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Biography: Dr. Donald E. Shobrys has 20 years experience in the design, development, and implementation of integrated planning and scheduling solutions. His career started at Exxon. He then spent 14 years with Chesapeake Decision Sciences, Inc., where he worked with over 70 companies worldwide and ultimately had responsibility for leading company operations. In addition to refining, the industries he has worked in include chemicals, consumer packaged goods, pulp and paper, metals, and semiconductors. He has also written and presented extensively on supply chain management and advanced planning and scheduling.

Dr. Shobrys helps client companies improve supply chain management processes, evaluate relevant technology, and successfully implement it. He is also on the Board of Directors of Supply Chain Consultants, Inc. He has engineering degrees from MIT and Northwestern, and a Ph.D. in Operations Research from Johns Hopkins.

The History of APS

"APS….is a new technology….revolutionary breakthrough…..greatest innovation since the assembly line."

Given this sample of comments directed towards APS, it may surprise some that companies have benefited from APS techniques for over 30 years. APS is a collection of well established solution methods made more accessible and effective by incremental improvements in a wide range of technologies. This view may not have the sizzle of the opening comments, but it means that an experience base exists that companies trying to implement APS can draw on.

There is a wide range of diversity in the perspectives that consultants, vendors, market analysts, and customers have on APS. This diversity stems from a number of factors.

- Business systems (legacy, MRP II, and ERP) are transaction based. Much of the analysis that occurs in APS is above the transaction level of detail. The systems architecture of these systems limited planning and scheduling capabilities to MRP, CRP, etc. until relatively recently. APS is new to many of the people that have worked with transaction based systems.
- Much of the past work with APS was done with in-house development. The plethora of vendors and products is a relatively new phenomenon.
- Many major consulting firms did not become active in this area until a well defined group of products and vendors emerged.

- The people currently covering APS come from a wide range of industries. APS penetrated different industries at different points in time. The timing was greatly influenced by when companies were able to manage the data needed to describe their business. The process industries saw early use, while use in discrete manufacturing occurred later.
- Vendors, many of whom are using similar solution methods, have differentiated themselves with creative descriptions and enthusiastic claims.
- Contributions to APS have come from APICS, artificial intelligence, computer science, decision support systems, industrial engineering, logistics, management science, operations research, and production operations management among others. Each area uses it's own vocabulary. In addition to creating confusion (even "planning" and "scheduling" do not have standard meanings), this also creates opportunities to reinvent the wheel.

APS has evolved from continuous improvement coupled with the synergistic incorporation of new technologies, which is a theme that John Layden illustrated in his article on the evolution of scheduling logic in the previous issue of APS (1). Let us step through this evolution, as seen by someone who has been active in this area for almost 20 years. This narrative is not totally comprehensive as it is heavily influenced by my own experiences. One key source of bias is that virtually all of the 60+ companies I have worked with have significant complexity and cost in their manufacturing operations. The projects focused in on manufacturing, or took an integrated view across procurement, manufacturing, and distribution.

APS BC (Before Computers)

Some key concepts imbodied in APS predate the existence of computers. One is the Gantt chart, which lets people view schedules and interactively update them. This concept came into being around the turn of the century, and since then people have created and maintained Gantt charts with colored rubber bands, blocks, pegs, and 3" by 5" cards. The notion of using mathematical models to solve planning problems occurred at least as early as the 1940's, when both the US and Soviet Union had people manually applying a new optimization technique called linear programming to solve logistics problems related to the war effort.

The 1950's and Early 1960's – Computers Become Available

The evolution of APS became linked to evolution of the computer. In the late 1950's and early 1960's, large companies started leasing computer time and then acquiring computers. Computers were used to look at a portions of planning problems, like optimizing around a few key material or energy balances subject to product demand and capacity constraints, or finding the lowest cost recipe for a batch of product. Linear programming was commonly used, and the models were the equivalent of small spreadsheet applications (40 to 60 balance equations and 60 to 100 decision variables).

Two of the first companies to provide optimization based planning tools were founded during this period (Bonner and Moore in 1957 and Haverly Systems in 1962).

A definition of optimization may help avoid confusion. A strict definition of an optimization technique is a solution method that is guaranteed to find the "best" answer to a problem, and is smart enough to know when it gets there. In addition, you usually can get a good idea of how long it will take to get there.
In today's common usage "optimization" is often applied to solution methods that simply look for improvement, and are not guaranteed to find the best solution. The techniques that simply look for improvement are also called heuristics, and they are often used with time limits or tolerances ("Give me the best solution you can find in ten minutes"). Confusion occurs when these definitions of optimization are used interchangeably, which sometimes occurs within a single sales presentation. Linear programming meets the strict definition of optimization, recognizes constraints, and often uses the economics around a problem (costs and revenues) to define the "best" solution.

Mid 1960's through Early 1970's – Applications Evolve

As computers continued to evolve, people were able to take a more complete view of planning problems. Tools evolved that considered an entire manufacturing site and identified the slate of operations that minimized cost or maximized profit. Some companies connected the computers and programs that optimized product recipes to the production equipment. People also started looking at distribution problems, while companies like Exxon built tools that gave an integrated view across feedstock acquisition, manufacturing, and distribution.
The size of production applications went from hundreds of decision variables in the early 1960's to thousands of decision variables around 1970, to tens of thousands in the late 1970's. Solution techniques like linear programming were also extended to address more difficult problems, like the yes/no decisions associated with adding production capacity, selecting production technology, or picking sites for distribution centers.

These applications often occurred in the process industries and at a planning level. Large refining and chemical companies like Amoco, Chevron, Exxon, Marathon and Shell were aggressive about purchasing large computers and placing them at manufacturing sites. These companies were also aggressive about data capture and integration. The business motivation was there because optimization techniques fit well with many of their manufacturing processes, and with the characteristics of their distribution networks.

Many companies developed their own tools internally for mainframe computing environments. The programs that solve linear programming problems were available from a number of sources. A classic example was MPS (later MPSX) from IBM. Some companies used existing solvers while others wrote their own. Many companies wrote code around solvers to manage the problems they would address. This custom code would collect data, organize it in the form needed by the optimizers, control the solution process, and then generate the reports that users wanted. Assembler, Cobol, FORTRAN, and PL/1 were all used as development languages. These programs ran in batch mode, and user interfaces were initially line editors and then full screen editors. Exxon even published a book about their planning system (2).

Computer based tools were developed to address elements of scheduling problems. Simulation was being used for design of manufacturing and distribution facilities. Simulation tools were also developed to calculate the consequences of schedules in terms of capacity and material consumption. Logic was developed for specific scheduling issues like sequencing activities or calculating lot sizes. Much of this was developed in-house using user interfaces and modes of interaction similar to those for planning.

Simulation based scheduling tools started to emerge in the 1970's. Pritsker was one early source. Another early product was CPPS from IBM, which started as a batch product and was converted to interactive use around 1975.

The major refining companies were active users of planning tools in the 1970s. Other industries were also actively using planning and scheduling applications. A series of internally developed tools had an integral role in the evolution of Federal Express (3). By the early 1980's Kelly Springfield, a tire manufacturer, and Philip Morris had planning and scheduling applications in place. Paper companies like St Regis and International Paper were also either implementing tools or had applications in place.

The 1980's – The Business Press Discovers APS

Creative Output Inc., led by Eli Goldratt, which was featured in the September 5, 1983 issue of Fortune Magazine. Their product, OPT, applied a series of debottle necking algorithms in a batch processing mode. A very aggressive sales organization capable of generating million dollar deals had captured a number of customers in discrete manufacturing. Creative Output withdrew from the market shortly after a legal dispute with M&M/Mars over expected benefits (4). Eli Goldratt expanded his Theory of Constraints philosophy and went on to a career as a well published manufacturing guru, while Creative Output alumni are still active in the APS arena with i2. The same Fortune article briefly mentioned Numetrix Decision Science, which later split into Numetrix and Chesapeake Decision Sciences, two early APS suppliers with interactive products that provided memory resident analysis.

During this time articles on the use of APS solution methods and products started appearing in Business Week, the Chicago Tribune, the New York Times, the Wall Street Journal, and the Washington Post. The biggest flurry of media attention centered on an algorithm developed by a young AT&T researcher named Narendra Karmarkar in 1984. This new technique for solving linear programming problems got front page treatment, and was aggressively promoted by AT&T as "a real breakthrough" that was "designed to solve …previously unsolvable problems." AT&T bundled the algorithm with one of their computers, priced it at $8.9 million, and called the product Korbx (5,6).

Rumor has it that only one sale of Korbx occurred, but virtually all modern LP solvers have incorporated solution methods based on Karmarkar's algorithm.

The 1980's also saw the introduction of personal computers and spreadsheets. Spreadsheets were a two edged sword. On the positive side, they introduced people to the use of interactive analysis for forecasting, planning and scheduling. In a number of companies with existing mainframe applications, users built simple approximations of the existing tools and migrated to them. Unfortunately, when mainframe applications died so did the infrastructure that was collecting and validating the underlying data. Many of the refining companies that were aggressive developing planning systems during the 1970s went backwards with respect to data quality and tool accuracy in the late 1980's.

In the mid 1980s many major chemical companies realized that they were becoming limited in their ability to offset decreasing margins with improvements to the manufacturing process, and started examining their supply chain activities. BASF, DOW, Du Pont, and Rohm and Haas all started initiatives with planning and scheduling tools. They used products, tools they developed in house, or products that they modified internally. The intent was to have a true supply chain focus, rather than implement point solutions for functional silos like manufacturing or distribution.

The MRP II vendors like Marcam and Datalogix responded by marketing their capabilities to the process industries. Some companies delayed development of APS tools while they determined whether their planning and scheduling needs would be met with MRP and CRP. By the early 1990's many major chemical companies had selected an APS vendor.

Many major airlines also had implemented sophisticated planning and scheduling systems. The AADT group of American Airlines (now Sabre Technologies) started building those systems for other airlines.

The late 1980's also saw the emergence of artificial intelligence (AI) and expert systems. Companies were formed to apply AI to production planning and scheduling, and investors and clients expected that once intractable problems would become tractable. Du Pont and IBM were aggressive in combining AI with existing technologies and generating applications. IBM developed a dispatch scheduling system (7). Du Pont co-sponsored the addition of expert system capabilities to the optimization, simulation, and heuristics in the MIMI product from Chesapeake Decision Sciences, Inc. The expert system was used in conjunction with those other capabilities for data validation, incorporation of heuristics, solution interpretation, and making planning output useful for scheduling (8). Real time expert systems products like G2 also emerged at this time. The AI community made subsequent contributions with techniques like constraint based programming and genetic algorithms.

Expectations for AI had been set at an extremely high level. There was disappointment over what AI ultimately delivered, and unfortunately some people still view it as a failure. Many AI developers felt that their technology should only be applied in a pure fashion, so a lot of time and effort went into recreating functionality developed with other tools in the 1960's and 1970's.

The late 1980's also brought graphical user interfaces. Vendors had tried combining a Personal Computer and it's native graphics capability with an additional card containing a second processor for more computational horsepower. With the emergence of OSF MOTIF as a graphics standard, interactive graphical user interfaces became a standard part of forecasting, planning, and scheduling tools. This technical innovation had the greatest impact on the marketability of APS. There was also a flurry of tools with animation capabilities that sparked an interest in using of animation for scheduling. While animation has proved useful for design and dispatching applications, interest in animation for scheduling has not been sustained.

The 1990's – The APS Market Booms and Products Proliferate

Consumer packaged companies (CPG) started to become more active with APS in the early 1990's. Although there were some early adopters in this market segment, this industry as a whole was slower in using APS techniques. This is true of the paper industry as well, despite the sophisticated approaches used for trim problems. A number of companies who had been able to implement relatively simple tools for manufacturing scheduling discovered they needed more sophistication to cover the number of SKU and location combinations they found in their distribution networks.

Many of these companies also made similar discoveries with respect to their forecasting capabilities. The simple tools used to generate revenue forecasts choked on the number of SKU and location combinations needed to provide the level of detail required for operational decisions.

The early 1990's also saw the introduction of imbedded SQL capabilities, allowing APS tools to interact more dynamically with relational databases. The availability of increasing amounts of computer horsepower at decreasing costs led to new solution methods, and expanded the size and complexity of the problems that were being addressed. Genetic algorithms became available. They grow multiple solutions at once, combining the best features of existing solutions to create new ones. People started using simulated annealing, which will let a solution get worse in the hopes that this will create pathways to even better solutions. Production tools with millions of decisions variables were developed, although if you create an application of this size, you are probably making your life more painful than it has to be.

The 1990's have also seen a proliferation of APS vendors across a wide range of industries. Companies like i2 and Fastman (Premier's previous name) made inroads with electronic assembly, metals, and discrete manufacturing. I2's most dramatic impact on the APS space was the introduction of brand oriented marketing and sales strategies to what had previously been a technology driven niche market, and soon they were in a race with Manugistics for revenue growth.

The reaction of the marketplace i2, Manugistics, and others caught the attention of the large consulting firms. They started allocating resources to products based on market success and client preferences, kicking off a slew of relationships.

APS has presented 2 major challenges to the larger consulting firms. It requires depth of application expertise, and the personnel development policies at many of these firms were traditionally focused on producing IT generalists who could manage and bring in major engagements. Annual staff turnover of 25% or more also hindered development of technical depth. In addition, rigid application of standard project methodologies can be a very ineffective way to implement APS. Domain expertise is still needed to determine how to use the project methodology effectively.

The mid 1990's also saw vendors move user interfaces to a Microsoft Windows environment via client server architecture, or move entire applications to a Windows NT environment. In addition to providing more intuitive user interfaces and reporting capabilities, this moved APS applications into an environment where low cost computer horsepower was increasing at an amazing rate.

The mid 1990's also saw APS use on the part of the semiconductor companies. These companies are extremely aggressive in changing production technology, and have products with extremely short life cycles. This makes it challenging to provide the knowledge base required for APS applications, particularly at the scheduling level. Initial use of APS techniques paralleled that in the process industry as companies like Harris Semiconductor (9), IBM, Intel (10), and Texas Instruments (11) started by developing internal solutions, with mixed results.
Finally, in the mid 1990's, APS captured the attention of the ERP vendors. Key attractions were the deal sizes generated in APS sales, a cost per user far above that received by the ERP vendors, and the rapid growth of the APS market. This kicked off an initial round of partnerships followed by acquisitions and internal development efforts by the ERP vendors. Some feel that, because of their size, the ERP vendors will ultimately dominate APS. If size was the driving factor, then IBM and AT&T should be dominating this space right now.

This brings us to the present, where we have the Internet, collaborative planning, the role of the supply chain in product design, and a host of other intriguing topics. I am sure that I have missed other companies that contributed to the development of APS. My apologies to any pioneers that I have omitted.

This brief narrative does show how collective improvements across a number of areas have culminated in what we know today as APS. The improvements have reduced the barriers to entry for companies seeking to improve their supply chain management functions. Compute power is much cheaper, data can be moved more readily, software products preclude the need for internal development, and the supply of consulting resources continues to expand. Companies seeking to play in this arena still have to address the major challenges associated with implementation:

- developing the infrastructure to provide integrated data of adequate quality,
- developing the internal skills to use these technologies effectively, and
- instilling the discipline to actively use these tools.

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