AIMMS User's Guide - AIMMS and Analytic Decision Support

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Part I

Introduction to AIMMS

Chapter 1

AIMMS and Analytic Decision Support

What is AIMMS*?*

The acronym AIMMS stands for

Advanced Integrated Multidimensional Modeling Software.

AIMMS offers you an easy-to-use and all-round development environment for creating fully functional *Analytic Decision Support* (ADS) applications ready for use by end-users. The software is constructed to run in different modes to support two primary user groups: *modelers* (application developers) and *end-users* (decision makers). AIMMS provides the ability to place all of the power of the most advanced mathematical modeling techniques directly into the hands of the people who need this to make decisions.

This chapter

This chapter is aimed at first-time users of the AIMMS modeling system. In a nutshell, it provides

- a description of the characteristics of Analytic Decision Support (ADS) applications,
- an overview of AIMMS as an ADS development environment, and
- some examples of its use in real-life applications.

1.1 Analytic decision support

Analytic decision support

Analytic decision support applications are usually interactive decision support systems with a strong internal emphasis on *advanced computational techniques* and that pertain to extensive problem analysis on the outside. They typically

- represent a complex and large-scale reality,
- organize and use large amounts of interrelated multidimensional data based on corporate and market information,
- use advanced arithmetic manipulations and/or optimization tools to find a solution,
- apply analytic techniques or perform "what-if" experiments to assess the consequences of making a decision under different scenarios,
- employ advanced visualization techniques to provide an insight into the solution and/or the problem complexity, and

- are subject to permanent change due to a changing reality or improved insights.

Increasing market need

With the world becoming daily more complex, decision makers around the world are in search of advanced decision support tools. Such tools can help them get insights into their decision problems, monitor the consequences of previous decisions, and help them take new decisions on a regular basis. There is substantial evidence that analytic decision support applications are becoming increasingly popular throughout industry and government, as the improved decisions generated by ADS applications imply increased profit and/or efficiency.

Supporting developments

A number of major developments in the last decade have increased the suitability of analytic decision support to tackle such problems:

- corporate databases are becoming increasingly mature and allow a quick follow-up to market changes,
- the increasing speed of PCs allows interactive use, even with complex applications,
- the visually attractive and convenient presentation using the standardized and user-friendly Windows environment makes complex processes more accessible to decision makers, and
- the availability of standardized and improved optimization tools allows ADS application developers to specify the problem without having to specify a complicated algorithm to solve it.

Applicable problem areas

Analytic decision support lends itself to a wide variety of decision support problems. The following list provides a non-exhaustive overview of the areas in which analytic decision support is applicable:

- strategic and tactical planning of resources in industry and government,
- operational scheduling of machines, vehicles, product flow and personnel,
- strategic evaluation studies in the areas of energy, environment, forestry and social policies,
- financial decision-making to support asset-liability management,
- economic decision-making to control market clearing and economic development, and
- technical decision-making to support the design and calibration of systems and objects.

1.2 AIMMS as an ADS development environment

AIMMS as ADS development environment

As an ADS development environment, AIMMS possesses a unique combination of advanced features and design tools which allow you to build complex ADS applications which are easily maintainable—in a fraction of the time required with conventional programming languages. Figure 1.1 provides a top-level overview of the components available in AIMMS.

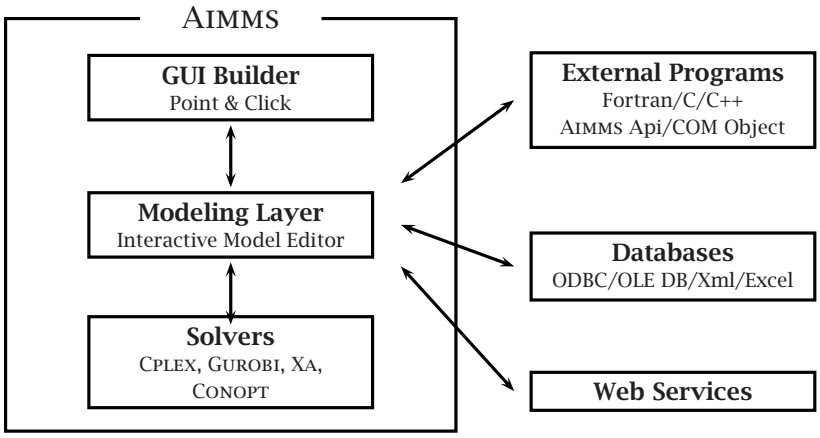

Figure 1.1: Graphical overview of AIMMS components

Multidimensional modeling language

The multidimensional modeling language in AIMMS offers a powerful index notation which enables you to capture the complexity of real-world problems in an intuitive manner. In addition, the language allows you to express very complex relationships in a compact manner without the need to worry about memory management or sparse data storage considerations. The combined declarations and procedures using these multidimensional structures can be organized, edited and displayed using an advanced interactive model editor.

Optimization modeling

One of the outstanding features of AIMMS is the capability of specifying and solving linear and nonlinear constraint-based optimization models. Using the same compact and rich notation available for procedural statements, symbolic constraints can be formulated in a simple and concise manner. With only a single instruction, an optimization model can be transferred to, and solved by, world- class solvers such as CPLEX, GUROBI and CONOPT.

Advanced language features

Selected advanced AIMMS language features include:

- a rich set of mathematical, statistical and financial functions,
- a powerful combination of (automatically updated) multidimensional definitions and procedural execution,
- the ability to easily express time-based models through the use of calendars and horizons, including support for rolling horizons with automatic aggregation and disaggregation, and
- the ability to associate units of measurement with model identifiers assuring unit consistency within expressions.

Integrated GUI builder

In addition to its versatile modeling language AIMMS offers an integrated tool for constructing a custom graphical user interface (GUI) for your decision support application. End-user screens can be created in an easy point-and-click manner, and can include such common graphical objects as tables, charts and curves, all closely linked to multidimensional identifiers in your model. Included, amongst other more advanced objects, are a Gantt chart for visualizing time-phased planning/scheduling applications, and a network flow object for visualizing two-dimensional maps and flows.

Advanced GUI tools

To support you in creating complete end-user interfaces in a quick and maintainable fashion, AIMMS offers the following advanced tools:

- the *template manager* enables you to create a uniform look and feel by allowing common objects (such as headers, footers, and navigation buttons) to be placed on hierarchically organized templates which can be inherited by multiple pages,
- the *page manager* allows you to specify a natural page order, with which you can guide an end-user through your application by adding special page manager-driven navigation controls to templates or pages,
- the *menu builder* enables you to create customized end-user menus and toolbars to be added to your templates and pages,
- the *identifier selection wizard* assists you not only in selecting complete model identifiers, or slices thereof, for graphical display, but also in quickly linking data from various page objects.

Integrated case management

Case management forms an important part of any decision support application, and enables end-users to run the model with varying scenarios. AIMMS also offers advanced data management, which allows you to create data categories for holding blocks of related data (for instance topology data, or supply and demand scenarios). Data sets associated with these data categories can be combined to form a single case, and thus can be shared by more than one case. In addition, to perform an extensive what-if analysis, you can select a large number of cases and run them in batch mode overnight.

Database connectivity

As data form the life blood of any decision support application, AIMMS offers extensive facilities to link your application to corporate databases using ODBC or OLE DB. Specialized wizards help you relate columns in a database table with the corresponding multidimensional identifiers in your AIMMS model. Once you have established such relationships, you can specify straightforward read and write statements to transfer data to and from the database.

Linkages to other applications

To facilitate the re-use of existing code, or to speed up computationally intensive parts of your application, AIMMS allows you to execute external procedures or functions in a DLL from within your model. External functions can even be used within the constraints of an optimization model. In addition, AIMMS offers an Application Programming Interface (API) as well as a number of COM interfaces which enables you to use your AIMMS model as a component from within an external application, to communicate data in a sparse fashion, and to execute procedures written in AIMMS.

Web services

Any AIMMS project can be configured to be exposed as a web service. This means that you can invoke a set of AIMMS procedures in your project from anywhere on the Internet, provided that you have a client application that features the calling of web services by the use of SOAP requests. Your client application does not necessarily have to adhere to the default AIMMS XML data format: by using so-called *attachment arguments* in your procedures, you can send your data in the format of your choice, provided that a mapping can be specified between this data and the identifiers in your AIMMS project.

User management

The AIMMS system has integrated facilities to create a database of end-users and link this database to one or more AIMMS-based applications. The end-user database contains information on the level of authorization of all end-users within an application. Through these authorization levels you can specify whether an end-user is allowed to access case data, view pages, modify data, and execute particular parts of the model.

Protecting your investment

The development of a professional decision support application usually represents a considerable investment in time and thus money. AIMMS offers facilities to protect this investment and to prevent unauthorized use of particular applications. Your project and the source code of your model can be shielded by using a security scheme based upon your own unique customer code. In addition, AIMMS allows you to create your own application-specific VAR licenses to restrict either the number of (concurrent) users or the lifespan of a license.

AIMMS comes complete with extensive documentation in the form of three books: *Extensive documentation*

- a User's Guide to explain the overall functionality and use of AIMMS,
- a Language Reference giving a detailed description of the AIMMS language, and
- a Modeling Guide introducing you to both basic and advanced modeling techniques.

All of these books are available in hard copy as well as in electronic form. In addition, each system comes complete with a collection of example applications elucidating particular aspects of the language and end-user interface.

1.3 What is AIMMS used for?

AIMMS is used worldwide as a development environment for all kinds of analytic decision support applications. To give you some insight into the areas in which AIMMS has been used successfully, this section describes a small subset of ADS applications, namely those in which Paragon Decision Technology itself has been involved (sometimes actively, sometimes at a distance). AIMMS *usage*

The crude oil scheduling system covers the allocation, timetabling, blending and sequencing activities from the waterfront (arrival of crude ships) via the crude pipeline to the crude distillation units. The result is a schedule for the discharge of crudes, the pipeline and the crude distillers (sequencing, timing and sizing of crude batches), plus planning indications on the arrival of new crude deliveries. Enhanced decision support includes improved and timely reaction to changes and opportunities (e.g. distressed crude cargoes, ship and pumping delays, operation disturbances) and improved integration between crude acquisition and unit scheduling. *Crude oil scheduling*

The strategic forest management system allows foresters to interactively represent large forested areas at a strategic level. Such a flexible decision framework can help in understanding how a forest develops over time. The system also allows one to explore forest management objectives and their trade-offs, plus the preparation of long-term forest management plans. *Strategic forest management*

The transport scheduling system for breweries allows end-users to interactively steer the flow of products through all phases of the brewing process from hops to bottled beer. The application can be used either in an automatic mode where the flow of products is totally determined by the system, or it can be used in a manual mode where the user can set or alter the flow using the Gantt chart. The system can also be used in a simulation mode to test the response of the entire brewery to varying demands over a longer period of time. *Transport scheduling in breweries*

Risk management

The risk management system for market makers and option traders has a wide functionality including the theoretical evaluation of derivatives, an extensive sensitivity analysis, the display of risk profiles, the generation of scenarios, the generation of price quotes and exercise signals, minimization of risk exposure, the calculation of exercise premiums and implied data (volatilities and interest rates), plus an overview of all transactions for any day.

Refinery blending

The refinery blending system is a blend scheduling and mixture optimization system. It is able to handle the complete pooling and blending problem, and optimizes both the blend schedules and the mixes under a complete set of (real- life) operational constraints. The system offers user flexibility in that the user can decide upon the number of components, fuel mixtures, long versus short term scheduling, and stand-alone versus refinery-wide scheduling.

Catalytic cracker support

Catalytic cracking refers to a refining process in which hydrocarbons are converted into products with a lower molecular mass. The catalytic cracking support system has three major components: (a) a graphical user interface consisting of interactive pages, validation routines, plus reporting and data handling facilities, (b) the model equations, including those for heat, yields, product properties, economics, and (c) an on-line process control environment with an off-line mode in which multiple studies with differing parameters and variables can be compared.

Data reconciliation

Data reconciliation is the process of making the smallest possible adjustment to a collection of measurements within a system such that the adjusted data values satisfy all the balance constraints applicable to the system. In the particular application in question, data reconciliation was applied to a chemical process, requiring that the relevant mass, component and thermodynamic balances be satisfied for all units within the system.

1.4 Comparison with other ADS tools

ADS development tools

There are several tools available in the market that can, in principle, be used as a development environment for analytic decision support applications. The most well-known are:

- spreadsheets,
- databases,
- programming languages, and
- multidimensional modeling languages.

Comparison

Spreadsheets, databases and programming languages all have their strengths as development tools for a large variety of applications. Advanced modeling systems such as AIMMS should not be seen as a complete replacement for these three development environments, but rather as a tool specifically designed for developing analytic decision support applications. The following paragraphs outline the advantages and disadvantages of each of these tools with respect to their suitability as a development environment for ADS.

Spreadsheet

If you are a fervent spreadsheet user, it seems only natural to build your ADS applications on top of a spreadsheet. However, this may not always be the best choice. A spreadsheet approach works well when:

- you don't need to specify a large number of relationships,
- there are only a few procedures to be written,
- the size of your data sets remains stable,
- the need to add or remove dimensions is limited, and
- you will carry out all the maintenance activities yourself.

When this is not the case, the AIMMS approach may offer a suitable alternative, because:

- specifying a large number of (often similar) relationships can be done using indexed identifiers and definitions for these identifiers,
- adding and managing both internal and external procedures is a straightforward task using the AIMMS language and model editor,
- modifying the size of any (index) set in AIMMS is natural, as there is a complete separation between structure and data,
- adding or removing dimensions takes place in the language and does not require the copying of cells or creating more worksheets, and
- not only can the structure of the entire model be made visible, but also the model editor allows someone else to create customized overviews of model structure for further maintenance.

Database

If you are a fervent database user, it seems only natural to build your ADS applications using a language such as Visual-C/C++, Delphi or PowerBuilder on top of a database such as Microsoft Access, and Oracle. However, this may not always be the best choice. Using a database approach works well when:

- all of the data for your application is already stored in a database,
- the end-user GUI requires relatively little programming,
- speed of data transfer is not crucial,
- there is a limited need to link to external solvers, and
- maintenance is carried out by yourself or another experienced programmer.

When this is not the case, the AIMMS approach may offer a suitable alternative, because:

- data transfer works well not only for data stored in a database, but also for data in ASCII and case files,
- the compact modeling language combined with the point-and-click GUI builder minimizes the amount of programming required,
- internal data transfer during (the sparse) execution is extremely fast and does not require the repeated transfer of data between external programs,
- standard links to solvers are built into AIMMS, and
- compact and simple data structures on the one hand, and point-and-click GUI construction on the other hand, help ease maintenance.

Programming language

If you are a fervent programmer, it seems only natural to build your ADS applications using languages such as C/C++ or Fortran. However, this may not always be the best choice. Using a programming language works well when:

- efficient data structures require relatively little effort,
- there are many procedures to be written,
- development times are not crucial,
- there is a limited need to link to external programs, and
- maintenance is carried out by yourself or another experienced programmer.

When this is not the case, the AIMMS approach may offer a suitable alternative, because:

- the standard multidimensional data structures in AIMMS require no special effort, and are efficient since all data storage and data manipulations are carried out in a sparse manner,
- writing procedures in AIMMS is at least as easy as in a programming language: their control structures are similar, and AIMMS has the advantage that no special data structures are required,
- specially developed tools for the construction of programs and GUIs minimize development time,
- standard links to databases and solvers are built into AIMMS, and
- compact and simple data structures on the one hand, and point-and-click GUI construction on the other, help to ease maintenance.

Comparison summary

Table 1.1 summarizes the most important issues that determine the suitability of the above development tools as a development environment for ADS applications. The table focuses on

- the initial development effort to create an ADS application,
- the subsequent time required for product maintenance (extremely important due to the permanently changing nature of ADS applications), and
- the openness of the environment with respect to data entry formats and third party components.

A '+' indicates that the product scores well in this area, a '–' indicates that it does not perform well in this area.

Building tool	**Development time**	**Maintenance time**	**Openness**	**Suitability as an ADS tool**
Spreadsheet	+	––	++	+
Database	+	–	+	+
Programming language	–	–	++	++
AIMMS	++	++	+	++

Table 1.1: Comparison of ADS development tools

Developer quote

In support of the comparison in Table 1.1, the following quote, from one of our customers, clearly expresses the advantages of using AIMMS as a development environment for ADS applications.

> *"Software development requires four tasks: definition, design, implementation and testing. When using* AIMMS*, the focus is on definition. The result is an implementation which can be immediately tested. I now spend the majority of my time working on the customer's problem, and verifying that we have got the requirements correct. My job is now that of an applications engineer, rather than a software engineer. One of our customers stated that our recent project with them (using* AIMMS*) was the first software project in their history not to have a single 'Software Functionality Problem Report' generated."*