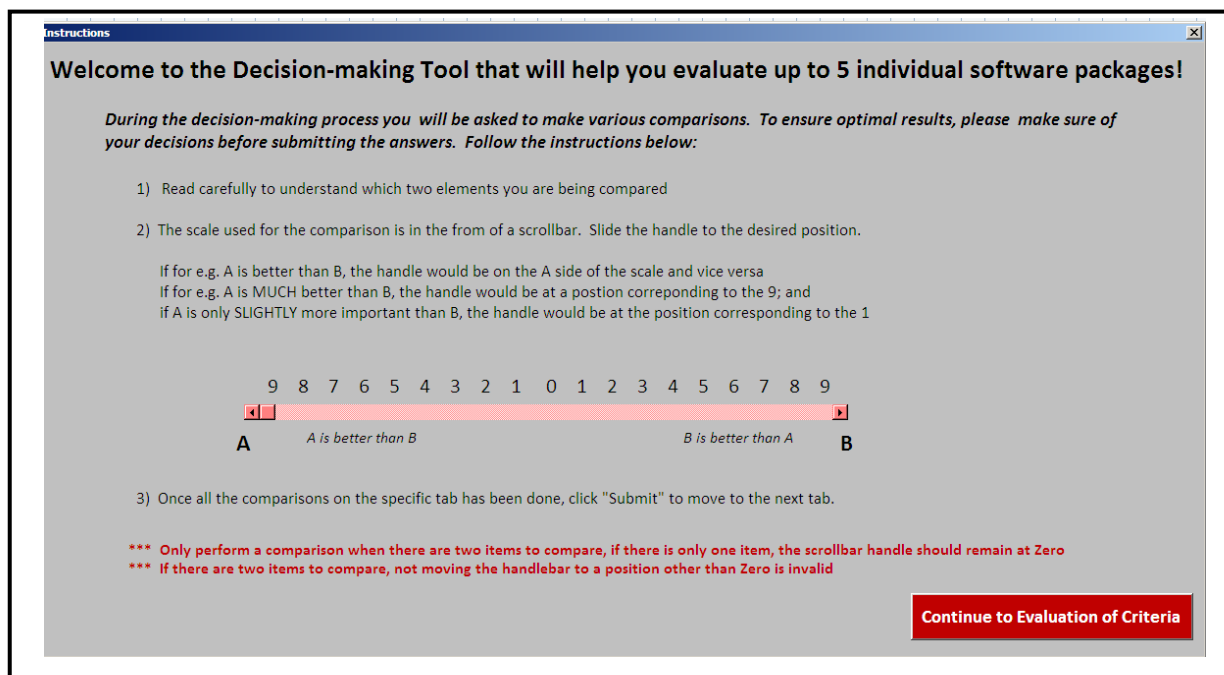


Figure 20 - Instructions screen of Decision-making tool

Once the “Continue to Evaluation of Criteria” button is clicked, the user can start with the evaluation of the criteria.

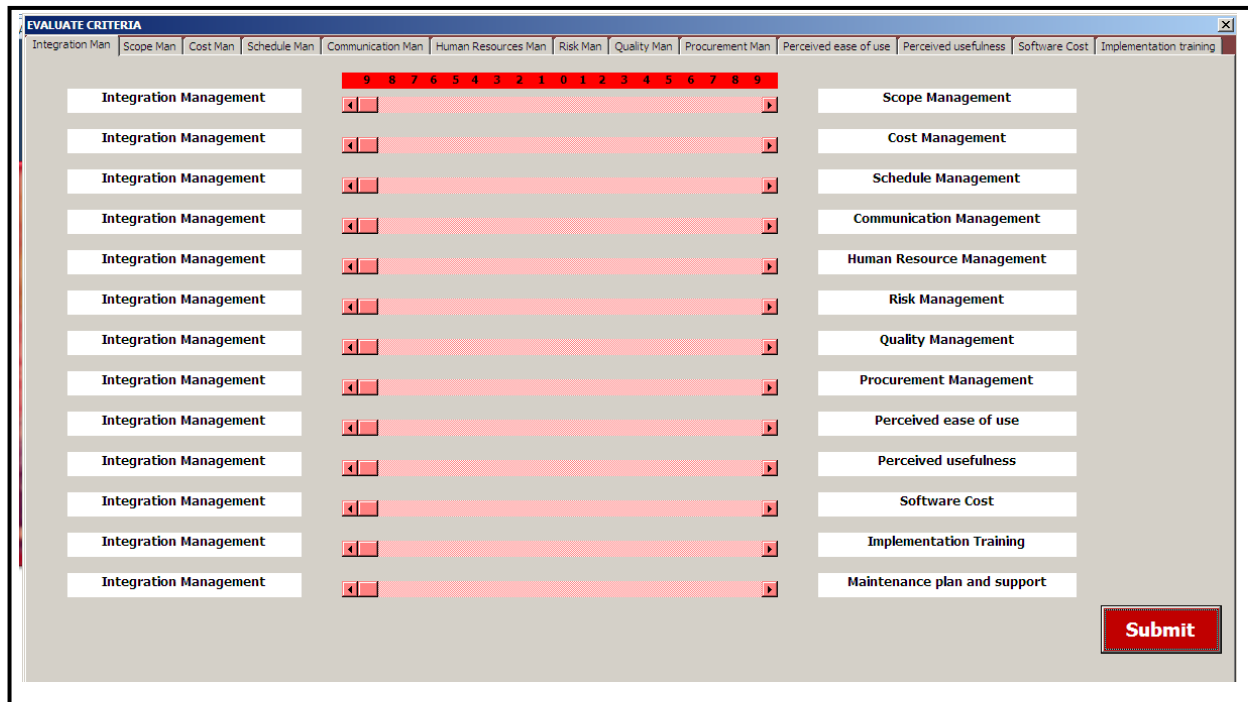


Figure 21 - Evaluation of Criteria

The user is prompted to move the handles of the scrollbar to the desired position and then clicks “Submit” to move to the next tab. The submit button triggers the Visual Basic coding shown in *Figure 22*. This enables the completion of the comparison matrix shown in *table 11*. This matrix is an integral part of the AHP method used to provide the final ranking of the criteria.

Table 11 - Comparison Matrix for criteria evaluation

	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	...
Criteria 1	1.00	9.00	9.00	9.00	9.00	...
Criteria 2	0.11	1.00				...
Criteria 3	0.11		1.00			..
Criteria 4	0.11			1.00		...
Criteria 5	0.11				1.00	...
.....	...	...	...	...	...	...

```

Private Sub CommandButton1_Click()

Dim c As Integer
Dim r As Integer
Dim i As Integer

c = 3 ' column
r = 2 ' row
i = 1 ' counter

'sets the first entry in the matrix to 1
Worksheets(3).Cells(r, c - 1).Value = "1"
Worksheets(3).Cells(r, c - 1).Interior.ColorIndex = 42

'the rating of the first to criteria
' Integration management is more important than scope management
If ScrollBar1.Value < 0 Then

'sets the entry in the matrix equal to the positional value of the scrollbar
    Worksheets(3).Cells(r, c).Value = Abs(ScrollBar1.Value)
'sets the corresponding cell to the value of the inverse of the positional value
    Worksheets(3).Cells(r + i, c - i).Value = 1 / Abs(ScrollBar1.Value)

    Else

' Scope management is more important than integration management
    If ScrollBar1.Value > 0 Then

'sets the entry in the matrix equal to the value of the inverse of the positional value
        Worksheets(3).Cells(r, c).Value = 1 / Abs(ScrollBar1.Value)
'sets the corresponding cell to the positional value of the scrollbar
        Worksheets(3).Cells(r + i, c - i).Value = Abs(ScrollBar1.Value)

        Else
'A zero rating isn't allowed
            MsgBox ("A zero was entered! Please move to another rating.")
        End If
    End If

End If

'move to the next column to compare integration management to cost management
c = c + 1
i = i + 1

```

**Figure 22 - Visual Basic coding for completion of matrix**

The process above is repeated for each scrollbar on all the tabs, until the “Submit” on the last tab is clicked. The user is then again navigated to the HOME sheet. Where he/she can then click on the “Evaluate alternatives” button. A userform asking the user to enter the software packages he/she would like to evaluate is shown, providing textboxes for these choices (*Figure 24*). Once the choices have been entered the user clicks the “initialize alternatives” button. This automatically sets up the comparisons between the different packages to be evaluated, by entering these choices into corresponding textboxes in the tabs to come (*Figure 23*). The visual basic coding performed in *Figure 21* is then repeated as the user moves the scrollbar handles to the desired positions.

**EVALUATE ALTERNATIVES**

HOME | Integration Man | Scope Man | Cost Man | Schedule Man | Communication Man | Human Resource Man | Risk Man | Quality Man | Procurement Man | Perceived Ease of use | Perceived usefulness | Software Cost | Training | Maintenance

Please insert the Alternatives you would like to evaluate here: (5 max)

Alternative 1: Diary / Dagboek (FIXED)

Alternative 2: Primavera project planner

Alternative 3: Ms project

Alternative 4: [Empty]

Alternative 5: [Empty]

Alternative 6: [Empty]

**Initialize Alternatives**

Figure 24 - Initialize Alternatives

**EVALUATE ALTERNATIVES**

HOME | Integration Man | Scope Man | Cost Man | Schedule Man | Communication Man | Human Resource Man | Risk Man | Quality Man | Procurement Man | Perceived Ease of use | Perceived usefulness | Software Cost | Training | Maintenance

INTEGRATION MANAGEMENT allows managers to keep a broad overview of the project and its strategic focus, and also allows them to not lose sight of the detail of single activities to be performed. (Project Plan Development, Project Plan Execution, Overall change control)

	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	
Diary / Dagboek	◀																			
Diary / Dagboek	◀																			
Diary / Dagboek	◀																			
Diary / Dagboek	◀																			
Diary / Dagboek	◀																			
Primavera project planner	◀																			
Primavera project planner	◀																			
Primavera project planner	◀																			
Primavera project planner	◀																			
Ms project	◀																			
Ms project	◀																			
Ms project	◀																			
	◀																			
	◀																			
	◀																			

**Submit**

Figure 23- Ranked initialized alternatives, by performing the three comparisons

The only difference in the coding for this userform is the fact that the default values of the rankings are zero, so if a ranking can't be performed a zero is present in the corresponding matrix.

## Appendix C – Evaluation Questionnaire



*Expert evaluation and opinion is the final step in the development methodology of the Decision-making tool for the selection of Project management Information System (PMIS) Software. The information obtained from this evaluation form will be used strictly for academic purposes. Please be sure to answer all the questions provided in a directly, as your opinion is valued and suggestions made will be considered in the finalization of the tool.*

- 1. Were the instructions provided in the tool clear and unambiguous to such an extent that the tool could be used effortlessly?**

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- 2. Did the scrollbar-format of the comparisons allow adequate rating of the criteria, or would you recommend another approach?**

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- 3. Does the evaluation of five software packages provide enough room to do a comprehensive evaluation?**

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**4. Does the “Summary of results” screen provide enough information to ensure the credibility of the conclusions made? What additional measures would you like to see before making a decision?**

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**5. Do the criteria, used as basis for the tool, provide an inclusive view of the different features important in Project Management Information Systems? What additional features, if any, do you think should be evaluated?**

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**6. Do you think the tool could be implemented in the project environment to enable project managers to make decisions on the most comprehensive software package?**

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**7. What recommendations do you have for additional features in the tool that would make it more comprehensive?**

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