

Enterprise-wide Requirements & Decision Management

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Abstract. Decision-making is one of the most fundamental processes contributing to a corporation's success, yet in many companies, decisions are often characterized as ad-hoc events without a clear linkage to supporting information, tradeoff studies, or clearly stated rationale. Furthermore, the "information" used to support these decisions is often in the form of complex, unstructured documents which lack clear linkages between their content. As a result, future decision-makers are often not able to benefit from the collective experiences of their predecessors. Consequently, there are no cycles of learning and the same mistakes are often repeated each time that a similar decision is made. It is clear that the most successful companies in the future will be those who can effectively manage and leverage the "intellectual capital" generated by the decision making process (the thinking engine of systems engineering) and the linkage of that process to essential supporting information. This paper describes an approach to address the deficiencies in the prevailing methods for requirements and decision management by proposing an enterprise-wide approach which provides for a true "learning organization" capability in the form of reusable decisions frameworks.

INTRODUCTION

Motorola and many other companies have pursued business process re-engineering as one way to drive critical process change. The goal is quicker delivery of systems and software to market while retaining or improving overall product quality and market acceptance. While these initiatives have netted solid improvements, they appear to be destined for long term failure unless serious attention is paid to the quality of the data and information being produced (Wand, et al, 1996).

Fueling these concerns, today's document-based processes (where the process is defined in terms of the document artifacts that are produced at each stage) tend to focus more attention on the format and outline of the document rather than its content. Documents promote a

"stream of consciousness" approach that leads to an inconsistent mixture of information types (everyone behaves differently, even the same author at a later time). This causes attribute data to be blended with object data (e.g., the requirements text is blended with comments about design, priority, schedule, etc.). In addition, data held in documents tend to lack some essential attributes (e.g., ownership, technical risk, etc.) and many if not all linkages to where the information came from (e.g., markets, decisions, features, etc.).

As the complexity of our systems continues to rise, a growing number of engineers, managers and marketing professionals are realizing that they must make dramatic process improvements in order to address the challenges of timely systems development in a strong competitive environment. Two critical elements are needed to provide the foundation for dramatic process improvements: 1) an information architecture with internal structures, optimized by domain; 2) Enterprise-wide decision making, technology & product planning, and requirements structuring methods. As reported previously (DeGregorio et al, 1996; DeGregorio 1997), Motorola, Inc., Communications Enterprise, (originally, this effort was initiated by the Land Mobile Products Sector or LMPS) is actively pursuing a project to address these critical elements.

The need for building this capability continues to grow and will track the phenomenal growth of the Intranet/Internet and the ability for everyone to access tremendous amounts of data through the World Wide Web. While this data provides an exciting research opportunity (Etzioni, 1996), it is largely unstructured and its validity is unknown. Its source should be qualified before it can be used as part of the decision making process. One positive outcome of this increased awareness and use of the Web is that people at all levels of the organization are becoming familiar with Web browsers. As they "surf" the Web, they are discovering the value of data being held in forms other than documents and they have begun to understand the

importance of structure.

BUILDING AN INFORMATION ARCHITECTURE

System and software process definition and improvement efforts typically focus on processes, tasks, and work products. The decision making network that drives the process and the information structures which results from the process are usually not given proper treatment.

While process definition is an important element, an equally important element is an information architecture and a set of domain dependent structures which support an overall enterprise system development process. Rapid cycle time improvements *cannot* be achieved without an underlying information architecture to hold the data defined by the business and systems development processes. The overall architecture encapsulates the key factors of business success. The architecture must define the essential data needed to drive and support development, define the key attributes about the data, establish relationships among the data, and establish ownership of the data. We are convinced that no enterprise can achieve its rapid systems development “time to market” goals without reasonable success of this critical step.

Fundamental Challenge. Many businesses have grown out of a strong technology-driven systems heritage. This situation typically gives rise to systems that display the “voice of the engineer” rather than “the voice of the customer.” If commercial businesses are going to become successful market-driven enterprises, they must make a dramatic shift in how they capture needs/wants, analyze them, and transform them into systems and products that meet marketplace needs. Marketing organizations must clearly capture, manage, and own a structured set of user requirements derived from market research, customer complaints and, customer suggestions. These requirements must then drive the entire development cycle including systems engineering, architecture, design, hardware and software engineering, manufacturing, and test (Stevens 1998).

Marketing and engineering perspectives of the requirements are equally important, and having a common location for user and system requirements, with a facility for relating them, will provide one mechanism for bridging the communications gap that exists between them (Workman 1995).

Motivations. Solutions for rapid cycle time systems development require a fundamental rethinking and restructuring of the business, marketing and engineering organizations and procedures to an information-based,

decision centric paradigm. Individual process improvement techniques are in-and-of themselves insufficient to produce the degree of required change. New processes are required which define clear decision-making responsibilities, facilitate rapid information distribution, and enable decisive program/project management and control.

Information Architecture. The information architecture has been instantiated using the DOORS database (Dynamic Object-Oriented Requirements System). The DOORS environment has been extended to include decision management and roadmap planning tools in addition to the core requirements management tools that are part of the DOORS environment.

This architecture unbundles the primitive elements of information from the paper containers in which they typically reside. Moreover the unbundled information is defined into structures which are reusable by way of those primitive data elements and their interface definitions. This eliminates duplicate data, and now “documents” become specific “views” of packaged data elements (that can also be printed), not the containers of the information.

An information-based approach supports requirements capture and management along with decision making, by providing the ability to make decisions based on relevant data and to record those decisions. Along with the introduction of this information-based approach, there are three new methods being introduced, which will be described later.

The information architecture provides the overall view of the structure. An important property of this structure is to retain a cohesive view of the inter-relationships of the data types that support and affect the requirements information.

In addition to the high-level views of the architecture, a lower level view of the information is needed to expose the information entities and their relationships inside each architectural component. The information entities correspond to objects used in the application domain as identified by application domain experts. It is also necessary to include the relationships between the entities thereby linking them into a cohesive system.

To satisfy the driving goal of becoming an information-based organization, the initial information model was mapped into a set of data structures. This design approach differs from a document-based system where all the data sets would tend to be of a hybrid nature (e.g., contract book) and contain a collection of various information types. As indicated earlier, the primary reason to be information-based is to eliminate

duplicate information and to allow for knowledge capturing relationships to be built between the information elements.

METHODS THAT DRIVE THE INFORMATION ARCHITECTURE

There are three new methods that are being introduced into Motorola's Communications Enterprise that leverage and drive the Information Architecture. First, a requirements structuring methodology (Stevens, 1998 & Stevens, et al, 1998); second a structured decision making and risk management methodology (Fitch, 1998); and third, a Technology & Product Planning methodology (Motorola, 1998). These are each critical in assisting managers, engineers and marketing professionals in making the transition from the inefficient document-based world to a highly content-focused information-based one.

Structuring Requirements. The first method, Structuring Requirements focuses on how to organize information into highly effective hierarchical structures that are optimized to hold specific kinds of data. Also defined are the essential attributes (e.g., priority, risk, etc.) of the objects in each structure.

This method defines how to identify and segment

the different types of requirements (e.g., user, system, business, customer, architecture, design, etc.). This segmentation is critical to reducing wasted effort and allowing for broader reuse of the requirements over time. Critical relationships are formed between different classes of requirements to show the evolution of this requirements as the system is developed.

Structured Decision Making and Risk Management.

Decisions are central to all effective system engineering processes (see Figure 1 & 2). The second method is Structured Decision Making and Risk Management, which allows all business, marketing, and engineering data to come together, in a way that makes sense to each discipline. Key points include:

- Proactive identification and planning a set of critical decisions that drive System Development. These decisions are depicted as a Decision Network.
- Decisions as the primary consumers and creators of requirements. The requirements for a product or system are the sum of the derived requirements from all upstream decisions. Tying decisions and requirements together in this manner enables true impact and trace analysis.
- On any one decision, we want to use a structured decision making approach to effectively capture the rationale. This is captured and communicated in the form of

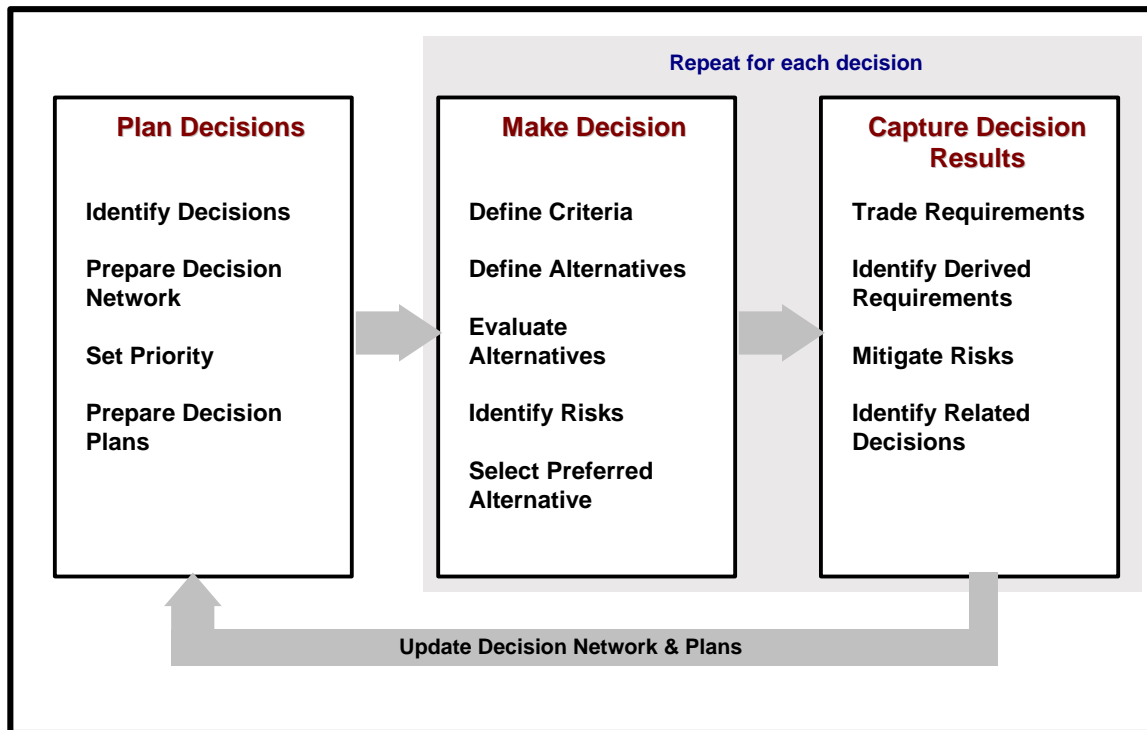


Figure 1. Decisions Driven Process (Fitch, 1998)

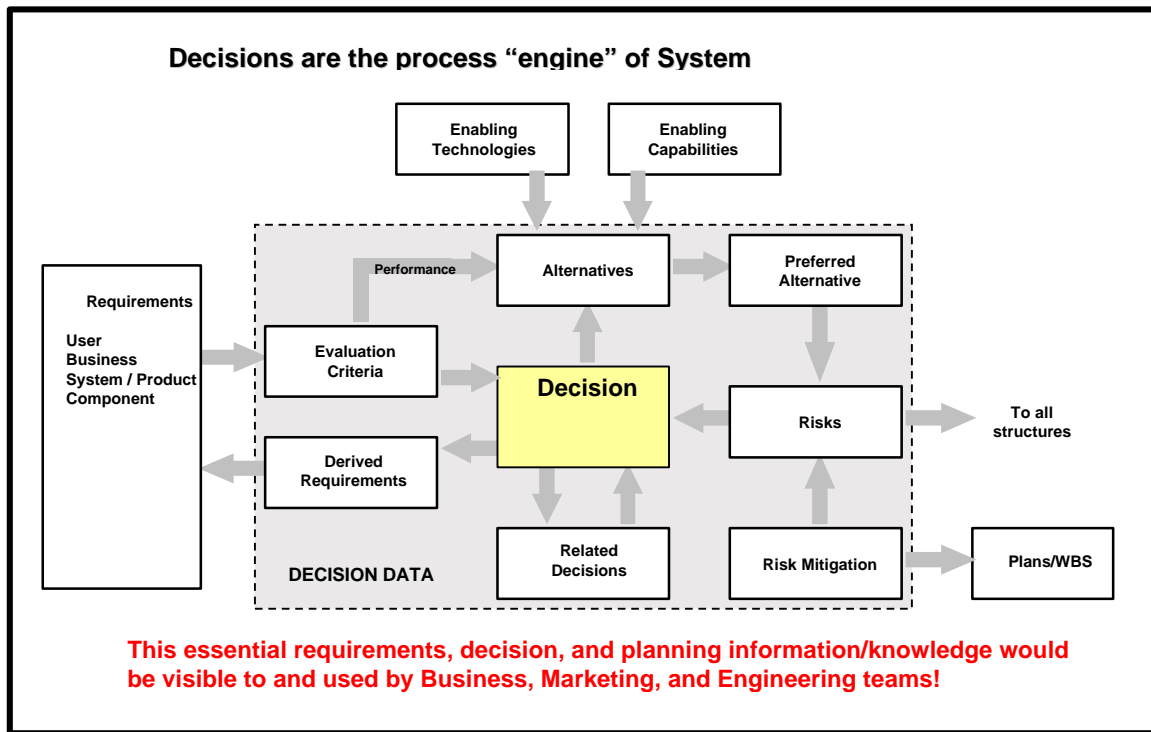


Figure 2. Decisions are the thinking “engine” of Business and Engineering Processes

evaluation matrices, which can be as simple as one by one or as large as needed to deal with the complexity of the tradeoff.

- Integrate Risk Management into the decision making process. It is important that this is not limited to just identification, but include mitigation at the point of evaluation.

Since decisions are central, we must capture the key relationships to other essential data (e.g., enabling technologies, product architectures, etc.). These tend to drive the alternatives that are being considered within a specific decision.

Effective management of complex systems development cannot happen without a structured approach to Requirements and Decision Management (RDM). RDM provides the basis for integrating requirements and decisions in such a way to make it possible to promote traceability, control and reuse. These capabilities support the “Learning Organization” concept (Senge, 1990). Figure 2 shows the relationship between the following 6 concepts. Requirements management is not possible without decision management. Improvement (moving from left to right within figure 2), is not possible without both capabilities.

- ✓ **Requirements Traceability.** All requirements are traceable to a valid source; none are *missing in action*. Full test coverage is assured. Gold-plating of requirements is reduced or eliminated.
- ✓ **Decision Traceability.** The rationale and driving requirements for key product and project decisions are captured. Derived requirements are captured at the point of decision-making.
- ✓ **Requirements Control.** Requirements are prioritized to reflect the *voice of the customer* and business needs. Requirements are analyzed and structured to ensure completeness, consistency, and feasibility.
- ✓ **Decision Control.** Decisions are made using a systematic, repeatable process. Decisions are effectively planned and prioritized. Decision relationships are understood, risks are managed and every decision has a clear owner.
- ✓ **Requirements Reuse.** Requirements for all products are maintained in integrated structures and are readily available. Common requirements are identified and leveraged.

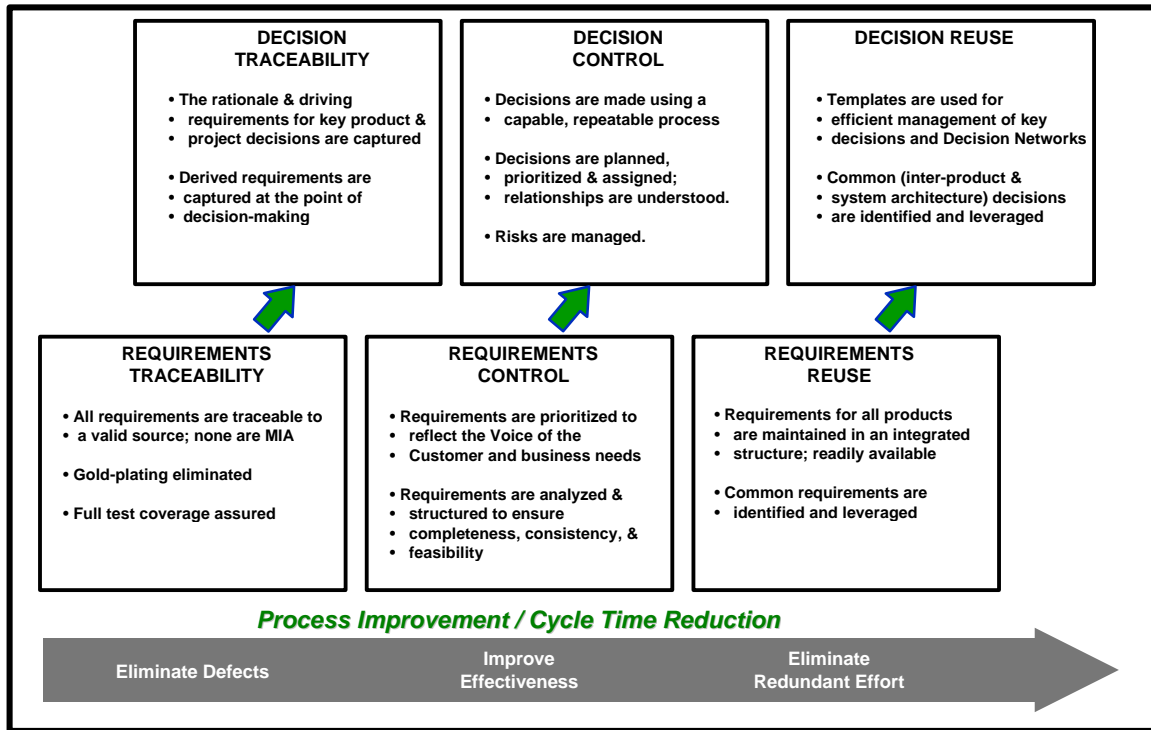


Figure 3. Dramatic Improvements possible when Requirements Management and Decision Management are Combined

- ✓ **Decision Reuse.** Templates are used for efficient proactive management of key decisions and decision networks. Common (inter-product and system architecture) decisions are identified and leveraged.

In support of capturing and manipulating decisions and their related data, we have specified and co-developed with QSS, a Decision & Risk Management Tool called DecisionLink™.

Roadmap Planning. Technology and Product Planning, is the third method that leverages and drives the Information Architecture. At technology-intensive companies, technology planning is a critically important activity. Companies that have been identified as having “best practices” in technology planning have established a structured process and fostered involvement between R&D and the business and marketing teams (Metz, 1996).

Technology planning at Motorola is a systematic process for forecasting and controlling the evolution of core technical competencies. Technology planning allows us to forecast critical competitive trends, build core competencies to gain/maintain competitive

advantage, build a “Technology Shelf” to reduce risks to business and product plans, and communicate viable solution options to product planners. This is done by building technology structures (three different types: availability, development, product) and planning technologies (visualized in the form of a technology roadmap that looks similar to a Gantt chart). In addition, technologies are linked to each other to capture dependencies, to competitive technology objects, and to related issues, decisions and plans.

In support of capturing and manipulating technology information and its relationships, we have specified and co-developed with QSS, a Technology Planning Tool called TechPlan™.

REQUIREMENTS MANAGEMENT TOOLS

When moving from a document-based to an information-based approach, it is important to provide navigation aids, views, and other supporting tools to help users locate, enter, use, and update information related to their job function. The core functionality of the DOORS tool provides many of the needed capabilities, but a number of extensions have been specified to supply additional functionality (DeGregorio, et al, 1996). In addition to the DecisionLink and TechPlan methods and tools, we have

specified a schema management and development tool, a document generation tool, and a Quality Function Deployment (QFD) tool.

TRAINING

Training and education is a critical component in the process of moving an organization from a document-based approach to one that leverages an information-based and decision centric approach. Workshops are commercially available for each of the key methods described in this paper. In addition, a new course will be developed to support understanding of the information architecture itself. It is strongly recommended that all training be done "Just-in-Time" and be workshop-based to minimize time lost and maximize understanding by using real project data.

USING A DECISION FRAMEWORK TO DEFINE SYSTEM, PRODUCT, SOFTWARE & COMPONENT ARCHITECTURES

One of the fastest growing communities of Requirements and Decision Management users within Motorola and in some of the external companies that are early adopters, is the use of decision networks to define and manage system, product, software & component architectures. It is such a powerful, focused use of the structured decision making approach, that we are planning on publishing a separate paper that describes this specific use in more detail. Architectures can be extremely complex and this approach not only captures the reference architecture and its evolution, but also the specific instantiated uses of the architecture. Complexity management and rationale captured about the architectural boundaries are just two of the essential elements of this approach.

STATUS & FUTURE DIRECTIONS

The results of our pilots within Motorola have been very positive, not just in the architecture arena, but across the board. This includes engineering, marketing and business planning teams. Requests for more information on how to build the information architecture, introduce the methods, and acquire DOORS with the add-on tools are coming from all parts of Motorola. In addition, much interest is coming from many companies outside of Motorola now that TechPlan, DecisionLink and their underlying methods workshops have been commercially introduced by QSS.

Motorola will continue to work with QSS to improve these first two tools and methods. In addition Motorola has specified three additional tools that are

critical for using DOORS in an information-based enterprise manner. Motorola will work with QSS to make these additional tools and methods available commercially worldwide.

CONCLUSIONS

Achievement of enterprise strategies for rapid systems development requires fundamental changes in the way commercial system engineering is done in a market-driven environment. Individual process improvement efforts do not have the scope necessary to drive fundamental change. An overall architecture is required to support the revolutionary changes necessary to realize the strategies. Additional requirements are placed on the architecture to push the organizations toward becoming an information-based enterprise rather than document-based. Furthermore the information architecture, if it is robust, is reasonably independent of any particular process model thereby increasing its scalability and extensibility.

Based on our actual pilot experiences, user feedback, and the large amount of interest being generated inside and outside of Motorola, we are sure we are on the right track! Our content focus has been found to be refreshing, yet challenging by the pilot users. We have discovered that once they clear the conceptual hurdle working outside a "document," they become extremely energized and productive, especially when they discover that they can relate their work to others and understand where it fits in the big picture.

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BIOGRAPHY

Gary DeGregorio is a Member of the Technical Staff and is leading the Requirements and Decision Management project within the Software & System Engineering Laboratory of Motorola Labs. He has worked in the area of systems and software engineering process, methods, and tool applied research for over 15 years, focusing on system requirements and decision management, knowledge/information architectures, as well as strategic technology and product planning methods and tools. Gary is an Associate of the Motorola Science Advisory Board, an award for technical achievement. Gary started his career at Motorola in 1977. He earned a BSEE and MSEE at the University of Illinois, Champaign. Gary is a member of the IEEE, the IEEE Engineering Management Society, the ACM and the International Council on Systems Engineering (INCOSE). Gary can be contacted at garyd@comm.mot.com.